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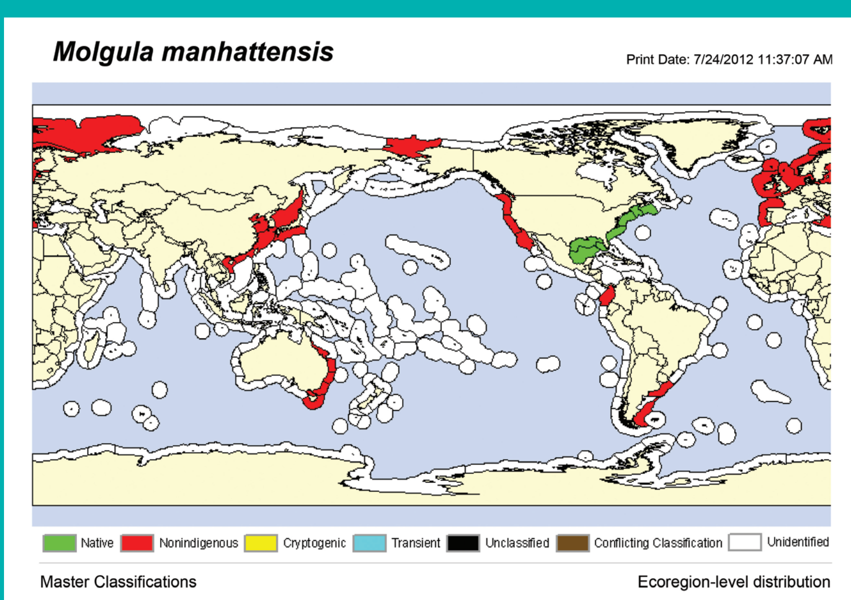

Report of Working Group 21 on Non-indigenous Aquatic Species

NORTH PACIFIC MARINE SCIENCE ORGANIZATION

PICES

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Report of Working Group 21 on Non-indigenous Aquatic Species

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Executive Summary

Aquatic non-indigenous species (NIS) continue to threaten marine ecosystems, including seafood safety and security. To inform risk assessments predicting the likelihood and consequences of new invasions, it is critical to understand global NIS distributions, habitat tolerances/preferences, potential dispersal vectors and probable impacts related to new incursions. To this end, the NIS database developed by the North Pacific Marine Science Organization (PICES) Working Group on *Non-Indigenous Aquatic Species* (WG 21), with funding from the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan through the Fisheries Agency of Japan, summarizes large-scale data which can be used by managers to develop monitoring programs for early detection or rapid response, and to make mitigation plans for higher-risk NIS to limit the impacts on native biodiversity, including commercially important species, and ecosystem structure and function.

The *Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific*, compiled through the activities of WG 21, synthesizes information from a variety of sources and can serve as a valuable resource for agencies and scientists tasked with managing and researching NIS in the North Pacific. Information included in the Atlas can help to identify and prioritize potential high-risk NIS and/or high-risk locations which can allow limited funding to be used effectively. The usefulness of the Atlas was illustrated most recently by the arrival of a large floating dock in Newport, Oregon, USA that had been set adrift by the 2011 Great East Japan Earthquake and tsunami – this document was consulted by experts to aid in the identification and ecological risk assessment of organisms attached to the dock.

Another lasting outcome from activities of WG 21 has been increased awareness and collaboration on NIS issues broadly, especially between PICES member countries and with developing countries and international organizations like the Northwest Pacific Action Plan (NOWPAP) and the Intergovernmental Oceanographic Commission's Sub-Commission for the Western Pacific (WESTPAC), fostered through Rapid Assessment Surveys (RAS) and RAS demonstration workshops. Capacity building has better prepared researchers both within and beyond PICES to deal with emerging NIS issues and is critical to better understanding invasion dynamics and maintaining safe and productive marine ecosystems.

As marine NIS represent a current and persistent risk to PICES member countries, the NIS database and other accomplishments of WG 21 have positioned PICES to better comprehend and advance marine NIS topics, including emerging vectors (*e.g.*, vessel biofouling, tsunami/marine debris), altered species distributions, risk assessment, and interactions/impacts on marine ecosystems (including structure, function, productivity, and resilience). There also is considerable interest about how projected global climate change will affect the introduction, spread and impacts of NIS in the North Pacific and to undertake risk identification to inform potential mitigation measures by PICES member countries. For example, global climate change and the associated decrease in Arctic ice cover, combined with the opening of new shipping routes, highlight the complexities of understanding marine NIS dynamics. Interest has been expressed by organizations such as ICES, NOWPAP and WESTPAC in addressing specific NIS vectors or taxa (*e.g.*, tunicates, bivalves, European green crab) of common interest to many PICES member countries. This will allow continued exchange of knowledge across the North Pacific where many previous incursions have occurred and is an appropriate interface with the international community.

There are many examples demonstrating that marine NIS are a significant stressor that can alter ecosystem structure and function, and thus there are strong linkages to the PICES FUTURE (**F**orecasting and

Understanding **T**rends, **U**ncertainty and **R**esponses of North Pacific **E**cosystems) program and the North Pacific Ecosystem Status Report. Thus, at a minimum PICES should establish an expert group that can continue to exchange information on changing marine NIS dynamics *via* the WG 21 NIS database. A continued NIS expert group could explore how climate change will alter NIS distributions around the North Pacific, including probable changes in NIS vectors (*e.g*., new shipping routes, expanding trade). Further, a new expert group could address how PICES member countries have been affected by NIS and what community responses have occurred due to NIS incursions in the North Pacific, an element directly aligned with FUTURE. This information would help inform policy and management options within each PICES member country.

WG 21 proposed several options for PICES' continued involvement in marine NIS issues, but the creation of an Advisory Panel on *Aquatic Non-indigenous Species* (AP-NIS) is the preferred option as it would allow continued progress on marine NIS issues, with the lowest resource commitment.

This report summarizes the activities and accomplishments of WG 21 in fulfilment of its terms of reference, and recommends the establishment of an Advisory Panel on *Non-indigenous Aquatic Species* to continue work on NIS in the North Pacific.

1 Background

Globally, non-indigenous species (NIS) are introduced intentionally or unintentionally to new locations across biogeographical boundaries by a variety of vectors, including commercial shipping, recreational boating, aquaculture transfers, and intentional and accidental release. The most consequential NIS in terms of impact are those that become invasive as it is these species that can increase their geographic ranges quickly, dominate their new habitats, and fundamentally alter ecosystem structure and function. In aquatic systems, invasive species pose a significant risk to native biodiversity and can potentially compromise food security and/or safety, especially for countries that rely heavily on seafood products. For example, in shellfish aquaculture, invasive tunicates have become a global concern because they can displace and compete with both native and cultured species and foul aquaculture gear and products, thus compromising long-term productivity and sustainability. Similarly, some invasive diatoms have been responsible for significant harmful algal bloom events that have threatened food safety for human consumption.

No country is immune from the threat of aquatic NIS as species continue to be redistributed by a number of vectors. However, by better understanding invasion dynamics and patterns it is possible to mitigate some of the risks associated with NIS. Effectively addressing this global threat requires knowledge across multiple spatial scales. Understanding global distributions, habitat preferences, potential dispersal vectors and probable impacts related to potential invaders is a key for risk assessments predicting the likelihood and consequences of new invasions.

The North Pacific Marine Science Organization (PICES) Working Group on *Non-Indigenous Aquatic Species* (WG 21) was created following a Marine Environmental Quality Committee (MEQ) workshop on "*Introduced species in the North Pacific*" held October 4, 2005, at the PICES Fourteenth Annual Meeting in Vladivostok, Russia (see Appendix 6). The workshop produced a recommendation and draft terms of reference for the creation of a working group on non-indigenous species. WG 21 was originally given a 3-year mandate that was extended and broadened following approval of a 5-year (April 1, 2007–March 31, 2012) project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" funded by the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) through the Fisheries Agency of Japan. The first meeting of WG 21 was held in Yokohama, Japan, in October 2006 (PICES Fifteenth Annual Meeting) and the Working Group's last meeting took place in Nanaimo, Canada in October 2013 (PICES Twenty-second Annual Meeting).

One of the major components of the PICES/MAFF project, conducted by WG 21 was to develop tools to assist managers in the prevention and mitigation of NIS and to share these tools with developing countries bordering the Pacific Ocean. WG 21's goal was to address two key elements required for early detection of, and rapid response to, invasions. The first initiative was the development of a comprehensive, searchable database and atlas of non-indigenous marine and estuarine species in the North Pacific (*Database Initiative*, with Dr. Henry Lee II, U.S. Environmental and Protection Agency, as the Principal Investigator). The second initiative was to conduct a series of Rapid Assessment Surveys (RAS) to develop and disseminate techniques for the quick detection and identification of non-indigenous species that presently exist in a variety of habitats in PICES member countries (*Taxonomy Initiative*, with Dr. Thomas Therriault, Fisheries and Oceans Canada, as the Principal Investigator).

In this report, we summarize the work that has been carried out by WG 21 (Appendix 2) to meet the objectives stated in the Terms of Reference (Appendix 1). The report includes a glossary for non-indigenous species terminology together with recommendations on their use (Section 2). The results from an extensive analysis of the database, where invasion patterns (taxa and vectors) in the North Pacific are compared and contrasted with other regions (Section 3). The outcome of a series of RAS conducted by WG 21 in PICES member countries and RAS demonstration and training workshops held in a number of Southeast Asian countries is provided in Section 4 (see also Appendix 5). The report includes an inventory of expertise and programs related to aquatic NIS in PICES member countries and initiatives on prevention and mitigation measures, including national policy and legislation (Sections 5 and 6), a summary of the collaboration between the International Council for the Exploration of the Sea (ICES) expert groups and PICES working groups on non-indigenous aquatic species (Section 7), followed by WG 21's summary and recommendations (Section 8).

2 Glossary for Non-indigenous Species Terminology: Definition and Recommendations of Terms

A glossary of non-indigenous species terminology is provided in Table 2.1. It includes the terms used in the database and *Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific* created by WG 21. Recommended terms are underlined and asterisks indicate the preferred definition where there is more than one. It should be noted that the terms are heavily weighted to North America and Europe, with no Asian sources.

Table 2.1 Glossary of non-indigenous species terminology.

Term	Definition	Synonyms	Source
Accidental introduction	Introduction of an aquatic organism, including "fellow travellers", by chance, not by design, *e.g.*, release of an organism in ship's ballast water.	Unintentional introduction	DFO, 2003
Adaptive management	A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.		EC, 2004 (Canadian Environmental Assessment Agency, Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners)
Alien species	1. Species of plants, animals, and micro-organisms introduced by human action outside their natural past or present distribution (EC 2004); 2. Species, subspecies or lower taxon introduced outside its normal past or present normal distribution; includes any part (*e.g.*, gametes, seeds, eggs or propagules) of such species that might survive and subsequently reproduce (Pheloung, 2003).	• Exotic species, introduced species, • <u>Non-indigenous species</u>, • Non-native species, • Foreign species	EC, 2004 (based on Convention on Biological Diversity Decision VI/23); Pheloung, 2003
Amphi-Atlantic species	Species that are found on both sides of the Atlantic Ocean; some are circumpolar with waterborne gametes but most are cryptogenic.		J. Pederson, pers. comm.
<u>Amphi-Pacific species</u>	Species that are found on both sides of the North Pacific Ocean.		this summary
Aquatic organism	Includes all organisms (finfish, molluscs, crustaceans, echinoderms and other invertebrates) and their life stages, defined as "Fish" in the [Canadian] Fisheries Act, as well as marine and freshwater plants.		DFO, 2003

Term	Definition	Synonyms	Source
Ballast water	1. Water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship (EC, 2004); 2. * Water, including its associated constituents (biological or otherwise), placed in a ship to increase the draft, change the trim or regulate stability (includes associated sediments, whether within the water column or settled out in tanks, sea chests, anchor lockers, plumbing, *etc*.) (BNZ, 2005).		EC, 2004 (based on International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004); BNZ, 2005
Biodiversity	Variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.		EC, 2004 (Convention on Biological Diversity, 1992)
<u>Biosecurity</u>	Measures that are intended to prevent the introduction of invasive alien species (pests and diseases) which pose a risk to plant and animal health, ecosystems and human health.		EC, 2004
Casual alien species	Alien species that may flourish and even reproduce occasionally in an area, but do not form self-replacing populations and rely on repeated introductions for their persistence.	• Waif, • Transient, • Occasional escapee, • Adventive, • Persisting after cultivation	IUCN SSC, 2007
Commodities	A type of organism, product, or other article being moved for trade or other purpose.		EC, 2004 (based on the definition in the International Plant Protection Convention ISPM #05 Glossary of Phytosanitary Terms, 2002)
<u>Conflict</u>	Classification used by Lee II and Reusser (2012) when available information is insufficient to make a decision among the conflicting classifications non-indigenous, native or cryptogenic within a location; used to highlight cases where at least some experts believe that there is sufficient information to consider a species introduced.		Lee II and Reusser, 2012
Containment	Application of measures in and around an infested area to prevent spread of an invasive alien species beyond a defined area.		EC, 2004 (for a sector-specific definition, see the International Plant Protection Convention ISPM #05 Glossary of Phytosanitary Terms, 2002)

Term	Definition	Synonyms	Source
Cryptogenic species	Species whose origins are unknown; cannot be classified as "native" ["indigenous"] or "non-native" ["non-indigenous"]. Note: "Cryptogenic" is used increasingly for species with taxonomic uncertainties, such as sibling or cryptic species. To avoid mixing uncertainty over invasion history versus taxonomic uncertainty, Lee II and Reusser (2012) restricted the use of cryptogenic to locations where there is some evidence for invasion.		Carlton, 1996; Lee II and Reusser, 2012; J. Pederson, pers. comm.
Ecosystem	A complex of organisms and their environment, interacting as a defined ecological unit (natural or modified by human activity, *e.g.*, agro-ecosystem), irrespective of political boundaries.		Pheloung, 2003
Ecosystem approach	A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.		EC, 2004 (Convention on Biological Diversity Decision V/6)
Ecosystem Engineer	1. *Species that create, destroy or modify habitat (Crooks, 2002). Note: the term is used to describe all species with the capacity to physically alter habitat, and is not limited to invasive species. 2. Subset of invasive species which change the character, condition, form or nature of ecosystems over a substantial area relative to the extent of that ecosystem (IUCN SSC, 2007).	• Transformer, • Edificator	Crooks, 2002; IUCN SSC, 2007
Endemic	1. Occurring constantly at low population levels; 2. * Used by zoogeographers to describe a species belonging or native [indigenous] to an area and occurring nowhere else.		EC, 2004 (based on the definitions in Frank and Gillett-Kaufman, 2006)
Enhancement	The release of fish [aquatic organisms] to augment the public resource; can be accomplished through fish culture techniques or through the introduction or transfer of wild fish [aquatic organisms].		DFO, 2003
Eradication	1. Application of measures to eliminate an invasive alien species from a defined area (EC, 2004); 2. * Removal of every individual and propagule of an invasive species so that only reintroduction could allow its return (Zavaleta *et al*., 2001).		EC, 2004 (for a sector-specific definition, see the World Organization for Animal Health (OIE) Terrestrial Animal Health Code, 2003); Zavaleta *et al*., 2001
Hitchhiker	An organism which inadvertently accompanies the shipment of species intended for introduction/ transfer.	Fellow traveller	DFO, 2003
Hybrid	Offspring of two animals or plants that are of different species.		DFO, 2003; EC, 2004
Import	Movement of aquatic organisms across national or [subnational] boundaries.		DFO, 2003

Term	Definition	Synonyms	Source
Intentional introduction	1. The deliberate movement and/or release by humans of an alien species outside its natural range (EC, 2004); 2. *Deliberate release, or holding, of live aquatic organisms in open water or within a facility with flow-through circulation or effluent access to the open-water environment outside its present range (DFO, 2003).		DFO, 2003; EC, 2004
Introduced species	1. Any species intentionally or accidentally transported and released by humans into an environment or facility with effluent access to open water or flow-through system outside its present range (DFO, 2003); 2. Species that arrive from outside their native range (J. Pederson, pers. comm.).	• Exotic species, • Non-indigenous species, • Non-native species	DFO, 2003 (based on ICES, 2003, updated in 2005); J. Pederson, pers. comm. from ICES WGITMO
Invasive species	1. * Harmful alien organisms whose introduction or spread threatens the environment, the economy, or society (EC, 2004); 2. Naturalized species that reproduce often in large numbers and are able to spread over a large area (IUCN SSC, 2007); 3. Alien species whose introduction does, or is likely to, cause economic or environmental harm or harm to human health (Carlton, 2002); 4. Alien species which become established in natural or semi-natural ecosystems or habitat, are an agent of change, and threaten native biological diversity (Carlton, 2002); 5. Alien species whose establishment and spread threaten ecosystems, habitats or species with economic or environmental harm (Pheloung, 2003); 6. Species that create problems usually measured in human terms (J. Pederson, pers. comm.); 7. Often incorrectly used as a synonym of 'non-indigenous' (Colautti and MacIsaac, 2004); 8. Native or NIS that have colonized natural areas (Colautti and MacIsaac 2004); 9. Discrimination of non-indigenous species established in cultivated habitats ('non-invasive') from those established in natural habitats ('invasive') (Colautti and MacIsaac, 2004); 10. Non-indigenous species that are widespread; 11. Widespread non-indigenous species that have adverse effects on the invaded habitat (Colautti and MacIsaac, 2004).		Carlton, 2002; Colautti and MacIsaac, 2004; EC, 2004 (based on the definition contained in the Convention on Biological Diversity Decision VI/23); IUCN SSC, 2007; J. Pederson, pers. comm.; Pheloung, 2003
Native species	Existing and having originated naturally in a particular region or environment.	Indigenous species	DFO, 2003; Lee II and Reusser, 2012

Term	Definition	Synonyms	Source
Naturalized species	1. * Alien species that reproduce consistently and sustain populations over many life cycles without intervention by humans, but do not necessarily invade natural, semi-natural or human-made ecosystems (EC, 2004); 2. Introduced species that have become established and have formed self-sustaining populations (DFO, 2003); 3. Non-indigenous species that are able to establish in undisturbed habitats (Colautti and MacIsaac, 2004).	Established species	Colautti and MacIsaac, 2004; DFO, 2003; EC, 2004
Noxious weed	1. Undesirable invasive plant (weed) that is referred to as such and controlled by legislation (EC, 2004); 2. * An anthropocentric term for plants, animals or other pests (not necessarily alien) that grow where they are not wanted and usually have detectable economic or environmental effects (IUCN SSC, 2007).	• Pest, • Harmful species, • Problem species	EC, 2004 (based on Global Strategy on Invasive Alien Species, 2001); IUCN SSC, 2007
Pathway	1. The routes by which species move from one locale to another, either within a country or between countries (EC, 2004); 2. Any means that allows entry or spread of a pest; combination of point of origin, vector and mode of entry (Pheloung, 2003); 3. Pathways are the broad routes by which an invasive species is transferred from one geographic area to another (Mandrak and Cudmore, 2010).		EC, 2004; Mandrak and Cudmore, 2010; Pheloung, 2003
Pest	Any species, strain or biotype of plant, animal or pathogenic organism injurious to animals, animal products, plants or plant products.		Pheloung, 2003
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing and/or treatment.		EC, 2004 (International Plant Protection Convention ISPM #05 Glossary of Phytosanitary Terms, 2002)
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there or present but not widely distributed and being officially controlled.		Pheloung, 2003
Range extension	The enlargement of the geographic area that is occupied by a species, usually through intentional human action; the extension is usually incremental, over short distances and contiguous.		DFO, 2003
Re-introduction	Release of a species to waters from which the species had been previously extirpated.		DFO, 2003
Release	The liberation of aquatic organisms to the natural environment; release can be unintentional, as in the escape of organisms from aquaculture facilities or during use as live bait.		DFO, 2003

Term	Definition	Synonyms	Source
Risk	1. The probability of a negative or undesirable event occurring; the likelihood of the occurrence and the magnitude of the consequences of an adverse event, a measure of the probability of harm and the severity of impact of a hazard (DFO, 2003); 2. The uncertainty that surrounds future events and outcomes, a function of the probability (chance, likelihood) of an adverse or unwanted event, and the severity or magnitude of the consequences of that event (EC, 2004).		DFO, 2003; EC, 2004 (based on Treasury Board of Canada Secretariat, 2001; Privy Council Office, 2000)
Risk analysis	The process that includes risk identification, risk assessment, risk management and risk communication.		DFO, 2003; EC, 2004
Risk assessment	1. The process of identifying and describing the risks of introductions or transfers of aquatic organisms having an impact on fisheries resources, habitat or aquaculture in the receiving waters before such introductions or transfers take place; the process of identifying a hazard and estimating the risk presented by the hazard, in either qualitative or quantitative terms (DFO, 2003); 2. The evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences, where economic consequences are interpreted to include environmental consequences (EC, 2004).		DFO, 2003; EC, 2004 (based on International Plant Protection Convention ISPM #05 Glossary of Phytosanitary Terms, 2002)
Risk communication	1. The open exchange of information and opinion, leading to a better understanding of risk and related decisions; the processes by which the results of the risk assessment and proposed risk management measures are communicated to the Decision-Making Authority and interested parties (DFO, 2003); 2. The interactive exchange of information on risk among risk assessors, risk managers and other interested parties (EC, 2004).		DFO, 2003; EC, 2004 (based on World Organization for Animal Health (OIE) Terrestrial Animal Health Code, 11th Edition, 2003)
Risk goods	Any organism, organic material, or other thing or substance that (by reason of its nature or origin) it is reasonable to suspect to constitute, contain or otherwise pose a risk that its presence in New Zealand will result in: a) exposure of organisms in NZ to damage, disease, loss or harm; or b) interference with the diagnosis, management or treatment, in NZ, of pests or unwanted organisms.		Hayden and Whyte, 2003
Risk management	1. The process of selection and implementation of options to reduce, to an acceptably low level, the risk of negative impact of introductions or transfers of aquatic organisms; the process of identifying, evaluating, selecting and implementing alternative measures for reducing risk (DFO, 2003); 2. The evaluation and selection of options to reduce the risk of introduction and spread of a pest (EC, 2004).		DFO, 2003; EC, 2004 (based on International Plant Protection Convention ISPM #05 Glossary of Phytosanitary Terms)

Term	Definition	Synonyms	Source
Significant impact	A predicted or measured change in an environmental attribute that should be considered in project decisions, depending on the reliability and accuracy of the prediction and the magnitude of the change within specific time and space boundaries.		DFO, 2003
Species	A group of interbreeding organisms that differs from, and are reproductively isolated from other such groups.		DFO, 2003; EC, 2004 (both based on ICES, 1988)
Stage 0 species	Native species resident in a donor region.	Indigenous species	Colautti and MacIsaac, 2004
Stage I species	Species that have been transported from their native range to a non-native location.		Colautti and MacIsaac, 2004
Stage II species	Non-indigenous species that survive transport and release.	Introduced species	Colautti and MacIsaac, 2004
Stage III species	Non-indigenous species that persist and reproduce in a non-native environment.	Established species	Colautti and MacIsaac, 2004
Stage IVa species	Geographically widespread non-indigenous species.		Colautti and MacIsaac, 2004
Stage IVb species	Ecologically dominant non-indigenous species.		Colautti and MacIsaac, 2004
Stage V species	Geographically widespread and ecologically dominant non-indigenous species.	Invasive species	Colautti and MacIsaac, 2004
Taxonomy	The theory and practice of describing, naming and classifying plants and animals.		EC, 2004
Transfer	The movement of individuals of a species or population of an aquatic organism from one location to another within its present range.		DFO, 2003
Transient	Species that temporarily migrate into an area as a result of unusual climatic conditions, such as El Niño. Their movement into the area is *via* natural mechanisms rather than mediated through human activities.	• Vagrant species, • Migrant species	Lee II and Reusser, 2012
Unknown	A species is classified as unknown when there is insufficient information to make a judgment as to its classification status		Lee II and Reusser, 2012
Unintentional introduction	An introduction which is not intentional.	Accidental introduction	EC, 2004
Vector	1. The means by which species from a source population follows a pathway to a new destination (EC, 2004). 2. The subroutes within pathways, and are the physical means by which a species is transported, usually by humans, from one area to another (Mandrak and Cudmore, 2010).		EC, 2004 (Global Strategy on Invasive Alien Species, 2001); Mandrak and Cudmore, 2010

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3 Assessment of the Status of Non-Indigenous Species in the PICES Area

3.1 Inventory of Currently Reported Non-indigenous Marine and Estuarine Species in the North Pacific

3.1.1 Development of a comprehensive database and atlas

With funding provided by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), WG 21 created a non-indigenous marine and estuarine species in the North Pacific database (herein referred to as the NIS database) and generated an *Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific* (herein referred to as the *Atlas*). The NIS database and *Atlas* (completed in 2012) synthesize and summarize the distribution, including invaded locations, of near-coastal and estuarine NIS in PICES member countries. The NIS database and *Atlas* integrate information from a number of sources (*e.g.*, peer-reviewed literature, agency reports, websites, *etc*.) written in multiple languages into a single document for use by scientists and resource managers. In addition to occurrence data from the published literature, the NIS database also includes occurrences detected during rapid assessment surveys (RAS). (The RAS and the standardized data collection protocols will be discussed and described in Section *4.2 North Pacific Marine Non-Indigenous Aquatic Species Taxonomy Initiative*). Some of the basic management uses of the distributional data in the *Atlas* and NIS database include:

1. Establishing a baseline of the number of reported NIS by ecoregion; by coupling this data with RAS and/or monitoring programs, it will be possible to detect new NIS.
2. Life history and environmental requirements for NIS can help identify what habitats and resources will be at greatest risk to an existing or new invader.
3. Analysis of source (native) region(s) of NIS can be used to determine high risk regions and to develop focused quarantine procedures for imports.
4. On a global scale, enumeration of the total number of ecoregions invaded by a species can help identify high risk invaders. Further, maps in the *Atlas* are a simple and visual approach to conveying the distribution of these species to managers and the public.

Species profiles containing distribution, invasion vectors, life history and habitat information were collated for 747 NIS found in PICES member countries, along with analyses of invasion patterns in the North Pacific (Table 3.1.1). A read-only version of the NIS database (completed in 2012) was developed to run on Windows XP and Windows Vista operating systems, in conjunction with Access 2003 and Access 2007. The database is being archived at the PICES Secretariat (www.pices.int) until such time as the software can be upgraded to work with newer operating systems and programs. The *Atlas* can be accessed at https://www.pices.int/projects/WG-21/Atlas_of_Non-indigenous_Marine_and_Estuarine_Species_in_the_North_Pacific.pdf.

Table 3.1.1 Database record statistics for non-indigenous species (NIS) in PICES member countries.

Description of records	No. of records
Total number of species in the database	1,340
Total number of NIS established somewhere in the North Pacific region other than their native range in the database*	747
Total number of native and NIS found in the 4 RAS (China, Korea, USA, Russia)*	665
Additional species included in the database added by member countries*	42
Total number of publications in the database	4,240
Total number of global distribution records of species by publication in the database	87,930
Total number of publication comments about the species in the database	4,125
Total number of alternate names (conventions, synonyms, misidentifications and misspellings) in the database	3,636
Total number of common names of species in the database	1,028
Total number of species linkages to publications	18,156

*Species counts are not mutually exclusive between these groups; RAS = rapid assessment survey.

3.1.2 Geographic and taxonomic scope of the data

The Marine Ecosystems of the World (MEOW) biogeographic schema, including the marine ecoregion names, were used as the framework for displaying the global distributions of the species in the NIS database.[1] This schema is hierarchical, consisting of four spatial levels from ocean basins (*e.g.*, Temperate North Pacific Realm) to "ecoregions" at the finest scale.

The Temperate North Pacific Realm captures most of the shorelines bordering the Pacific Ocean of the PICES member countries. This realm was divided into the Northeast Pacific (NEP) and Northwest Pacific (NWP) regions to allow transoceanic comparisons (Fig. 3.1.1). The Hawaii Ecoregion, which is in the Eastern Indo-Pacific Region, was included to provide broader coverage of the U.S. states within the North Pacific. For complete coverage of China and Japan, five ecoregions in the Central Indo-Pacific (Southern China, Gulf of Tonkin, South China Sea Oceanic Islands, South Kuroshio, and Ogasawara) were included. Collectively these five ecoregions are called the Northern Central Indo-Pacific (NCIP). The total geographical extent for the North Pacific consists of 22 MEOW ecoregions, and the Arctic ecoregions bordering the United States (*e.g.*, Eastern Bering Sea), Canada (*e.g.*, Beaufort Sea), and Russia (*e.g.*, Siberian seas) were not considered during the data collection phase and have not been included in the invasion pattern analyses.

Within these ecoregions, NIS were considered in the analysis if they were either established or potentially established (unknown) in at least one of the 22 ecoregions to ensure that NIS were not excluded solely based on limited data. The taxonomic scope includes fungi, protozoa, micro- and macro-algae, marine plants, fishes, and all macro-invertebrate groups. Bacteria, mammals, amphibians, and reptiles were not considered. Emergent marsh plants (other than *Spartina*) were not included, in part due to the difficulty in obtaining information on marsh species in Asia. Species that are primarily freshwater but have documented salinity tolerances and/or have been reported to occur in brackish waters were included, although freshwater species that only incidentally occur in low salinity regions were excluded. Primarily terrestrial species were excluded but species commonly found in the supralittoral and coastal zones were considered.

[1] http://worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas

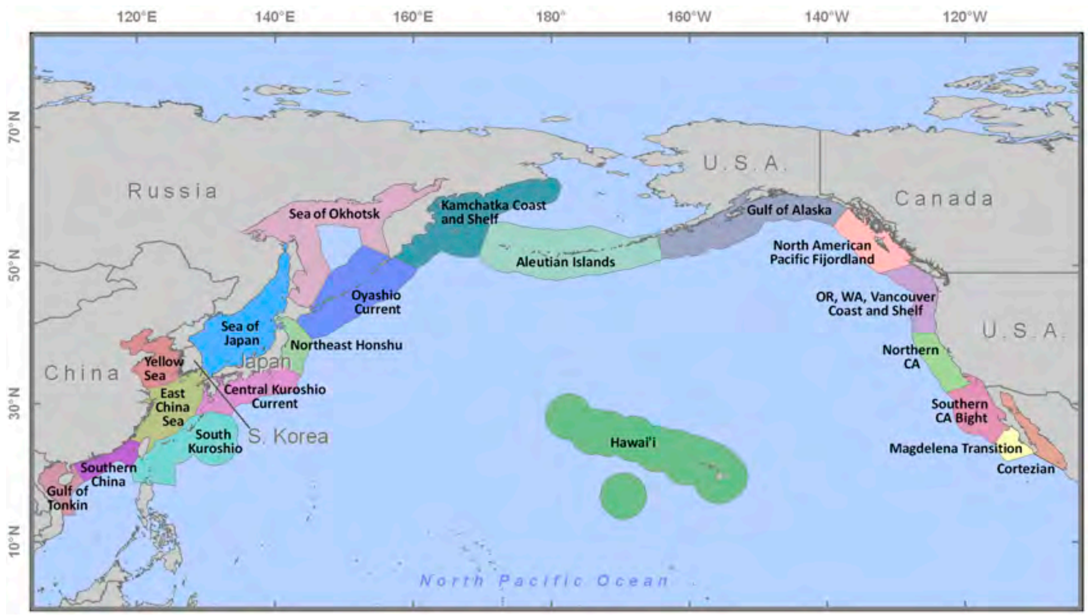

Fig. 3.1.1 Map of marine ecoregions associated with PICES member countries in the North Pacific. Two ecoregions, Ogasawara Islands and Puget Trough/Georgia Basin, are not shown. From Lee II and Reusser, 2012.

In addition to the species distribution and publication records, life history (*e.g.*, salinity, reproduction), invasion (*e.g.*, vector pathways), and habitat attributes were collected for each of the 747 established NIS in the North Pacific. The best way to view and access these data is from the generated species profiles compiled in the *Atlas* (https://www.pices.int/projects/default.aspx). For example, *Molgula manhattensis*, a solitary tunicate native to the Atlantic coast of North America has invaded both sides of the Pacific Ocean (Fig. 3.1.2). This NIS is a major component of fouling communities and can grow on cultured oysters and other bivalves, although it has not been reported to be a major aquaculture pest like other invasive tunicates.

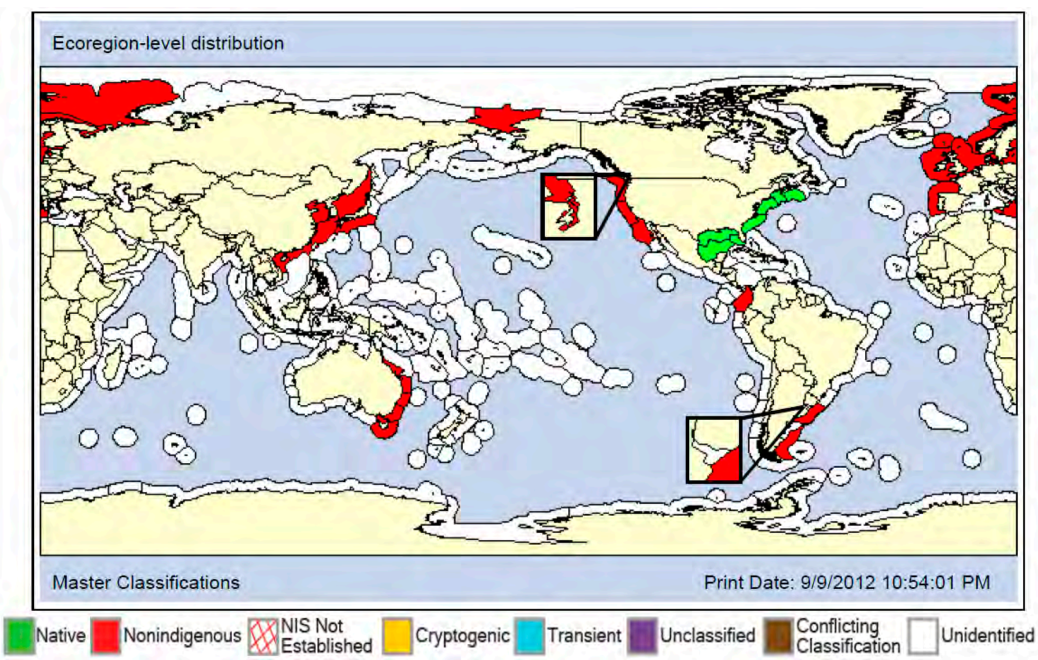

Fig. 3.1.2 Global distribution of *Molgula manhattensis*, a solitary tunicate indigenous to the Atlantic coast of North America. From Lee II and Reusser, 2012.

3.1.3 Species classifications

Within the NIS database species are assigned to six classifications – Native, Non-indigenous, Cryptogenic, Transient, Unknown, or Conflict – at any of the four biogeographic levels (realm to ecoregion). The following definitions were used for these classifications:

Native: An indigenous species that occurs naturally in the area.

Non-indigenous: A species that has been introduced into an area through human activities, whether accidently or on purpose. Other terms used include alien, aquatic nuisance species (ANS), exotic, introduced, non-native, adventive, and naturalized. Use of "invasive" was limited to NIS that have or are likely to cause adverse ecological, economic, or human health impacts.

Cryptogenic: Cryptogenic species are not clearly native or introduced based on current information. As originally defined, this term was to capture uncertainty regarding a species biogeography and invasion history. However, "cryptogenic" is used increasingly for species with taxonomic uncertainties, such as sibling or cryptic species. To avoid mixing uncertainty over invasion history *versus* taxonomic uncertainty, we restricted the use of cryptogenic to locations where there is some evidence for invasion. Cryptogenic species were not included in the counts of NIS for a location.

Unknown: A species is classified as unknown when there is insufficient information to make a judgment as to its classification status.

Transient: Transient species are those that temporarily migrate into an area as a result of unusual climatic conditions, such as El Niño. Their movement into the area is *via* natural mechanisms rather than mediated through human activities, and they were not included in the counts of NIS for a location. The terms "vagrant" or "migrant" have been used in a similar fashion.

Conflict: In some cases, invasion experts disagree as to whether a species is non-indigenous *versus* native or cryptogenic within a location. If the available information was insufficient to make a decision among the conflicting classifications, a term "conflict" is used. Using "conflict" over "cryptogenic" is to highlight the cases where at least some experts believe that there is sufficient information to consider a species introduced. "Conflict" species were included in the counts of NIS within a location.

3.1.4 Natural history attributes and species profiles

Natural history attributes of a species can assist in predicting the likelihood that it will invade an area and possible consequences if an invasion occurs. For example, salinity and depth ranges help define what habitats a species might invade, while trophic level can help define the type of impact an invader could have in a newly invaded ecosystem. An additional objective of the NIS database was to develop a hierarchical topology to organize different types of natural history attributes.

In the *Atlas* much of the information contained in the database is presented as "species' profiles". The profiles are generated using a standardized format for the information and are limited to two pages for each species. With a key to the profiles, a user readily can determine the class value or quantitative value for any of the attributes included without the need to use the database.

3.1.5 Caveats and updates

This is one of the few attempts made to synthesize a variety of data at a basin scale. It is not the final answer, particularly since the type and extent of data varied widely across taxa and geographical locations. By illustrating knowledge gaps in a standardized fashion, there is now a framework to promote finding missing information in the literature and/or collecting the data in the laboratory or field.

Existing literature was used to the extent possible to classify species as native or non-indigenous, but in many cases, decisions were made with limited information in locations scattered across the globe. As such, classifications should be taken as “hypotheses”, subject to further taxonomic, biogeographical, and genetic analysis. In many cases, if existing data were inadequate, the term “unclassified” was used as the default.

Another source of uncertainty is the population status of NIS. NIS with an “unknown” population status were included in counts of species within an ecoregion or region. Inclusion of species with an “unknown” population status may inflate the number of established NIS, and this issue arises more frequently with species in the NWP and NCIP rather than in the NEP and Hawaii, especially for aquaculture species.

3.1.6 Publications

The following journal articles have been published on the development and structure of the NIS database:

Lee II, H. and Reusser, D.A. 2012. Atlas of Nonindigenous Marine and Estuarine Species in the North Pacific. Office of Research and Development, National Health and Environmental Effects Research Laboratory, EPA/600/R/12/631.

Otani, M., Furota, T., Yokoyama, H. and Katoh, M. 2009. Development of database for marine nonindigenous species by PICES. *Bull. Plankton Soc. Japan* **56**: 183–189.

Reusser, D.A. and Lee, H. 2011. Evolution of natural history information in the 21st century – developing an integrated framework for biological and geographical data. *J. Biogeogr*. **38**: 1225–1239.

3.2 Geographic Invasion Patterns in the North Pacific

3.2.1 Total number of NIS in the North Pacific per taxonomic group and ecoregion

For the present analysis, a species is considered introduced at the region level if it is introduced in any of the ecoregions making up the region, even if it is native in another ecoregion within the same region. An analysis of the taxonomic composition of the 747 NIS reported from the 23 ecoregions in the North Pacific, Hawaii, and Northern Central-Indo Pacific and included in the database as of 2012, revealed that four phyla constituted more than 70% of the NIS (Fig. 3.2.1) – Arthropoda (224), Chordata (Tunicata + Fish) (114), Mollusca (110), and Annelida (89). The number of NIS per ecoregion is provided in Figure 3.2.2. More detailed taxonomic breakouts of geographic invasion patterns on the species level can be found in the *Atlas*.

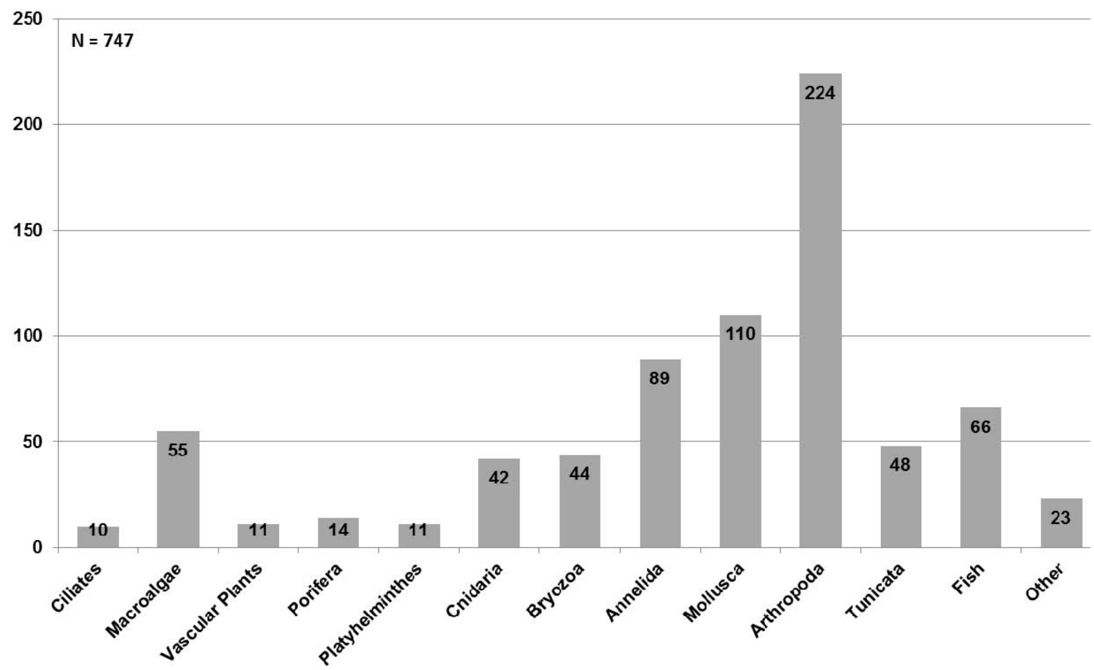

Fig. 3.2.1 Total number of non-indigenous species (NIS) in the North Pacific region and South China by taxa.

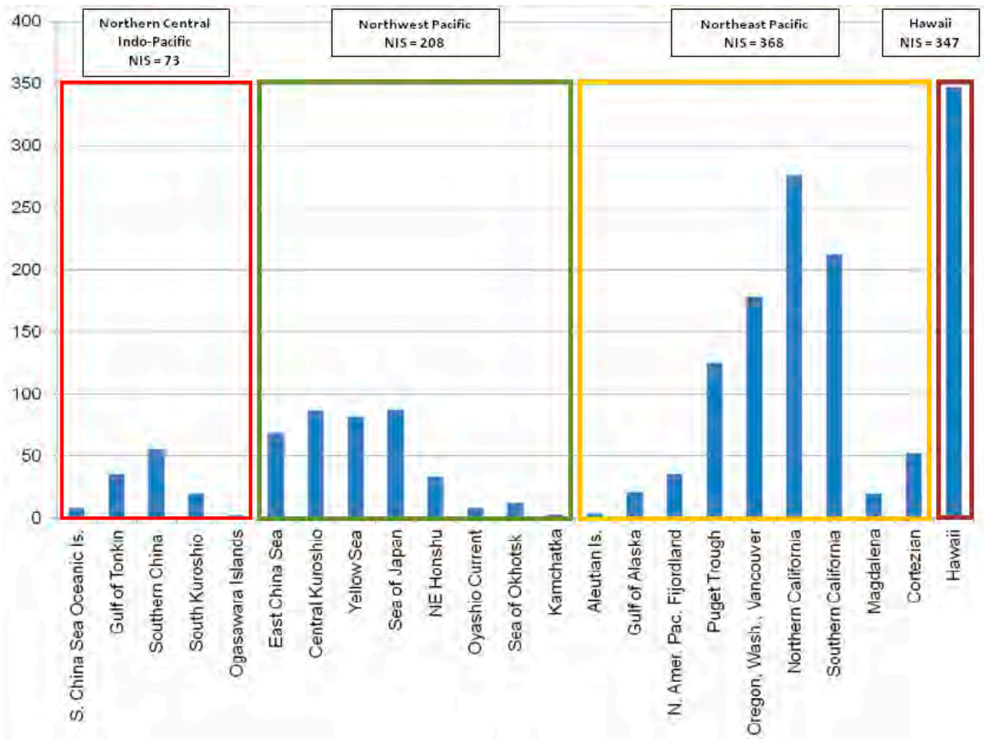

Fig. 3.2.2 Number of reported NIS by marine ecoregion in the central/northern North Pacific. Boxes around ecoregions identify major regions in the North Pacific and the northern portion of the Indo-Pacific in addition to the total number of NIS reported from these regions. From Lee II and Reusser, 2012a.

It should be noted that the number of NIS is quite large, and is likely to increase. Following the completion of the NIS database in 2012, it has not been updated. A common portal to add information, update the database and share information is missing. There were plans to make the database a web-based application, but it has not been realized to date.

3.2.2 Vectors

An evaluation of the major vectors by which NIS were transported to the NEP, Hawaii, and NWP was conducted (Fig. 3.2.3). Vectors analyzed here included ballast water discharges, hull fouling, intentional stocking, aquaculture escapees, aquaculture-associated species, and aquarium/plant trade. Aquaculture escapees are species that are intentionally stocked but that escaped into the wild. Aquaculture-associated species live on, or in association with, an aquaculture species and are accidently transported along with them (*i.e.*, hitchhikers). It is important to recognize that many, if not most, NIS are polyvectic and can be transported by more than one vector. Thus, the values in Figure 3.2.3 sum to more than 100%. Further, the primary introduction vector may differ from those contributing to spread at smaller spatial scales.

Hull fouling and ballast water were important vectors in all three locations (Fig. 3.2.3). One major difference among locations was the importance of intentional stocking and aquaculture escapees in the NWP compared to the NEP and Hawaii. The high percentage in the NWP reflects the active aquaculture efforts in Asia, although for many of these species it is not known if they have actually established wild populations in Asia. Another difference was the importance of aquaculture-associated species in the NEP, which accounted for approximately 42% of NIS. To a large extent this reflects the large number of NIS introduced *via* the importation of Atlantic oyster (*Crassostrea virginica*) from the U.S. East Coast and the Pacific oyster (*C. gigas*) from Asia. Though non-native oysters have been introduced into both the NWP and Hawaii, they do not appear to have been imported to same extent (volume/frequency) or way (adults with hitchhikers) as in the NEP.

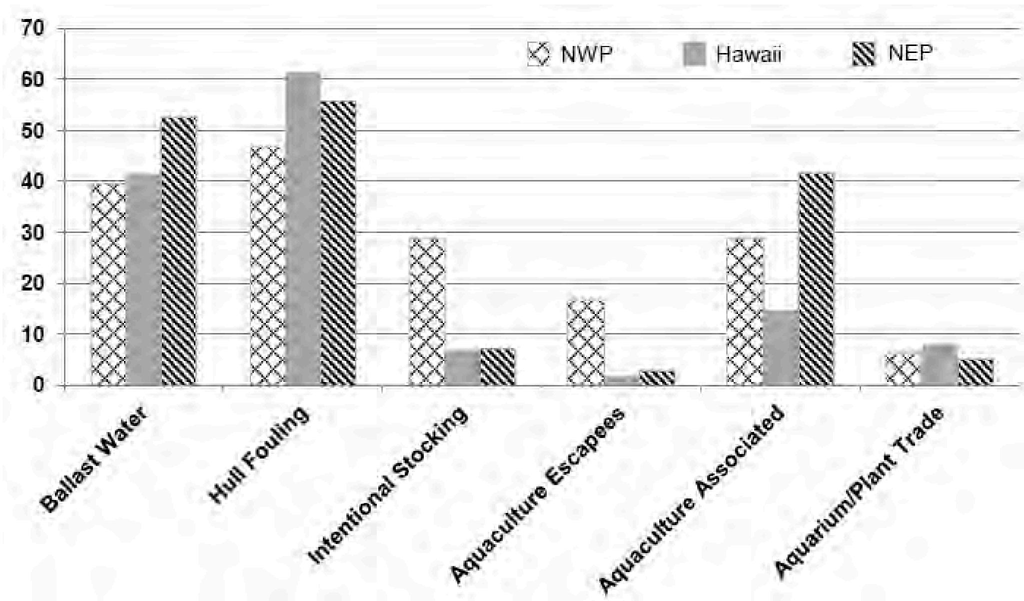

Fig. 3.2.3 Percentage of the total number of NIS within the Northwest Pacific (NWP), Hawaii, and Northeast Pacific (NEP) that were potentially transported by each of the six most important vectors. The North Central Indo-Pacific (NCIP) was not included in this analysis. Because species can be transported by multiple vectors, the sum within an ecoregion can exceed 100%.

3.2.3 NIS in the North Pacific – Analysis of the inter-regional transfer of species and comparisons with other regions

Introduction

The objective of a subsequent more in-depth analysis of the NIS database was to examine the transfer of aquatic species across the North Pacific *via* various vectors, and to compare the patterns found in the North Pacific with other oceanic regions. This analysis was based on the regions described in the *Atlas* (Fig. 3.2.4) but encompassed only NIS established in the NWP region, the NEP region, and the Hawaii ecoregion. Although the Hawaii ecoregion is part of the Eastern Indo-Pacific region, Hawaii is the only ecoregion in the EIP region that is part of the North Pacific. To enable comparisons where the native range of NIS includes both areas inside and outside the North Pacific, it is referred to as a separate "region" in the in-depth analysis for simplicity. The NCIP region, which includes five ecoregions in the northern Indo-Pacific was not included as it does not form a natural biogeographic entity (Lee II and Reusser, 2012a,b). Thus, in the in-depth analysis the "North Pacific" refers only to the NWP, the NEP, and Hawaii. The patterns found in the North Pacific were compared and contrasted to three other marine regions, the Northwest Atlantic (NWA), the Northeast Atlantic (NEA), and the Mediterranean using a combined dataset with information on aquatic NIS established in all six regions. The comparisons and contrasts were made for the following seven taxa: bivalves, amphipods, isopods, decapods, barnacles, tunicates, and ray-finned fishes as these tend to be well studied/documented taxa.

Another objective of the in-depth analysis was to examine the geographic origin of the NIS that have established in the North Pacific. However, as the introduction of species can be the result of primary introductions (from the species' native range) or secondary spread (from previously invaded sites where the species is non-native), the status as native/non-native in a given area is often associated with much uncertainty. Therefore, only information on the native range of a given NIS was included in the in-depth analysis. We recognize that species may have been introduced to and transferred within the North Pacific from sites where they are non-native, rather than introduced directly from areas where they are native (stepping stone invasions).

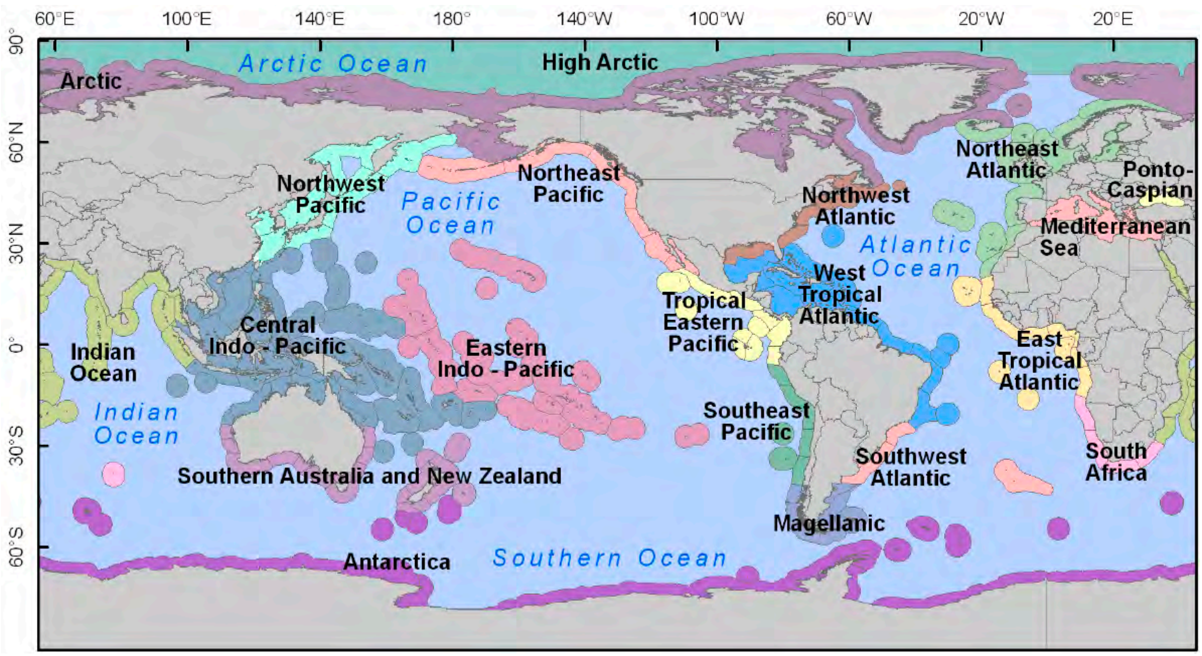

Fig. 3.2.4 Map of region divisions. From Lee II and Reusser, 2012a.

NIS in the North Pacific

Three categories of NIS were examined: a) species native to the North Pacific, b) species non-native to the North Pacific but identified as native to other regions in the world, and c) species non-native to the North Pacific but whose native range is unknown (henceforth referred to as "origin unknown"). In order to examine the transfer of those three categories of NIS across the North Pacific *via* various vectors, a series of questions was addressed:

Question 1. *What proportion of the NIS in the North Pacific has been identified as native vs. non-native to the North Pacific, and for what proportion is the origin unknown?*

Question 2. *What regions in the North Pacific represent donor vs. receiving regions for aquatic NIS in the North Pacific?*

Question 3. *How many of the species that are non-native to the North Pacific, or with origin unknown, have established a) in only one of the regions in the North Pacific, b) in two regions, or c) in all three regions?*

Question 4. *What is the geographic origin (i.e., region where native) of NIS that are non-native to the North Pacific?*

Question 5. *By which vectors have different taxa been introduced to different regions in the North Pacific?*

The answer to the first question aimed to provide a measure of the relative contribution of the three categories of NIS in the North Pacific to the total number of NIS. The analysis carried out to address the second question included only species native to at least one region in the North Pacific. Questions 3 and 4 focused on species that are non-native to the North Pacific, and aimed at assessing how widespread they are within the North Pacific and their geographic origin. The fifth question focused on the relationship between taxa and vectors, and aimed at exploring whether a specific taxon has been more frequently introduced to a specific region in the North Pacific by a specific vector.

Comparison with other regions

For the combined dataset, the following questions were addressed:

Question 6. *Are there differences between regions regarding the number of NIS established from different taxa?*

Question 7. *Are there differences between regions regarding the geographic origin (i.e., region where native) of NIS from different taxonomic groups?*

Question 8. *In the North Atlantic, which region is a donor vs. receiving region for various taxa?*

Question 9. *Are there differences between regions regarding the vector responsible for introducing different taxa?*

Methods

Dataset

In order to answer questions 1 to 5, data on population status and native range of NIS in the North Pacific and their associated vectors from the NIS database were extracted (Lee II and Reusser, 2012b) using the same criteria as for the vector analysis described in the *Atlas* (Figs. 25–60, Lee II and Reusser, 2012a). Only species identified as NIS in at least one of the three regions in the North Pacific were included in the dataset. Species recorded as "cryptogenic" (*i.e*., species that are not clearly native or introduced based on current information) or "transient", or "unclassified" (*i.e*., there was insufficient information to make a judgment as to its origin) in a given region were not included in the count of NIS in that region. Note that a species that has been identified as NIS in one region can be cryptogenic, transient or unclassified in another region. Note also that a given species can be non-native to a region where it is also native; this occurs when a species native to one ecoregion has established in another ecoregion where it is non-native. The regions where species were recorded as native were identified from the maps in the NIS database. While the Hawaii ecoregion is part of the Eastern Indo-Pacific (EIP) region, Hawaii is the only ecoregion in the EIP region that is part of the North Pacific. To enable a comparison of the native range of NIS native to areas inside and outside the North Pacific, Hawaii was considered a separate "region" in this analysis.

In order to answer questions 6 to 9, a combined dataset with information on NIS established in the North Pacific, the NWA, the NEA, and the Mediterranean was compiled from a range of sources. In addition to the previously exported data from the NIS database (Lee II and Reusser, 2012b), the combined dataset included information from other sources in the published literature (Galil, 2009; Gollasch *et al.,* 2009; Gollasch *et al*., in prep.; Ruiz *et al*., 2000; Streftiaris *et al*., 2005; Zenetos *et al*., 2010) and online databases (the National Exotic Marine and Estuarine Species Information System (Fofonoff *et al*., 2003), the Baltic Sea Alien Species Database (2007), the CIESM database (The Mediterranean Science Commission, 2002), DAISIE (2008), the National Introduced Marine Pest Information System (NIMPIS, 2009), FishBase (Froese and Pauly, 2013), SeaLifeBase (Palomares and Pauly, 2013)) as well as data from the NIS database for the three regions in the North Atlantic. We recognize that the compiled dataset may differ in the degree of completeness for different taxa and regions, especially regarding the number of NIS in the NWA which is based on the species included in the NIS database and the publication by Ruiz *et al*. (2000). The native region of the species not included in the NIS database was assessed by comparing different sources of information where available.

NIS in the North Pacific

The dataset for the North Pacific was divided into three categories: a) species native to the North Pacific, b) species identified as native to regions outside of the North Pacific, and c) species of unknown origin. The number of NIS in the three regions was compared and contrasted, and the major donor regions of NIS were identified. The six most important vectors responsible for the introduction of NIS to the North Pacific, as identified in the *Atlas* (*i.e*., ballast water, hull fouling, intentional stocking/release, aquaculture escapees, aquaculture associated, and aquarium/plant trade) were compared for the following taxonomic groups (following the *Atlas*): Cilipohora; Phaeophyceae; Phylum Biliphyta – Rhodophyta; Phylum Viridaeplantae – Chlorophyta; Phylum Magnoliophyta; Phylum Porifera; Phylum Platyhelminthes, Phylum Cnidaria – Anthozoa, Hydrozoa, and Scyphozoa; Phylum Bryozoa; Phylum Annelida – Clitellata and Polychaeta; Phylum Mollusca – Bivalvia and Gastropoda; Phylum Arthropoda, Amphipoda, Isopoda, Musida, Decapoda, Copepoda, Cirripeda, Pycnogonida, and Insecta; and Phylum Chordata – Tunicata and Actinopterygii. As these taxonomic groups (subphylum/class/subclass) which make up the larger taxonomic groups Macroalgae, Phylum Cnidaria, Phylum Annelida, Phylum Mollusca, Phylum Arthropoda, Phylum Chordata, often show different patterns regarding the vector responsible for their introduction, the results for these larger taxonomic groups were not included (as it would not be very informative).

Comparison with other regions

The comparison of the North Pacific with other regions was done for the following taxonomic groups: Mollusca – Bivalvia; Arthropoda – Cirripeda, Amphipoda, Ispopda, and Decapoda; and Chordata – Tunicata and Actinopterygii. Here, the total number of NIS per region per taxon was compared and contrasted. For each taxon, the native range of the NIS in each region was compared. While the NIS database includes finer scale information on vectors (*e.g*., ballast water and hull fouling are sub-categories of "shipping"; aquaculture associated, intentional stocking/release, aquaculture escapees, aquaculture associated are sub-categories of "fishery"), other data sources often indicated only broader categories of vectors such as "shipping" and "fishery". In the comparison with other regions, only broader categories of vectors responsible for introduction of NIS were compared for the six regions: shipping (including both hull fouling and ballast water), fishery (including intentional stocking/release, aquaculture escapees, aquaculture associated), shipping and fishery (a species has been introduced *via* both shipping and fishery), other vectors (neither shipping nor fishery, *e.g*., ornamental trade or canals), vector unknown. Note that the category "other vectors" represents species transferred exclusively *via* vectors other than shipping or fishery, but that many of the species included in the categories shipping, fishery, and shipping and fishery may have been introduced/transferred also *via* other vectors. While the NIS database listed both actual and potential vectors, other sources of information often listed only the actual vector responsible for the introduction. The information on vectors from sources other than the NIS database may therefore underestimate the importance of a specific vector for a given species.

Results

NIS in the North Pacific

Number of NIS in the different regions in the North Pacific and their native range

A total of 746 species were included in the analysis (Table 3.2.1). Of these, 238 species (or 31.9%) were identified as native to the North Pacific, 358 species (or 48.0%) were identified as native to regions outside the North Pacific, and 150 species (or 20.1%) were of unknown origin.

Of the 238 species native to the North Pacific, the majority (163 or 68.5%) were native to the NWP, while 63 species (or 26.5%) were native to the NEP. Only 3 species (1.3%) were native to Hawaii. Eight species (3.4%) were native to more than two regions, while only 1 species (0.4%) was native to all three regions. This latter species is the brown algae *Desmarestia ligulata*, which is native to the northernmost ecoregion in the NWP but has established non-native populations in the Yellow Sea.

Table 3.2.1 Number of NIS in the North Pacific according to the geographic origin of NIS and region where these species have established or establishment status is unknown.

Native to North Pacific	**Region where native**	**# sp.**	**Region where NIS**	**# sp.**
Native to 1 region	NWP	163	NWP	22
			NWP & NEP	4
			NEP	91
			Hawaii	32
			NEP & Hawaii	12
			All 3 regions	2
	Hawaii	3	Hawaii	1
			NWP	2
	NEP	63	NEP	6
			NEP & NWP	2
			NWP	15
			Hawaii	35
			NEP & Hawaii	1
			NWP & Hawaii	4
Native to >1 region	NWP & NEP	8	NWP & Hawaii	1
			NWP	2
			NEP	4
			Hawaii	1
	All 3 regions	1	NWP	1
			TOTAL native to North Pacific:	*238*
Non-native to North Pacific			**Region where NIS**	**# sp.**
Established in 1 region			NWP	54
			Hawaii	118
			NEP	85
Established in >1 region			NWP & NEP	43
			NWP & Hawaii	7
			NEP & Hawaii	22
			All 3 regions	29
			TOTAL non-native to North Pacific with known origin:	*358*
Origin unknown			**Region where NIS**	**# sp.**
Established in 1 region			NWP	14
			Hawaii	67
			NEP	51
Established in >1 region			NWP & NEP	3
			NWP & Hawaii	2
			NEP & Hawaii	10
			All 3 regions	3
			TOTAL non-native to North Pacific with unknown origin:	*150*
			TOTAL NIS	**746**

NWP = Northwest Pacific, NEP = Northeast Pacific

In the NWP, with a total of 210 NIS, 55 species (or 26.2%) are native to the North Pacific (Table 3.2.2). The majority of the NIS in this region (133 species or 63.3%) are non-native to the North Pacific, while 22 species (or 10.5%) are of unknown origin. Of the species native to the North Pacific that are NIS in the NWP, the majority are native to this region (32 species or 58.2%; this includes the species that are native to the NWP only, the NWP and the NEP, and all three regions), while 21 species (or 38.2%) are native to the NEP only (Table 3.2.2). A larger number of the NIS in the NWP are native to the NWP than the number native to the NEP.

Table 3.2.2 Number of NIS in the three North Pacific regions and their geographic origin.

	Area where NIS		
Area where native	**NWP**	**Hawaii**	**NEP**
NWP only	28	46	109
Hawaii only	2	1	0
NEP only	21	40	9
NWP and NEP	3	2	4
All three regions	1	0	0
TOTAL native to the North Pacific	*55*	*89*	*122*
Non-native to the N Pacific	133	176	179
Origin unknown	22	82	67
TOTAL per region	*210*	*347*	*368*

In Hawaii, with a total of 347 NIS, 89 species (or 25.6%) are native to the North Pacific. As in the NWP and the NEP, the majority of the NIS (176 species or 50.7%) are non-native to the North Pacific, while 82 species (or 23.6%) are of unknown origin. Of the species native the North Pacific that are NIS in Hawaii, the majority are native to the NWP only (46 species or 51.7%) while 40 species (or 44.9%) are native to the NEP only. Only 1 species (or 1.1%) is native to Hawaii.

In the NEP, with a total of 368 NIS, 122 species (or 33.2%) are native to the North Pacific. The majority of the NIS in this region (179 species or 48.6%) are non-native to the North Pacific, while 67 species (or 18.2%) are of unknown origin. Of the species native to the North Pacific that are NIS in the NEP, the majority are native to the NWP only (109 species or 89.3%), while 13 species (or 10.7%) are native to the NEP (this includes the species that are native to the NEP only, the NWP and the NEP, and all three regions)**.**

The majority of the NIS in all three regions are non-native to the North Pacific. Of the species native to the North Pacific that have been identified as NIS in the North Pacific, the majority of the NIS in all three regions are native to the NWP. Thus, the NWP is a major source region for NIS not only to the NEP and Hawaii, but also to the NWP. This is a result of the transfer of species within the NWP region to ecoregions where they are not native. However, relatively few of the NIS in the NEP and Hawaii are native to these same regions. The NEP is an important source region for NIS to the NWP and Hawaii, while relatively few NIS native to Hawaii have established in the NWP and NEP.

Geographic origin of the NIS non-native to the North Pacific

Of the species non-native to the North Pacific (Table 3.2.1), the majority (257 species or 71.8%) had established in only one region, 72 species (20.1%) had established in two regions, and 29 (7.8%) had established in all three regions.

Of the species with unknown origin, the majority (132 species or 88.0%) had established in only one region, 15 species (10.0%) had established in two regions, and 3 species (2.0%) had established in all three regions.

In the NWP, the NW Atlantic and the NE Atlantic are the two dominating source regions, with 50 species (or 37.6%) and 51 species (or 38.3%) of the NIS non-native to the North Pacific being native to these regions (Fig. 3.2.5). Two other regions appear as important source regions: the W Tropical Atlantic and the Mediterranean, each with 38 native species (28.6%) being NIS in the North Pacific. Although the NWP is neighbouring the Central Indo-Pacific, with 14 NIS in the NWP being native to both regions, the Central Indo-Pacific does not appear as an important source region for NIS to the NWP. Only 16 species native to the Central Indo-Pacific (but non-native the NWP) have established in the NWP. (This could be a result of under reporting).

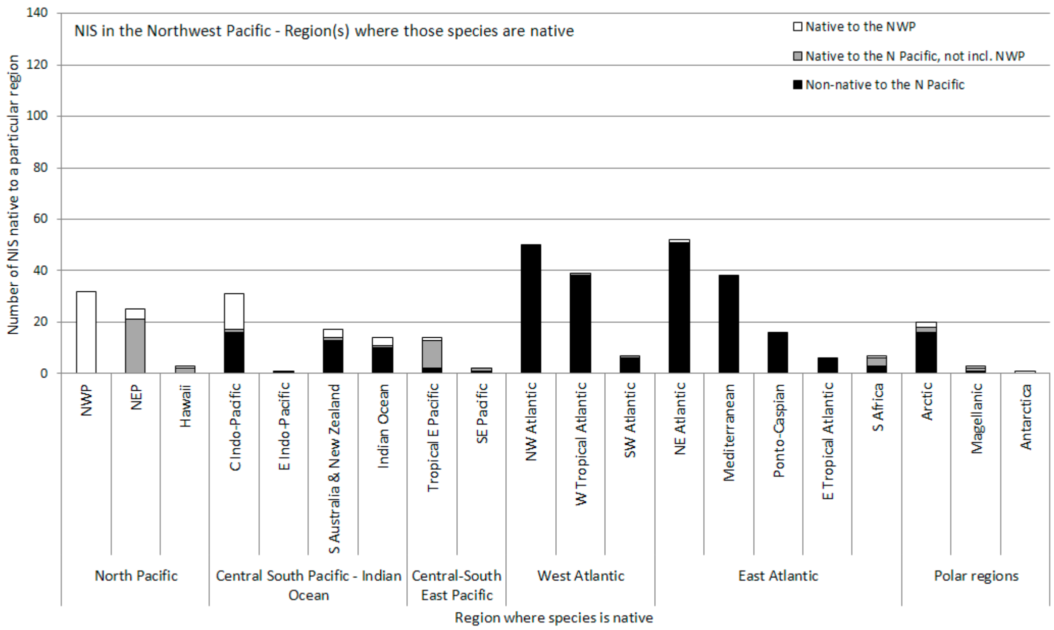

Fig. 3.2.5 Regions where the NIS in the Northwest Pacific (NWP) are native. The graph shows three categories of NIS: Those native to the NWP, those native to the other two regions in the North Pacific, and those non-native to the North Pacific. Many species are native to more than one region, and the sum of the number of species native to the different regions is therefore, larger than the total number of NIS in the NWP. The graph illustrates the geographic extent of the native range of the NIS in the NWP, *e.g.*, many of the species native to the NWP are also native to the Central Indo-Pacific, while many of the species native to the NEP are also native to the Tropical Eastern Pacific.

In Hawaii, the Central Indo-Pacific is the most important source region for NIS, with only one species being native to both regions. However, many of the NIS native to the Central Indo-Pacific are also native to the NWP and/or the NEP, which are also important source regions. Other important source regions are the Indian Ocean, the W Tropical Atlantic, and the NW Atlantic (Fig. 3.2.6).

In the NEP, the NWP appears as the largest source region, with 113 species native to the NWP having established in the NEP. Of the species non-native to the North Pacific, the majority of the NIS are native to the NW Atlantic (99 species or 55.3%). Three other regions appear as important source regions: the W Tropical Atlantic (36.3%), the NE Atlantic (32.4%), and the Mediterranean (21.2%) (Fig. 3.2.7).

Thus, the four most important source regions for NIS to the NWP and NEP from regions outside the North Pacific are the same. They are all in the North Atlantic, but their order of importance is different in the NWP and the NEP. For NIS in Hawaii, the Central Indo-Pacific and the Indian Ocean appear to be more important source regions. The NE Atlantic and the Mediterranean, both important source regions for NIS in the NWP and NEP, are less important as source regions for NIS in Hawaii.

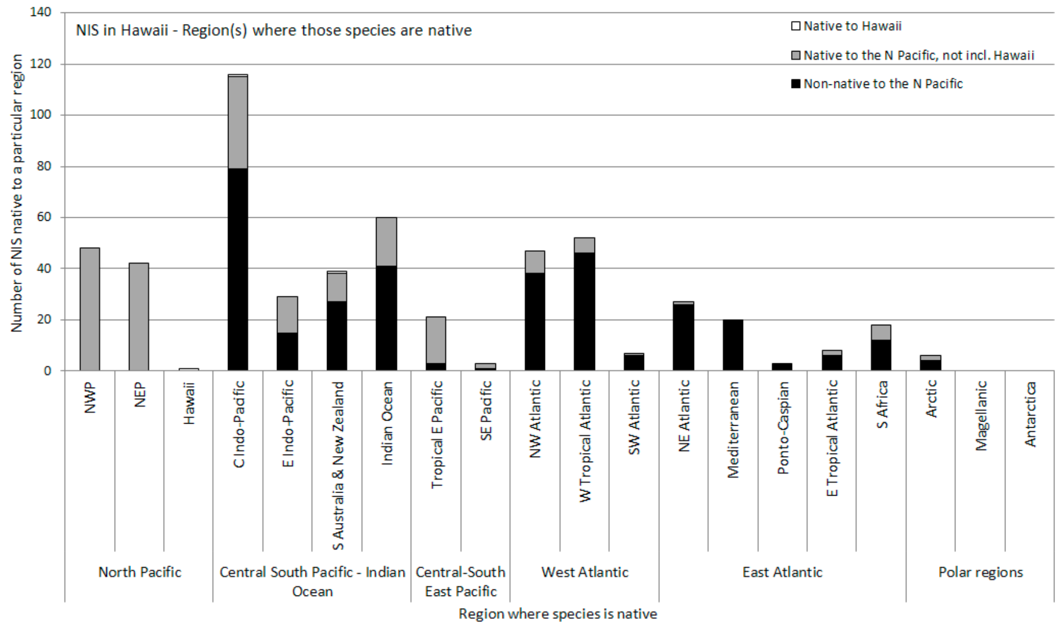

Fig. 3.2.6 Regions where the NIS in Hawaii are native. The graph shows three categories of NIS: Those native to Hawaii, those native to the other two regions in the North Pacific, and those non-native to the North Pacific. Many species are native to more than one region, and the sum of the number of species native to the different regions is therefore, larger than the total number of NIS in the Hawaii. The graph illustrates the geographic extent of the native range of the NIS in Hawaii, *e.g.*, the NIS in Hawaii are dominated by species native to the Central Indo-Pacific, many of which are also native to the NWP and the NEP.

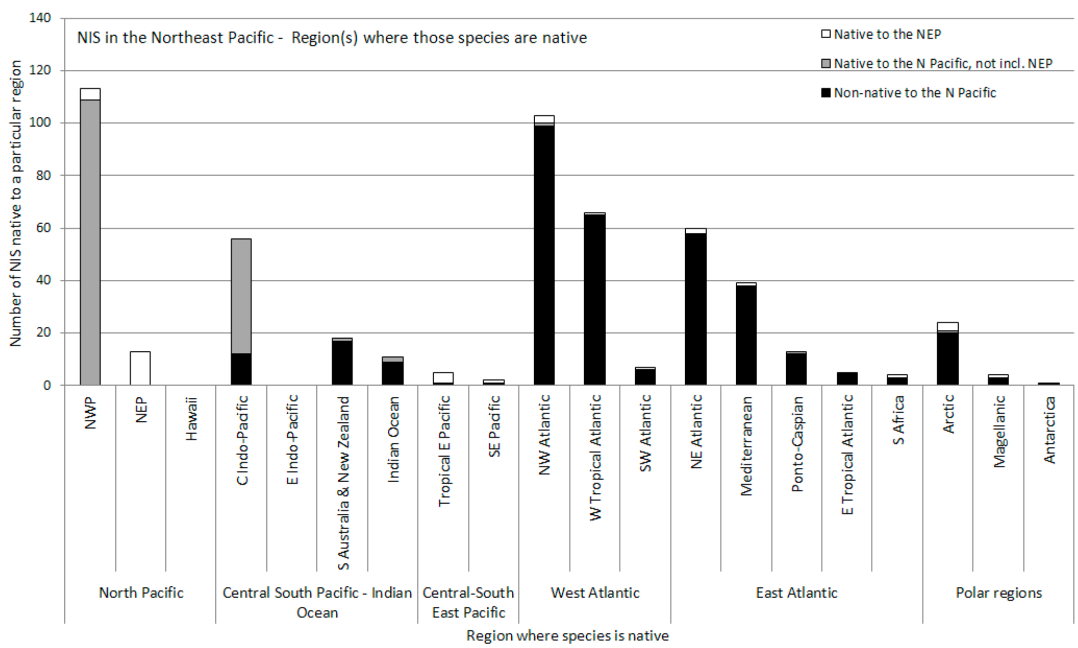

Fig. 3.2.7 Regions where the NIS in the Northeast Pacific (NEP) are native. The graph shows three categories of NIS: Those native to the NEP, those native to the other two regions in the North Pacific, and those non-native to the North Pacific. Many species are native to more than one region, and the sum of the number of species native to the different regions is therefore, larger than the total number of NIS in the NEP. The graph illustrates the geographic extent of the native range of the NIS in the NEP, *e.g.*, many of the NIS in the NEP are native to the NWP as well as the Central Indo-Pacific.

Vectors responsible for the introduction of NIS in the North Pacific

Of all the NIS in the North Pacific, 87.9% are transferred by the six most important vectors (listed in Fig. 60 in the *Atlas;* Lee II and Reusser, 2012a; Table 3.2.3). Note that one species can be introduced by multiple vectors, and the sum of the number of species in a given taxon transferred by individual vectors (see Fig. 3.2.8) can therefore be larger than the total number of species transferred by all those vectors together.[2] The six most important vectors account for the transfer of ≥80% of the NIS from most taxonomic groups, with the exception of brown algae, Magnoliophyta, Isopoda, and Insecta (Table 3.2.3 and Fig. 3.2.8). For Clitellata, solid ballast is also an important vector (accounting for 71.4% of the introductions). For Magnoliophyta, habitat restoration is an important vector (accounting for 63.6% of the introductions). For the insects, no vector of introduction is known for 46.7% of the species.

Most taxonomic groups follow similar patterns regarding the vectors that are responsible for their introduction. However, bivalves show differences between regions, with hull fouling being a more important vector in Hawaii than the NWP and NEP (Fig. 3.2.8n). For decapods, intentional stocking appears to be a more important vector in NWP than in the other regions (Fig. 3.2.8s). For ray-finned fishes, intentional stocking and aquaculture escapees are more important vectors for introduction in the NWP than in Hawaii and the NEP (Fig. 3.2.8y).

[2] Example: Of the 26 species of Rhodophyta transferred by the six most important vectors, 11 are transferred via ballast water, 20 via hull fouling, 7 via intentional stocking/release, and 14 via aquaculture associated.

Table 3.2.3 Number of NIS from different taxonomic groups in the North Pacific and associated regions transferred by the six major vectors: ballast water, hull fouling, intentional stocking/release, aquaculture escapees, aquaculture associated, and aquarium/plant trade. Where there are differences between the number of NIS spread by the six major vectors and the total number of NIS, vectors other than the six major vectors are important, or the vector is unknown.

	North Pacific			NWP			Hawaii			NEP		
	# NIS spread by 6 major vectors	Total # NIS	% species transferred by major vectors	# NIS spread by 6 major vectors	Total # NIS	% species transferred by major vectors	# NIS spread by 6 major vectors	Total # NIS	% NIS transferred by major vectors	# NIS spread by 6 major vectors	Total # NIS	% species transferred by major vectors
Ciliophora	10	10	100.0	1	1	100.0	2	2	100.0	9	9	100.0
Macroalgae (All)	46	55	83.6	17	19	89.5	13	15	86.7	27	32	84.4
Phaeophyceae	11	17	64.7	7	9	77.8	2	3	66.7	6	9	66.7
Biliphyta-Rhodophyta	26	28	92.9	6	6	100.0	9	9	100.0	18	20	90.0
Viridaeplantae-Chlorophyta	9	10	90.0	4	4	100.0	2	3	66.7	3	3	100.0
Magnoliophyta	3	11	27.3	0	3	0.0	2	4	50.0	2	8	25.0
Porifera	14	14	100.0	1	1	100.0	9	9	100.0	6	6	100.0
Platyhelmintes	11	11	100.0	3	3	100.0	5	5	100.0	5	5	100.0
Cnidaria (All)	40	42	95.2	13	15	86.7	20	20	100.0	25	25	100.0
Anthozoa	9	11	81.8	2	4	50.0	5	5	100.0	6	6	100.0
Hydrozoa	24	24	100.0	11	11	100.0	9	9	100.0	17	17	100.0
Scyphozoa	6	6	100.0	0	0	–	5	5	100.0	2	2	100.0
Bryozoa	42	44	95.5	14	14	100.0	22	22	100.0	24	26	92.3
Annelida (All)	76	89	85.4	16	17	94.1	41	47	87.2	43	49	87.8
Clitellata	6	7	85.7	1	1	100.0	0	0	–	6	7	85.7
Polychaeta	69	81	85.2	15	16	93.8	40	46	87.0	36	41	87.8
Mollusca (All)	107	110	97.3	38	41	92.7	41	41	100.0	50	50	100.0
Bivalvia	52	53	98.1	20	21	95.2	22	22	100.0	22	22	100.0
Gastropoda	55	57	96.5	18	20	90.0	19	19	100.0	28	28	100.0
Arthropoda (All)	177	223	79.4	40	43	93.0	80	116	69.0	94	102	92.2
Amphipoda	45	50	90.0	6	7	85.7	20	20	100.0	33	37	89.2
Isopoda	27	34	79.4	4	4	100.0	15	21	71.4	19	20	95.0
Mysida	6	6	100.0	0	0	–	1	1	100.0	5	5	100.0
Decapoda	27	28	96.4	15	16	93.8	10	10	100.0	5	5	100.0
Copepoda	21	22	95.5	3	3	100.0	2	3	66.7	18	18	100.0
Cirripeda	14	14	100.0	11	11	100.0	4	4	100.0	5	5	100.0
Pycnogonida	12	12	100.0	1	1	100.0	12	12	100.0	0	0	–
Insecta	13	45	28.9	0	1	0.0	11	40	27.5	2	5	40.0
Chordata (All)	111	114	97.4	44	44	100.0	55	57	96.5	47	48	97.9
Tunicata	47	48	97.9	10	10	100.0	29	29	100.0	22	23	95.7
Actinopterygii	64	66	97.0	34	34	100.0	26	28	92.9	25	25	100.0
Other	19	23	82.6	9	9	100.0	7	9	77.8	6	8	75.0
TOTAL	656	746	87.9	196	210	93.3	297	347	85.6	338	368	91.8

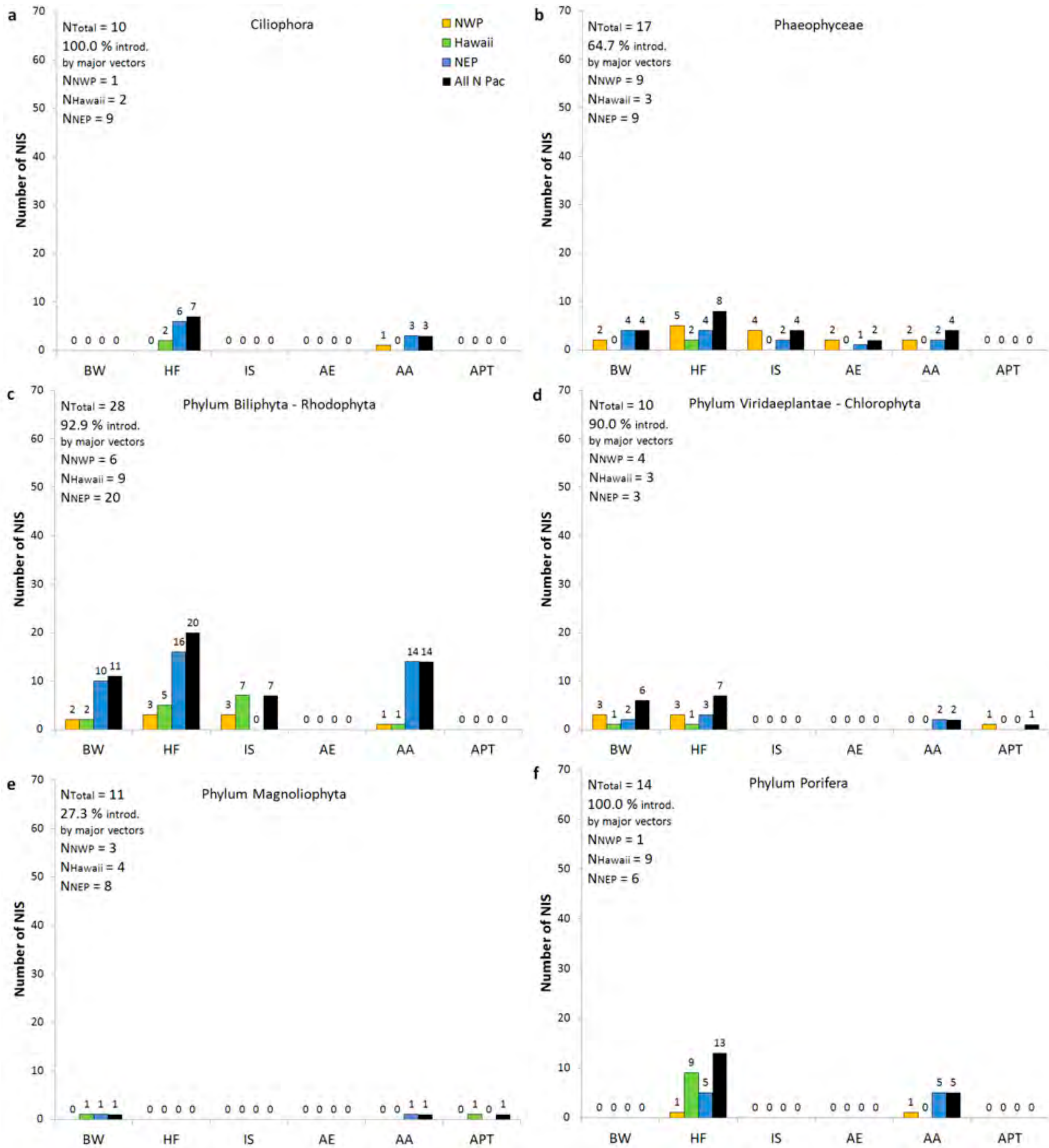

Fig. 3.2.8 (a–f) The number of species of different taxonomic groups transferred by the six most important vectors: ballast water (BW), hull fouling (HF) intentional stocking/release (IS), aquaculture escapees (AE), aquaculture associated (AA), and aquarium/plant trade (APT). The numbers in the plots indicate the total number of NIS in each region, while the numbers above the bars indicate the number of NIS transferred by the different vectors. The % indicates the % of the total number of species transferred by the six most important vectors.

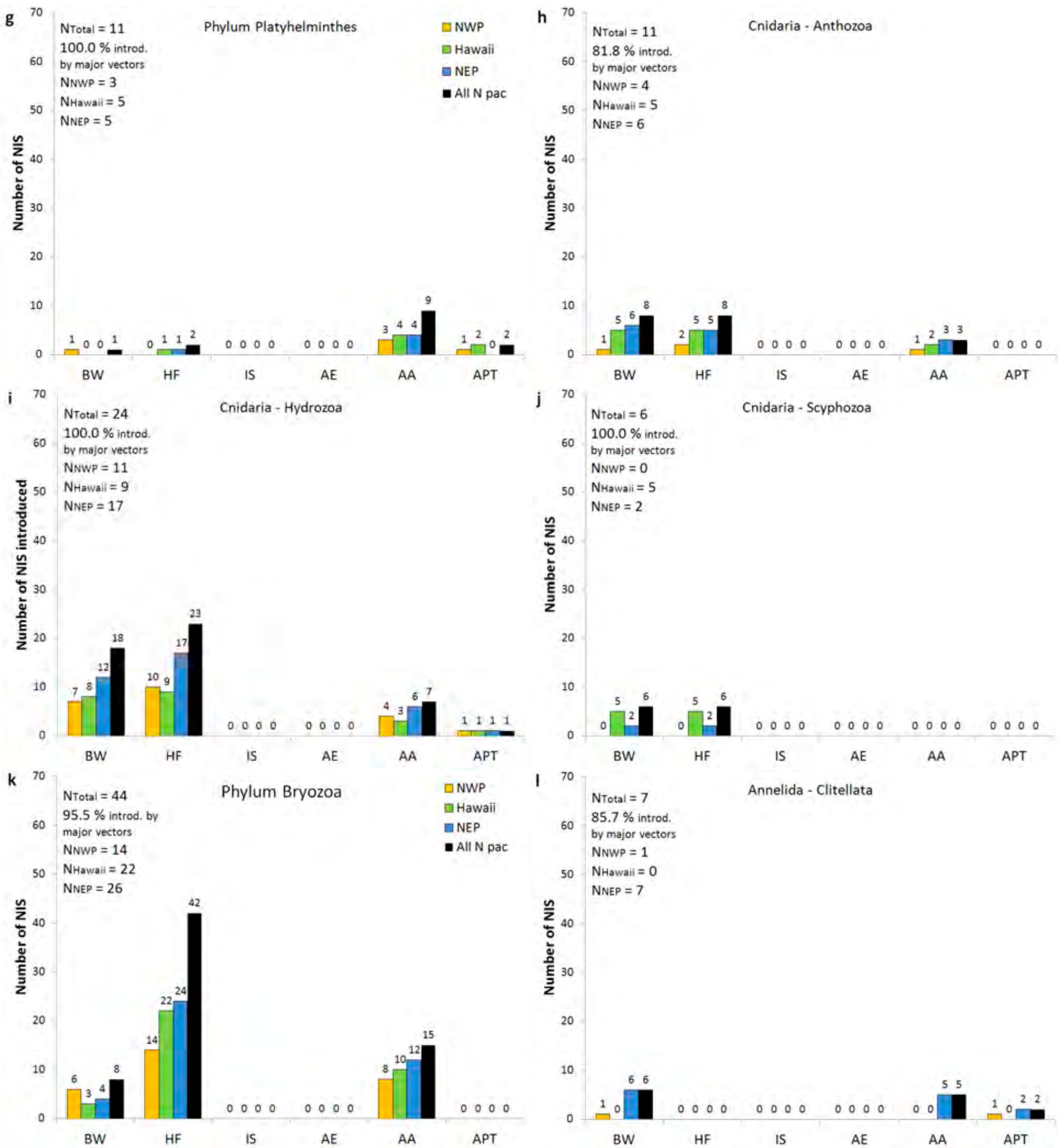

Fig. 3.2.8 (g–l) Continued.

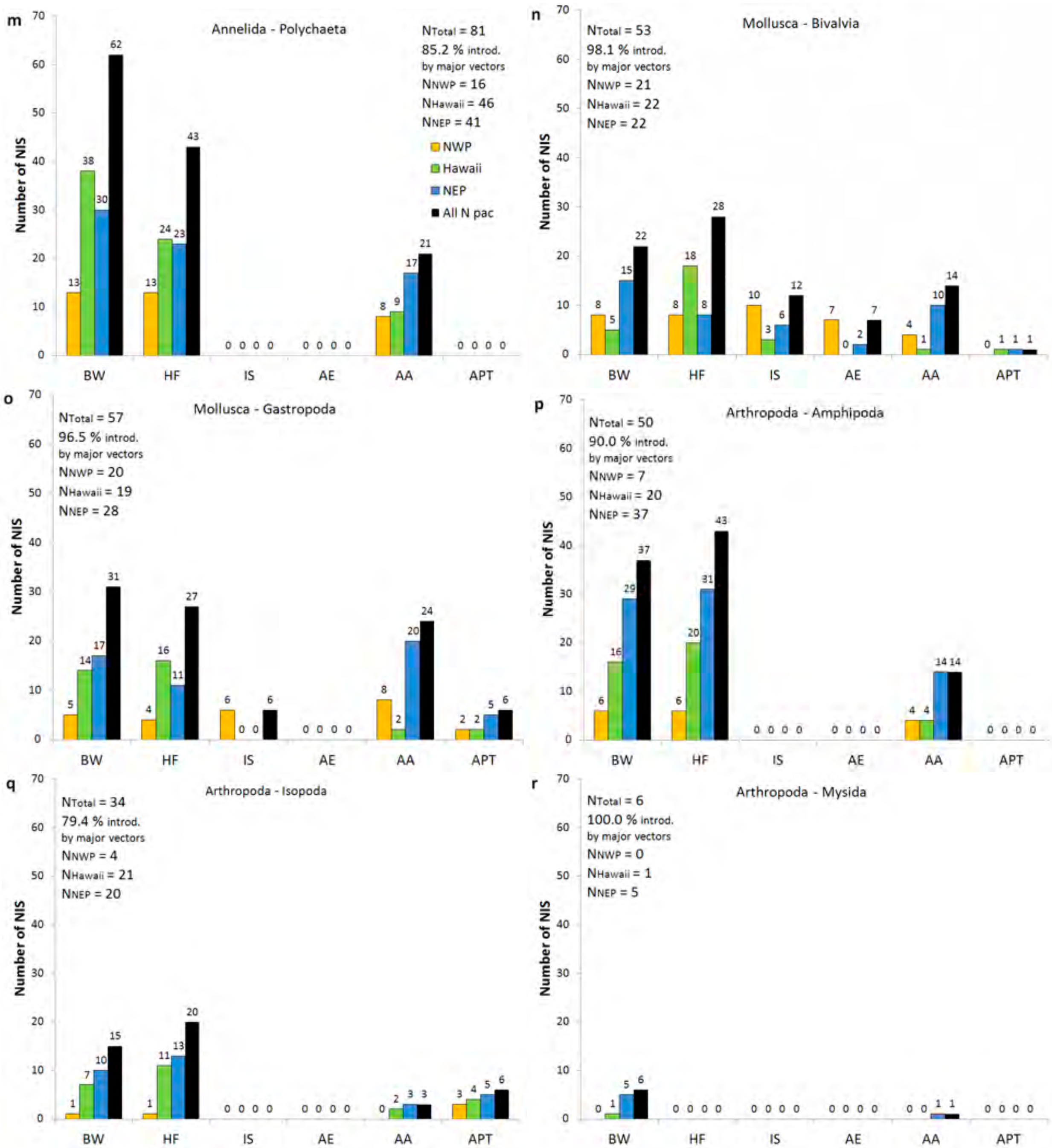

Fig. 3.2.8 (m–r) Continued.

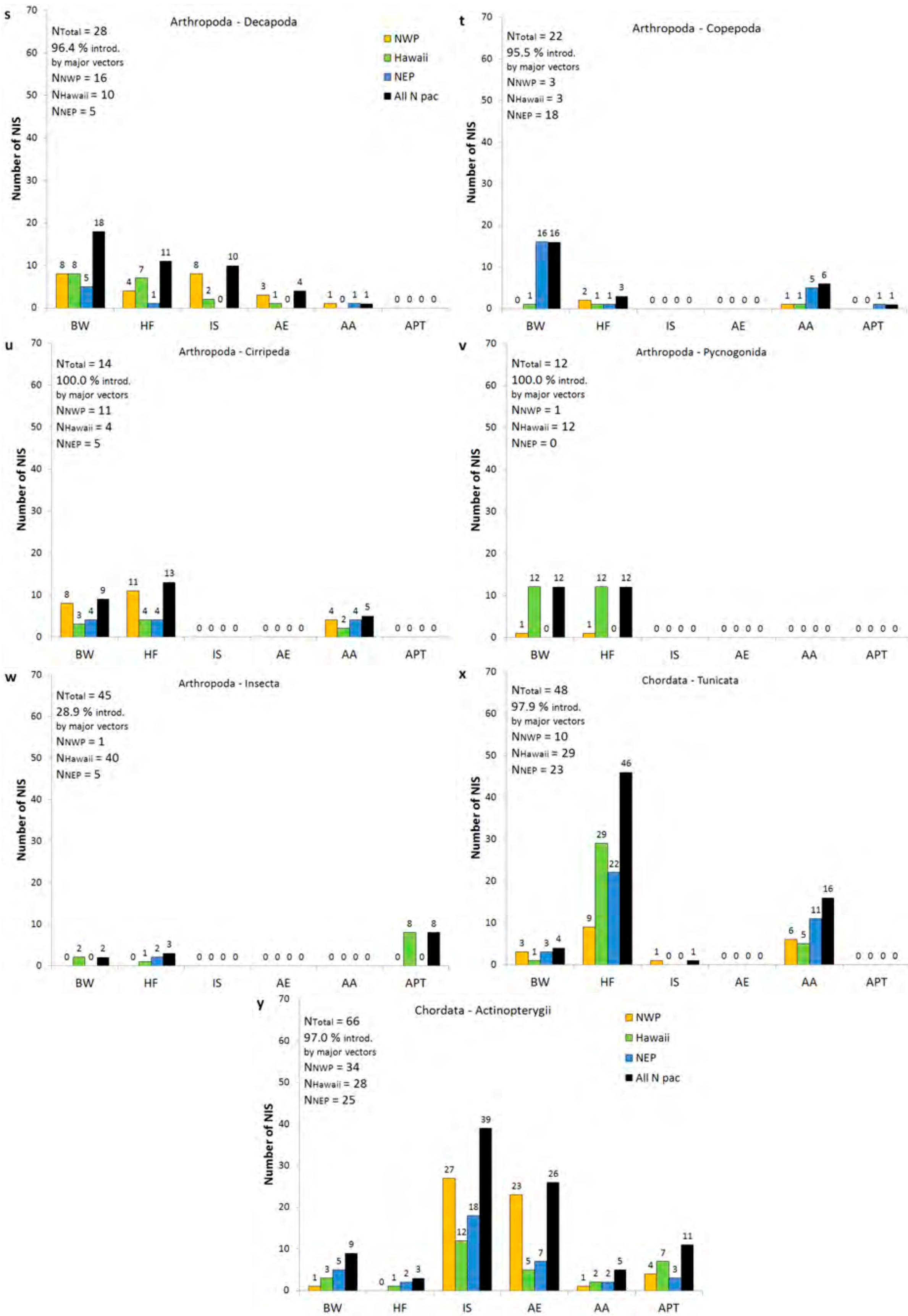

Fig. 3.2.8 (s–y) Continued.

Comparisons with other regions

Number of NIS from seven major taxonomic groups and their geographic origin

The Mediterranean had the highest total number of NIS from the seven taxonomic groups (318 species), followed by the NEP (137 species), Hawaii (134 species), the NWP (105 species), and the NEA (84 species). The NWA had the lowest number of NIS (71 species) (Fig. 3.2.9).

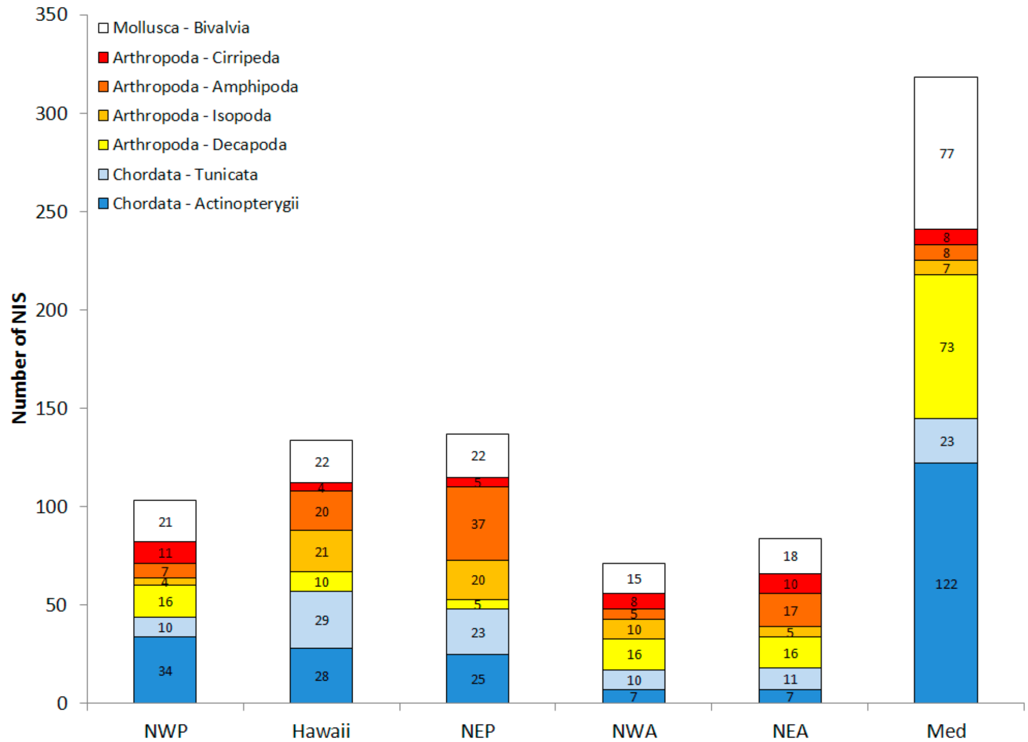

Fig. 3.2.9 Total number of NIS from seven taxonomic groups in the regions in the North Pacific and the North Atlantic.

A) Bivalves

The highest number of non-native bivalve species was recorded in the Mediterranean (77 species), more than three times that of any other region, with the Indian Ocean being the major donor region (Appendix 3, Table A3.1). Hawaii and the NEP both had 22 non-native bivalve species, and the NWP had 21, with the Central Indo-Pacific being a major donor region of species to Hawaii, and the NWP and the Central Indo-Pacific being major donor regions of species to the NEP. The NEA and the NWA had the lowest number of non-native bivalve species (18 and 15 species, respectively). A higher number of bivalve species native to the NWA had established in the NEA (6 species) and the Mediterranean (5 species) than *vice versa* (2 species native to the NEA, one of these also native to the Mediterranean, had established in the NWA).

B) Amphipods

The highest number of non-native amphipod species was recorded in the NEP (37 species), with the NWP and the NWA being the major donor regions (11 species each) and many amphipod species of unknown origin (Appendix 3, Table A3.2). Hawaii had 20 species of non-native amphipod species, the NEA 17 species. Few non-native amphipod species were found in the Mediterranean (8 species), the NWP (7 species) and the NWA (5 species). Two amphipod species native to the NWA had established in the NEA, while one species from the NEA and one species from the Mediterranean had established in the NWA.

C) Isopods

The highest number of non-native isopod species was recorded in Hawaii (21 species) and the NEP (20 species), followed by the NWA (10 species) and the Mediterranean (7 species) (Appendix 3, Table A3.3). The lowest numbers of non-native isopod species were recorded in the NEA (5 species) and the NWP (4 species). There were no apparent donor regions for this taxon. No isopods native to the NWA had established in the NEA or the Mediterranean, while 3 species native to the NEA and 2 the Mediterranean, have established in the NWA.

D) Decapods

The Mediterranean had the highest number of non-native decapod species (73 species) more than four times than any other region, with the Indian Ocean being the major donor region (Appendix 3, Table A3.4). The NWP, the NWA and the NEA had 16 non-native decapod species each with no apparent donor region, Hawaii had 10 species (most native to the Central Indo-Pacific) and the NEP had 5 species. A higher number of decapod species native to the NWA had established in the NEA (5 species) and the Mediterranean (6 species) than *vice versa* (1 species native to both NEA and the Mediterranean had established in the NWA). Four species native to the NEA had established in the Mediterranean, but no species native to the Mediterranean had established in the NEA.

E) Barnacles

The NWP had the highest number of non-native barnacle species (11 species) followed by the NEA (10 species), the NWA and the Mediterranean (8 species each), and the NEP (5 species) (Appendix 3, Table A3.5). Hawaii had the lowest number of non-native barnacle species (4 species). There were no apparent donor regions for this taxon. While no barnacle species native to the NEA and the Mediterranean had established in other regions in the North Atlantic, species native to the NWA had established in the NEA (2 species) and the Mediterranean (3 species).

F) Tunicates

Hawaii had the highest number of non-native tunicate species (29 species), with the Central Indo-Pacific being the major donor region, and many species of unknown origin (Appendix 3, Table A3.6). The NEP had 23 species of non-native tunicates, with the NWP and the Central Indo-Pacific being major donor regions. Many of the 23 species of non-native tunicates in the Mediterranean were native to the Central Indo-Pacific, and many were of unknown origin. The other three regions had similar numbers of non-native tunicate species: NWP (10 species), NWA (10 species) and NEA (11 species) with no apparent donor regions. There was no apparent pattern of transfer of tunicate species across the Atlantic, with only 1–2 species transferred between each region.

G) Ray-finned fishes

The Mediterranean had the highest number of non-native ray-finned fishes (122 species), with the majority of the species being native to the Indian Ocean (Appendix 3 Table A3.7). The NWP had the second highest number of non-native ray-finned fishes (34 species), with the NWA being a major donor region. Hawaii and the NEP followed with 28 and 25 non-native species, respectively. The majority of the non-native fishes in Hawaii were native to the Central Indo-Pacific while the majority of the non-native ray-finned fishes in the NEP were native to the NW Atlantic. There were few non-native ray-finned fishes in the NWA and NEA. Regarding the transfer of ray-finned fished across the North Atlantic, a high number of species native to the NWA and the NEA had established in the Mediterranean (22 and 20 species, respectively) while few species native to the Mediterranean had established in NWA and NEA (3 and 1 species, respectively). Twelve species native to the NWA had established in the NWP and 2 species native to the NWP had established in the NWA.

Thus, the number of NIS from any of these seven taxonomic groups in a given region is highly variable. While the Mediterranean has the highest number of non-native species of bivalves, decapods, and ray-finned fishes, the NWP has the highest number of non-native species of barnacles, the NEP has the highest number of non-native species of amphipods, and Hawaii has the highest number of non-native species of isopods and tunicates.

The importance of different donor regions also varies across taxa and regions. While the Central Indo-Pacific is a major donor region for NIS to the Mediterranean as well as to Hawaii (see Fig. 3.2.6 for Hawaii), of the seven taxonomic groups contrasted and compared here, it is a donor region mainly for bivalves and ray-finned fishes (to both regions), decapods (to the Mediterranean), and tunicates (to Hawaii).

Regarding the transfer across the North Atlantic from the NWA to the regions in the northeastern Atlantic (the NEA and the Mediterranean) and *vice versa*, the "direction of the flow" varies across taxa. For bivalves, decapods, and barnacles, a higher number of species native to the NWA has established in the northeastern regions than *vice versa*. For Isopods, the NWA has received species native to the regions in the northeastern Atlantic. For amphipods, tunicates, and ray-finned fish there was no dominating direction in the transfer of species.

<u>Vectors responsible for introducing NIS to the different regions</u>

Shipping, often together with fishery, was the major vector for the introduction of bivalves to most regions (Fig. 3.2.10a). In Hawaii, most introductions were attributed to shipping alone. In the NWP, fishery alone was the major vector. In the Mediterranean, nearly half of all non-native bivalves had been introduced *via* other vectors, mainly through the Suez Canal.

The introductions of amphipods to all six regions were attributed mainly to shipping, often together with fishery (Fig. 3.2.10b). In the NEA, a third of the introductions were attributed to fishing only.

Shipping alone was the major vector for the introduction of isopods to all six regions. Shipping together with fishery contributed to a small proportion of the introductions in all regions except the NWP and the Mediterranean (Fig. 3.2.10c). In the NEP and the Mediterranean a small number of introductions were attributed to vectors other than shipping and fishery.

Fishery alone was the major vector for the introduction of most non-native decapods established in the NWP, NWA, and the NEA (Fig. 3.2.10d). Shipping alone was the major vector for introductions to Hawaii. Most non-native decapods in the Mediterranean had been introduced through the Suez Canal.

Shipping together with fishery was a major vector for the introduction of barnacles to all regions (Fig. 3.2.10e). Fishery alone was responsible for a small number of species in the NWA and the NEA. In the Mediterranean, the introduction of a low number of species was attributed vectors other than shipping and fishery.

Shipping, often together with fishery, was the major vector for the introduction of tunicates in all regions (Fig. 3.2.10f). However, in Hawaii most introductions of tunicates were attributed to shipping only. In the Mediterranean, the vector responsible for the introduction of a third of the species was unknown.

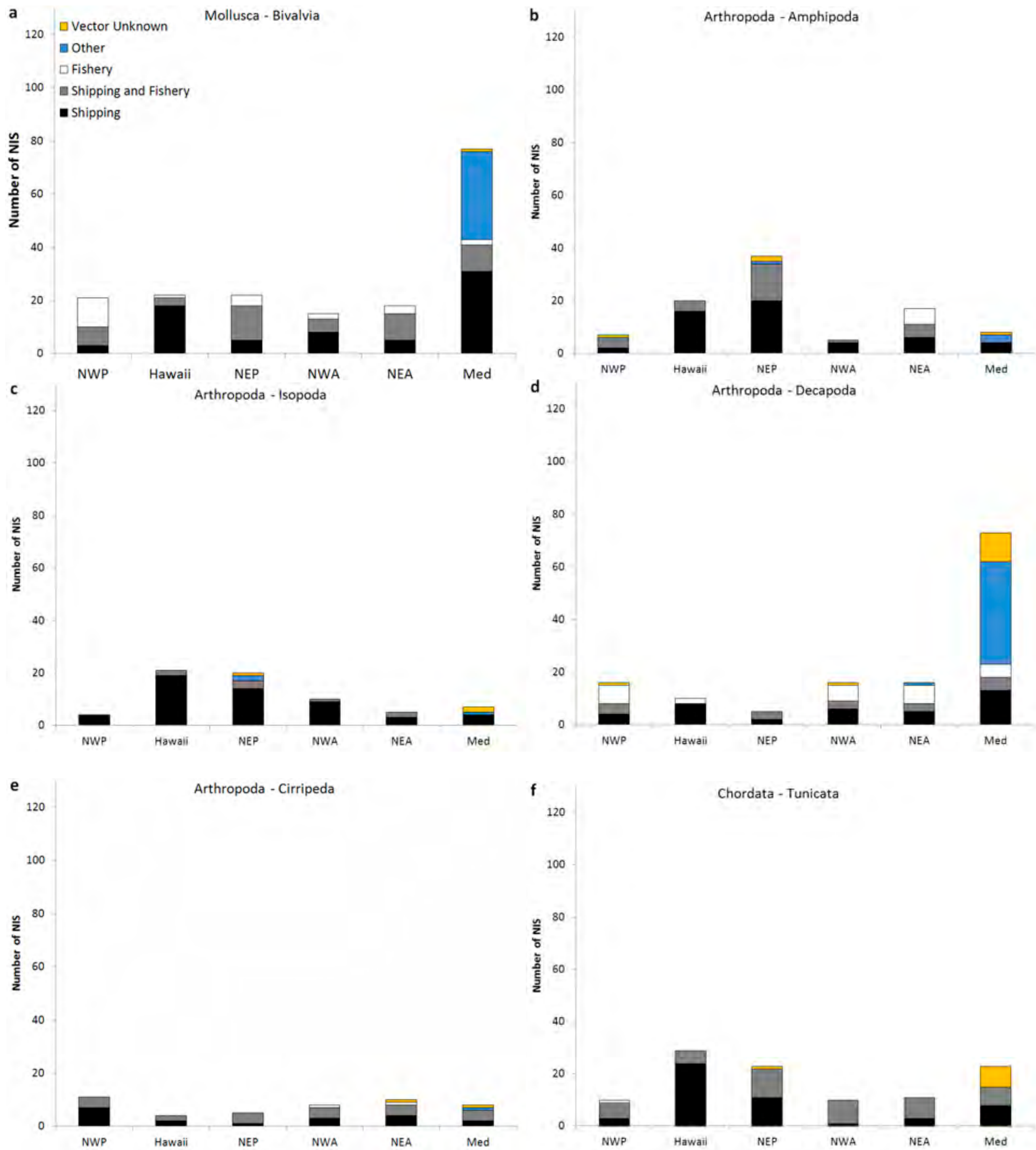

Fig. 3.2.10 (a–f) Vectors responsible for the introduction of NIS from different taxa to the different regions in the North Pacific and the North Atlantic NWP = Northwest Pacific, NEP = Northeast Pacific, NWA = Northwest Atlantic, NEA = Northeast Atlantic, Med = Mediterranean.

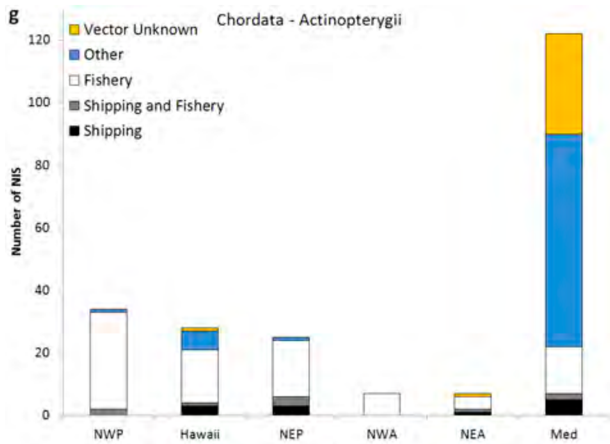

Fig. 3.2.10 (g) Continued.

Fishery alone was the major vector responsible for the introduction of ray-finned fishes in all six regions, except for the Mediterranean, where the majority of species had been introduced through the Suez Canal (Fig. 3.2.10g).

The importance of a particular vector thus varies across taxa and regions. While shipping is an important vector for introductions of NIS across most taxa, shipping alone (*i.e.*, introductions that are not also attributed to fishery) is the dominating vector only for the introductions of amphipods and isopods. Few introductions, other than those of ray-finned fishes, have been attributed to fishery alone. For the introduction of ray-finned fishes, shipping plays only a minor role. In Hawaii, shipping alone is the dominating vector of introduction for most taxa, with the exception of ray-finned fishes and barnacles. In the NWP, most bivalve introductions are attributed to fishery, as a result of intentional introductions. In the NEA, many amphipod introductions are also a result of intentional introductions (stocking).

Discussion and conclusions

Answers to the questions posed earlier in subsection *3.2.2 NIS in the North Pacific* are provided below.

NIS in the North Pacific

Answer to question 1. *What proportion of the NIS in the North Pacific has been identified as native vs. non-native to the North Pacific, and for what proportion is the origin unknown?*

Of the 746 NIS in the North Pacific, about a third of the species (238 species or 31.9%) are native to another region or ecoregion in the North Pacific. Almost half (358 species or 48.0%) of the NIS have been identified as native to regions outside of the North Pacific, while one fifth (150 species or 20.1%) of the NIS are non-native to the North Pacific but their native region is unknown.

Answer to question 2. *What regions in the North Pacific represent donor vs. receiving regions for aquatic NIS in the North Pacific?*

The Northwest Pacific is a major donor region of NIS native to the North Pacific and transferred to other ecoregions and regions within the North Pacific. Not only is the NWP a donor region of NIS to the NEP and Hawaii, but many species native to the NWP have been transferred to other ecoregions in the NWP where they are not native. In the NEP, the region with the highest overall number of NIS (with 368 species in total, 122 of these are native to the North Pacific), 109 of these are native to the NWP only. In Hawaii (with 347 NIS, 89 of these native to the North Pacific) more than half (or 46 species) are native to the NWP only while 45% (or 40 species) are native to the NEP only. The NWP has the lowest total number of NIS (210 species, 55 of these native to the North Pacific), with 28 species native to the NWP.

Answer to question 3. *How many of the species that are non-native to the North Pacific, or with origin unknown, have established a) in only one of the regions in the North Pacific, b) in two regions, or c) in all three regions?*

The majority of the NIS in the North Pacific that are native to regions outside the North Pacific have established in only one region in the North Pacific (389 of the 508 species non-native to the North Pacific) and are thus not very widespread. 17% of the species have established in two regions, while only 6% have established in all three regions.

Answer to question 4. *What is the geographic origin (i.e., region where native) of NIS that are non-native to the North Pacific?*

Four regions in the Atlantic are important source regions for NIS to the NWP and the NEP, namely the NW Atlantic, the W Tropical Atlantic, the NE Atlantic, and the Mediterranean. The Central Indo-Pacific and the Indian Ocean appear as more important donor regions for NIS to Hawaii.

Answer to question 5. *By which vectors have different taxa been introduced to different regions in the North Pacific?*

While most taxonomic groups show similar patterns regarding the vectors that are responsible for their introduction, there are substantial differences across taxa. The six most important vectors (ballast water, hull fouling, intentional stocking/release, aquaculture escapees, aquaculture associated, and aquarium/plant trade) account for the transfer of ≥80% of the NIS from most taxonomic groups, with the exception of brown algae, Magnoliophyta, Isopoda, and Insecta. Solid ballast is also an important vector for Clitellata, while habitat restoration is an important vector for Magnoliophyta. For insects, no vector of introduction is known for nearly half of the species. For some taxa, there are regional differences regarding the importance of different vectors. For bivalves, hull fouling is a more important vector in Hawaii than in the NWP and NEP. For decapods, intentional stocking appears to be a more important vector in NWP than in the other regions. For ray-finned fishes, intentional stocking and aquaculture escapees are more important vectors for introduction in all three regions of the North Pacific, but they are even more important in the NWP than in Hawaii and the NEP.

Comparison with other regions

Answer to question 6. *Are there differences between regions regarding the number of NIS established from different taxa?*

There are differences across regions regarding the number of NIS established from the seven taxonomic groups that were examined. While the Mediterranean has the highest number of non-native bivalves, decapods, and ray-finned fishes, the NWP has the highest number of non-native barnacles, the NEP has the highest number of non-native amphipods, and Hawaii has the highest number of non-native isopods and tunicates.

Answer to question 7. *Are there differences between regions regarding the geographic origin (i.e., region where native) of NIS from different taxonomic groups?*

The importance of different donor regions varies across taxa and regions, but there were clear patterns only for some of the six regions and seven taxa examined. The western Indo-Pacific is generally a major donor region for NIS to the Mediterranean, but only for bivalves, decapods, and ray-finned fishes. The Central Indo-Pacific is a major donor region for NIS to Hawaii, but only for bivalves, tunicates, and ray-finned fishes.

Answer to question 8. *In the North Atlantic, which region is a donor vs. receiving region for various taxa?*

Regarding the transfer of species across the North Atlantic (*i.e.*, from the NWA to the NEA and the Mediterranean, and *vice versa*), which region that is the donor or receiving region varies across taxa. The NWA appears as a donor region for bivalves, decapods, and barnacles, as a higher number of species native to the NWA has established in the northeastern regions than vice versa. For isopods, the NWA has received species native to the regions in the northeastern Atlantic. For amphipods, tunicates, and ray-finned fishes there was no dominating direction in the transfer of species.

Answer to question 9. *Are there differences between regions regarding the vector responsible for introducing different taxa?*

While shipping is generally considered an important vector for the introduction of NIS from most taxa around the world, the importance of different vectors varies across taxa and regions. In the six regions examined, shipping is the dominating vector for the introduction of isopods, amphipods, barnacles and tunicates, for the latter three taxa often in combination with fishery (aquaculture associated). In the NEA, many amphipod introductions are also a result of intentional introductions (stocking). Shipping plays only a minor role for the introduction of ray-finned fishes, with most introductions being attributed to fishery alone. However, in the Mediterranean, with the highest number of ray-finned fishes, most introductions are the result of migration through the Suez Canal. Shipping and fishery are both important vectors for the introduction of bivalves and decapods. However, in the NWP, most bivalve introductions are attributed to fishery alone, while shipping is more important in the Mediterranean. In Hawaii, shipping alone is the dominating vector of introduction for most taxa, with the exception of ray-finned fishes.

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4 Capacity Building: Training and Outreach

4.1 North Pacific Marine Non-Indigenous Aquatic Species Taxonomy Initiative

Within the context of the PICES project on the "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*", the primary objectives of the Taxonomy Initiative were to:

1. Develop training opportunities to improve capacity with respect to NIS, with an emphasis on capacity building in developing countries;
2. Develop and improve collaboration on NIS among PICES member countries and between PICES and other international organizations; and
3. Develop tools that will allow open and transparent sharing of information both within PICES and beyond.

The Taxonomy Initiative, generously funded by MAFF, focused on rapid assessment surveys for native and non-native species in a variety of habitats in commercial ports of PICES member countries, and on a collector survey to characterize the distribution of fouling organisms at a number of locations in each PICES member country.

4.1.1 NIS collaborations and Rapid Assessment Surveys

Given the continued exchange of species globally by various introduction vectors, especially species redistributions around the North Pacific, it is important to establish collaborations among taxonomists and invasion biologists on both sides of the Pacific Ocean in order to truly understand species' distribution patterns and hence invasion patterns. To foster collaborations among NIS researchers, a series of four PICES Rapid Assessment Surveys (RAS) was conducted with the help of local hosts (Table 4.1.1).

Table 4.1.1 PICES Rapid Assessment Surveys in four PICES member countries.

RAS	Location	Date	Local hosts
I	Dalian, China	October 20–23, 2008	Drs. Lijun Wang and Li Zheng, National Marine Environmental Monitoring Center, State Oceanic Administration
II	Jeju, Korea	October 19–22, 2009	Drs. Kyoungsoon Shin and Junghoon Kang, South Sea Environment Research, Korea Ocean Research and Development Institute
III	Newport, USA	October 18–20, 2010	Dr. John Chapman, Hatfield Marine Science Center
IV	Vostok, Russia	October 8–14, 2011	Dr. Vasily Radashevsky, A.V. Zhirmunsky Institute of Marine Biology

A standardized data collection protocol was developed for the RAS. A description is provided in Appendix 4. This protocol, which outlines the methodologies that should be used to carry out a RAS, is useful for monitoring programs to detect newly arriving species. In addition, dissemination and outreach of the developed protocol and database framework to developing countries will help them in addressing NIS issues. (This is described in subsection *4.1.2 Demonstration workshops*).

RAS are one approach to quickly characterize the native, non-native, and cryptogenic species present in different locations. These are qualitative surveys that allow rapid depiction of the species composition within each location surveyed, not the abundance of any specific species. Quantitative surveys to estimate population sizes could be done subsequently, if needed, but are too time consuming for rapid assessments. Although specific methods vary slightly, based on habitats being sampled or taxonomic groups being characterized, WG 21 has developed methodologies that have been used within PICES member countries to identify non-indigenous species in both intertidal and subtidal habitats.

For the PICES project, commercial ports in PICES member countries were surveyed as ports have a greater probability of containing non-indigenous species (see number of NIS associated with shipping above). The surveys focused on two major port ecosystem components, namely intertidal and subtidal habitats. The rational for surveying ports is that not only do these locations serve as a recipient environment for organisms transported by commercial shipping (ballast water, ballast sediment, hull fouling), they also often have high levels of secondary traffic (*e.g.*, recreational or small craft, aquaculture transfers) and tend to be more disturbed than natural environments, a factor that could enhance invasion success.

Data from each of the surveys has been archived in the PICES WG 21 NIS database of marine and estuarine species. Complete details of each survey can be found in a series of issues of the PICES Press newsletter (see Appendix 7). Brief summaries from these articles are provided below.

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The first article (pp. 30–32) provides a summary of the preliminary results from the first RAS conducted in Dalian, China, in 2008. Two commercial ports were targeted in this RAS: Dalian on the Yellow Sea and Bayu Quan on the Bohai Sea. Samples were collected and processed by the international team of participants who also carried out species identification and classification (native, non-native, cryptogenic). Three species (all bivalve molluscs) were classified as non-indigenous. In addition, the article outlines the objectives, rationale, and goals for carrying out an RAS, together with a summary of the methodology used. The role of the RAS as a forum for taxonomic experts from the American and Asian sides of the Pacific to discuss the organisms encountered, share knowledge, and compare sampling methods is discussed.

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The second article (pp. 38–40) provides a summary of the preliminary results from the second RAS in 2009. In this survey collector plates had been deployed at different locations within each of the following Korean ports: Busan, Masan, Jangmok, and Ulsan the summer prior to the PICES Annual Meeting. The collector plates where subsequently processed in Jeju, the week prior to the Meeting by the international team of participants. Four species were classified as non-indigenous: one bivalve mollusc, one cirriped, one amphipod and one polychaete.

PICES Press Vol. 19, No. 1

The third article (pp. 27–29) provides a summary of the preliminary results from the third RAS conducted in Newport, Oregon, USA, in 2010. In this RAS, intertidal and shallow subtidal habitats of two Oregon estuaries (Coos Bay and Yaquina Bay) were sampled using collectors, traps, scrapings, and by diver collections. A seawater reservoir tank at the Hatfield Marine Science Center in Yaquina Bay was drained and sampled for fouling organisms. Classification of species as native, non-native or cryptogenic occurred following species identification by RAS team members. Fourteen species were classified as non-indigenous: four algae, six ascidians, three polychaetes, and one crustacean.

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The fourth article (pp. 26–29) provides a summary of the preliminary results from the fourth RAS conducted in Peter the Great Bay and Vostok Bay, near Vladivostok and Nakhodka, Russia. As the previous year's RAS in Newport was particularly successful for polychaetes, small crustaceans, and marine algae, it was decided to focus on these groups again in 2011. In this RAS, most of the sampling was conducted in and around Vostok Bay in a range of habitats (small harbors, rocky points, mud flats). Collector plates were deployed for about 5 months prior to the RAS. Two sets of these plates were recovered from Vostok Bay harbors and one from the international harbor in Vladivostok.

Collecting standardized RAS data allowed distinction of native, non-indigenous and cryptogenic species, and comparisons of invasions within and among countries. Through these surveys, we now have a much better understanding of the invasion patterns of several taxonomic groups, including algae, amphipods, polychaetes (worms), and ascidians (tunicates or sea squirts). The surveys also provided collaboration opportunities for a number of countries and participants. These established contacts and networks will serve as a lasting legacy of the project.

4.1.2 Demonstration workshops

Given the global nature of biological invasions, it is critical to engage those working on this important topic outside of PICES' six member countries, especially those locations adjacent to the PICES region where the potential transport of NIS is expected to be high, such as Southeast Asia. One way to share information on invaders and build capacity to better understand invasion dynamics and maintain safe and productive marine ecosystems is to hold demonstration workshops to provide participants with the tools needed to conduct their own surveys. As NIS continue to be a priority research topic for two other regional intergovernmental organizations, the Intergovernmental Oceanographic Commission's Sub-Commission for the Western Pacific (WESTPAC) and Northwest Pacific Action Plan (NOWPAP), PICES worked with these two organizations in preparing the workshops. Specifically, three demonstration workshops on "*Rapid assessment survey methodologies for non-indigenous species*" were hosted during the project (Table 4.1.2). Over 50 participants from China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand, and Vietnam received training.

Each workshop aimed to:

1. Provide hands-on training to researchers concerned about the potential introduction of NIS, especially those from developing countries;
2. Introduce participants to the PICES NIS database (and later *Atlas*); and
3. Foster collaboration between PICES and WESTPAC, NOWPAP, and interested researchers, especially those within developing countries.

During the demonstration workshops, a full PICES RAS was not carried out. The workshops provided participants with general information about NIS and why vigilance and being proactive is required, using a series of short lectures, hands-on experience in making field collections in a variety of coastal environments, and laboratory experience using keys and reference material to identify organisms collected. In addition, workshop participants were introduced to the developed NIS database which provides one means to enhance communication on NIS around the Pacific Ocean and beyond. Details of the first two workshops can be found in PICES Press (Appendix 7). Details of the third (and final) workshop in Nagasaki, Japan, have not been published.

Table 4.1.2 PICES demonstration workshops on Rapid Assessment Survey techniques and applications.

Co-convenors	Date and location	Participating countries
Dr. Hiroshi Kawai (Kobe University, Japan) Dr. Hisashi Yokoyama (National Research Institute of Aquaculture, FRA, Japan) Dr. Thomas Therriault (Fisheries and Oceans Canada)	July 13–15, 2010 Marine Station of Kobe University's Center for Inland Seas, Awaji Island, Japan	Indonesia, Japan, Malaysia, Philippines, Singapore, Thailand, Vietnam
Dr. Suchana (Apple) Chavanich (Chulalongkorn University, Thailand/WESTPAC) Dr. Hiroshi Kawai (Kobe University, Japan) Dr. Thomas Therriault (Fisheries and Oceans Canada)	July 19–21, 2011 Phuket Marine Biological Center, Phuket, Thailand	China, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Thailand, Vietnam
Dr. Takeo Kurihara (Seikai National Fisheries Research Institute, Japan) Dr. Suchana (Apple) Chavanich (Chulalongkorn University, Thailand/WESTPAC) Dr. Sangjin Lee (NOWPAP) Dr. Thomas Therriault (Fisheries and Oceans Canada)	February 8–9, 2012 Seikai National Fisheries Research Institute, FRA, Nagasaki, Japan	China, Indonesia, Japan, Korea, Philippines, Thailand, Vietnam

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The first demonstration workshop (pp. 30–31) was held at the Marine Station of Kobe University's Center for Inland Seas, Awai Island, Japan, in 2010. Participants were invited to learn about PICES activities on non-indigenous marine species and to receive training in Rapid Assessment Survey techniques. The workshop exposed participants to (1) a background about marine non-indigenous species and why vigilance is required, using a series of short lectures, (2) hands-on experience in making field collections in a variety of coastal environments, and (3) laboratory experience using keys and reference material to identify the organisms collected. Since the workshop focused on background and techniques, actual taxonomic experts were not utilized in this demonstration. Workshop participants visited a number of sites around Osaka Bay where they were shown techniques to sample a variety of different habitats, received training in the application of collector plates, and thereafter identified and classified the collected samples. The participants were also introduced to the PICES NIS database. Due to the overwhelmingly positive feedback from workshop participants, with many participants eager to initiate aspects of RAS within their home countries, it was decided to hold a larger demonstration workshop in 2011 in Thailand.

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The second demonstration workshop (pp. 30–31) was held at the Phuket Marine Biological Center, Phuket, Thailand, in 2011. This workshop followed the same format as the workshop held the previous year. The participants were exposed to techniques for sampling a variety of different habitats around the Center right on the Andaman Sea.

Overall, this project has allowed for capacity building in non-PICES member countries and has strengthened linkages with both WESTPAC and NOWPAP on NIS research. See an outreach brochure developed as one of WG 21's final products (Appendix 5).

4.2 Database Training Workshop

The initial database training workshop for WG 21 members was held in March 2008, in Busan, Korea. Since 2009, training on the functions and utility of using the NIS database has been provided to PICES member countries during WG 21 meetings at each PICES Annual Meeting. Technology transfer workshops were conducted for the participants of the joint PICES/ICES meeting held in conjunction with the Fifth Marine Bioinvasions Conference (May 2007, Boston, USA) and RAS demonstration workshops (Table 4.1.2). Individual database training was also provided at the Sixth Marine Bioinvasions Conference (August 2009, Portland, USA) and at PICES Annual Meetings.

Posters and/or presentations on the utility, framework and data available in the NIS database and *Atlas* were given at PICES Annual Meetings in Dalian, China (2008), Jeju, Korea (2009), Portland, USA (2010), and Khabarovsk, Russia (2011); and at the meetings of the Estuarine Research Society in Oregon, USA (2010 and 2012), Pacific Estuarine Research Society in Oregon, USA (2010), and Coastal and Estuarine Research Foundation in Florida, USA (2011). The NIS database and *Atlas* were also presented at a WESTPAC (Intergovernmental Oceanographic Commission's Sub-Commission for the Western Pacific) workshop on non-indigenous species in 2009 in Bangkok, Thailand. The database was also presented at the RAS demonstration workshops in Phuket, Thailand (2011) and in Nagasaki, Japan (2012).

5 Initiatives on Prevention and Mitigation Measures

5.1 ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2005

The *ICES Code of Practice on the Introductions and Transfers of Marine Organisms* (the "Code of Practice") was adopted in 1973. The *Code of Practice* was developed by ICES in collaboration with the *European Inland Fisheries Advisory Commission* (EIFAC), and the *Food and Agriculture Organization of the United Nations* (FAO). Since 1973, the Code of Practice has evolved following repeated modifications and updates, most recently in 2005.

While the Code of Practice was originally designed for the ICES member countries concerned with the North Atlantic and adjacent seas, all countries across the globe are encouraged to implement it.

The Code sets forth recommended procedures and practices to reduce the risks of adverse effects arising from intentional introductions and transfers of marine (including brackish water) organisms. It applies to the movement and translocation of non-native species for fisheries enhancement and marine aquaculture purposes and to introductions done for re-stocking and enhancement purposes. The Code also recommends procedures to reduce the risk of unwanted introductions of species that can accidentally be released into the wild, including species that are part of live trade (*e.g.*, species used for aquaria, ornamentals, bait, and food), species that are introduced and transferred for research purposes, biocontrol, genetically modified organisms, and polyploids.

The Code of Practice addresses three levels of concern associated with introductions and transfers of non-indigenous species. The first concern is that introduced and transferred species may escape cultivation and become established in the receiving environment where they can have an impact on native species and the receiving environment. The second concern is the potential genetic impact of introduced and transferred species relative to the mixing of farmed and wild stocks as well as to the release of genetically modified organisms. The third concern is the risk of inadvertently introducing harmful organisms (pathogens, parasites, and other "fellow travellers") associated with the target species.

The Code outlines a consistent transparent process for the evaluation of a proposed new introduction, including detailed biological background information and evaluation of risks. The Code is presented in a manner that permits broad and flexible application to a wide range of circumstances and requirements in many different countries, while at the same time adhering to a set of basic scientific principles and guidelines.

The Code is divided into ten sections of recommendations relating to: (I) a strategy for implementation, (II) the steps to take prior to introducing a new species, (III) the steps to take after deciding to proceed with an introduction, (IV) policies for ongoing introductions or transfers which have been an established part of commercial practice, (V–VII) the steps to take prior to releasing genetically modified organisms, and (VIII–X) the steps to take prior to releasing polyploidy organisms.

ICES member countries contemplating new introductions are requested to present to the Council a detailed prospectus on the rationale and plans for any new introduction of a marine (and brackish water) species. The ICES Working Group on Introductions and Transfers of Marine Organisms may thereafter be requested by the Council to consider the prospectus and comment on it. The Working Group may request more information before commenting on a proposal. If an introduction or transfer proceeds following approval, the ICES member country is requested to keep the Council informed by providing details of the broodstock established and the fate of the progeny *via* progress reports after a species is released into the wild.

The text of the ICES Code can be found at http://info.ices.dk/pubs/Miscellaneous/Codeofpractice.asp.

In Canada, a formal review process is in place to evaluate the risk of introductions of harmful NIS associated with introductions and transfers. The national process is described in Section *5.4 National Policy and Legislation Targeting Non-native Aquatic Species in PICES Member Countries*.

5.2 IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments

5.2.1 Conditions for the Convention coming into force

In 2004, the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The Convention has not yet come into force. In order for it to come into force, it must be ratified by at least 30 countries representing at least 35% of the world's tonnage. It is currently (as of March 2014) ratified by 38 countries representing 30.38% of the world's tonnage. The Convention will come into force one year after the conditions are met.

5.2.2 Which ships the standards apply to

The Convention applies to all vessel types operating in the aquatic environment which are designed to carry ballast water and are entitled to fly the flag of a Party to the Convention. This includes submersibles, floating craft and platforms, including floating storage units and floating production storage and offloading units. The Convention calls for ships to conduct a ballast water exchange or to meet a concentration-based ballast water discharge standard in accordance with a gradually implemented schedule linked to the year the ship was constructed (< 2009; in 2009; > 2009) and the amount of ballast carried on board the ship (< 1,500 m^3; ≥ 1,500 m^3 or ≤ 5,000 m^3; ≥ 5,000 m^3).

5.2.3 What the standards are

The Convention includes two regulations that define ballast water management standards: Regulation D-1 addresses the Ballast Water Exchange standard and Regulation D-2 details the Ballast Water Treatment Performance standard.

Ships performing ballast water exchange (Regulation D-1) are required to do so with an efficiency of at least 95% volumetric exchange. Acceptable methods for ballast water exchange are the Sequential Method, the Flow-through Method and the Dilution Method. Noting that ballast water exchange presents significant operational concerns and challenges, and that it may not provide a totally effective solution to reduce the spread of unwanted aquatic organisms and pathogens from ships' ballast water over time, the Convention requires an upgrade to the installation of ballast water treatment systems in accordance with a specified schedule.

The treatment technologies currently available or being developed can generally be grouped under three broad categories based on their primary mechanism for rendering the organism inactive:

- Mechanical systems (filtration, cyclonic separation, electro-mechanical separation),
- Physical disinfection (ultraviolet light/ultrasounds, cavitation, de-oxygenation), and
- Chemical treatment (disinfecting biocides, electrolytic chlorination).

The D-2 standard is the metric used to measure the efficacy of the treatment system and it applies to the system as installed on board and used in actual operations. The criteria are in the form of specific limits on aquatic life in the ballast discharge.

Ships conducting ballast water management in accordance with this regulation shall discharge:

- Less than 10 viable organism per m^3 > 50μ in minimum dimension, and
- Less than 10 viable organisms per ml < 50μ and > 10μ in minimum dimension, and
- Less than the following concentrations of indicator microbes:
  - Toxicognic *Vibrio cholerae* less than 1 colony forming unit (cfu) per 100 ml, or less than 1 cfu per 1 gram zooplankton samples,

- *Escherichia coli* less than 250 cfu per 100 ml,
- Intestinal *Enterococci* less than 100 cfu per 100 ml.

All treatment systems must be type approved by an Administration under a robust protocol which requires that they satisfy this standard in full scale operations. In any port or offshore terminal, an officer authorized by a Party to the Convention may board a vessel to which the Convention applies and test the ballast water discharge for compliance by taking samples.

As the Convention is not yet binding globally, actions to address the issue of invasive species are increasingly occurring at national, regional and local levels. More than a dozen individual nations and regions have introduced specific regulations addressing the discharge of ballast in their waters. Some of these nations and regions have introduced local ballast water management requirements. A small number of these jurisdictions may prohibit the discharge of ballast water entirely, require chlorination, or restrict in-port discharge to an approved onshore reception facility. As of March 2014, three PICES member countries had ratified the Convention:[3] Canada, Korea, and Russia.

5.2.4 Additional information

For a summary of national regulations targeting ballast water, see Lloyd's Register: National ballast water management requirements.[4] Currently (as of March 2014), regulations targeting ballast water are mandatory only in Canada and the U.S. They are the only PICES member countries with ballast water sampling programs. While Canada and the U.S. have developed guidelines for ballast water sampling, IMO has developed guidelines for ballast water sampling, ballast water management plans, ballast water management systems and other processes.[5]

[3] http://www.imo.org/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx
[4] http://www.lr.org/sectors/marine/documents/175149-national-ballast-water-management-requirements.aspx
[5] http://www.imo.org/OurWork/Environment/BallastWaterManagement/Pages/BWMGuidelines.aspx

5.3 IMO Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species

IMO has developed the *2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species* (Resolution MEPC.207(62)) which aim to reduce the risk of transferring biofouling NIS attached to the underwater hull and in niche areas of ships. The Guidelines have been approved and were adopted as an IMO Resolution at the Marine Environmental Protection Committee. Being a Resolution, the Guidelines are not mandatory and do not require signing by member states. Instead, they are voluntary guidelines. The Guidelines are intended to provide useful recommendations on general measures to minimize the risks associated with biofouling for all types of ships and are directed to States, shipmasters, operators and owners, shipbuilders, ship cleaning and maintenance operators, port authorities, ship repair, dry-docking and recycling facilities, ship designers, classification societies, anti-fouling paint manufacturers and suppliers, and any other interested parties. A State should determine the extent that the Guidelines are applied within that particular State. However, the Guidelines do not include information about what is considered an acceptable level of biofouling and how to measure it.

The IMO Guidelines are available at www.imo.org/blast/blastDataHelper.asp?data_id=30766.

The U.S. has developed national regulations addressing hull fouling. The U.S. regulations follow the IMO recommendations and are described in this document in Section *5.4 National Policy and Legislation Targeting Non-native Aquatic Species in PICES Member Countries*.

5.4 National Policy and Legislation Targeting Non-native Aquatic Species in PICES Member Countries

5.4.1 Canada

The Canadian federal, provincial and territorial governments introduced *An Invasive Alien Species Strategy for Canada*[6] in 2004, with the objective to prevent new invasions, detect and respond rapidly to new invasive alien species, and manage established invasive alien species through eradication, containment, and control. The strategy includes measures to help prevent introductions of invasive alien species from other countries, or of species which have moved from one ecosystem to another within Canada.

Fisheries and Oceans Canada (DFO) is the federal department providing national leadership on aquatic invasive species. DFO introduced the *Canadian Action Plan to Address the Threat of Aquatic Invasive Species*.[7] The Action Plan addresses unintentional/unauthorized introductions that are a result of activities that involve handling of *e.g*., aquarium fish, live baitfish, live fish for the food trade, transgenic aquatic organisms, or plants in the horticultural trade that are accidentally introduced to and establish in the wild.

There are procedures in place for authorized introductions under the *National Code on Introductions and Transfers of Aquatic Organisms*[8] that apply to all aquatic organisms in fresh water and marine habitats introduced or transferred into fish rearing waters or fish rearing facilities for the purpose of aquaculture, stocking for commercial and recreational fishing, and biocontrol. Applications for introductions and transfers are reviewed by a Federal-Provincial Introductions and Transfers Committee in each province. In the review process, a risk assessment which is an adaptation of internationally acknowledged models and processes (including the ICES Code of Practice) is used to evaluate the potential risk of (a) harmful alterations of natural ecosystems, (b) negative effects on native stocks, and (c) introducing and spreading pathogens and parasites and other "fellow travellers".

In Canada, regulations targeting aquatic invasive species (AIS) are embedded in the existing federal and provincial regulatory framework. Two federal *Acts* are particularly relevant to prevent the introduction and spread of AIS to the Canadian Pacific coast: The federal *Fisheries Act* was amended in 2012[9] to better respond to the invasive species challenge, and now provides authorities for managing aquatic invasive species. *Aquatic Invasive Species Regulations*[10] under the *Fisheries Act* are under development, and are expected to include (a) a list of species affected by the regulations, (b) prohibition protocols to avoid the introduction and spread of AIS by restricting activities such as importation, transport and possession of live AIS in various locations, (c) permissions to authorize specific low risk activities related to AIS in Canada, and (d) authorities for control and eradication activities.

Canada ratified the IMO *Ballast Water Management Convention* in 2010, and has developed federal regulations that address ballast water. Ballast water is regulated in the *Ballast Water Control and Management Regulations*[11] under the *Canada Shipping Act*, 2001. These regulations are harmonized to the maximum extent possible with current U.S. and international provisions, including the IMO Ballast Water Management Convention. Transport Canada is the federal department with regulatory responsibility for the shipping

[6] http://www.ec.gc.ca/eee-ias/default.asp?lang=En&n=1A81B051-1
[7] http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/index-eng.htm
[8] http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code-eng.htm
[9] http://www.dfo-mpo.gc.ca/far-rlp/habitat_prevention-eng.htm
[10] http://canadagazette.gc.ca/rp-pr/p2/2015/2015-06-17/html/sor-dors121-eng.php
[11] http://laws-lois.justice.gc.ca/eng/regulations/SOR-2011-237/FullText.html

pathway. Ballast water exchange has been mandatory nationally since 2006 for ships arriving from outside the Canadian exclusive economic zone. Canada has an ongoing sampling program of residual water and sediment from the ballast tanks of ships, led by Transport Canada. In addition, the Port of Vancouver has additional regulations which prohibit ballast water discharge until samples have been taken and analyzed (see Lloyd's Register, Section 5.2.4)

5.4.2 Japan

The Japanese government introduced the *Basic Policy for Preventing Adverse Effects on Ecosystems Caused by Invasive Alien Species*[12] in 2004.

The *Invasive Alien Species Act* (*IAS Act*) was adopted in June 2004 and put into force in June 2005. The purpose of the *IAS Act* and the *Basic Policy* is to prevent adverse effects to Japanese ecosystems, human safety, agriculture, forestry, and fisheries caused by alien species. While the *IAS Act* regulates only intentional introductions of species, the *Basic Policy* addresses both intentional and unintentional introductions.

The *Basic Policy* outlines the principles concerning the selection of IAS, the handling of IAS, and the mitigation of IAS by the national government and other entities. The *Basic Policy* also points out the importance of monitoring, early detection, and rapid response to eradicate or manage established invaders to reduce spread, and addresses the importance of increasing scientific knowledge about the impacts of IAS and of informing and educating the public.

The *IAS Act* prohibits the import, raising, planting, storing or carrying without permission of species that are designated as IAS. Restrictions apply also to species closely related to IAS that are likely to cause adverse effects. Such species are designated Uncategorized Alien Species (UAS) until investigated, after which ministers categorize those species into IAS or other alien species, which require no restriction. Species that require no restriction but cannot be clearly distinguished from (*i.e*., look similar to) IAS or UAS must be accompanied by a certificate bearing the type name (so-called Living Organisms Required to have a Certificate Attached (LORCA) during their importation in order to verify their types). The list of designated IAS, UAS, and LORCA was proposed by academic experts based on properties of living organisms and the draft list was circulated to the domestic public for comments while World Trade Organization sanitary and phytosanitary measures notification was being made.

The *Act* applies only to species introduced to Japan in 1868 or later. Only taxonomic groups that can be identified without the use of special equipment are covered by the *IAS Act*. Fungi, bacteria, viruses and other microscopic organisms are not covered by the *Act*. Genetically modified organisms (GMOs), plant pests, and diseases infectious to humans and livestock should not be designated IAS as they are covered by other *Acts*. The movement of living organisms that are included in ballast water is not covered by the *IAS Act*.

The *Basic Policy* also states that "If the person who instigated the act that led to the necessity of emergency mitigation is known, said person shall, in principle, receive a claim for repayment of the necessary costs".

Japan has not ratified the International Convention for the Control and Management of Ships' Ballast Water and Sediments, and has not developed a national strategy or a regulatory framework that addresses ballast water issues.

5.4.3 People's Republic of China

In China, there are several *Laws* and *Regulations* that address AIS. The *Marine Environment Protection Law* (2000) Article 25 regulates intentional introductions (stocking, aquaculture). It requires introductions of marine species to be subject to scientific assessment to avoid damages to marine ecosystems.

[12] http://www.env.go.jp/en/nature/as.html

The *Fisheries Law of the People's Republic of China* (2004), Article 17, addresses disease prevention. It requires quarantine to be executed for the import and export of aquatic fingerlings to prevent the transfer of disease.

The *Regulation on the Prevention and Control of Vessel-induced Pollution to the Marine Environment* (2009), Article 15, states that ships that contain ballast "shall comply with laws, regulations and relevant standards and the relevant international conventions ratified or acceded by China". However, China has not ratified the IMO Ballast Water Management Convention, and China has not developed a national policy or regulations that address ballast water.

In addition, a *Regional Strategic Action Plan* on marine invasive species is envisaged for South East Asia through member states of the Coordinating Body for the Seas of East Asia (COBSEA) United Nations Environment Programme. China and Korea are members of COBSEA.

5.4.4 Republic of Korea

In Korea, the Ministry of Oceans and Fisheries has the regulatory responsibility for marine invasive species. The purpose of the *Conservation and Management of Marine Ecosystem Act* is to protect marine ecosystems from artificial damage and conserve or manage marine ecosystems.[13] Article 23 (Management of Organisms Disturbing Marine Ecosystems) and Article 24 (Management of Harmful Marine Organisms) prohibits unauthorized introductions of AIS and provides authorities for managing AIS. The purpose of the *Marine Environment Management Act*[14] is to prevent any danger and injury due to either damage of the marine environment or marine pollution and create a clean and safe marine environment. The Ministry carries out baseline monitoring of marine ecosystems and coastal wetlands. The Ministry also develops risk assessment tools and carries out research on the management of marine invasive species, including rapid response and long-term response.

Korea ratified the IMO Ballast Water Management Convention in 2009. In 2007, the Korean government enacted and proclaimed the *Ballast Water Management Act* which reflects the Convention.[15] The *Act* and the implementing regulation of the *Act* will take effect on the day that the IMO Ballast Water Management Convention comes into force. As of November 2013, ships that have loaded ballast water within 80 km of the Fukushima nuclear power plant and within six ports along the northeast coast of the island of Honshu are recommended to exchange their ballast water in the open sea prior to entering a Korean port.

5.4.5 Russia

Russia has not developed a national strategy targeting AIS specifically. However, The National Strategy of Biodiversity Conservation in Russia, The Environmental Doctrine of the Russian Federation, and The Strategy for Conservation of Rare and Endangered Species of Animals, Plants, and Fungi provide a policy framework for biodiversity conservation that also considers the control of the use, distribution, and management of alien species and genetically modified organisms. The framework points out the need to identify pathways, draw up an inventory and monitoring strategy, forecast invasions, and prevent hybridization between native species and closely related invasive species.

Russia has no specific laws that target only AIS, but several Federal *Laws* are applicable to the prevention of the introduction and management of AIS. The Federal *Law on the Conservation of the Environment* prohibits the unauthorized production, raising and use of non-native organisms. This *Law* also requires "development of

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[13] http://www.moleg.go.kr/english/korLawEng?pstSeq=57724&rctPstCnt=3&searchCondition=AllButCsfCd&searchKeyword=conservation
[14] http://www.moleg.go.kr/english/korLawEng?pstSeq=52755&pageIndex=2&searchCondition=AllButCsfCd&searchKeyword=management
[15] http://www.bairdmaritime.com/index.php?option=com_content&view=article&id=3994%3Akorea-policy-and-development-trends-in-ballast-water-management-systems&catid=116%3Aenvironment&Itemid=211&showall=1

effective measures for preventing their uncontrolled reproduction". The Federal *Law on the Animal World* allows for the acclimatization of non-native animals if authorization has been given by the government and the requirements for environmental safety has been taken into consideration. The Federal *Law on Hunting and Conservation of Game Resources and on Amending Specified Legislative Acts of the Russian Federation* allows the introduction, relocation and hybridization of game species based on scientifically substantiated recommendations, if authorization has been given. The *Regulations on the Federal Supervisory Natural Resources Management Service* provides authorities to the Federal Supervisory Natural Management Service to issue licences for introducing non-native animals to Russia. The Federal *Law on the Specifically Protected Natural Territories* "prohibits the introduction of living organisms for their acclimatization on the territory of the state wildlife reserved areas and national parks".

The following *Laws* apply to fishery only: The Federal *Law on Fishery and Conservation of Water Biological Resources* regulates the introduction or re-introduction of species for the purpose of fishing. The *Order of Measures for Acclimatization of Water Living Resources* defines the order of measures for acclimatization of aquatic living resources in water bodies with fishery capabilities. The Federal *Laws on the Exclusive Economic Zone of the Russian Federation* and *on the Continental Shelf of the Russian Federation* obliges people fishing in the Russian exclusive economic zone and on the continental shelf not to introduce non-native organisms to these waters and to comply with the requirements of the quarantine regime.

Russia ratified the IMO Ballast Water Management Convention in March 2012 and has national regulations in place, but they will not come into force until the Convention comes into force. However, two Russian ports in the North Pacific are taking measures to prevent ballast water in their harbours: the Prigorodnoye Port which requires tankers to exchange ballast water in the open sea, and the Port of Nakhodka which has ballast water reception facilities.

5.4.6 United States of America

A 1999 Executive Order established the National Invasive Species Council (NISC)[16] which is comprised of representatives from 13 federal departments and agencies of the U.S. government. Coordinated through the Council, these agencies are working together to address invasive species issues both domestically and abroad. The Council receives advice from the Invasive Species Advisory Committee, which was created through the passage of the Federal *Advisory Committee Act*. The NISC adopted a National Management Plan in January 2001 that was updated in 2008. The 2008–2012 National Invasive Species Management Plan[17] outlines five Strategic Goals for the Federal response (including overall strategy and objectives) to the problem of invasive species: prevention; early detection and rapid response; control and management; restoration; organizational collaboration. The U.S. legislation explicitly addresses the prevention, mitigation, and eradication of invasive species, thereby minimizing their adverse effects on the U.S. and international economies, environment, and human, plant, and animal health. The main agencies responsible for managing marine invasive species are: the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service (USFWS).

The National Ocean Policy, established by Presidential Executive Order on July 19, 2010, includes nine National Priority Objectives that address pressing issues such as climate change and ocean acidification. A strategic action is being developed for each one of these objectives.[18] Invasive species components are being incorporated into strategic action plans to:

- Identify and prevent high-risk introductions of non-native species;
- Increase research capacity to document economic and ecological impacts; and
- Establish interagency partnerships to bring together expertise, strengths and resources to control existing populations.

[16] http://www.invasivespecies.gov/
[17] http://www.invasivespecies.gov/main_nav/mn_NISC_ManagementPlan.html
[18] http://www.whitehouse.gov/ administration/eop/oceans

Three Federal *Acts* are relevant to prevent the introduction and spread of AIS to the U.S. Pacific coast: The *Lacey Act* of 1900,[19] amended in 1998, was originally designed to protect game wildlife. Its role has increased to prohibit parties from bringing non-native species that have the potential to become invasive into the United States. The *Lacey Act* gives the USFWS the power to list a species as "injurious" and regulate or prohibit its entry into the U.S.

Imports and transfers of aquatic organisms into the U.S. are regulated under the USFWS Title 50 authority. Movements within the U.S. are controlled by permits issued at the State level. In 2013, the *Invasive Fish and Wildlife Prevention Act*, addressing imports and transfers was proposed to Congress (*i.e.*, as a bill). The purpose of this *Act* is to establish an improved regulatory process for injurious wildlife to prevent the introduction and establishment in the United States of nonnative wildlife and wild animal pathogens and parasites that are likely to cause harm. The bill has not yet been enacted into a law.[20]

The U.S. has not ratified the IMO Ballast Water Convention. However, the U.S. (including Hawaii) has ballast regulations in place that apply to all ships arriving from outside the U.S. exclusive economic zone. The *National Invasive Species Act* (NISA) was enacted in 1996 with the purpose to prevent the introduction of non-indigenous species to the United States *via* ballast water. The U.S. Coast Guard (USCG) has established both regulations and guidelines[21] that address ballast water, and new ballast water management requirements entered into force in June 2012. Following these new requirements, ships will be required to have onboard ballast water management treatment systems that prevent invasive species from being shipped into U.S. waters that will probably make mid-ocean ballast water exchange insufficient.[22] The USCG has an ongoing sampling program of residual water and sediment from the ballast tanks of ships. In addition, regulations in the State of California require ships arriving to California waters and carrying ballast water taken on at a location >1 nautical mile away from the port of arrival, to either exchange their ballast water in mid-ocean waters or the ballast water must undergo treatment.[23]

The U.S. has developed national regulations addressing hull fouling (USCG Regulation 33 CFR §151.2050[24]) that entered into force June 21, 2012. Following these regulations, U.S. ships are required carry a Biofouling Management Plan in accordance with the IMO guidelines and to remove fouling organisms from the vessel's hull, piping and tanks on a regular basis. In addition, the State of California has proposed changes to Article 4.8 Biofouling Management Regulations for Vessels Operating in California Waters[25], but these changes have not yet been adopted.

The *Clean Boating Act*[26] (CBA) of 2008 has the objective to reduce water pollution and the spread of invasive species by recreational boating in U.S. rivers, lakes, coastal waters, and waters out to 12 nautical miles from shore. The USCG has enforcement authority under the CBA.

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[19] http://www.fws.gov/international/laws-treaties-agreements/us-conservation-laws/lacey-act.html
[20] https://www.govtrack.us/congress/bills/113/hr996/text
[21] http://www.uscg.mil/hq/cg5/cg522/cg5224/bwm.asp
[22] http://www.dnv.com/industry/maritime/publicationsanddownloads/publications/newsletters/technical_regulatory/2012/new_us_ballast_water_management_requirements.asp
[23] http://www.slc.ca.gov/Spec_Pub/MFD/Ballast_Water/Laws_Regulations.html
[24] http://www.dnv.com/industry/maritime/publicationsanddownloads/publications/newsletters/technical_regulatory/2012/uscg_requirements_to_fouling_maintenance_in_the_ballast_water_management_plan.asp
[25] http://www.slc.ca.gov/spec_pub/mfd/ballast_water/laws_regulations.html
[26] http://water.epa.gov/lawsregs/lawsguidance/cwa/vessel/CBA/about.cfm

6 Inventory of Expertise and Programs Related to Non-indigenous Aquatic Species in PICES Member Countries

6.1 Non-indigenous Aquatic Experts Databases

In addition to the databases listed below, other databases not directly related to the North Pacific and/or PICES member countries, may be useful for contacting taxonomic experts, such as the National Exotic Marine and Estuarine Species Information System (NEMESIS; http://invasions.si.edu/nemesis/), FISHBASE (http://www.fishbase.org/), Ocean Biogeographic Information System (OBIS; http://www.iobis.org/), World Register of Marine Species (WoRMS; www.marinespecies.org), Southern California Association of Marine Invertebrate Taxonomists (SCAMIT; www.scamit.org), and Census of Marine Life (CoML; www.comlsecretariat.org). Note that the nomination of experts is not standardized between the databases in Table 6.1.1.

Table 6.1.1 Non-indigenous aquatic experts databases.

Database	Geographic region	Description
Alaska Invasive Species Working Group, http://www.uaf.edu/ces/aiswg/members.html	USA (Alaska)	• Working group for the State of Alaska tasked with coordinating NIS issues; • Not an expert database, *per se*, but experts could be found by contacting members of the Working Group.
Aquatic Invasions Research Directory (AIRD), http://invasions.si.edu/aird/search.html	USA	• Created by the Smithsonian Environmental Research Center; • Is a free database designed to promote information transfer, coordination, and collaborative research on the invasion of aquatic ecosystems; • Contains current information on people, research, technology, policy and management issues relevant to aquatic invasions.
Aquatic Nuisance Species (ANS) Task Force Experts Directory, http://www.anstaskforce.gov/default.php	USA	• Database was designed to direct users to invasive species experts; • Is set up as a 2-tier system with the first tier accessible to the public. The public portion of the database will guide user to a state contact who acts as a filter for information and identifications. If they cannot answer the question, they can log in to the second tier experts; • Generally lists ANS coordinators, by state, for the United States of America

Table 6.1.1 Continued.

Database	Geographic region	Description
Biological Invasions Researcher Database, http://www.bio.miami.edu/nsfinvdb/	International, but mainly USA	• Is a product of the USDA-NSF-EPA Interagency PI Meeting on the "*Role of applied and basic research in the management of biological invasions*" held in Washington DC (October 17–18, 2005); • Is a public database where investigators working on invasive species can find potential collaborators with skills that they seek; • Is open to registration by anyone working on invasive species ecology; • Provides links to a variety of other web sites on invasive species.
Database of Experts on Biodiversity Study in China, http://monkey.ioz.ac.cn/bwgcciced/english/cesis/expert.htm, http://monkey.ioz.ac.cn/bwgcciced/english/cesis/invasive.htm	China	• Is part of the China Species Information System (CSIS); • Three networks have been set up (Expert Network, Nature Reserve Network and Public Network) for biodiversity conservation in China in order to promote cooperation and communication among experts, nature reserves and public; • Anyone doing research or management on biodiversity conservation in China may be included in the Expert Network.
Delivering Alien Invasive Species Inventories for Europe (DAISIE) European Alien Species Expertise Registry, http://www.europe-aliens.org/	Europe	• Links and mobilizes current expertise in biological invasions to contribute knowledge and data to meet the requirements in dealing with invasive alien species; • Contains details on individual experts with respect to taxonomic expertise, geographic units, and thematic areas; • Experts world-wide are invited to register.
Fauna Europaea – Taxonomic Expertise http://www.faunaeur.org/experts.php	International	• More of a taxonomic expertise site as opposed to an NIS expertise site.

6.2 National Research and Monitoring Programs and Collaboration Initiatives

In addition to the programs listed in Table 6.2.1, there are often information networks within countries to exchange information on NIS, monitoring programs that are not established or standardized, and research programs that are not coordinated on a national level.

Table 6.2.1 National research and monitoring programs in PICES member countries.

Program	Description
Canada	
Canadian Aquatic Invasive Species Network II (CAISN II), http://www.caisn.ca/en/index.php	CAISN is a national research network that includes 30 researchers from 12 partner universities and six federal laboratories. The research focuses on four broad themes: Early Detection; Rapid Response, Aquatic Invasive Species as Multiple Stressors; and Reducing Uncertainty in Prediction and Management.
Canadian Council on Invasive Species (CCIS), http://www.bcinvasives.ca/partners/national-invasive-species-working-group	CCIS works collaboratively across jurisdictional boundaries to support actions and information that can help reduce the threat and impacts of invasive species CCIS is a federal society composed of representatives from the provincial and territorial invasive species councils, committees, and coalitions representing the majority of provinces and territories in Canada.
Fisheries and Oceans Canada Aquatic Invasive Species (AIS) Program, http://www.dfo-mpo.gc.ca/Library/346439.pdf, http://www.dfo-mpo.gc.ca/science/coecde/ceara/index-eng.htm	The Program was initiated in 2005 by Fisheries and Oceans Canada (DFO) to respond to the invasive species challenge. From 2005–2010 $3 million was spent on research, covering a wide range of issues, including research linked to the prevention of new invasions and the management of established and spreading invaders (containment, eradication, and control). Much of the funded research targeted the shipping pathway and invasive tunicates in the aquaculture industry. The Program supplemented other AIS activities in Canada such as the Canadian Aquatic Invasive Species Network research and DFO's risk assessments carried out by the Centre of Expertise for Aquatic Risk Assessment (CEARA). Together, these activities targeted most of the species listed by the provinces and regions as being of elevated concern. The results from the projects have been used to provide scientific advice in support of regulations, policy and management strategies, and have been communicated to a wide range of stakeholders.
Genomics Research and Development Initiative (GRDI), http://grdi-irdg.collaboration.gc.ca/eng/about/	GRDI is developing molecular tools that can be applied for the early detection of AIS. The current focus is on developing the molecular methods, selecting the appropriate gene regions (multiple) for each taxa and populating a baseline library of native and non-indigenous species to be able to compare field data to.
China	
–	–
Japan	
–	–

Table 6.2.1 Continued.

Program	**Description**
Korea	
Korea Institute of Ocean Science and Technology (KIOST), http://www.kiost.ac	KIOST is a government-supported research institute in the field of ocean research and development. It is in charge of the "National Survey of Marine Ecosystem", which is an obligatory national survey of the coastal marine ecosystem in Korea by the *Conservation and Management of Marine Ecosystem Act*. The nationwide survey is carried out along the entire coastal area in Korea at a 10-year interval (2006–2015). The survey covers all major ports and is part of a port-based early detection system. KIOST carried out a project named Development of Port Environmental Risk Assessment Technology (PERAT) from 2007–2010. The objective was to provide scientific support for ballast water treatment systems (BWTs) and develop a port management program that would assist the implementation of a Ballast Water Management plan. The project entailed visiting as many ships and ports as possible. Biological and environmental information was collected from ballast tanks and analyzed with vector analysis. Port baseline surveys were carried out within harbor limits. By investigating risky characters, viability, and source of NIS inside the ballast tanks, port-specific management programs have been developed and updated and accompanied by port baseline surveys. Results from the project have been used to provide scientific advice to concerned parties in charge of ballast water, including government, shipping companies and other national institutes. KIOST is developing ballast water treatment systems and land-based and shipboard testing for the type approval of ballast water management systems in Korea according to the Provisional Regulation of Type Approval of Ballast Water Management System.
Russia	
–	–
USA	
National Environmental Coalition on Invasive Species (NECIS), http://www.necis.net/	NECIS is a national partnership of several major environmental organizations that provides a united expert and scientific voice on invasive species policy. Its leaders include scientists, lawyers, activists, and advocates with many years of experience on invasives policy.
National Invasive Species Council (NISC), http://www.invasivespeciesinfo.gov/index.shtml	NISC was established to ensure that U.S. federal programs and activities to prevent and control invasive species are coordinated, effective and efficient. NISC members are the Secretaries and Administrators of 13 federal departments and agencies to provide high-level coordination on invasive species. Co-Chairs are the Secretaries of Commerce, Agriculture, and the Interior. NISC receives advice from and consults with the Invasive Species Advisory Committee, a group of nonfederal experts and stakeholders.
The North Pacific Landscape Conservation Cooperative (NPLCC), http://www.northpacificlcc.org/	The U.S. Fish and Wildlife Service (USFWS) is leading the NPLCC, one of the many LCCs in a new national network aimed to address large-scale conservation issues like climate change and invasive NIS through a collaboration of natural resource agencies and universities. The NPLCC includes estuarine and coastal waters from northern California to southeast Alaska.

Table 6.2.1 Continued.

Program	**Description**
United States Geological Survey (USGS) Invasive Species Program, http://www.usgs.gov/ecosystems/invasive_species/	The USGS Invasive Species Program provides methodologies and information to address threats to ecological systems and native species due to the introduction and spread of invasive species.
Pacific Marine and Estuarine Fish Habitat Partnership (PMEP), http://www.pacificfishhabitat.org/	As part of the National Fish Habitat Action Plan, USFWS and NOAA are helping lead the formation of a new PMEP. PMEP is a consortium of organizations focused on U.S. West Coast fish habitat in the region's estuaries and nearshore marine waters. This effort could be a source of additional resources for non-indigenous species monitoring and control.
Canada and United States	
Western Regional Panel on Aquatic Nuisance Species, http://www.fws.gov/answest/	The Western Regional Panel on Aquatic Nuisance Species was formed in 1997 to help limit the introduction, spread and impacts of aquatic nuisance species into the Western Region of North America. The Panel is composed of representatives from State, Provincial, and Federal agencies as well as private water interests.

7 Collaboration between ICES Expert Groups and PICES WG 21

There are two ICES expert groups that address aquatic NIS. The Working Group on Ballast and Other Ship Vectors (WGBOSV) which provides scientific support to the development of international measures aimed at reducing the risk of transporting non-native species *via* shipping activities and the Working Group on Introduction and Transfers of Marine Organisms (WGITMO), which deals with aquatic alien species that have an influence on and/or occur in the marine environment.

7.1 Joint Meetings of the Related ICES Working Groups and PICES WG 21

In 2007 and 2009, joint back-to-back meetings of the PICES and ICES working groups on NIS were held. The first joint meeting, attended by PICES WG 21, ICES WGITMO, and the ICES/IOC/IMO WGBOSBV, was held in Cambridge, Massachusetts, USA, concurrent with the 5th Marine Bioinvasions Conference, May 25–26, 2007. The following points were emphasized:

- Potential projects for "*Development of the prevention systems for harmful organism's expansion in the Pacific Rim*";
- Lack of taxonomic expertise limiting ICES-PICES exchange;
- Need for the registry of taxonomic experts;
- Addition of AIS (Aquatic Invasive Species) data based on NISBase;
- Use of bivalve molluscs for database testing;
- Ballast water and biofouling as potential vectors;
- ICES Ballast Water Sampling Guidelines – review of ballast water issues, including early detection, rapid response, impacts, costs, successes, and failures from world-wide examples; role of government and citizens in an EDRR (Early Detection and Rapid Response) system.

Suggestions for future co-operation included:

- *ICES Code of Practice for the Introduction and Transfer of Marine Organisms*;
- Risk assessments or analysis;
- Guidelines for sampling ballast water;
- Other areas for joint projects, including hull fouling.

The second joint meeting was held in 2009, when guests from ICES WGITMO attended the fourth Annual Meeting of WG 21 (PICES-2009, Jeju, Korea). The Chairs and Co-Chairs of the Working Groups also met during the 6th Marine Bioinvasions Conference, held August 24–27 2009, in Portland, USA.

In addition, there is an ongoing liaison between the ICES and PICES Working Group Chairs, including a sharing of meeting reports and project status.

7.2 Recommendations for Enhanced Linkages between ICES and PICES

As the introduction and spread of NIS will continue, establishing global linkages between international organizations working with different ocean basins should be a priority. Collaborations between PICES and ICES, such as a joint working group, could be a portal for sharing information and directed collaboration. This would facilitate the exchange of knowledge across ocean basins, and provide an opportunity to collaborate on marine and brackish water NIS on a larger scale. These collaborations would benefit understanding of the invasion process, including the different pathways and vectors and individual species, as it would enhance access to expertise when working on specific species. Collaboration could be initiated as joint research projects, large-scale risk assessments or international RAS.

Given shared interests in marine science issues, PICES and ICES have revised a framework for strategic collaboration[27] that should include NIS. For example, ICES has three strategic initiatives,[28] one of them being the Strategic Initiative on Biodiversity Science and Advice (SIBAS)[29] where NIS constitute a key piece of SIBAS' mandate, and WG 21 has fed into SIBAS. Any new PICES expert group dealing with NIS should be aware of SIBAS and make linkages to it.

At the working level, there could be enhanced linkages through workshops and special sessions at international conferences and meetings. For example, there will be a joint ICES/PICES Theme Session at the 2014 ICES Annual Science Conference, in A Coruña, Spain,[30] entitled "*The increasing importance of biofouling for marine invasions: an ecosystem altering mechanism*". There could be enhanced linkages between PICES and ICES through a joint meeting/special session at the next Marine Bioinvasions Conference scheduled for January 2016 in Sidney, Australia, and the 10th International Marine Bioinvasions Conference tentatively scheduled for 2018 in Argentina. There is opportunity for ICES to become more involved in the Scientific Steering Committee of the International Conference on Marine Bioinvasions.

While the PICES NIS database/*Atlas* was presented to ICES, the database is now closed and there is currently no mechanism to get additional data from ICES. However, if a common portal to add information, update the database and share information is developed, ICES should be invited to contribute to the future development of the database.

Linkages could also be made between ICES and PICES, as ICES develops advice to implement the European Union's Marine Strategy Framework Directive[31] (adopted in June 2008), and NIS are considered during the development of monitoring programs.

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[27] http://www.pices.int/publications/pices_press/volume20/v20_n1/pp_13_SG-SP.pdf
[28] http://www.ices.dk/explore-us/how-we-work/Pages/default.aspx
[29] http://www.ices.dk/community/groups/Pages/SIBAS.aspx
[30] http://www.ices.dk/news-and-events/asc/ASC-2014/Pages/default.aspx
[31] http://ec.europa.eu/environment/water/marine/directive_en.htm

8 Summary and Recommendations

During its term (2005–2013) WG 21:

- Reviewed and recommended terminology that will clarify future communication among PICES member countries on marine NIS,
- Completed an inventory of NIS around the North Pacific (as of 2012),
- Reviewed international and national policies in place (as of 2012) to reduce the risk of marine NIS,
- Identified potential mechanisms to engage on marine NIS issues with the broader scientific and regulatory community, and
- Conducted training and capacity building activities.

Thus, WG 21 has successfully completed its terms of reference. However, this does not mean that the problem of marine NIS has been solved in the North Pacific as marine NIS represent a current and persistent risk to PICES member countries. Although there is considerable work still ahead, the NIS database, *Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific* and other accomplishments of WG 21 have positioned PICES well to better understand and advance marine NIS topics, including emerging vectors (*e.g*., vessel biofouling, tsunami/marine debris), altered species distributions, risk assessment, and interactions/ impacts on marine ecosystems (including structure, function, productivity, and resilience). As the next logical step, the completed comprehensive database on marine NIS distributions can now be utilized to gain insight to the changes and impacts of NIS around the North Pacific. Recently, the information on NIS distributions/ tolerances in the database was used by Canada to identify potential high risk species associated with tsunami debris as a result of the 2011 Great East Japan Earthquake of magnitude 9.0. Also, there is considerable interest about how projected global climate change will affect the introduction, spread and impacts of NIS in the North Pacific and to undertake risk identification to inform potential mitigation measures by PICES member countries. Global climate change and the associated decrease in Arctic ice cover, combined with the opening of new shipping routes, pose questions related to the introduction and spread of NIS. Interest has been expressed in addressing specific NIS vectors or taxa (*e.g.*, tunicates, bivalves, European green crab) of common interest to many PICES member countries. Collaboration with other international organizations on NIS will be a benefit to PICES, and organizations such as ICES, NOWPAP and WESTPAC have expressed interest in continuing to work with PICES on marine NIS issues. Information in this report can be used to identify priority topics for potential future activities on marine NIS within PICES. Since marine NIS are a priority for many PICES member countries and currently only ballast water will be regulated under the IMO (*via* the International Convention for the Control and Management of Ships' Ballast Water and Sediments), PICES would be the appropriate intergovernmental organization to exchange information on marine NIS in the North Pacific including, but not limited to, changing NIS distributions, emerging vectors, risk assessment, impact characterization, and policy/management development. This will allow continued exchange of knowledge across the North Pacific where many previous incursions have occurred and is an appropriate interface with the international community (*e.g.*, ICES, NOWPAP, IMO). Thus, at a minimum PICES should establish an expert group that can continue to exchange information on changing marine NIS dynamics *via* the WG 21 NIS database.

There are many examples demonstrating that marine NIS are a significant stressor that can alter ecosystem structure and function. Thus, given the NIS database and *Atlas*, there is a strong linkage to the PICES FUTURE program and the North Pacific Ecosystem Status Report. The information in the database could be used to develop a NIS indicator related to anthropogenic stress and/or ecosystem health. However, to implement this in the context of FUTURE and/or the North Pacific Ecosystem Status Report, it would be necessary to update this index as a time series for each ecoregion: a task that could easily be accomplished by a PICES expert group such as an advisory panel. A continued NIS expert group would allow the exploration of climate change models on the most probable changes in NIS distributions around the North Pacific and the identification of likely changes in NIS vectors (*e.g*., new shipping routes, expanding trade). Further, this new expert group could address how PICES member countries have been affected by NIS and what community responses have occurred due to NIS incursions in the North Pacific. This information could help inform policy and management options within each PICES member country and is aligned with recent PICES efforts to include more socio-economic elements.

WG 21 considered several potential options for PICES' continued involvement in marine NIS issues but the option of simply moving forward with annual or biennial topic sessions associated with PICES Annual Meetings was determined to be unsustainable without a formal group structure to organize and oversee activities. Thus, WG 21 recommends the establishment of an Advisory Panel on *Aquatic Non-indigenous Species* (AP-NIS) for continuing aquatic NIS activities in the North Pacific. This preferred option would allow continued progress on marine NIS issues, with the lowest resource commitment.

Advisory Panel on *Aquatic Non-indigenous Species* (AP-NIS)

Suggested parents: MONITOR and/or BIO

Proposed terms of reference:

1. Continue to share information on aquatic non-indigenous species (NIS) in the North Pacific *via* an updated NIS database;
2. Exchange information on updated regulations/policy, best practices for monitoring, early detection, rapid response, and control/containment options;
3. Develop a better understanding of changing distributions of NIS and invasion pathways and vectors in the context of global climate change including expected changes in water temperature, salinity, oxygen, and pCO_2;
4. Plan workshops/sessions/symposia related to NIS topics. (For example a joint PICES/ICES Theme Session on "The increasing importance of biofouling for marine invasions: an ecosystem altering mechanism" was held at the 2014 ICES Annual Science Conference.);
5. Work with other international, intergovernmental organizations (*e.g*., ICES, NOWPAP and WESTPAC) and/or countries to accomplish these terms of reference, especially those related to data/information exchange;
6. Prepare regular reports on accomplishments.

Appendices

Appendix 1

WG 21 Terms of Reference

2005–2007

1. Complete an inventory of all aquatic nonindigenous species **(**NIS) in all PICES member countries, together with compilation and definitions of terms and recommendations on use of terms. Summarize the situation on bioinvasions in the Pacific and compare and contrast to other regions (*e.g*., Atlantic, Australia, *etc*.);
2. Complete inventory of scientific experts in all PICES member countries on aquatic NIS subject areas and of the relevant national research programs/projects underway;
3. Review and evaluate initiatives on mitigation measures (*e.g*., ICES Code of Practice for the Introduction and Transfer of Marine Organisms, IMO Ballast Water Management Convention and others such as the Canadian Introductions and Transfers Code);
4. Summarize research related to best practices for ballast water management;
5. Coordinate activities of the PICES WG on aquatic non-indigenous species with related WGs in ICES through a joint back-to-back meeting of the PICES and ICES Working Groups on invasive species in 2007/8;
6. Develop and recommend an approach for formal linkages between PICES and ICES on aquatic non-indigenous species;
7. Publish final report summarizing results and recommendations.

Revised in 2008

1. Assesses the status of Non-Indigenous Aquatic Species in the PICES area by:
   - completing an inventory of currently reported estuarine and marine aquatic non-indigenous species in PICES member countries;
   - compiling definitions of terms and making recommendations on use of terms;
   - summarizing the situation on bioinvasions in the North Pacific; and
   - comparing and contrasting to other regions.
2. Assemble an inventory of expertise and programs related Non-Indigenous Aquatic Species in PICES member countries by compiling:
   - a list of existing databases of Non-Indigenous Aquatic Species experts in PICES member countries; and
   - sources of information on relevant national research and monitoring programs.
3. Summarize initiatives on prevention and mitigation measures (*e.g*., ICES Code of Practice for the Introduction and Transfer of Marine Organisms; IMO Ballast Water Management Convention and national policies of PICES member countries), and develop recommendations for best practices for prevention and mitigation.
4. Promote collaboration between ICES and PICES Working Groups on non-indigenous species by:
   - holding joint meetings of the ICES and PICES WG-21 as conveniently possible; and
   - developing and recommending an approach for enhances linkages between ICES and PICES on Non-Indigenous Aquatic Species.
5. Develop a comprehensive Non-Indigenous Aquatic Species Database.
6. Establish a North Pacific Marine Non-Indigenous Aquatic Species taxonomy initiative.
7. Publish an interim report in 2010 and a final report in 2012 summarizing results and recommendations.

Appendix 2

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Appendix 3

Number of NIS in Different Regions in the North Pacific and the North Atlantic According to Taxonomic Group

Table A3.1 Number of non-native bivalve species in the different regions in the North Pacific and the North Atlantic.

		Region where NIS					
Bivalves		**NWP**	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
	Total NIS	21	22	22	15	18	77
Region where native							
North Pacific	NWP	5	7	11	3	7	24
	NEP	2	1	0	0	0	0
	Hawaii	0	0	0	0	0	2
Central South Pacific - Indian Ocean	C Indo-Pacific	7	12	9	5	7	44
	E Indo-Pacific	0	2	0	1	1	8
	S Australia & NZ	1	5	0	1	2	9
	Indian Ocean	2	8	0	3	1	55
Central-South East Pacific	Tropical E Pacific	0	0	0	0	0	0
	SE Pacific	0	0	0	0	1	0
West Atlantic	NW Atlantic	5	2	7	4	6	5
	W Tropical Atlantic	5	2	4	3	5	5
	SW Atlantic	0	0	0	1	0	2
East Atlantic	NE Atlantic	4	0	2	2	0	1
	Mediterranean	4	0	2	1	0	0
	Ponto-Caspian	1	0	1	2	2	1
	E Tropical Atlantic	0	0	0	1	0	1
	S Africa	0	1	0	1	0	4
Polar regions	Arctic	1	0	2	0	2	1
	Magellanic	0	0	0	0	0	0
	Antarctica	0	0	0	0	0	0
	Origin unknown	1	4	3	1	1	1

Table A3.2 Number of non-native amphipod species in the different regions in the North Pacific and the North Atlantic.

Amphipods		**Region where NIS**					
		NWP	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
	Total NIS	7	20	37	5	17	8
Region where native							
North Pacific	NWP	0	2	11	1	3	1
	NEP	1	1	1	1	0	0
	Hawaii	0	0	0	0	0	0
Central South Pacific - Indian Ocean	C Indo-Pacific	0	3	3	0	0	0
	E Indo-Pacific	0	0	0	0	0	0
	S Australia & NZ	0	0	0	0	0	0
	Indian Ocean	0	1	1	1	1	4
Central-South East Pacific	Tropical E Pacific	1	1	0	1	0	0
	SE Pacific	0	0	0	0	0	0
West Atlantic	NW Atlantic	4	5	11	**0**	2	0
	W Tropical Atlantic	2	2	7	0	1	0
	SW Atlantic	0	1	0	0	0	0
East Atlantic	NE Atlantic	4	4	6	1	1	0
	Mediterranean	1	2	3	1	0	**0**
	Ponto-Caspian	0	0	1	1	8	0
	E Tropical Atlantic	0	0	0	0	0	0
	S Africa	0	0	0	0	0	0
Polar regions	Arctic	2	1	1	1	0	0
	Magellanic	0	0	0	0	0	0
	Antarctica	0	0	0	0	0	0
	Origin unknown	2	7	12	1	2	1

Table A3.3 Number of non-native isopod species in the different regions in the North Pacific and the North Atlantic.

Isopods		**Region where NIS**					
		NWP	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
	Total NIS	4	21	20	10	5	7
Region where native							
North Pacific	NWP	0	1	5	1	1	0
	NEP	1	2	0	1	2	2
	Hawaii	0	0	0	0	0	0
Central South	C Indo-Pacific	0	3	2	3	0	0
Pacific	E Indo-Pacific	0	2	0	1	0	0
- Indian Ocean	S Australia & NZ	0	1	4	0	0	1
	Indian Ocean	0	2	1	4	0	2
Central-South	Tropical E Pacific	1	2	0	1	2	2
East Pacific	SE Pacific	0	0	0	0	0	0
West Atlantic	NW Atlantic	0	0	1	0	0	0
	W Tropical Atlantic	0	1	1	0	0	0
	SW Atlantic	0	0	0	0	0	0
East Atlantic	NE Atlantic	2	4	3	3	0	1
	Mediterranean	2	4	3	2	1	0
	Ponto-Caspian	0	0	0	0	0	0
	E Tropical Atlantic	0	1	0	1	0	1
	S Africa	0	0	1	0	0	1
Polar regions	Arctic	0	0	0	0	0	0
	Magellanic	0	0	0	0	0	0
	Antarctica	0	0	1	0	0	0
	Origin unknown	0	8	4	1	1	0

Table A3.4 Number of non-native decapod species in the different regions in the North Pacific and the North Atlantic.

		Region where NIS					
Decapods		**NWP**	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
	Total NIS	16	10	5	16	16	73
Region where native							
North Pacific	NWP	4	3	3	4	7	13
	NEP	4	0	0	2	3	1
	Hawaii	1	0	0	0	0	5
Central South Pacific - Indian Ocean	C Indo-Pacific	4	7	3	5	4	28
	E Indo-Pacific	0	4	0	0	1	4
	S Australia & NZ	0	3	0	0	1	2
	Indian Ocean	2	6	0	2	1	48
Central-South East Pacific	Tropical E Pacific	3	0	0	1	0	1
	SE Pacific	0	0	0	0	0	0
West Atlantic	NW Atlantic	3	1	1	5	5	6
	W Tropical Atlantic	2	1	1	3	2	7
	SW Atlantic	1	0	0	0	2	1
East Atlantic	NE Atlantic	3	0	1	1	0	4
	Mediterranean	3	0	1	1	0	0
	Ponto-Caspian	1	0	0	0	1	1
	E Tropical Atlantic	0	0	0	0	0	8
	S Africa	2	1	0	0	0	1
Polar regions	Arctic	1	0	0	1	2	0
	Magellanic	0	0	0	0	0	0
	Antarctica	0	0	0	0	0	0
	Origin unknown	0	2	0	0	0	2

Table A3.5 Number of non-native barnacle species in the different regions in the North Pacific and the North Atlantic.

Barnacles		**Region where NIS**					
		NWP	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
	Total NIS	11	4	5	8	10	8
Region where native							
North Pacific	NWP	0	1	1	2	2	2
	NEP	1	0	1	2	0	0
	Hawaii	0	0	0	0	0	0
Central South Pacific - Indian Ocean	C Indo-Pacific	2	2	2	2	2	2
	E Indo-Pacific	0	0	0	0	0	0
	S Australia & NZ	1	0	0	1	1	1
	Indian Ocean	1	2	2	2	2	3
Central-South East Pacific	Tropical E Pacific	1	0	0	1	1	0
	SE Pacific	0	0	0	0	0	0
West Atlantic	NW Atlantic	3	2	3	1	2	3
	W Tropical Atlantic	3	2	3	1	2	3
	SW Atlantic	2	2	1	0	1	1
East Atlantic	NE Atlantic	1	0	0	0	1	0
	Mediterranean	1	0	0	0	0	0
	Ponto-Caspian	1	0	0	0	0	0
	E Tropical Atlantic	0	0	0	0	1	0
	S Africa	0	0	0	0	0	0
Polar regions	Arctic	0	0	0	0	0	0
	Magellanic	0	0	0	0	0	0
	Antarctica	0	0	0	0	0	0
	Origin unknown	2	0	0	0	1	0

Table A3.6 Number of non-native tunicate species in the different regions in the North Pacific and the North Atlantic.

		Region where NIS					
Tunicates		**NWP**	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
Total # NIS		10	29	23	10	11	23
Region where native							
North Pacific	NWP	3	6	9	5	6	5
	NEP	1	0	0	1	0	0
	Hawaii	0	0	0	0	0	0
Central South	C Indo-Pacific	1	12	8	4	4	7
Pacific	E Indo-Pacific	0	0	0	0	0	1
- Indian Ocean	S Australia & NZ	1	4	4	1	3	3
	Indian Ocean	0	3	1	0	0	4
Central-South	Tropical E Pacific	1	1	1	0	1	1
East Pacific	SE Pacific	1	1	1	0	1	1
West Atlantic	NW Atlantic	1	0	2	1	1	2
	W Tropical Atlantic	1	0	2	1	1	4
	SW Atlantic	0	0	0	0	0	0
East Atlantic	NE Atlantic	4	2	3	2	1	1
	Mediterranean	4	2	3	2	1	1
	Ponto-Caspian	2	0	1	2	1	1
	E Tropical Atlantic	0	0	0	0	0	0
	S Africa	0	0	0	0	0	1
Polar regions	Arctic	1	0	1	1	0	0
	Magellanic	0	0	0	0	1	0
	Antarctica	0	0	0	0	1	0
	Origin unknown	0	12	4	1	0	8

Table A3.7 Number of non-native ray-finned fishes in the different regions in the North Pacific and the North Atlantic.

Ray-finned fishes		Region where NIS					
		NWP	**Hawaii**	**NEP**	**NWA**	**NEA**	**Med**
Total # NIS		34	28	25	7	7	122
Region where native							
North Pacific	NWP	7	9	5	2	1	46
	NEP	2	1	0	2	1	16
	Hawaii	0	0	0	0	0	27
Central South	C Indo-Pacific	6	15	3	0	0	61
Pacific	E Indo-Pacific	1	12	0	0	0	45
- Indian Ocean	S Australia & NZ	1	5	0	0	0	25
	Indian Ocean	4	12	2	1	0	84
Central-South	Tropical E Pacific	0	0	0	0	0	18
East Pacific	SE Pacific	0	0	0	0	0	14
West Atlantic	NW Atlantic	12	4	14	1	2	22
	W Tropical Atlantic	8	7	9	0	2	19
	SW Atlantic	1	0	0	0	0	13
East Atlantic	NE Atlantic	5	0	2	2	1	20
	Mediterranean	7	0	2	3	1	0
	Ponto-Caspian	4	1	1	1	3	1
	E Tropical Atlantic	2	1	1	1	0	29
	S Africa	1	6	1	0	0	22
Polar regions	Arctic	6	1	6	2	0	2
	Magellanic	0	0	0	0	0	1
	Antarctica	0	0	0	0	0	0
	Origin unknown	0	0	0	0	0	0

Appendix 4

WG 21 Rapid Assessment Survey Framework

RAS standardized data collection protocol

Purpose

This rapid assessment survey (RAS) will identify native, non-native and cryptogenic species present at ports in PICES member countries. Although it may not be possible to characterize all habitat types within a port, this survey focuses on major ecosystem components, namely *intertidal* and *subtidal habitats*. Intertidal habitats will be sampled using both a timed walk and quadrat/grab sampling methods. Subtidal habitats will be sampled using (tunicate) collectors, trapping for macrofauna (primarily crabs) and a survey of the fouling communities on floating docks and their associated structure. The RAS is a *qualitative survey* (not a quantitative one) meant to capture the species composition within each port surveyed. The assignment of native, non-native or cryptogenic status will occur following species identification based on literature accounts, general rules for classification of status (*e.g*., Chapman and Carlton, 1991), and discussion by the sampling team consisting of members of WG 21. It is essential that the taxonomy is resolved to the greatest extent possible. However, where there is uncertainty in species identification a species name should not be “forced”, as this might increase the risk of misidentification.

Access

Based on our first RAS survey in China it is now clear that port security is an issue and that an international sampling team might not be allowed access to a given port. Thus, it is imperative that the host country identify the specific requirements (port authority or country) and determine the feasibility of gaining access to potentially secure locations for sampling. As soon as possible, each country needs to appoint a contact person for the survey. This contact person will work with the lead Principal Investigator (PI), Dr. Therriault in planning and execution of the RAS. Dr. Therriault should be notified as soon as possible as to whether sampling will be done by the international sampling team or in advance by the host country.

Timing

Although many invertebrate species (not all) would appear in greater abundances during the warmer, summer months, sampling will coincide with the annual PICES meeting. As agreed, the RAS will be conducted in the host PICES member country the week prior to the annual meeting (generally mid-October). Thus, some taxonomic groups might not be encountered during the RAS, resulting in incorrect classification as ‘not present’ at the sampled locations. This is expected and is one limitation of this type of RAS. To fully characterize a site, sampling should be repeated during other seasons. If possible, some sampling should be conducted during the summer months when daylight tides are lower. Samples can be preserved for identification later and can be used to supplement any collections made by the international sampling team.

Taxonomy

The goal and success of this type of survey requires the participation of taxonomic experts with broad knowledge of their taxonomic group, in addition to the participation of taxonomic generalists that are able to help with sampling and species identification (primarily *via* the use of identification keys). This type of survey also provides training to the generalists. Given the limited budget, the RAS will be conducted using as many taxonomic experts from the host country as possible with participation from members of WG 21. Participation of students is encouraged for logistical support and training. Due to the contribution by the Japanese government, we have some funds available to cover travel/accommodation costs associated with host country taxonomists as well as some funds to cover the costs of "key" taxonomic experts not readily available in the host country. Given one goal of the project is to resolve and/or identify potential non-indigenous species transported across the North Pacific, it is highly desirable to have taxonomic experts from both the eastern and western Pacific for each taxonomic group targeted (or potentially expected) during the survey.

Given that the taxonomy for some species will be controversial, it is imperative that voucher specimens are maintained for future reference. It is expected that the host PICES member country would maintain their respective RAS collections in suitable archives. Further, all species records will be entered into the PICES WG 21 Nonindigenous Species Database (many at the time of the survey but others following species verification where necessary). The major taxonomic groups likely to be encountered are provided in Appendix A and the host PICES member country should identify local experts for these groups who can participate in the RAS. If local experts are not available, other experts may be identified from other countries as needed.

Sampling sites

Given that not all species will be found in all habitat types, sampling needs to encompass as many habitat types as possible. Thus, where possible, sampling teams should strive to sample two separate intertidal and two separate subtidal locations within each port. It is recommended that one intertidal and one subtidal location be sampled each day for each port. Thus, this RAS will capture at least four different locations within a port over a two day period. Also, where necessary, permission and permits may be required and should be obtained in advance if possible.

Sampling methods

Site description

At each sampling site it is important that a general physical site description be made, including an accompanying diagram of the site. General information that should be collected include the number and types of habitats encountered (*e.g*., mudflat, oyster reef, *etc*.), relative size of these habitats, notable site attributes (*e.g*., marina present, shellfish aquaculture present, river/creek draining across the beach, *etc*.), and general biological communities observed (*e.g*., barnacles present on floats above the water and mussels present below, boulder community dominated by mixed algae, *etc*.). In addition, specific site data needs to be recorded including latitude, longitude, sampling day, sampling time, sampling team members, temperature, salinity, *etc*. Also, a number of photographs documenting the site characteristics should be taken for future reference and report writing.

Environmental variables

At each site environmental variables should be measured including temperature, salinity, and dissolved oxygen. If possible, other variables that could be measured include total dissolved solids (TDS), chlorophyll *a*, and Secchi disc depth. For intertidal zones it is important to measure beach slope and intertidal zone length. For subtidal zones it is important to note the tidal amplitude and maximum water depth.

Subtidal survey (collector sampling)

These passive collectors are deployed 4–6 months in advance of collection. When retrieved, the Petri dishes attached to the collector lids are individually stored in Zip-lock (or other self-sealing plastic) bags and labelled (collection date, collector number, sampling depth, Petri dish number). If processing is not immediate then dishes need to be preserved in either 3.7% formalin or 95% ethanol (NOTE: ethanol preservation is required for genetic analyses). Any large macrofauna should be recorded as should any species that is present on the collector lids but not readily observed on the individual Petri dishes.

Subtidal survey (floating docks and associated structures)

Due to the floating nature of these structures the sampling is NOT tide dependent and should be conducted before or after the intertidal sampling, depending on the time of the daylight low tide. Time spent surveying the floating structure should be restricted to 1 hour for the sampling team which will allow standardization among sampling sites. Additional time will be required for measurement of environmental variables and site characterization, so sampling teams should allow about 2 hours to complete this part of the survey. At each site larger organisms can be identified *in situ* if possible and voucher photographs taken. All medium to small organisms should be collected. Any organism that cannot be positively identified or look different need to be collected for taxonomic identification at the laboratory. Samples should be collected by taking scrapings of the fouling community at different locations along the floating structure. If possible, divers or snorkelers can be deployed to make collections on the underside of the floating structure or along the support pilings. Scrapings should be collected using aquarium nets to prevent organisms from falling off and escaping.

Subtidal survey (trapping)

In order to characterize the mobile macrofauna such as crabs, baited crab traps should be deployed for 24 hours and retrieved. Generally, traps would be deployed the day before the subtidal/intertidal surveys and retrieved when the sampling team returns to conduct the survey the following day. The traps would be re-set the day of the survey and collected the following day following the survey. All organisms should be retained for identification/measurement prior to release or destruction. In our surveys we have used the Fukui square multispecies marine trap (FT-100) and found they work well. Also, bait may change depending on country of sampling but we found that herring works well. Simply ensure the bait is in a bait jar that is suspended inside the trap.

Intertidal survey (timed walk)

If possible, sampling should be conducted when low tides are maximal thereby exposing significant portions of the intertidal zone for sample collection. Following site characterization (and environmental measures) the sampling team should proceed to randomly walk the intertidal zone (beach) to maximize the number of microhabitats visited. The time of the timed walk should be consistent among sampling sites and should be 1 hour in total with 20 minutes spent in each of the low, mid and high intertidal zones. Additional time will be required for environmental sampling and site characterization so sampling teams should arrive at the beach about 2 hours before the daylight low tide. During the timed walk larger organisms should be identified *in situ* if possible and voucher photographs taken. All medium to small organisms should be collected. Any organism that looks different needs to be collected for later taxonomic identification. Any species that cannot be positively identified in the field needs to be retained for verification at the laboratory.

Intertidal survey (quadrat sampling/grab sampling)

There are two methods to characterize the infaunal community, Ekman (or similar) sediment grabs for smaller benthic organisms and quadrat sampling (50 cm × 50 cm × 30 cm deep) for larger organisms (*e.g.*, bivalves). Replicate Ekman grabs should be made at each of the three intertidal heights (low, mid and high) and sieved through 1 mm mesh. Replicate quadrat samples should be made at each of the three intertidal heights and also should be sieved but due to the larger size of the target organisms the sieve size can be 3 mm. Generally this type of digging would occur in areas where clam siphons are noted. Although our survey is focused on macroorganisms, unsieved samples could be archived for microorganisms such as dinoflagellates, foraminifera, diatoms, *etc*.

Reference

Chapman, J.W. and Carlton, J.T. 1991. A test of criteria for introduced species: the global invasions by the isopod *Synidotea laevidorsalis* (Miers, 1881). *J. Crustacean Biol*. **11**: 386–400.

Major taxonomic groups expected to be identified

Plants/Algae
Porifera
Cnidaria/Hydroids
Polychaetes
Nemerteans/Oligochaetes/Platyhelminthes
Molluscs (Gastropods/Bivalves)
Crustaceans (Amphipods/Decapods/Isopods/Barnacles)
Bryozoans
Ascidians
Echinoderms

Sampling equipment/laboratory supplies

Field equipment
Field guides
Maps/charts/permission forms (permits)
Duct tape (or other strong adhesive packing tape)
Shovels/spades/trowels/rakes
Scrappers/spatulas
Nets (aquarium)
Ekman grabs (for sediment sampling)
50 cm × 50 cm quadrat
Buckets
Sieves (1mm and 3 mm mesh)
Magnifying glasses (hand lenses)
Traps and jars with bait
Line (rope) and floats
Jars/bags (leak-proof)
Labels
Data sheets
Field notebooks
Pencils/pens/sharpies (or other permanent waterproof markers)
Cameras (digital high resolution preferable)
GPS units
Inclinometer (to measure beach slope)
Rangefinder (to measure beach length)
Tape measures (100 m)
Thermometers
Refractometers (YSI meters)
Dissolved oxygen meters
Secchi discs
Coolers with ice packs (if samples to be processed that day)
Totes/boxes (if samples to be preserved and archived)
Preservatives (formalin, ethanol)

Laboratory supplies
Field guides
Taxonomic keys
Literature/monographs
Dissecting microscopes
Compound microscopes
Microscope/desk light sources
Microscope equipment (slides, cover slips, forceps, pipettes, *etc*.)
Dissecting equipment (scalpels, forceps, probes, *etc*.)
Glass dishes/petri dishes
Photographic equipment including microscope cameras
Preservatives (formalin, ethanol, stains, *etc*.)
Squeeze bottles
Scintillation vials/jars/bags (leak-proof)
Labels
Plant press
Herbarium materials
Ample bench space
Supply of water (seawater and freshwater)
Fume hoods/sinks
NIS database (MS Access)

General
Vehicle to access sampling sites
Raingear
Boots/waders
Gloves

Appendix 5

Other Products of WG 21

Outreach brochure

What are non-indigenous species?

Non-indigenous species (NIS) are species that have been introduced to new locations outside their native range primarily due to human-mediated activities such as shipping and mariculture. Once established in these new locations, introduced species can have a profound and disastrous impact on ecosystem structure and functions that can ultimately threaten productivity and seafood security. For example, introduced species can have an effect on important commercial species though several mechanisms including competition for food and habitat and by predation.

The project

In 2007, PICES Working Group on *Non-indigenous Aquatic Species* (WG 21) embarked on a 5-year project entitled "Development of prevention systems for harmful organisms' expansion in the Pacific Rim" with funding provided by the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF). WG 21's tasks were to address two key elements required for early detection and rapid response. The first initiative was the development of a comprehensive, searchable database and atlas of non-indigenous marine and estuarine species in the North Pacific. The second initiative was to conduct a series of rapid assessment surveys (RAS) to develop and disseminate techniques for the quick detection and identification of non-indigenous species that presently exist in a variety of habitats of PICES member countries (Canada, China, Japan, Korea, Russia and the United States).

Prevention and detection

Prevention is the first line of defence against NIS. Knowledge about the distribution of potential NIS, dispersal vectors, and their ecological characteristics allows one to characterize their invasion risk. With this information in hand, managers can determine the likely extent and type of risk associated with a new invader and the best course of action for mitigating the impacts of new invaders that can affect local species.

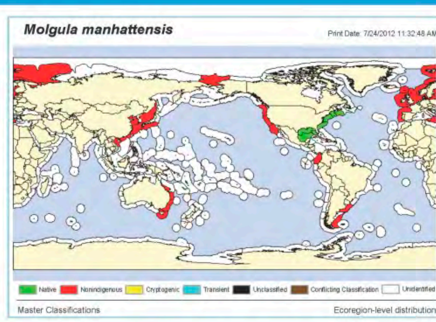
The PICES database allows large-scale collection of this data which can then be used by managers to develop monitoring programs for early detection or rapid response and make mitigation plans for higher-risk NIS to limit the impacts on native biodiversity and commercially important species.

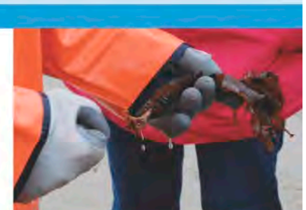
When a potential NIS is first detected, local authorities often are unable to identify the organism and valuable time is lost while species identity is being confirmed along with its preferred ecological requirements (*e.g.*, salinity, temperature, habitat substrate) and its history of invasion success. If a NIS is unsuited for its new location, it will have a low probability of survival and establishment, and there may be no need to implement control or mitigation measures. On the other hand, if conditions are ideal and the species has successfully invaded other areas, with negative impacts, then very quick action may be required.

Database and Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific

The database and Atlas contain profiles of 747 non-indigenous species reported from PICES member countries. The profiles include maps of their global distribution, invasion vectors, life history and habitat information that were collated along with an analysis of their invasion patterns in the North Pacific region. As an example, the distribution of the tunicate *Molgula manhattensis* is shown. This widespread invader, which is native to the Northeast Atlantic, has spread to both the eastern and western North Pacific.

The database and Atlas also contain numerous references to scientific papers that scientists and managers can consult when assessing risks posed by potential NIS, including choosing the most appropriate course of action which can range from immediate and comprehensive eradication to ongoing monitoring.





A sample of *Undaria pinnatifidar*: This Japanese kelp has invaded other parts of the world's coastlines.

(Photo credit: Christopher N. Janousek, U.S. Environmental Protection Agency)

Rapid Assessment Surveys (RAS)

Given the continued exchange of species globally by various vectors, especially species redistributions around the North Pacific, it is important to establish collaborations between taxonomists and invasion biologists on both sides of the Pacific Ocean in order to truly understand species distribution patterns and hence invasion patterns. To foster collaborations among NIS researchers, a series of four PICES RAS was conducted with the help of local hosts in Dalian, China, 2008; Jeju, Korea, 2009; Newport, United States, 2010; and Vladivostk, Russia, 2011. Through these collaborations, we now have a much better understanding of the invasion patterns of several taxonomic groups, including algae, amphipods, polycheates (worms), and ascidians (tunicates or sea squirts).

2011 PICES RAS near Vostok Bay, Russia

2009 PICES RAS near Jeju, Korea

2010, Awaji Island, Japan

2011, Phuket, Thailand

2012, Nagasaki, Japan

Capacity Building – Training and Outreach

Given a number of vectors redistributing species around the Pacific Ocean, building capacity, especially in developing countries, is critical to better understand invasion dynamics and maintain safe and productive marine ecosystems. One way to share information on global invaders is to hold demonstration workshops to provide participants with the tools needed to conduct their own surveys.

Three demonstration workshops on "Rapid Assessment Survey Methodologies for Non-Indigenous Species" were hosted – Awaji Island, Japan, in 2010; Phuket, Thailand, in 2011; and Nagasaki, Japan, in 2012. The primary goal of these workshops was to increase awareness about marine and estuarine NIS and to provide "hands-on" experience for participants, especially those from developing countries. Over 50 participants from China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand, and Vietnam have received training.

The ability to provide training to early career scientists will increase our global capacity to respond to ever increasing issues related to NIS. In addition to having early career scientists participate in the RAS and demonstration workshops, over 20 early career scientists were able to present their research on NIS at international conferences world-wide.

Summary

This PICES/MAFF project has made it possible for countries to share information quickly and efficiently, especially details where the species originated and when it arrived. These data are critical for successfully mitigating the impacts of NIS on local environments and economies.

A lasting benefit from the project has been increased awareness and collaboration on NIS issues, especially taxonomic exchanges between PICES member countries and with international organizations like NOWPAP and WESTPAC. The Atlas serves as a valuable resource for agencies and scientists tasked with managing and researching non-indigenous species in the North Pacific, while RAS techniques can be applied around the Pacific or beyond.

Acknowledgements

PICES gratefully acknowledges the generous contribution of the Japanese Government and all those who have participated and contributed to the completion of the database and Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific, and to the rapid assessment surveys.

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Appendix 6

Meeting Reports and Topic Session/Workshop Summaries from Past PICES Annual Meetings Related to WG 21

PICES Thirteenth Annual Meeting (PICES XIII)
October 14–24, 2004
Honolulu, USA

Extracted from:

2004 Summary of Scientific Sessions and Workshops at PICES XIII

MEQ Topic Session (S5)
Natural and anthropogenic introductions of marine species

Co-sponsored by the International Council for the Exploration of the Sea (ICES)

Co-Convenors: William P. Cochlan (U.S.A./PICES), Yasuwo Fukuyo (Japan/PICES) and Stephan Gollasch (Germany/ICES)

Background

Species introductions are among the most prevalent of human activities affecting natural ecosystems. In the marine environment, introductions, including most aquaculture initiatives, have resulted in both positive and negative effects. The transport of invasive species, such as phytoplankton, is thought to stem from range extensions associated with fluctuating oceanographic conditions (*e.g.*, El Niño), severe storm events (*e.g.*, typhoons), and human activities (*e.g.*, ballast water). The impact of transport processes on species distributional changes in North Pacific waters is not fully understood. Relative to the terrestrial environment, the study of introductions, and the potential for new species to become invasive, is in its infancy in marine systems. Emerging work includes introduction vectors, life history characteristics of invasive species, ocean conditions responsible for invasions, ecosystem resistance to invasion, and potential for eradication or mitigation of introductions once established. This session sought to answer three fundamental questions: 1) What is known about different transport mechanisms? 2) What is the magnitude of ecological and economic effects arising from the transport of species? and 3) What steps can be taken to minimize real or potential effects of existent and future invasive species? The current session is particularly timely given that the IMO Ballast Water Management Convention was signed in February 2004, and is now awaiting ratification.

Summary of presentations

The session consisted of 11 oral presentations and 1 poster, representing authorship from five PICES nations: Canada, Japan, Korea, Russia and the United States, and six non-PICES nations: Australia, Germany, Ireland, Italy, Mexico and New Zealand, as well as ICES. Despite the broad range of invasive topics selected for this session, the attendance was modest. The late cancellation of one oral presentation permitted careful discussion and additional questions for each of the talks: an opportunity well received by those in attendance. The session's presentations were organized around 1) the case histories of invasives, including both pelagic and benthic organisms, 2) descriptive and mathematical analyses of invasive vectors and their relative importance in various marine systems, and 3) management of invasion vectors, followed by discussion of any aspect of the session and consideration of future workshop ideas.

After brief introductory remarks by one of the co-convenors (S. Gollasch), the first invited speaker (Gustaaf Hallegraeff) discussed the role of ship's ballast water in spreading harmful algal bloom (HAB) species in Australian coastal waters, including the presence of culturable *Pseudo-nitschia* diatoms and *Pfiesteria piscisida* dinoflagellates in ballast waters. His presentation also discussed the special problem of invasive cysts, methods to determine if these invasive cysts have firmly established themselves in new environments, and the treatments to remove invasive species in ballast waters or destroy their viability. The next two speakers continued with case histories of invasive species, including the seaweed *Undaria pinnatifida* and their molecular identification (Shinya Uwai), and a Russian study of the invasive success of benthic species (polychaetes and phoronids) in the more ecologically stressed and contaminated regions of the Peter the Great Bay (Tatiana Belan).

Majorie Wonham, our next invited speaker, discussed the various hypotheses used to describe the apparent increase in marine biological invasions. Using existent data sets (from six independent marine systems), she demonstrated that often more than one model (linear, exponential and exponential) can describe temporal invasion trends, and outlined the difficulty of interpreting species invasions without consideration of both introduction rates and survival probabilities. Stephan Gollasch (invited ICES speaker) posed the question of whether ballast water was the key vectors for aquatic species invasions. His presentation reviewed the relative importance of the various vectors for species introductions in twelve marine regions around the world, and demonstrated that hull fouling, ballast water and aquaculture were the most important vectors in all regions considered. However, his analysis also showed that the relative importance of these vector is regionally specific, and that hull fouling, not ballast waters, was the dominant vector in 60% of the regions considered; a conclusion which suggests that increased international regulation of ballast water introductions will not necessarily eliminate or decrease species invasions in all regions. Dan Minchin continued with the theme of vectors, and showed the importance of small craft, (open boats, yachts and cruisers) in transporting invasive species, and how their relative importance has appeared to increase with the growing number of citizens capable of owning and operating such craft. His analysis also demonstrated the importance of marinas as exchange points for invasives from the primary vector of shipping to the secondary vector of small craft which further increase their range extension to areas inaccessible by shipping alone.

Yasuwo Fukuyo, in a series of back-to-back presentations, outlined the IMO Ballast Water Management Convention, its history and articles, and most importantly the challenges present in obscure wording (*e.g.*, viability) and the availability of reliable scientific methods to support the performance standards outlined in the Convention. A very promising technique (Special Pipe) designed in Japan to terminate ballast water organisms using shear stress and cavitation was described, and its tests of efficacy presented. Jennifer Boehme outlined a verification system to ensure that mid-ocean ballast water exchange procedures are actually conducted based on the optical characteristics of chromophoric dissolved organic matter (CDOM) present in the original ballast water. She showed that statistics could be effectively used to discriminate the variability of CDOM florescence in various oceanic and coastal regions, and that such an analysis could offer a verification system independent of port salinity. Scott Godwin described recent efforts to identify and control species introductions associated with hull-fouling - the principal invasive vector in Hawaiian waters, using a risk-management approach based on a relative fouling risk associated with various vessels and the dynamics of their arrival in Hawaiian ports. The final oral presentation by Stephan Gollasch was an introduction to the history, practices and work products resulting from the ICES efforts on the introductions of marine organisms. He concluded with a number of suggestions including the establishment of a PICES Working Group on *Species invasions* (not limited to HABs), and the reciprocal attendance of PICES and ICES members at their annual meetings and working sessions. He urged PICES member countries to follow the "ICES Code of Practice for the Introduction and Transfer of Organisms" when planning species introductions, and emphasized the need for both regional and global networks to most efficiently deal with biological invasions, given that an invasive species could originate from a non-PICES nation.

The session was concluded by a lively discussion led by Dr. Fukuyo where representatives of all PICES member countries in attendance agreed upon the establishment of a Working Group on *Marine invasive species*. Such a working group will serve as a means to create awareness of the species invasion problem, encourage additional scientific research on the issue, and enhance funding opportunities dealing with marine invasive initiatives in PICES member countries, and eventually may support the timely ratification and implementation of the IMO Ballast Water Management Convention.

<u>List of papers</u>

Oral presentations

Gustaaf M. Hallegraeff (Invited)
Range extensions and ship ballast water transport of harmful algal bloom species in the Australian region

Shinya Uwai, Wendy Nelson, Luis E. Aguilar-Rosas, Sung Min Boo and Hiroshi Kawai
Introduced seaweeds - Genetic diversity of introduced and native *Undaria pinnatifida*

Tatyana A. Belan
Anthropogenic invasion of some benthic species in the coastal areas

Marjorie J. Wonham and Elizaveta Pachepsky (Invited)
What do temporal trends in invasion records really mean?

Stephan Gollasch (Invited)
Ballast water - The key vector for aquatic species invasions?

Dan Minchin, Anna Occhipinti, Oliver Floerl and Dario Savini
Small craft as a vector of exotic species

Yasuwo Fukuyo
The Ballast Water Convention and its inherent, but inevitable incompleteness for the prevention of biological invasion

Jennifer Boehme and Mark Wells
Ballast water exchange verification using the optical characteristics of dissolved organic matter

Yasuwo Fukuyo, Takeaki Kikuchi, Katsumi Yoshida and Seiji Kino
Onboard ballast water treatment using the special pipe to terminate aquatic organisms

L. Scott Godwin
Marine invasive species transported by vessel hull fouling: Potential management approaches

Stephan Gollasch
ICES and biological invasions - introduction to the work of ICES Working Group on Introductions and Transfers of Marine Organisms and ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors

Poster

Alexei M. Orlov
Ichthyofaunal exchange between northwestern and northeastern Pacific: Possible directions and mechanisms

PICES Fourteenth Annual Meeting (PICES XIV)
September 29–October 9, 2005
Vladivostok, Russia

Extracted from:

2005 Summary of Scientific Sessions and Workshops at PICES XIV

MEQ Workshop (W2)
Introduced species in the North Pacific

Co-sponsored by the International Council for the Exploration of the Sea (ICES)

Co-convenors: Yasuwo Fukuyo (Japan/PICES), Stephan Gollasch (Germany/ICES) and Glen Jamieson (Canada/PICES)

Background

The workshop concerned the status of introduced organisms in member countries and progress in developing inventories of introduced species; reports of activities related to research on vectors, including natural (currents and organisms such as turtles and birds), and anthropogenic (ballast water, hull fouling, fisheries, *etc*.) ones; reports of activities related to the Ballast Water Management Convention, especially measurement of compliance with ballast water exchange protocols, and measurement of effectiveness and development of systems of ballast water treatment. The workshop aimed to have a discussion on the establishment of a Working Group on introduced species under MEQ.

Summary of presentations

Fourteen of 15 scheduled speakers presented papers, with contributors from both PICES and ICES members. Papers presented ranged from descriptions and listings of NIS by geographic area, the characteristics of species that increase their survival if transported to new areas and habitats, the consequences of NIS on ecosystems, research requirements to address recently approved guidelines in the Ballast Water Management Convention that were established at MEPC 53 in July 2005, and the implications from using approved chemicals or products to treat water (possible within the Convention) for control of NIS, and finally, the characteristics of bacterial communities found in ballast water tanks and their reduction as a result of before and after mid-ocean exchanges.

Discussion following the presentations included the impact of global warming on NIS spread, the utility of risk assessment in identifying the most important introduction vectors, the challenges in developing mitigation measures, and how changing water characteristics (quality and heat discharge) seem to be favouring survival rates on new invaders.

The workshop discussion included a proposal to establish a new PICES Working Group on invasive species.

List of papers

Oral presentations

Alexander Yu. Zvyagintsev
Introduction of species into the northwestern Sea of Japan

Li-Jun Wang and Bin Wang
Marine introduced species in China seas and action plans

Hiroshi Kawai, Takeaki Hanyuda and Shinya Uwai
Macroalgal diversity of hull communities on trans-ocean coal carriers

Glen Jamieson, Colin Levings, Dorothee Kieser and Sarah Dudas
Marine and estuarine non-indigenous species in the Strait of Georgia, British Columbia, Canada

John E. Stein
Invasive species in the North Pacific – review of US research

Mitsunori Iwataki, Hisae Kawami, Kazumi Matsuoka, Takuo Omura and Yasuwo Fukuyo
Phylogeny and geographical distribution of *Cochlodinium polykrikoides* population (Gymnodiniales, Dinophyceae) collected from Japanese and Korean coasts

Sergej Olenin (Invited)
Xenodiversity versus biodiversity: Invasive alien species in European coastal marine ecosystems

Stephan Gollasch
Overview on introduced aquatic species in Europe – With focus on ICES Member Countries

Dan Minchin (Invited)
Vectors and processes involved in biological invasions

Akiko Tomaru, Yasuwo Fukuyo, Masanobu Kawachi and Hiroshi Kawai
Effect of mid-ocean exchange of ballast water on bacterial community in ballast tanks

Yasuwo Fukuyo, Katsumi Yoshida and Shin-ichi Hanayama
Importance of inputs from scientists to effective implementation of ballast water management convention

Shinichi Hanayama and Miyuki Ishibashi
Efforts of IMO to avoid secondary toxicity risk on the marine environment by chemical treatment of Ballast Water Management System

Helge Botnen and Stephan Gollasch
Tests of a ballast water treatment system onboard an ocean-going vessel and hints on a new sampling device for larger volumes of water

John E. Stein
Advantage of organizing a PICES Working Group on marine bioinvasions for future cooperation among PICES and ICES

Stephen Gollasch
Recommendation from the Chairman of ICES/IOC/IMO WGBOSV for the consideration by PICES in preparing the TOR for the new PICES Working Group

extracted from:

2005 REPORT OF MARINE ENVIRONMENTAL QUALITY COMMITTEE

Proposals for new subsidiary bodies (Agenda Item 11)

Based on discussions at this year's PICES/ICES Workshop on "*Introduced species in the North Pacific*" (Agenda Item 9), the Committee proposes a Working Group on *Non-indigenous aquatic species* to be coordinated with related Working Groups in ICES. Terms of reference, suggested members, and possible Co-Chairmen were provided (*MEQ Endnote 3*).

MEQ Endnote 3
Proposal for a Working Group on *Non-indigenous aquatic species* (acronym: WGNIAS)

Proposed terms of reference

1. Complete an inventory of all aquatic nonindigenous species **(**NIS) in all PICES member countries, together with compilation and definitions of terms and recommendations on use of terms. Summarize the situation on bioinvasions in the Pacific and compare and contrast to other regions (*e.g.*, Atlantic, Australia, *etc*.);
2. Complete inventory of scientific experts in all PICES member countries on aquatic NIS subject areas and of the relevant national research programs/projects underway;
3. Review and evaluate initiatives on mitigation measures (*e.g.*, ICES Code of Practice for the Introduction and Transfer of Marine Organisms, IMO Ballast Water Management Convention and others such as the Canadian Introductions and Transfers Code);
4. Summarize research related to best practices for ballast water management;
5. Coordinate activities of the PICES WG on aquatic non-indigenous species with related WGs in ICES through a joint back-to-back meeting of the PICES and ICES Working Groups on invasive species in 2007/8;
6. Develop and recommend an approach for formal linkages between PICES and ICES on aquatic non-indigenous species;
7. Publish final report summarizing results and recommendations.

Possible Co-Chairmen

MEQ recommends Dr. Yasuwo Fukuyo or alternate from Japan as the Asian Co-Chairman, and Drs. Glen Jamieson or Darlene Smith (Canada) as the North American Co-Chairman.

MEQ also proposes a PICES representative to join as a Co-Chairman for the ICES/IOC/IMO Working Group on *Ballast and Other Ship Vectors* and/or the ICES Working Group on *Introductions and Transfers of Marine Organisms*, and the reverse, have an ICES representative (*e.g*., Dr. Stephan Gollasch) as Co-Chairman of the proposed PICES Working Group on *Non-indigenous aquatic species*. Joining an ICES Working Group allows connections on global issues, such as IMO guidelines that are relevant to ballast water management.

Recommended membership

Canada: Thomas Therriault, Dorothee Kieser, Michel Gilbert, Glen Jamieson (if not Co-Chairman)
China: Lijun Wang, Hao Guo
Korea: Kyung Soon Shin, Chang-Kyu Lee, Sam Geon Lee
Japan: Shinichi Hanayama, Hiroshi Kawai, Toshio Furota
Russia: Alexander Zvyagintsev, Vadim Panov
U.S.A: Mark Wells, Ted Grosholz, Henry Lee, Blake Feist, Greg Ruiz, Judith Pederson.

PICES Fifteenth Annual Meeting (PICES XV)
October 13–22, 2006
Yokohama, Japan

REPORT OF WORKING GROUP 21 ON NON-INDIGENOUS AQUATIC SPECIES

The Working Group on *Non-indigenous aquatic species* (WG 21) held its first meeting on October 13, under the chairmanship of Ms. Darlene Smith. A list of participants can be found in *WG 21 Endnote 1*. Dr. Graham Gillespie served as the rapporteur. The draft agenda was reviewed and adopted without changes (*WG 21 Endnote 2*).

Terms of Reference (Agenda Items 4-6)

The participants reviewed WG 21 Terms of Reference (TOR) approved at PICES XIV (October 2005, Vladivostok, Russia). Progress toward accomplishing these Terms of Reference and developing a plan for their completion were discussed concurrently as TOR were reviewed: A summary of discussion is reported after each TOR.

TOR#1 *Complete an inventory of all aquatic non-indigenous species (NIS) in all PICES member countries together with compilation and definitions of terms and recommendations on use of terms. Summarize the situation on bioinvasions in the Pacific and compare and contrast to other regions (*e.g.*, Atlantic, Australia,* etc.*)*:

<u>Should the inventory of NIS include freshwater as well as marine species?</u>
This was discussed at some length with the conclusion that the NIS list would include marine and estuarine species but would not include exclusively freshwater species. This decision was based on PICES' focus as a marine science organization and the large magnitude of species if freshwater NIS were included. It was suggested to explicitly indicate that "*The organismal domain of WG 21 will be non-indigenous aquatic taxa that spend any life history stage in marine, estuarine, or brackish systems (this includes anadromous and catadromous taxa)*".

<u>Should WG 21 create a new on-line database or take advantage of existing systems such as NISBASE (http://www.NISBASE.org/nisbase/ index.jsp) or the Global Invasive Species Information Network (http://www.gisnetwork. org/ pubs.html)?</u>
WG 21 recognizes that the creation of a new PICES on-line database would require resources, both human and financial. WG 21 members will investigate the existing internet databases and provide their preferences on how to proceed with this issue. [Action]

Drs. Henry Lee and Deborah Reusser will make contact with both the USGS-Gainesville and the Smithsonian about the process of linking into NISBASE. [Action]

<u>Definitions of terms and recommendations on use of terms</u>
A number of countries (China, Russia, Japan) do not have definitions described in law or policy, but do have terms that are generally used to describe non-indigenous species that may or may not be harmful. In Canada and the United States the implication of harmful is associated with invasive.

The Chairman will compile definitions from Canada, the U.S. and the ICES Working Group on *Introductions and Transfers of Marine Organisms* (WGITMO), and will seek input from China, Korea, Japan and Russia. Following this meeting draft PICES definitions will be produced for subsequent discussion and agreement.

<u>Summarize the situation on bioinvasions in the Pacific and compare and contrast with other regions</u>
This was discussed briefly and requires additional thought as it is potentially a large undertaking. It was noted that "situation" is a somewhat vague term. WG 21 seeks advice from MEQ on what is meant by "situation". It was suggested that "situation" could include a summary of national legislation/policy, research programs and management programs. It could also include a

description of the major invasive species and the impacts they are having. [Action]

TOR#2 *Complete inventory of scientific experts, in all PICES member countries, on aquatic non-indigenous species subject areas and of the relevant national research programs/ projects underway*:

An inventory of scientific experts
It was concluded that if distribution of an inventory of scientific experts was limited to PICES members that this should not be an issue. Should the inventory receive wide distribution, this will need to be re-visited.

The participants discussed the relative scarcity of taxonomic expertise in all member countries, with the situation perhaps most pressing in Western Pacific countries. The Census of Marine Life (CoML) was identified as an example of international exchange of taxonomic expertise, but it was noted that CoML has a limited lifespan. A joint ICES/PICES workshop was discussed as a means to continue centralizing expertise after CoML has completed its term.

The need to explore linkages between classical taxonomy and molecular techniques was also discussed. It was suggested that this would be an ideal theme for a future symposium.

Dr. Adolf Kellermann suggested that the PICES and ICES Working Groups may wish to produce a compilation of vernacular names, and that ICES and PICES could consider joint financial support of such an undertaking. The participants also brought up the possibility of PICES translating critical taxonomic keys into a common language (English). This is not exactly the same as a compilation of vernacular names.

The U.S. has conducted Rapid Assessment Surveys which are week-long field surveys attended by a broad range of taxonomic experts.

ToR#3 *Review and evaluate initiatives on mitigation measures (*e.g.*, ICES Code of Practice for the Introduction and Transfer of Marine Organisms; IMO Ballast Water Management Convention and others such as the Canadian Introductions and Transfers Code)*:

Again, this TOR is a significant project. For now, documents will be compiled and made available to WG 21 members. The list of documents was expanded beyond the suggested examples to add material from Australia and New Zealand, the Canadian Shipping Act and U.S. Management Plans and included the following documents:

- Australian guidelines for managing marine pest biofouling risks;
- RAC-SPA Action Plan concerning species introductions and invasive species in the Mediterranean Sea;
- Risk assessment of ballast water mediated species introduction: A Baltic Sea approach;
- Guidelines for controlling the vectors of introduction into the Mediterranean of alien species and invasive marine species: Hull fouling.

It was suggested that the documents be reviewed for commonalities and uniqueness. [This action was not assigned.]

Jeffery Herod is to supply a report developed by a Technical Advisory Group to the California State Lands Commission for Ballast Water Performance Standards. This report includes summary of best available information and IMO guidelines. [Action]

References to California reports:
http://ucce.ucdavis.edu/files/filelibrary/5802/25917.pdf
http://www.slc.ca.gov/Division_Pages/MFD/MFD_Programs/Ballast_Water/Ballast_Water_Default.htm
http://www.slc.ca.gov/Division_Pages/MFD/MFD_Programs/Ballast_Water/Documents_of_Interest.htm

References to National U.S.A. reports:
http://www.anstaskforce.gov/Species%20plans/national%20mgmt%20plan%20for%20mitten%20crab.pdf
http://www.anstaskforce.gov/Species%20plans/Mitten_Crab_NMP_Implementation_Table_092905.pdf
http://www.anstaskforce.gov/Species%20plans/Final%20NMP%20for%20the%20Genus%20Caulerpa%20111005.pdf

TOR#4 *Summarize research related to best practices for ballast water management*:

It was noted that only Canada and the U.S. have ballast water sampling programs.

Suggested sources for information included the U.S. Coast Guard and U.S. Geological Survey (USGS), and Richard Emmett at the USCG Washington DC office was recommended as a contact. The Northeast Midwest Institute website (http://www.nemw.org) summarizes ballast water legislation in the U.S.

Dr. Blake Feist has provided contact information for USGS work on development of molecular markers for verifying that ballast water exchange has occurred (Dr. Rusty Rodriguez, USGS/Biological Resources Division, Western Fisheries Research Center, ph.: 206-526-6596, e-mail: rusty_rodriguez@usgs.gov).

The ICES/IOC/IMO Working Group on *Ballast Waters and Other Ship Vectors* (WGBOSV) is in the process of developing a Technical Manual for Ballast Water Sampling. It was suggested that a draft of the document be distributed to WG 21 members.

Russian participants indicated that they were interested in ballast water sampling methods. Responsibility for collecting and summarizing available material will be assigned later. [Action]

TOR#5 *Coordinate activities of WG 21 on non-indigenous aquatic species with related WGs in ICES through a joint back-to-back meeting of the PICES and ICES Working Groups on invasive species in 2007/2008*:

The participants agreed that the objectives of the coordination of WG 21 and WGITMO and WGBOSV activities would be the sharing of information and avoidance of duplication of effort. This would be facilitated through joint meetings, cooperative document development, and post-meeting information exchange (*e.g*., through email summaries or web postings).

A joint meeting of ICES and PICES Working Groups was suggested. The most viable option seemed to be a meeting in conjunction with the 5th International Marine Bioinvasions Conference (May 2007, Cambridge, U.S.A.). Other possible venues include the spring meeting of WGITMO and WGBOSV (March 2007, Dobrovnik, Croatia) and PICES XVI (October 2007, Victoria, Canada).

Potential agenda items include: discussion of taxonomic issues and development of taxonomic expertise exchanges between ICES and PICES member countries; completion of a ballast water sampling technical manual; development/ completion of Codes of Practice for ship hull fouling and port sampling; discussion of rapid response and control options; and consistency of information gathered, collated and distributed.

The possibility of using PICES funds to provide travel support for WG 21 members was discussed. Clarification was to be sought from the PICES Executive Secretary.

TOR#6 *Develop and recommend an approach for formal linkages between PICES and ICES on non-indigenous aquatic species*:

The participants suggested that (1) ICES and PICES Working Groups' Terms of Reference should be shared, and (2) a joint ICES/PICES fund for taxonomic specialist exchange be established. Dr. Kellermann indicated that ICES would seriously consider this.

Other linkages discussed included joint meetings, cooperative document development (*e.g.*, ballast water sampling guidelines, code of practice for hull fouling) and formal communication of minutes or meeting reports through e-mail and the web.

TOR#7: *Publish final report summarizing results and recommendations*:

Not much discussion took place on this point, and no formal dates or targets were set. WG 21 needs to make more progress toward accomplishing the Terms of Reference before diving into discussion of the final report.

Currently WG 21 has a 3-year mandate ending 2008. This is in contrast with WGITMO and WGBOSV which have been operating for many years. Depending on the future success of WG 21 in achieving its Terms of Reference and the extent of interest of PICES member countries, PICES may wish to consider creating a Section on non-indigenous aquatic species following the termination of WG 21.

PICES XVI – Proposal for a Topic Session on invasive species (Agenda Item 7)

WG 21 members agreed to propose a full-day MEQ Topic Session on non-indigenous species to be held at PICES XVI. During an extensive discussion, the following key areas for the session were suggested (*WG 21 Endnote 3*):

- Evolutionary consequences of invasions: "Know too much about ecology? Evolutionary consequences of marine NIS invasions on native species". Studies abound documenting ecological impacts (*i.e.*, displacement, mortality, *etc*.) of NIS upon native populations, but there are comparatively few studies that demonstrate evolutionary impacts. As such, abstracts that address the topic of evolutionary impacts of NIS on native biota have to be solicited, and specifically, these abstracts need to demonstrate clear evolutionary responses of native species to selective pressure from invasive NIS. For example, a NIS invading and displacing a native species is an ecological consequence, but a native species evolving new anti-predator defenses in response to the invasion of an NIS is an evolutionary response;
- Ecosystem effects of bioinvasions;
- Impacts of climate change projections (and oceanographic variability) on bioinvasions: "Global climate change and its influence on the range expansion of NIS, and the amplitude and frequency of bioinvasions – it is not just for natives anymore";
- Criteria used to identify species as native or non-native.

A balance must be reached between having too many topic areas *vs*. a very narrow selection that would reduce participation. Submitted abstracts that closely adhere to the theme would have priority for oral presentation, those that are more generally related to NIS can be accommodated for oral presentation as space allows or presented as posters.

Travel funds are requested from PICES for 2 invited speakers to attend the session. Should the session be approved, invited speakers must be secured as soon as possible. A few names were suggested (James Carlton, Chad Hewitt, Nicholas Bax, John Chapman, Andrew Cohen, David Pimentel, David Lodge, Michelle Mack, Daniel Simberloff, Ted Grosholz).

Discussion of potential joint ICES/PICES meetings (Agenda Item 8)

Two options for a joint meeting of ICES/PICES were discussed. The first is to take advantage of WG 21 members' participation in the upcoming 5th International Marine Bioinvasions Conference in May 2007 (see Agenda Item 9). The second is to have it in conjunction with PICES XVI in October 2007. The following topics for discussion at the joint meeting were proposed:

- ballast water sampling methods;
- NIS databases;
- taxonomic challenges;
- ICES Code of Practice for ship hull fouling;
- rapid response and control options.

It was suggested that a member of the U.S. Aquatic Nuisance Species Task Force be invited to the joint meeting. The issue of travel funds was raised by a number of WG 21 members.

Fifth International Marine Bioinvasions Conference (Agenda Item 9)

Dr. Judith Pederson provided an overview of the Conference to be held May 21–24, 2007, in Cambridge, Massachusetts, U.S.A. Details can be found on the Conference website at http:/massbay.mit.edu or http://www.mit.edu/mitseagrantweb. Deadline for abstracts submission is January 2007. All WG 21 members are encouraged to attend the conference.

Informal round table discussion on priority aquatic invasive species issues in PICES-member countries (Agenda Item 10)

Canada – Discussion included: developing data standards related to geo-referencing and format and coding standards (including taxonomic issues related to standard species codes) as they relate to information transfer from regional to national initiatives; a summary of programs underway related to ballast water; bioinvasion biology, surveys and monitoring; risk assessment; rapid response plans and citizen engagement. Vectors of particular concern are ballast water, fouling, live seafood and aquarium trades.

China – Priority issues were non-native seagrass (*Spartina*) that invaded from North America in the 1960s and an exotic bivalve that invaded from

Hong Kong and competes for food resources with cultured species.

Japan – Discussion focused on benthic community invasion in Tokyo Bay, including high densities of Mediterranean [European?] green crab, North American spider crab and Atlantic quahog clams. Interestingly, these species are dominant in polluted areas which limit their interaction with native species.

Russia – Priority issues were increased natural dispersal of tropical species in response to global warming; increased risk of invasion due to shipping traffic to a proposed oil terminal; and species of particular concern (tunicates and spionid polychaetes).

U.S. – Discussion points included development of control management plans; increased awareness in the scientific community of NIS issues (the possibility of research projects as vectors); the need to develop information bases for native species (as our native is someone else's invader); and the need to be cognizant of potentially large ecological effects of relatively small species (*e.g.*, *Potamocurbula*).

Summary of recommendations to MEQ

WG 21 seeks MEQ approval of the following recommendations:

1. To hold a joint meeting of WG 21 with the ICES Working Group on *Introductions and Transfers of Marine Organisms* and the ICES/IOC/IMO Working Group on *Ballast Waters and Other Ship Vectors*, in fulfillment of one of its Terms of Reference. The meeting would be convened May 25-26, 2007, in Cambridge (U.S.A.), immediately following the 5th International Marine Bioinvasions Conference. Travel funds from PICES are requested to permit 1 Chinese and 1 Russian member to attend the Conference and the joint meeting.

2. To convene a Topic Session at PICES XVI in Victoria, Canada. This session would focus on the following key areas:
   - Evolutionary consequences of invasions;
   - Ecosystem effects of bioinvasions;
   - Impacts of climate change projections (and oceanographic variability) on bioinvasions;

   Travel funds from PICES are requested for 2 invited speakers for this session.

3. To request that Russia nominate Dr. Vasily Radashevsky as a member of WG 21, and that he be named as WG 21 Co-Chairman.

WG 21 Endnote 1

Participation list

Members

Evgenyi Barabanshchikov (Russia)
Blake Feist (U.S.A.)
Toshio Furota (Japan)
Graham Gillespie (Canada)
Henry Lee II (U.S.A.)
Bruce Mundy (U.S.A.)
Darlene Smith (Canada, Chairman)
Lijun Wang (China)

Observers

Galina Gavrilova (Russia)
Jeffrey Herod (U.S.A.)
Anders Jelmert (Norway, ICES WGBOSV)
Adolf Kellermann (ICES)
Judith Pederson (U.S.A., ICES WGITMO)
Vasily Radashevsky (Russia)
Deborah Reusser (U.S.A.)
Chiemi Tezuka (Japan)

WG 21 Endnote 2

WG 21 meeting agenda

1. Welcome and introductions
2. Nomination of a rapporteur
3. Adoption of agenda
4. Review of WG 21 Terms of Reference
5. Review of progress in accomplishing the Terms of Reference
6. Develop a plan for completing the Terms of Reference
7. PICES XVI – Proposal for a Topic Session on invasive species
8. Discussion of potential joint ICES/PICES meetings
9. Fifth International Marine Bioinvasions Conference
10. Informal round table discussion on priority aquatic invasive species issues in PICES member countries

WG 21 Endnote 3

Proposal for a 1-day MEQ Topic Session at PICES XVI on
"*Non-indigenous species: Climate change, evolutionary consequences and ecological impacts*"

The global community is becoming increasingly aware of the importance of invasions of non-indigenous species in the marine environment. The issue is extremely complex. This session will be limited to three sub-topics of interest to PICES member countries:

1) Global climate change is further complicating the study and prediction of bioinvasions and its influence on the range expansion of non-indigenous species (NIS) and the amplitude and frequency of bioinvasions. This is particularly the case in areas where bioinvasions have been halted by climatic conditions. We are seeking presentations that document the impact of climate change on marine bioinvasions.
2) Studies abound documenting ecological impacts (*i.e*., displacement, mortality, *etc*.) of NIS upon native populations, but there are comparatively few studies that demonstrate evolutionary impacts. As such, we are soliciting papers that address the topic of evolutionary impacts of NIS on native biota, and specifically, presentations that demonstrate clear evolutionary responses of native species to selective pressure from invasive NIS. For example, a NIS invading and displacing a native species is an ecological consequence, but a native species evolving new anti-predator defenses in response to the invasion of a NIS is an evolutionary response.
3) Finally, we seek presentations that show the ecological impacts of bioinvasions that have led to declines in wild fisheries and mariculture.

Recommended convenors: Blake Feist (U.S.A.) and Graham Gillespie (Canada).

PICES Sixteenth Annual Meeting (PICES XVI)
October 26–November 5, 2007
Victoria, Canada

REPORT OF WG 21 ON NON-INDIGENOUS AQUATIC SPECIES

The Working Group on *Non-Indigenous Aquatic Species* (hereafter WG 21) held its second meeting October 26–27, 2007, under the co-chairmanship of Ms. Darlene L. Smith and Dr. Vasily Radashevsky. A list of participants and meeting agenda can be found in *WG 21 Endnotes 1* and *2*.

Country/Agency reports (Agenda Items 2)

Canada

Fisheries and Oceans Canada (DFO) is the federal government agency responsible for marine non-indigenous species in Canada. The DFO non-indigenous species program consists of three elements: research, monitoring and risk assessment. DFO has also worked with the National Science and Engineering Research Council of Canada to establish a national research program called the Canadian Aquatic Invasive Species Network (CAISN). CAISN includes scientists from 19 Canadian universities and several DFO laboratories. The primary species of concern include: European green crab, tunicates (5–7 species), New Zealand mudsnail and perciform fishes in freshwater.

People's Republic of China

It is estimated that there are about 140 marine alien species in China. Mariculture and international shipping are the two main vectors by which non-indigenous species are introduced to China. *Spartina alterniflora* and *Spartina anglica* were introduced in 1979 to protected beaches and had spread extensively causing major ecological damage. *Mytilopsis sallei* has also been introduced and is causing serious damage to the mariculture industry and native species. Another non-indigenous species is *Crepidula onyx* which reduces biodiversity and fouls pisciculture cages. Some harmful algae blooms species are suspected to have been introduced to the China seas *via* ballast water. They have caused economic losses to aquaculture and fisheries operations with serious environmental and human health impacts.

China has established the following targets by the year 2010:

- To develop a basic understanding of the present status of marine alien invasive species in coastal China, such as exotic species and their distributions, invasive species distribution and impacts, *etc*.;
- To establish prevention and control systems for marine alien invasive species;
- To establish methods to assess the impacts of marine biological invasions.

By the year 2015, through strengthening the study of marine exotic invasive species ecology, a basic understanding of mechanisms of invasion will be built up. Meanwhile, technologies for elimination and control of invasive species will be developed to control or reduce the impacts resulting from a few dominant invasive species.

Republic of Korea

In 2007, harmful algal blooms (HABs) occurred from August–September (a total of 44 days). These included *Cochlodinium polykrikoides* from the South Sea to Japan/East Sea, and *Chattonella* spp. in Chonsu Bay (Yellow Sea). Total damage was about $US 12 million, mostly to halibut, red bream, *etc*.

Research activities associated with HABs and invasive species include:

- Rapid detection of *Cochlodinium* using sandwich hybridization and whole cell hybridization;
- Development of molecular techniques for detection of *Pfiesteria* and *Pfiesteria*-like sp.;
- National Census of Marine Ecosystem (conducted by "Law of Marine Ecosystem Conservation and Management"; the 1st phase is

from 2006–2015 (10yrs), and the budget of US$1.5 million for 2007);

- National Institute of Marine Bioresources (established by "Law of Marine Ecosystem Conservation and Management"; the construction period is from 2007–2013 (5yrs), with the total budget of US $150 million, and the budget of US$ 25 million for 2008);
- Marine invasive species: Preparation of "Manual for Field Study"; barnacle monitoring (Ulsan port, Guryongpo port); general observation at Baekryung Is. (Yellow Sea), Ulreung Is. (Japan/East Sea) and Chuja Is. (South Sea);
- Development of ballast water treatment and monitoring (conducted by KORDI under "Marine Environment Management Law", with the budget of US$ 0.2 million);
- Development of ballast water treatment system and preparation of "Field Manual of Ballast Water Monitoring".

Russia

The current status of non-indigenous fish species distribution and abundance in Peter the Great Bay was given. There are 19 non-indigenous fish species found in this area. The general conclusions of this work are:

- A composition of non-indigenous fish species in the estuaries of Peter the Great Bay was determined. Due to a significant part in biomass of all the fishes (*e.g*., 10% and 13% in the ichthyofauna of Artemovka and Razdolnaya Rivers, respectively), they are of great importance in the functioning of estuary ichthyocenes of the rivers.
- In the early 2000s, Khanka bitterlings *Acanthorodeus chankaensis*, lookup *Culter alburnus*, lazy gudgeon *Sarcocheilchthys czerskii*, *Sarcocheilchthys* sp., Soldatov's catfish *Silurus soldatovi*, European pike-perch *Sander lucioperca* and northern snakehead *Channa argus* were introduced into the Razdolnaya River.
- Silver carp, bigheads, grass carp and European pike-perch form ephemeral, not numerous populations that include only adult individuals. Rounded gudgeon, Khanka bitterlings, *Acanthorodeus* sp., Korean sawbelly, lazy gudgeon, northern snakehead and lookup have formed independent populations in Razdolnaya River. The quantity of lookup in Razdolnaya River has now reached a commercial value.

United States of America

Three main agencies in the United States are responsible for managing marine invasive species: National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service (F&WS). Some of the major invaders on the U.S. Pacific Coast are:

- European green crab (dominant competitor; regulates the structure of benthic communities through predation; at high densities limits the distribution of some benthic invertebrates);
- Various species of tunicates (high potential for environmental and ecosystem damage; overgrow and displace native sea grasses, sponges, hydroids, anemones, limpets, oysters, mussels, scallops, barnacles, bryozoans, and other species of sea squirts; negative effects on aquaculture industry);
- Snowflake coral (threatens Hawai'i's $30-million-a-year black coral industry; hull fouling and aquarium trade).

NOAA along with the U.S. F&WS, and the U.S. Maritime Administration, in cooperation with various States, conducts research on ballast water treatment technologies at two facilities, one located at the Great Lakes and one located in NOAA's North West Region.

The Aquatic Nuisance Species Task Force, headed by NOAA and the U.S. F&WS, supports development of management plans for aquatic nuisance species in the United States. Resources for research are limited, with the majority going towards management. A major focus now is rapid response planning. Hazard Analysis of Critical Control Point (HACCP) is currently being investigated as a model for responding to invasive species.

EPA is focused on the results of a recent court decision requiring the Agency to regulate ballast water discharge, including all boats with outboard motors. EPA will use the discharge standards of the International Maritime Organization.

Dr. Mark Sytsma gave a presentation on the status of a *Spartina* spp. invasion on the Pacific coast of the United States and provided details of the management and eradication programs.

Science presentations (Agenda Item 3)

Three presentations were given by WG 21 members from the People's Republic of China, the Russian Federation and Japan:

- Lijun Wang: *Assessment of the genetic impact of introduced* Strongylocentratus intermedius *on native sea urchin populations*;
- Vasily Radashevsky: *Studies on invasive species in the Far-Eastern Part of Russia*;
- Hiroshi Kawai: *Biogeography and trans-ocean introductions of the green algae* Ulva spp. *from/to Japan, deduced from the identifications based on molecular markers*.

WG 21 terms of reference (Agenda Item 4)

WG 21 proposes to amend its terms of reference to reflect practical constraints on the work and the two projects funded with the Japanese voluntary contribution (*WG 21 Endnote 3*). These were submitted for approval to the MEQ Committee.

Joint PICES-ICES meeting summary and further co-operation (Agenda Item 5)

Dr. Judith Pederson provided the summary of the joint meeting of PICES WG 21, ICES WG on *Introductions and Transfers of Marine Organisms* (WGITMO) and ICES/IOC/IMO WG on *Ballast and Other Ship Vectors*, (WGBOSBV) held May 25–26, 2007, in Cambridge, U.S.A., with emphasis on the following points:
- Potential projects for "*Development of the prevention systems for harmful organism's expansion in the Pacific Rim*";
- Lack of taxonomic expertise limiting ICES-PICES exchange;
- Need for the registry of taxonomic experts;
- Adding AIS (Aquatic Invasive Species) data based on NISBase;
- Use bivalve molluscs for database testing;
- Ballast water and biofouling as potential vectors;
- ICES Ballast Water Sampling Guidelines – review of ballast water issues, including early detection, rapid response, impacts, costs, successes, and failures from world-wide examples; role of government and citizens in an EDRR (Early Detection and Rapid Response) system.

Suggestions for future co-operation include:
- ICES Code of Practice for the Introduction and Transfer of Marine Organisms;
- Risk assessments or analysis;
- Guidelines for sampling ballast water;
- Other areas for joint projects, including hull fouling.

Database prototype (Agenda Item 6)

The morning session of the second day opened with a presentation on the WG 21 marine non-indigenous species (MNIS) database prototype that Dr. Henry Lee II and Ms. Deborah Reusser had developed based on the EPA-USGS PCEIS (Pacific Coast Ecosystem Information System) spatial database. Dr. Lee gave an overview of the database that is designed to provide biological, ecological and geo-spatial information. Each attendee received a copy of the manual and a disk with the program. The initial exercise is to enter invasive bivalves of the North Pacific for testing the prototype database. With the database, species information can be entered, edited, and exported. With the input of standardized data across the countries, the data are easily queried. The morning session focused on the details of using the database and issues that arose during the discussion. The major items and action items or conclusions that emerged from the discussion are described below.

The database uses Microsoft Access as the software for developing relationships among the various components, and this poses a problem for Macintosh users who rely on FileMaker as the database management software.

Action item: Determine how to link File Maker to Access.

The prototype is built so that members from each PICES country can enter and maintain their own database. The main menu offers a variety of options: searching for species, adding/editing species, adding publications, exporting and importing data, documentation, acknowledge-ments, and exiting. One of the important decisions to be made by the group was the level of biographic detail that would be captured by the program. The Nature Conservancy biogeography regions were used as the basis for making decisions. The bio-geographic hierarchy extends from the North Temperate Pacific Realm > Provinces > Eco-region > Waterbody Eco-region > Sub-component in Waterbody > Site Specific (latitude/longitude).

Consensus decision is to: (1) extend to the Waterbody Eco-region and sub-divisions as this would permit analysis of the data appropriate to the scale for PICES countries; and (2) include latitudes and longitudes as database fields.

Adding a reference with each species, either as a publication or as the name of the person entering the data, is required. The program has several features that make entering the data easier, including options for removing and editing data, accessing publication data, adding relevant ecosystem and MNIS data, and viewing and extracting data. In order to test the database, it was initially suggested that each country would input data on bivalves, however, some countries may add other data, *e.g.*, barnacles. Each country will input data and a training workshop on use of the database will be held to walk through the revised protocols. For several countries, it would take time to identify the individuals who would input the data.

Action item: Each country will input data over the next couple of months and correspond with Ms. Reusser if any problems are encountered. Ideally the data entry should be completed before December 31, 2007.

Consensus decision is: to hold a workshop to evaluate the protocols and reach final agreement on standards, data elements and data entry templates for the MNIS database on January 30–31, 2008, in Seattle, U.S.A.

Action item: Each country is to submit names of two representatives to be invited to attend the workshop to Ms. Smith by November 30, 2007, especially countries where visas are needed.

Update: Dates and location were changed to March 3–5, 2008 in Busan, Korea.

Planning for PICES XVII (Agenda Item 7)

WG 21 proposed a 1-day Topic Session (including posters) on marine non-indigenous species to be held at PICES XVII (*WG 21 Endnote 4*). This session will focus on ecological and economic impacts of marine non-indigenous species and ballast water technologies. Potential invited speakers are: David Pimentel, Andrew Cohen, James Carlton, Daniel Simberloff (for the Eastern Pacific) and Jiakuan Chen (for the Western Pacific).

Work plan for database and taxonomy initiatives (Agenda Item 8)

In April 2007, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency (JFA) of Japan, provided a voluntary contribution to PICES for a project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*". The project is anticipated to run for five years (from April 1, 2007 to March 31, 2012). It has two distinct components, one on MNIS and the other on HABs conducted by WG 21 and Section on *Ecology of Harmful Algal Blooms in the North Pacific* (HAB-S), respectively.

Within the MNIS sub-project, two initiatives have been identified: (1) development of a MNIS database; and (2) development of a taxonomic system to allow identification and documentation of MNIS establishment outside of their native range. Details for activities under the Database Initiative are outlined in Agenda Item 6. Under the Taxonomic Initiative, WG 21 proposes to conduct a rapid MNIS assessment survey in each PICES member country. These assessments will focus on two port locations within the member country hosting the PICES Annual Meeting and be held immediately prior to the Annual Meeting, using taxonomic experts and students from the host country and Pacific Rim experts as needed. The first rapid assessment survey is scheduled for October 19–23, 2008, in conjunction with PICES XVII. The proposed surveys will be complemented by sub-tidal collectors for biofouling organisms deployed at selected sites in PICES member countries. A revised work plan for 2008–2009 can be found in *WG 21 Endnote 5*.

Sixth International Marine Bioinvasions Conference (Agenda Item 9)

Dr. Gil Rilov presented an overview of the 6th International Conference on "*Marine bioinvasions*" to be held in late August or early September 2009, at Portland State University (PSU), Portland, Oregon, U.S.A. Dr. Sytsma will serve as the local host.

The *Marine bioinvasions* Conference has focused on scientific and management issues related to marine introductions and focused on vectors, distribution, ecological impacts and evolutionary consequences, and related topics. The Conference also continues to identify new topics and emerging issues. As with the 5th Conference, co-sponsorship by the U.S. National Sea Grant Office, the International Council for the Exploration of the Sea (ICES) and PICES is welcome. Planning for the Conference is still in the initial stages. WG 21 is interested in supporting the Conference and requested to have a representative on the Scientific Steering Committee (SSC). Dr. Yoon Lee (Korea) volunteered to serve on the SSC. It was also suggested to propose that a special session on Pacific Rim invasive species be included in the program. Conference organizers requested the following financial support from PICES:

- 2007–08 Fiscal Year $10,000
- 2008–09 Fiscal Year $10,000
- 2009–10 Fiscal Year $30,000

Aquatic invasive species/climate change connection (Agenda Item 10)

How can WG 21 promote further discussion and/or research regarding the aquatic invasive species/climate change connection in the North Pacific? Dr. Paul Heimowitz raised this as an important upcoming issue and advised that the American Aquatic Nuisance Species Task Force will be discussing this issue at its meeting on November 27, 2007. The state of research on this issue is still in its infancy. The ICES WGITMO has provided some information relating invasions to current and temperature changes to OSPAR Commission. Discussion concluded that researchers will have to focus on this issue in the future and that there will be a need to distinguish between expansion range of non-indigenous species and expansion range of native species.

Next WG 21 meeting (Agenda Item 11)

WG 21 members propose to meet for two days at PICES XVII in Dalian, China. The purpose of this meeting will be to:

- review the draft report due at the end of WG 21's current mandate;
- review progress of the database project and develop a work plan for Year 3; and
- review progress of the taxonomy project (including the rapid assessment survey) and develop a work plan for Year 3.

The Co-Chairmen closed the meeting by thanking everyone for their full participation, and by giving special thanks to the meeting guests who provided valuable input.

WG 21 Endnote 1

Participation list

Members

Evgenyi I. Barabanshchikov (Russia)
Blake E. Feist (U.S.A.)
Graham E. Gillespie (Canada)
Paul Heimowitz (U.S.A.)
Hiroshi Kawai (Japan)
Henry Lee II (U.S.A.)
Sam-Geon Lee (Korea)
Yoon Lee (Korea)
Vasily Radashevsky (Russia, Co-Chairman)
Darlene L. Smith (Canada, Co-Chairman)
Mark D. Sytsma (U.S.A.)
Thomas W. Therriault (Canada)
Lijun Wang (China)
Li Zheng (China)

Observers

Hak Gyoon Kim (Korea)
Judith Pederson (U.S.A.)
Deborah Reusser (U.S.A.)
Gil Rilov (U.S.A.)
Greg Ruiz (U.S.A)

WG 21 Endnote 2

WG 21 meeting agenda

<u>October 26, 2008</u>

1. Opening remarks and introductions
2. Country/Agency reports (15 minutes presentation + 5 minutes discussion each)
3. Science presentations (15 minutes presentation + 5 minutes discussion each)
4. WG 21 terms of reference: Discussion on progress and plans for completion
5. Joint PICES-ICES meeting summary and further co-operation (J. Pederson)

<u>October 27, 2007</u>

6. Database prototype: presentation (H. Lee II and D. Reusser) and discussion (All)
7. Topic Session on non-indigenous aquatic species at PICES XVII (Dalian, China)
8. Development of detailed work plan for database and taxonomy initiatives (including planning of the 2008 workshop) funded by a voluntary contribution from Japan
9. Sixth International Conference on "*Marine bioinvasions*" (2009): Discussion of PICES WG 21 support/involvement
10. How can WG 21 promote further discussion/ research on the aquatic invasive species/ climate change connection in the North Pacific? (P. Heimowitz)
11. Next WG 21 meeting and closing remarks

WG 21 Endnote 3

Proposed revisions to WG 21 terms of reference

1. Initiate compilation of an inventory of marine non-indigenous species in PICES member countries together with a compilation of definitions of terms and recommendations on use of these terms. Summarize the situation on bioinvasions in PICES member countries;
2. Increase taxonomic capacity of PICES member countries through rapid assessment surveys and possibly through creation of a web-based taxonomy tool;
3. Initiate compilation of an inventory of scientific experts on marine non-indigenous species subject areas and of the relevant national research programs and projects underway in PICES member countries;
4. Summarize existing requirements for ballast water management (*e.g.*, discharge and monitoring requirements) in PICES member countries;
5. Summarize research related to impacts of ballast water and best practices for ballast water management in PICES member countries;
6. Coordinate activities of the PICES WG 21 with related Working Groups in ICES through joint meetings of these groups;
7. Develop and recommend an approach for formal linkages between PICES and ICES on aquatic non-indigenous species;
8. Publish final report summarizing results and recommendations.

WG 21 Endnote 4

Proposal for a 1- day Topic Session at PICES XVII on
"*Consequences of non-indigenous species introductions*"

Non-indigenous species (NIS) are ubiquitous throughout the World's marine, coastal and estuarine waters. There is little doubt that human mediated dispersal of NIS and subsequent establishment of NIS has altered biodiversity, species assemblages, food web dynamics, and trophic structure and interactions in marine ecosystems. These alterations have ecological, biological, evolutionary and economic consequences, especially in coastal and estuarine systems. It is ironic that mariculture and the global shipping trade have been identified as the most affected economically, given that these two activities are often identified as the primary vectors of marine NIS introductions. This session will address the impacts of marine NIS on the ecosystems in which they have invaded. Examples of impacts include, but are not limited to, biological, ecological, evolutionary, and economic. While abstracts addressing any type of economic impact will be considered, preference will be given to research projects focusing on ballast water and bio-fouling diagnostic and treatment technologies.

Convenors: Blake Feist (U.S.A.) and TBD

WG 21 Endnote 5

A 2008/2009 work plan for database and taxonomy initiatives of a marine non-indigenous species (MNIS) project funded by a voluntary contribution from Japan

DEVELOPMENT OF A COMPREHENSIVE MNIS DATABASE

Principal Investigator

Dr. Henry Lee II (Environment and Protection Agency, U.S.A.)

Database development

A template for standards and elements of relevant scientific data (scientific and common names, native range distribution and invasion range distribution(s), life histories, habitat requirements, ecological roles, impacts of invasions, and management and mitigation measures undertaken in invaded countries) will be developed and documented, based on the United States Environmental Protection Agency (EPA) and the United States Geological Survey (USGS) "Pacific Coast Ecosystem Information System" (PCEIS) spatial database.

Beta testing of the database

Focus will be on entry of data for a pilot NIS taxon (bivalves) by all PICES member countries. In situations where limited NIS bivalve data exist, another NIS taxa or native data will be used for testing purposes. Potential limitations identified through this exercise will be discussed at the proposed inter-sessional meeting.

Meeting to obtain consensus on database format, standards and elements

An inter-sessional meeting of WG 21 will be held after beta testing is completed (mid-winter 2008, in either Seattle, U.S.A. or Korea) to evaluate the database protocol and to reach final agreement on standards, data elements and data entry templates.

RAPID ASSESSMENT SURVEYS IN PICES MEMBER COUNTRIES

Principal Investigator

Dr. Thomas Therriault (Fisheries and Oceans Canada)

Purpose

Non-indigenous species (NIS) have the potential to alter habitats and biological diversity and can have economic and ecological impacts. There is a need for good taxonomy and consistency for sampling approaches in PICES member countries and other Pacific Rim countries. To better understand MNIS in PICES member countries, rapid assessment surveys will be carried out to gather and compare species information among countries. We have a unique opportunity at the 2008 PICES Annual Meeting in Dalian, China, to conduct the first rapid assessment survey and include taxonomic experts and students from each member country. If successful, this would be repeated in subsequent years in each PICES country the year they host the PICES Annual Meeting. All data collected would be entered into the PICES MNIS database being developed by WG 21.

Rapid assessment survey scope

Two separate locations in each country will be selected. Locations will be determined by the host country and could include areas near international shipping ports and aquaculture facilities as these are two major vectors for the introduction of marine non-indigenous species. Within each of the two locations, three different habitats will be selected for rapid assessment:

- intertidal habitat;
- floating docks/structures (*e.g.*, aquaculture facilities) that support subtidal biofouling organisms; and
- pilings/piers associated with commercial shipping activities that support biofouling organisms.

A total of six sampling sites will be assessed during the survey characterizing both the native and non-native species using available taxonomic experts. All species encountered during the survey (or found on collectors or in traps) will be identified to the lowest taxonomic level possible. For 2008, it is suggested to focus the survey on Dalian Port (Yellow Sea) and Ba Yu Quan (Bohai Sea) as both are close to the Annual Meeting site and represent two different marine environments. The proposed locations have to be confirmed by the State Oceanic Administration.

Methods

The proposed project will examine community assemblages in both intertidal and subtidal habitats through two components:

The first component is sampling native and non-native species in various marine habitats such as:

- intertidal shoreline;
- commercial shipping piers or docks;
- floating structures such as aquaculture facilities; and
- baited traps to sample mobile fauna such as decopods (*e.g.*, crabs).

The second component will capture settlement of biofouling organisms over a period of 6 months. To do this we will:

- deploy settlement plates and collectors 6 months prior to the rapid assessment survey to sample subtidal biofouling communities;
- other PICES member countries wishing to do so, may also deploy settlement plates and collectors at the same time to provide additional information for comparison.

Previous rapid assessment surveys in the United States have used standardized methods and they may be referred to for establishing a protocol for PICES member countries. Two examples can be found in the following papers:

- Cohen, A.N. *et al.* (2000) Report of the Washington State Exotics Expedition 2000: A rapid assessment survey of exotic species in Elliot Bay, Totten/Eld Inlets and Willapa Bay. In: Washington State Department of Natural Resources, Olympia WA, pp. 46.
- Cohen, A.N. *et al.* (2005) Rapid assessment survey for exotic organisms in southern California bays and harbors, and abundance in port and non-port areas. Biological Invasions 7: 995–1002.

Required resources

Each rapid assessment survey will require the participation of the PICES host country's taxonomic experts representing the variety of non-indigenous marine taxa that have had significant negative ecological or economic consequences. These may include taxonomists specializing in ascidians (tunicates), crustaceans (crabs, barnacles, amphipods), mollusks (gastropods, bivalves), worms (polychaetes), cnidarians (hydroids, anemones) and algae. Taxonomic experts and students (primarily from the host country) who are familiar with these groups will form the bulk of the assessment team. The rest of the team could include experts from PICES member countries and other Pacific Rim countries. Representatives from other PICES member countries who will be involved in future rapid assessments should also participate. This approach ensures that highly qualified individuals confirm species identification while allowing training for students and taxonomic generalists. The list of experts from the host country should be provided 6 months in advance of the rapid assessment survey to permit sufficient time to identify additional required experts from other countries. Judith Pederson, Chairman of the ICES Working Group on *Introductions and Transfers of Marine Organisms*, will serve as a resource person for this project.

Vehicles will be needed to transport the rapid assessment survey team to sampling sites. A small boat will be required to access potential floating/pier sites. The following sampling gears will be needed: (1) standard plankton nets for sampling phytoplankton and zooplankton; (2) standard traps (Fukui folding traps?) and groundlines for sampling decapods; and (3) tools (rakes, shovels, screens) to sample intertidal infaunal organisms. SCUBA divers, if available, could be used to sample subtidal species, but this is optional. Laboratory facilities with compound light microscopes and stereoscopes (dissecting scopes) will be required. Specimens will be photographed. Preliminary identifications are made in the field. However, all samples are taken back to a laboratory for verification and archiving. Some effort should be made to identify in advance and provide taxonomic reference books for each country (some may have to be purchased).

Funding

Travel and accommodation expenses for taxonomic experts and students will be covered under the taxonomy initiative of the MNIS project funded by a voluntary contribution from the Japanese government.

PICES Seventeenth Annual Meeting (PICES-2008)
October 24–November 2, 2008
Dalian, China

Extracted from:

Summary of Scientific Sessions and Workshops at PICES-2008

MEQ Topic Session (S8)
Consequences of non-indigenous species introductions

Co-Convenors: Blake Feist (U.S.A.) and Mingyuan Zhu (China)

Background

Non-indigenous species (NIS) are ubiquitous throughout the world's marine, coastal and estuarine waters. There is little doubt that human-mediated dispersal of NIS and subsequent establishment of NIS has altered biodiversity, species assemblages, food web dynamics, and trophic structure and interactions in marine ecosystems. These alterations have ecological, biological, evolutionary and economic consequences, especially in coastal and estuarine systems of all PICES member countries. It is ironic that mariculture and the global shipping trade have been identified as the most affected economically, given that these two activities are often identified as the primary vectors of marine NIS introductions. While there are many threats to the biota and ecosystem integrity of the North Pacific, the threat of marine NIS is arguably the least understood.

Summary of presentations

The presentations covered a variety of marine NIS topics relevant to all PICES member countries. The central themes included biogeography, potential and observed impacts, monitoring, vectors, and rapid response. There were a total of 17 oral presentations and 1 poster prepared for this session, with representation from each PICES member country.

The invited speaker, Dr. Edwin "Ted" Grosholz (Department of Environmental Science and Policy, University of California, Davis, U.S.A.) started the session by providing an overview of marine NIS consequences in coastal and nearshore systems. The consequences he described ran the gamut of spatio-temporal scales, ranging from community up through ecosystem levels. His presentation set the stage for the remaining talks as he touched on impacts (socio-economic as well as ecological), vectors, case studies, and policy/management implications.

The second presentation was an overview of biogeographic patterns of invasion in near-coastal and estuarine communities in the Northeast Pacific (NEP) based on surveys by the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) and the EPA/USGS synthesis of native and non-native species in the "Pacific Coast Ecosystem Information System" (PCEIS) database. This was followed by a series of four presentations that addressed vectors of introduction. These included: the occurrence of non-indigenous polychaetes in Russian ports; the origin, expansion, and fate of introduced populations of non-indigenous macroalgae (from East Asia including Japan, Oceania, North America, *etc.*); distribution, origin and vectors of marine NIS on the Pacific coast of Canada; and, spatio-temporal variability in the abundance and size of *Nemopilema nomurai* in Korean waters, with implications for vectors.

The next four presentations were organized around an impacts (potential and documented) theme. The presentations covered topics including: changes in the biogeography of harmful dinoflagellates and raphidophytes along the Chinese coast, as well as strong northward shifts in the spatial distribution of *Phaeocystis globosa* and *Karenia mikimotoi* blooms; consequences of NIS that have been introduced for marine aquaculture in China, including secondary introductions such as pathogens; the range expansion and potential community level impacts of European green crab on the Pacific coast of Canada; and, impediments of native Olympia oyster recovery due to interactions with non-indigenous aquatic species along coastal Oregon.

Following these presentations, we learned about the application of autonomous underwater vehicles (AUV) for detecting invasive tunicate prevalence in deeper marine waters; rapid response plans and their utility in quickly eradicating newly discovered NIS; coupling of individual based models (IBMs) with existing 3D ocean circulation models for predicting the northward range expansion of European green crab along the west coast of North America; and, Dr. Thomas Therriault presented results from a multi-year, interdisciplinary program for identifying, tracking and understanding biological and economic impacts of NIS in Canada.

Dr. Darlene Smith, Co-Chair of Working Group on *Non-indigenous Aquatic Species* (WG 21), introduced the final two presentations. These presentations showcased two of the major products from the Working Group: the Rapid Assessment Surveys in PICES member country ports and the North Pacific NIS database (supported by the Ministry of Agriculture, Forestry and Fisheries of Japan). The Rapid Assessment Surveys have been coordinated by Dr. Thomas Therriault (DFO Canada) and they provide valuable information about the prevalence of marine NIS in ports around the Pacific. Dr. Deborah Reusser and Dr. Henry Lee, II have led development of the North Pacific non-indigenous species database, which is a spatially explicit database of all known NIS occurrences in all PICES member countries.

List of papers

Oral presentations

Edwin Grosholz (Invited)
A new agenda for addressing the impacts and management of coastal invasions

Henry Lee II, Deborah Reusser, Walter Nelson and Janet Lamberson
Changes in latitude, changes in attitude – Emerging biogeographic patterns of invasion in the Northeast Pacific

Vasily I. Radashevsky
Unknown vector of organism transportation with ballast water between the Northwest Pacific and Southwest Atlantic

Takeaki Hanyuda, Shinya Uwai, Judie Broom, Wendy Nelson and Hiroshi Kawai
Origin and dynamics of two non-indigenous algal populations (*Undaria pinnatifida*, Phaeophyceae; and *Ulva pertusa*, Ulvophyceae) using molecular markers

Graham E. Gillespie, Thomas W. Therriault and Glen S. Jamieson
Marine non-indigenous species on the Pacific coast of Canada: Distribution, origin and vectors

Soo-Jung Chang, Won-Duk Yoon and Yoon Lee
Spatio-temporal variability in the abundance and size of *Nemopilema nomurai* (Scyphozoa: Rhizostomeae) in Korean waters

Jinhui Wang, Yanqing Wu, Yutao Qin and Yihong Li
The threat of potential alien species in the East China Sea and a mitigation strategy

Lijun Wang
Species introduced for marine aquaculture and their impacts in China

Graham E. Gillespie and Thomas W. Therriault
Biology and ecological impacts of the European green crab, *Carcinus maenas*, on the Pacific coast of Canada

Steven S. Rumrill
Interactions with non-indigenous aquatic species pose an impediment to recovery of native Olympia oyster (*Ostrea conchaphila*) populations within Coos Bay, Oregon, USA

Thomas W. Therriault, Graham E. Gillespie and Glen S. Jamieson
Looking for non-indigenous species in Canada: Preliminary results from a multi-year, multi-discipline program

Judith Pederson, Victor Polidoro, James Morash, Justin G. Eskesen, Dylan Owens, Franz Hover and Chrys Chryssostomidis
Advancing technologies to identify marine invaders in support of fisheries management

Paul Heimowitz
Rapid response plans for aquatic invasive species

Blake E. Feist, Kevin See, Carolina Parada and Jennifer Ruesink
Predicting the northward range expansion of non-indigenous European green crab (*Carcinus maenas*) along the west coast of North America

Darlene Smith
Introduction of a PICES project on marine non-indigenous species supported by the Ministry of Agriculture, Forestry and Fisheries of Japan

Thomas W. Therriault
Rapid Assessment Surveys: PICES WG-21's approach

Deborah Reusser and Henry Lee II
Evolution of biogeography in the 21st Century – Development of a North Pacific non-indigenous species database

Poster

Xuezheng Lin and Xiaohang Huang
Introduced marine organisms in China from Japan and their impacts

REPORT OF WG 21 ON *NON-INDIGENOUS AQUATIC SPECIES*

The Working Group on *Non-Indigenous Aquatic Species* (hereafter WG 21) held its third meeting October 24–25, 2008, under the co-chairmanship of Ms. Darlene L. Smith and Dr. Vasily Radashevsky. A list of participants and meeting agenda can be found in *WG 21 Endnotes 1* and *2*.

AGENDA ITEM 2
Taxonomy initiative

In 2007, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan, provided funding to PICES for a project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" to develop international systems to collect, exchange and store relevant data. The project is anticipated to run for 5 years (from April 1, 2007 to March 31, 2012).

The project is made up of two components, one on marine non-indigenous species (MNIS) conducted by WG 21 and one on harmful algal blooms conducted by the Section on *Ecology of Harmful Algal Blooms in the North Pacific* (HAB-S). The MNIS sub-project is divided into two initiatives, one on the development of a MNIS database and the other on a taxonomic system to allow identification and documentation of MNIS establishment outside of their native habitat. The latter initiative, which is being led by Dr. Thomas Therriault, consists of four key elements: (1) the identification of taxanomic needs in PICES member countries, (2) the carrying out of rapid assessment surveys, (3) the initiation of standardized collector plate surveys, and (4) the development of taxonomic information system/tools.

The first WG 21 Rapid Assessment Survey (RAS) to assess the presence of non-indigenous species was conducted from September 20–23, 2008, in Dalian, China. Dr. Lijun Wang of the National Marine Environmental Monitoring Center, SOA, was the local organizer. In addition to Drs. Therriault and Wang, the RAS team included Dr. Graham Gillespie (Pacific Biological Station, Canada) and Ms. Darlene Smith (National Headquarters, Fisheries and Oceans Canada); Dr. Hiroshi Kawai (University of Kobe, Japan); Dr. Li Zheng and Mr. Zhisong Cui (First Institute of Oceanography, SOA, China); Drs. Vasily Radashevsky, Eduard Titlyanov, Tamara Titlyanova (Institute of Marine Biology, FEB RAS, Russia) and Dr. Liudmila Budnikova (Pacific Research Institute of Fisheries and Oceanography, Russia); Drs. Blake Feist (Northwest Fisheries Science Center, NMFS, U.S.A.) and Judith Pederson (MIT Sea Grant Program, U.S.A.).

Two commercial ports (Dalian on the Yellow Sea and Bayu Quan on the Bohai Sea) were sampled by Dr Wang prior to the RAS. A third site, Ling Shui Qiao Beach, Dalian, was sampled by RAS participants on October 22, 2008. A total of 59 species were identified in Dalian Port, 29 species in Bayu Quan Port, and 60 on Ling Shui Qiao Beach. Dr. Therriault will produce a formal report of the Dalian RAS and will provide a written protocol for the RAS and collector plate surveys at a later date. Canada will provide collectors to countries wishing to deploy collector plates, and all data from the rapid assessment and collector plate surveys will be entered into the non-indigenous species database.

Professor Toshio Furota presented the results of a rapid assessment survey he conducted in Tokyo Bay, Japan. In summary, two sites were sampled; the Port of Tokyo and Piers off Haneda Airport in the inner Tokyo Bay. A total of 67 species and/or taxonomic groups were identified of which 15 are considered non-indigenous. The complete report from the Tokyo Bay rapid assessment survey can be found in *WG 21 Endnote 3*.

AGENDA ITEM 3
Non-indigenous species database

The second sub-project funded by MAFF (see Agenda Item 2) was the development of a comprehensive MNIS database led by Dr. Henrey Lee II (U.S. Environment and Protection Agency, U.S.A.) and Ms. Deborah

Reusser (USGS-Western Fisheries Research Center at Marine Hatfield Science Center, U.S.A.). This initiative involves the development and population of a database of marine/estuarine species that can be queried for distributional, ecological, and physiological data at different taxonomic levels and spatial distributions. The database includes: species, a hierarchal biogeography at the realm, province and ecoregion level, ecosystem type, salinity, life history and development, habitat, temperature, trophic level and feeding, amd invasion vectors.

A working copy version of the database was distributed to all WG 21 members at the meeting and assistance was provided by Ms. Reusser to ensure that it was successfully installed. January 2009 was established as the deadline for entry and submission of existing non-indigenous species by countries to Ms Reusser. The final version database, complete with query and output functions, picture storage, PDF storage and automated import utilities, will be completed by October 2009. Additional data entry and a possible web-based application will be discussed at PICES-2009 in Jeju, Korea.

AGENDA ITEM 4

WG 21 revised terms of reference

Given the refocusing of WG 21's work on the two MAFF-funded projects, WG 21 reviewed its current terms of reference and revised them (*WG 21 Endnote 4*) to reflect content and duration of the activities (*WG 21 Endnote 5*) under these projects. They were submitted to the MEQ Committee for approval.

AGENDA ITEM 5

6th International Conference on Marine Bioinvasions

Dr. Judith Pederson presented information on the 6th International Conference on Marine Bioinvasions to be held August 24–29, 2009 in Portland, Oregon, U.S.A. The Conference is entitled "*Marine bioinvaders: Agents of change in a changing world*" and details can be found at http://www.clr.pdx.edu/mbic. The themes are:

- Ecological and evolutionary impacts, including potential shifts with global change;
- Predicting the scale and diversity of invasions in the face of global change;
- Measuring and predicting spread on regional and global scales;
- Invasion patterns over time and space: does the past predict the future?
- Advances in detection, identification and tracking-to-origin capabilities;
- Management, rapid response, eradication and restoration.

The conference organizers are seeking financial support from PICES. Dr. Therriault volunteered to serve as a member of the conference's scientific steering committee. Dr. Yoon Lee (Korea) is already a member.

AGENDA ITEM 6

Possible cooperation between the Northwest Pacific Action Plan (NOWPAP) and PICES

Dr. Jeung Sook Park, Scientific Affairs Officer of NOWPAP Regional Coordination Unit, presented a statement on possible cooperation between NOWPAP and PICES. WG 21 reviewed it and concluded that while sharing information is desirable, there were insufficient details to make a recommendation to MEQ.

AGENDA ITEM 7

Recommendations

The Working Group recommends that the MEQ Committee approve:

a. The revised terms of reference, with deliverables and milestones;
b. Extend the lifespan of WG 21 until PICES-2012 (October 2012) to reflect the duration of the MAFF funding;

c. Support the 6th International Conference on Marine Bioinvasions conditional on the organizers' acceptance of significant PICES input;
d. Support a 2-day meeting of WG 21 at PICES-2009 in Korea.

WG 21 Endnote 1

Participation list

Members

Evgenyi Barabanshchikov (Russia)
Blake Feist (U.S.A.)
Toshio Furota (Japan)
Graham Gillespie (Canada)
Paul Heimowitz (U.S.A.)
Masaya Katoh (Japan)
Hiroshi Kawai (Japan)
Henry Lee II (U.S.A.)
Zheng Li (China)
Wang Lijun (China)
Vasily Radashevsky, (Russia, Co-Chairman)
Deborah Reusser (U.S.A.)
Darlene Smith (Canada, Co-Chairman)
Thomas Therriault (Canada)

Observers

Ingrid Burgetz (Canada)
Liudmila Budnikova (Russia)
Jinho Chae (China)
Zhisong Cui (China)
Ted Grosholz (U.S.A.)
Glen Jamieson (Canada)
Judith Pederson (U.S.A.)
Steven Rumrill (U.S.A.)
Yasunori Watanabe (Japan)

WG 21 Endnote 2

WG 21 meeting agenda

1. Opening remarks and introductions
2. Taxonomy initiative
3. Non-indigenous species database
4. WG 21 revised terms of reference
5. 6th International Conference on Marine Bioinvasions
6. Statement on possible cooperation between the Northwest Pacific Action Plan (NOWPAP) and PICES
7. WG 21 Recommendations to MEQ Committee:

WG 21 Endnote 3

Results of Rapid Assessment for marine invasion in Tokyo Bay conducted in 2008

Toshio Furota[1], Satoko Nakayama[2], Masanori Taru[1], Eijiro Nishi[3], Taiji Kurozumi[4], Tomoyuki Komai[4], Teruaki Nishikawa[5], and Ko Tomikawa[6]

[1] Toho University,
[2] Japan Wildlife Research Center,
[3] Yokohama National University,
[4] Natural History Museum and Institute, Chiba,
[5] Nagoya University,
[6] Hiroshima University.

Observation Locations and Methods

A. Port of Tokyo

1. Suspended artificial panels (32×55 cm black acrylic) from a floating dock at Museum of Maritime Science in Port of Tokyo. Every 1 m deep form 1 m to 4 m near bottom. Established on May 11, 2008, and observed on September 22, 2008.
2. Hand collection in intertidal and subtidal bottoms by SCUBA at Daiba Beach and Museum of Maritime Science in Port of Tokyo. Conducted on September 15, 2008.

B. Piers Off Haneda Airport inner Tokyo Bay

1. Hand collection by SCUBA divers. Surface to bottom (20 m), conducted on July 15, 2008.

Preservation and identification

All samples were preserved in 10 % neutralized see-water formalin.

Conclusion

A total of 67 species and/or taxonomic groups were identified. Among them, 17 species were judged to non-indigenous species, which consisted mainly of sessile species, except for 4 free-living ones; an Atlantic clam, *Mericenaria marcenaria*, a mud amphipod, *Monocorophium insidosum*, a small spider crab, *Pyromaia tuberculata*, and a Mediterranean green crab, *Carcinus aestuarii* This strongly indicates that the benthic community in inner Tokyo Bay had been dominated by invasive species. Four major vectors of marine invasion with human activities had been suggested; attaching on ship hauls, sea chests, ballast waters, and intentional or unintentional transplantation with imported fishery species. Action to prevent the marine invasion has not been conducted in Japan. These suggest that there is a possibility of further invasions of marine organisms into the bay, and this will cause change of the benthic community in Tokyo Bay. Monitoring observation for next invasion could be required.

WG 21 Endnote 4

WG 21 revised terms of reference

1. Assesses the status of Non-Indigenous Aquatic Species in the PICES area by:
   - completing an inventory of currently reported estuarine and marine aquatic non-indigenous species in PICES member countries;
   - compiling definitions of terms and making recommendations on use of terms; and
   - summarizing the situation on bioinvasions in the Pacific and compare and contrast to other regions in the Northern hemisphere.

2. Assemble an inventory of expertise and programs related Non-Indigenous Aquatic Species in PICES member countries by compiling:
   - a list of existing databases of Non-Indigenous Aquatic Species experts in PICES member countries; and
   - sources of information on relevant national research and monitoring programs.

3. Prevention and mitigation measures:
   - summarize initiatives on prevention and mitigation measures (*e.g.*, ICES Code of Practice for the Introduction and Transfer of Marine Organisms; IMO Ballast Water Management Convention and national policies of PICES member countries); and
   - develop recommendations for best practices for prevention and mitigation.

4. Promote collaboration between ICES Working Groups on Non-Indigenous Species by:
   - holding joint meetings of the ICES and PICES WG 21 as conveniently possible; and
   - developing and recommending an approach for enhances linkages between ICES and PICES on Non-Indigenous Aquatic Species.

5. Develop a Non-Indigenous Aquatic Species Database for the PICES area.

6. Establish a North Pacific Marine Non-Indigenous Aquatic Species taxonomy initiative including:
   - Conducting rapid assessment surveys and collector surveys; and
   - Developing taxonomic tools.

7. Publish an interim report in 2010 and a final report in 2012 summarizing results and recommendations.

WG 21 Endnote 5

Deliverables and milestones to complete WG 21 terms of reference

DELIVERABLE	PROJECT LEAD	MILESTONES
1) Assesses the status of Non-Indigenous Aquatic Species in the PICES area by:		
a) completing an inventory of currently reported estuarine and marine aquatic non-indigenous species in PICES member countries;	Henry Lee	January 15, 2009 – Countries to send data. March 31, 2009 – Inventory completed.
b) compiling definitions of terms and making recommendations on use of terms;	Thomas Therriault	October 2009 – To be completed.
c) summarizing the situation on bioinvasions in the North Pacific;	Henry Lee	October 2009 – Draft manuscript to be completed. October 2010 – Submitted to a peer-reviewed journal.
d) compare and contrast to other regions.	To be determined	October 2011
2) Assemble an inventory of expertise and programs related Non Indigenous Aquatic Species in PICES member countries by:		
a) compiling a list of existing databases of Non-Indigenous Aquatic Species experts;	Blake Feist	October 2009 – To be completed.
b) compiling sources of information on relevant national research and monitoring programs in PICES member countries.	Thomas Therriault	October 2012
3) Prevention and mitigation measures:		
a) summarize initiatives on prevention and mitigation measures (*e.g.*, ICES Code of Practice for the Introduction and Transfer of Marine Organisms; IMO Ballast Water Management Convention and national policies of PICES member countries);	Paul Heimowitz	October 2009 – Henry Lee to summarize IMO; Judith Pederson to summarize ICES Code of Practice; Paul Heimowitz to lead on mitigation.
b) develop recommendations for best practices for prevention and mitigation.	Paul Heimowitz	October 2012 – To be completed.
4) Promote collaboration between ICES and PICES Working Groups on Non-Indigenous Species by:		
a) holding joint meetings of the ICES and PICES WG-21 as conveniently as practical;	Darlene Smith, Vasily Radashevsky, Judith Pederson	May 2007 – Joint meeting held concurrent with 5th Marine Bioinvasions Conference. August 2009? – Joint meeting to be held concurrent with 6th Marine Bioinvasions Conference.
b) developing and recommending an approach for enhances linkages between ICES and PICES on Non-Indigenous Aquatic Species.	Darlene Smith, Vasily Radashevsky, Judith Pederson	Annually – Share meeting reports and project status. Ongoing liaison between the ICES and PICES chairs.

5) Develop a comprehensive Non-Indigenous Aquatic Database		
a) Develop a database prototype;	Henry Lee, Deborah Reusser	Completed October 2007.
b) Intercessional workshop to test the revised prototype and establish database structure in Busan, hosted at NFRDI;	All	Completed March 2008 in Busan, Hosted by NFRDI.
c) Enhanced prototype based on intercessional workshop;	Henry Lee, Deborah Reusser	Completed October 2008.
d) Final comments on the database to Henry Lee and Deborah Reusser;	All WG 21 members	Comment period closes December 31, 2008.
e) Transmission of current NIS data to Henry Lee preferably in the database or by spreadsheet (See ToR 1);	All WG 21 members	Deadline January 15, 2008.
f) Compiled data	Henry Lee	Deadline March 31, 2008.
g) Final Version 1 of the stand alone database including query functions;	Henry Lee , Deborah Reusser	October 2009 – Final working version of the database.
h) Recommendation on Web-based application;	All WG 21 members	October 2009
i) Development of Web-based application, if approved;	TBD	To be completed October 2012.
j) Continued data entry.	All WG 21 members	Annually until October 2012.
6) Establish a North Pacific Marine Non-Indigenous Aquatic Species taxonomy initiative	Thomas Therriault	
a) Dalian Rapid Assessment Survey;	Thomas Therriault, Lijun Wang	Completed October 2008.
b) Busan Rapid Assessment Survey;	Thomas Therriault, TBD	October 2009
c) A demonstration RAS will be held in Japan for developing countries. Countries to be invited may include Vietnam, Malaysia, Indonesia, Philippines, Thailand and Mauritius;	Thomas Therriault, TBD	Date to be determined between April 2010 and March 2011.
d) Rapid assessment in Russia;	Thomas Therriault, TBD	October 2011
e) Final Report.	Thomas Therriault	October 2012
7) Publish an interim report in 2010 and a final report in 2012 summarizing results and recommendations	Darlene Smith, Vasily Radashevsky	October 2009 – Web brochure outlining the Non-indigenous Aquatic Species issues and WG 21's work on taxonomy and database. October 2010 – Interim report summarizing results and recommendations. October 2012 – Final report summarizing results and recommendations.

PICES Eighteenth Annual Meeting (PICES-2009)
October 23–November 1, 2009
Jeju, Korea

REPORT OF WG 21 ON *NON-INDIGENOUS AQUATIC SPECIES*

The fourth annual meeting of the Working Group on *Non-Indigenous Aquatic Species* (hereafter WG 21) was held under the co-chairmanship of Ms. Darlene L. Smith from October 23–24, 2009. There was participation from all PICES countries and guests from ICES WGITMO, IOC WESTPAC and NOWPAP. Twenty-five WG-21 members and guests attended the meeting (*WG 21 Endnote 1*). The meeting agenda can be found in *WG 21 Endnote 2*.

AGENDA ITEM 2
2009 inter-sessional highlights

WG 21 was active throughout the year planning working group activities and interacting with other multilateral organizations. The following are the highlights of these activities:

- Dr. Thomas Therriault, the Principal Investigator of the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) funded Taxonomy Initiative visited Busan and Jeju Island, Korea, in March 2009 to plan a collector plate and Rapid Assess Survey (RAS). This ultimately resulted in a very successful RAS in Jeju (see PICES Press Vol. 18, No. 1, pp. 38–40). WG 21 conducted a 4-day (October 19–22, 2009) RAS in Jeju prior to the PICES Annual Meeting. Participants were from 5 PICES member countries (Canada, Japan, Korea, Russia and United States) as well as from ICES WGITMO and IOC WESTPAC. Collectors from 4 locations (Busan, Ulsan, Masan and Jang Mok) analyzed the samples at the Jeju Biodiversity Institute. Field sampling was conducted at Seongsan Beach. Analysis is being finalized and will be entered into the database. Working Group members, Drs. Junghoon Kang and Kyoungsoon Shin of KORDI, were instrumental in the success of this exercise and WG 21 thanks them.
- Ms. Darlene Smith was invited to give a presentation on WG 21's activities at an IOC WESTPAC workshop on "*Marine invasive species and management in the western Pacific region*" in Bangkok, Thailand (June 4–5, 2009). This resulted in a formal invitation and acceptance for IOC WESTPAC to attend the WG 21 meeting as an observer at PICES-2009. It is also likely that IOC WESTPAC representatives will participate in the demonstration workshop on "*An introduction to rapid assessment survey methodologies for application in developing countries*" to be hosted by Japan in July 2010.
- PICES co-sponsored the 6th International Conference on Marine Bioinvasions held in Portland, Oregon, from August 24–29, 2009. This financial support enabled a number of WG 21 members to attend the Conference. The meeting was attended by all the Chairs and Co-Chairs of the working groups and a numbers of members. The working groups' activities were shared. This resulted in an invitation to WG 21 to present the Non-indigenous Species database at the WGBOSV meeting in Hamburg, Germany in March 2010. It was also agreed that the PICES and ICES Working Groups would meet again following the 7th Marine Bioinvasions Conference to be held in Barcelona, Spain in 2011.

AGENDA ITEM 3
Taxonomy initiative

The Rapid Assessment Survey (RAS), as part of the taxonomic initiative under the MNIS sub-project which is part of the project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" is funded by a voluntary contribution to PICES from the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan. The project is anticipated to run for 5 years (from April 1, 2007 to March 31, 2012).

In addition to the RAS conducted in Jeju, Korea, collector surveys were undertaken in China and Japan. Dr. Li Zheng presented results from Qingdong and Qingdao, China. Collectors were also put out by Canada and United States but analysis not yet complete.

Two proposals (Tokyo Bay and Osaka Bay) for a demonstration RAS workshop were presented by Dr. Hiroshi Kawai. WG-21 selected the Osaka Bay proposal based on the following criteria: cost, biodiversity, facilities and logistics. The demonstration RAS workshop will be held in July 2010 with the precise date to be determined shortly. IOC WESTPAC will be invited to participate and will conduct its own RAS later in the fall 2010.

AGENDA ITEM 4
Marine non-indigenous species database initiative

The marine non-indigenous species database is the other MNIS sub-project funded by MAFF. Ms. Deborah Reusser and Dr. Henry Lee II reported on the following upgrades to the database:

a. Ability to add images,
b. Ability to add pdf files,
c. Ability to output maps to pdf or to a printer,
d. Bulk import utility,
e. Utility to produce spreadsheets of information by species.

The latest version of the database was installed on Working Group members' laptops at the meeting. Development of the database will be finished March 31, 2010. WG 21 members agreed to submit data quarterly to Dr. Lee for wrap-up. However, they were not able to resolve the question of a web-based application or long-term maintenance of the database.

AGENDA ITEM 5
Glossary of terms and definitions

A draft of a glossary was completed by Mr. Graham Gillespie. WG 21 members will review the glossary and add terms that are missing. Mr. Gillespie will then sort and compare the entries and prepare a final version by October 2010.

AGENDA ITEM 6
Compilation of databases of NIS experts including taxonomists

Dr. Blake Feist prepared a draft compilation of NIS experts. WG 21 members will review the draft and Dr. Feist will produce a final version by January 2010 to be posted on the Working Group's webpage.

AGENDA ITEM 7
Summary of marine bioinvasions in the North Pacific

Dr. Lee reported on progress on the marine bioinvasions database. Data entry is slower than planned. WG 21 members agreed to supply data in a timely manner as discussed above. They also agreed that an atlas of NIS species, with distribution maps and ecological characteristics, would be the best way to communicate a summary of marine bioinvasions in the North Pacific. The atlas would be a PICES publication and brochure, with a CD, and pdf file posted on the PICES website. The atlas will be completed October 2010 with publication in 2011.

AGENDA ITEM 8
Korean port environmental risk assessment technology

Dr. Junghoon Kang presented Korea's efforts to develop environmental risk assessment technologies for ports. This includes monitoring and risk assessment.

AGENDA ITEM 9
ICES Code of Practice on Introductions and Transfers of Marine Organisms

Dr. Judith Pederson, Chair of ICES WGITMO, presented a summary of the ICES Code of Practice on Introductions and Transfers of Marine Organisms. A number of ICES member countries, including Canada, use this code as a basis for their approvals of transfers of marine organisms in their aquaculture industries. This summary will be included in WG 21's final report in 2012.

AGENDA ITEM 10
International Maritime Organization Ballast Water Standards

Dr. Lee presented a summary of IMO Ballast Water Standards. To date, no PICES member countries have ratified the IMO convention on ballast water. Dr. Lee's summary will be included in WG 21's final report in 2012.

AGENDA ITEM 11
Topic Session proposal

WG 21 recommends a ½-day Topic Session on "*Join the club: Integrating non-indigenous species with other anthropogenic influences on coastal ecosystems*" at PICES-2010 (*WG 21 Endnote 3*). We believe that the PICES 2010 Annual Meeting in Portland is particularly well suited for this proposed topic session. First, since much of the research on the impacts of NIS on coastal marine systems occurs in North America, Portland would serve as a convenient hub for this special session. Second, The Center for Lakes and Reservoirs (CLR) at Portland State University (PSU) is an internationally renowned Center that focuses on NIS research and serves as a conduit for much of the NIS research that occurs on the West Coast of the United States.

Proposed budget: $3,500 to cover travel of 2 keynote speakers.

AGENDA ITEM 12
Recommendations to MEQ

The Working Group recommends that the MEQ Committee approve:
a. Holding a 4- to 5-day demonstration RAS workshop in Japan (MAFF funding),
b. Holding a 4-day Rapid Assessment Survey in Oregon (MAFF funding),
c. Holding a 2-day Working Group meeting at PICES-2010,
d. Advising Science Board that WG 21 intends to publish an atlas of non-indigenous species in the North Pacific in 2010,
e. Approving a ½-day Topic Session at PICES-2010 in Portland, Oregon, and travel support for 2 keynote speakers.

WG 21 Endnote 1

Participation list

Members

Evgenyi Barabanshchikov (Russia)
Blake E. Feist (U.S.A.)
Graham Gillespie (Canada)
Hao Guo (China)
Junghoon Kang (Korea)
Hiroshi Kawai (Japan)
Henry Lee II (U.S.A.)
Deborah Reusser (U.S.A.)
Kyoungsoon Shin (Korea)
Darlene Smith (Canada, Co-Chairman)
Thomas Therriault (Canada)
Hisashi Yokoyama (Japan)
Li Zheng (China)

Observers

Judith Pederson (ICES)

and others

WG 21 Endnote 2

WG 21 meeting agenda

1. Opening remarks and introductions
2. 2009 inter-sessional highlights
3. Taxonomy initiative (funded by MAFF)
4. Marine non-indigenous species database initiative (funded by MAFF)
5. Glossary of terms and definitions
6. Compilation of databases of NIS experts including taxonomists
7. Summary of marine bioinvasions in the North Pacific
8. Korean port environment risk assessment technology
9. ICES Code of Practice on Introductions and Transfers of Marine Organisms
10. International Maritime Organization Ballast Water Standards
11. Topic Session proposal
12. WG 21 recommendations to MEQ

WG 21 Endnote 3

Proposal for a ½-day Topic Session on
"*Join the club: Integrating non-indigenous species with other anthropogenic influences on coastal ecosystems*" at PICES-2010

When people think of anthropogenic forcing in coastal marine ecosystems, commercial fishing, aquaculture, pollution and urbanization usually come to mind. Another type of anthropogenic forcing, typically not classified as such, is the presence of non-indigenous species (NIS). While the occurrence and subsequent impacts of NIS in coastal ecosystems are usually not classified as anthropogenic, the mechanisms of their introductions are, by definition, anthropogenic.

The Advisory Panel on Anthropogenic Influences on Coastal Ecosystems (AICE-AP), under the auspices of FUTURE, identified NIS as an exemplary anthropogenic impact on coastal marine systems. Further, in order to begin addressing the three key questions identified as priorities for FUTURE research activities, AICE and COVE (Climate, Oceanographic Variability and Ecosystems) Advisory Panels made it a priority to either establish new PICES expert groups or to build on and extend existing activities in PICES. Working Group 21

(*Non-indigenous Aquatic Species*) was one of the existing expert groups that was specifically suggested to "form an association with AICE". Therefore, we propose a PICES Topic Session dedicated to NIS as an anthropogenic influence on coastal ecosystems, which would facilitate the priorities set forth by the aforementioned advisory panels

If we wish to integrate NIS with other anthropogenic influences, we need a better understanding of ecosystem or regional impacts of NIS. Many, if not most, studies on the impacts of NIS in marine systems are done at small spatiotemporal scales, *i.e.*, typically over small areas (1 m^2) or under controlled circumstances with single species interactions. Conclusions from these studies are often scaled up and extrapolated to entire ecosystems or regions, but the extrapolations are limited by the fact that NIS consequences for whole ecosystems are not limited to single species interactions within homogeneous habitats. The dynamics of NIS impacts vary over space and time. Processes occurring over seasonal, annual and decadal time horizons interact in complex ways with habitat type, condition and availability, native species assemblages, trophic interactions, and food web dynamics. Understanding these complexities requires restructuring how we think about NIS invasions and their impacts on the health of coastal systems. Including and integrating NIS invasions with other anthropogenic influences would help advance our objective of getting a better understanding of the ecosystem and regional impacts of NIS introductions.

Problems arising from the existence of NIS in coastal systems should be addressed using an ecosystem based approach. Continuing to study and manage NIS invasions as single species problems must be replaced by examining NIS within the context of the systems in which they invade. For example, global climate change is expected to have clear consequences with regard to future NIS introductions, establishment, and range expansion of currently established populations. Ignoring this complex interaction will only hinder efforts to control established populations and prevent new introductions. Integrating NIS invasions with existing anthropogenic stressors will facilitate a holistic approach to addressing the challenges facing our coastal marine ecosystems.

Recommended Convenors: Blake Feist (USA) and Hiroshi Kawai (Japan)

Suggested invited speakers:

- John J. Stachowicz, Professor, Department of Evolution and Ecology, University of California, Davis (tentative) to speak on ecosystem and regional consequences of marine NIS invasions in coastal systems;
- Toshiyuki Yamaguchi, Professor, Department of Earth Science, Chiba University, Japan (tentative) to speak on Biogeography and impacts of recently introduced non-indigenous barnacles in Japan.

PICES Nineteenth Annual Meeting (PICES-2010)
October 22–31, 2010
Portland, USA

Extracted from:

Summary of Scientific Sessions and Workshops at PICES-2010

MEQ/FUTURE Topic Session (S12)
Anthropogenic forcing in North Pacific coastal ecosystems: Understanding changes in ecosystem structure and function

Co-Sponsored by: *IMBER*

Co-Convenors: *Blake Feist (U.S.A.), Hiroshi Kawai (Japan), Olga Lukyanova (Russia), Steven Rumrill (U.S.A.) and Thomas Therriault (Canada)*

Background

The North Pacific marine environment has provided a diverse and valuable series of ecosystem services to coastal communities for many thousands of years. Ocean and land-based anthropogenic activities are now widely recognized to have a strong influence on ecological processes throughout the North Pacific marine ecosystem. Anthropogenic influences such as commercial fishing, aquaculture, pollution, and urbanization are particularly strong in coastal waters where they impose a wide variety of multiple stressors that can impact fundamental ecosystem functions, critical processes, and marine biodiversity. Changes in the physical and biological environment perturb native communities, often resulting in disruption of species interactions and trophic relationships that can negatively impact productivity and diminish ecosystem resilience. In addition, large scale processes such as regime shifts, ocean oscillations, and climate variability can alter near-shore processes. For example, introduced species can negatively impact native communities, and commercial shipping and recreational activities can be a powerful vector for changes in the geographic distribution of marine and estuarine species. Similarly, changing ocean conditions have facilitated the continued pole-ward range expansion of a number of marine organisms, often with unknown impacts on the ecosystems they are moving into. Recent range expansion (*e.g.*, Humboldt squid) and population eruptions (*e.g.*, jellyfish) on both sides of the Pacific have had negative consequences for native flora and fauna.

Application of an ecosystem-based approach to coastal management would provide a template to better understand multiple stressors in coastal systems. Continuing to study and manage these stressors independently as single problems must be replaced by examining multiple stressors within the context of the ecosystems they are altering. Further, global climate change is expected to have clear consequences with respect to future species introductions, establishment, and range expansion. Ignoring complex interactions will only hinder management efforts. Thus, integrating non-indigenous species invasions with existing anthropogenic stressors will facilitate a holistic approach to addressing the challenges facing our coastal marine ecosystems.

Summary of Presentations

This session explored the characterization, understanding, and forecasting of the influence of multiple anthropogenic stressors in North Pacific coastal ecosystems. For example, how do non-indigenous species interact with other anthropogenic stressors? The presentations dealt with a high-level overview of stressors in various North Pacific ecosystems (*e.g.*, overharvesting, urbanization, habitat alteration and loss, mariculture, HABs, pollution, non-indigenous species, *etc.*) and the types of impacts that have been observed, especially those linked to changes in biodiversity and productivity (*e.g.*, extinctions, species interactions, trophic cascades).

List of papers

Oral Presentations

John J. Stachowicz (Invited)
Changing biodiversity and the functioning of coastal marine ecosystems

Steven S. Rumrill, Alicia R. Helms and Adam S. DeMarzo
Potential influence of multiple anthropogenic stressors on restoration and recovery of native Olympia oysters (*Ostrea lurida*) in the Coos Bay estuary, Oregon, USA

Olga N. Lukyanova, Sergei A. Cherkashin and Mikhail V. Simokon
Multiple stressors impact on the ecosystem of Peter the Great Bay (Japan/East Sea)

L.I. Bendell
Influence of near bottom mariculture structures on intertidal diversity

Thomas A. Okey, Andrew Day, Laura A. Loucks, Jennifer Spencer and Kathryn Wallace (Invited)
An application of Integrated Ecosystem Assessment in the marine areas of the West Coast of Vancouver Island to support integrated planning and management

Jameal F. Samhouri, Cameron H. Ainsworth, D. Shallin Busch, William L. Cheung and Thomas A. Okey
The importance of community interactions for predicting climate change impacts

D. Shallin Busch, Cameron H. Ainsworth, Jameal F. Samhouri, William L. Cheung, John Dunne and Thomas A. Okey
Evaluating uncertainty in estimates of how climate change may impact Northeast Pacific marine ecosystems

R. Ian Perry, Diane Masson, David L. Mackas and Gisele Magnusson
Developing ecosystem-based management in a human-dominated marine system: The Strait of Georgia, Canada

Lingbo Li, Tony Pitcher and Robert Devlin
Investigating potential ecological impacts of growth-hormone transgenic coho salmon using a marine ecosystem model

Toshiyuki Yamaguchi, Yuu Ohshiro, Masashi Kiuchi, Michio Otani, Ikuo Ueda and Hiroshi Kawai (Invited)
The introduction of the Titan Barnacle, *Megabalanus coccopoma* (Darwin, 1854) (Cirripedia: Balanomorpha) to Japan

Vasily I. Radashevsky
World wide dispersal of mudworm *Boccardia proboscidea* Hartman, 1940 (Annelida, Spionidae)

Shang Chen, Tao Xia, Guoying Du, Huiyang Wang, Li Wang and Dachuan Ren
Quantification of influence of *Spartina* spp. invasion on coastal wetland ecosystem services: Yancheng case study, China

Thomas W. Therriault, Claudio DiBacco, Leif-Matthias Herborg and Graham E. Gillespie
The importance of scale for predicting impacts of stressors in nearshore environments: An example using European green crab (*Carcinus maenas*) invasions in British Columbia

Peter S. Ross, Donna Cullon, Andrea Buckman and John K.B. Ford
Climate change may exacerbate pollution impacts in marine mammals of the North Pacific Ocean

Burke Hales, Jesse Vance, Sue Cudd, Mariona Segura, Wiley Evans and Alan Trimble
Changing carbonate chemistry and the future of oysters in the eastern North Pacific boundary system

Tatiana Yu. Orlova, Inna V. Stonik, O.G. Schevchenko and Vladimir I. Ponomarev
Long-term changes in phytoplankton communities in Amursky Bay (the north-western part of the East/Japan Sea) under eutrophic conditions

Elizabeth Logerwell, Mary Baker and Amy Merten
Natural resource damage assessment in Arctic waters

Xianshi Jin, Xiujuan Shan, Xiansen Li, Jun Wang, Yi Cui and Tao Zuo
Long-term variations of ecosystem structure in the Laizhou Bay, China

Vjacheslav. S. Labay
Variability of macrobenthos structure in coastal waters of northern Sakhalin Island (Okhotsk Sea) around oil- and gas extracting objects

TatianaV. Morozova, Tatiana Yu. Orlova, Boris A. Burov, Alexander Yu. Lazaryuk, Sergey P. Zakharkov and Vladimir I. Ponomarev
Dinoflagellate cysts as indicators of eutrophication in the Amursky Bay, Sea of Japan (East Sea)

Poster Presentations

Vjacheslav. S. Labay
Malacostraca (Crustacea) – A new species in coastal waters of Aniva Bay (Okhotsk Sea, Sakhalin Island)

Takeo Kurihara, Hideki Takami, Takeharu Kosuge, Susumu Chiba, Masatsugu Iseda and Takenori Sasaki
Area-specific temporal changes of species composition and species-specific range shifts in rocky-shore molluscs associated with a warming Kuroshio Current

Ferdinand A. Mkrtchyan, Vladimir F. Krapivin, V.I. Kovalev, V.V. Klimov
An adaptive system to identify pollutants on the water surface

Alexandra S. Kondakova and Andrey P. Chernyaev
Anthropogenic hormone substances in coastal waters of Peter the Great Bay (Japan/East Sea)

Andrey P. Chernyaev and Anna S. Vazhova
Oil pollution in Nakhodka Bay (Japan/East Sea)

Yasuhiro Kamimura and Jun Shoji
Effects of environmental conditions on growth-selective survival of juvenile black rockfish *Sebastes cheni* in a vegetated habitat in the central Seto Inland Sea, Japan

Yulia V. Koudryashova, Tatiana L. Chizhova, Evgeniya E. Solodova and Nina N. Belcheva
Age-specific oxidative stress response to cadmium in the scallop *Mizuhopecten yessoensis*

Alexander Sevastyanov, Anastasia Chernova and Tatyana Lishavskaya
Results of long-term pollution monitoring in Peter the Great Bay (Sea of Japan)

Takuma Morita, Yuji Iwamoto and Jun Shoji
Significance of estuarine habitat as nursery for yellowfin sea bream *Acanthopagrus latus*: Comparison of feeding, growth and possible predators for larvae and juveniles in two habitats around Ohta River estuary northern Hiroshima Bay, Japan

Young Shil Kang, Won-Chan Lee, Sok Jin Hong and Dong-Wook Kim
Seasonal and spatial variability in the zooplankton community in Masan Bay, Korea

Jung-Hoon Kang, Oh Youn Kwon, Kyoungsoon Shin and Man Chang
Distribution of potentially risky heterotrophic *Noctiluca scintillans* and port specific capacity based on port baseline surveys in Korea

Guo Ying Du, Shang Chen, Tao Xia, Dachuan Ren, Li Wang and Min Wang
Valuation of ecological capital in coastal area of Shandong province, China

Ik Kyo Chung, Jung Hyun Oak, Sang-Rae Lee and Jeong Ha Kim
Estimation of the seaweed biomass by the extensive field survey

Hee Won Park, Jae Bong Lee , You Jung Kwon, Chang Ik Zhang and Sung Il Lee
Estimating optimum size of stock enhancement in marine ranching ecosystem

Sangjin Lee and Mark Walton
Threats to marine and coastal biodiversity in the NOWPAP region

REPORT OF WORKING GROUP ON *NON-INDIGENOUS AQUATIC SPECIES*

The Working Group on *Non-indigenous Aquatic Species* (hereafter WG 21) held its fifth meeting October 23–24, 2010 under the co-chairmanship of Ms. Darlene Smith and Dr. Vasily Radashevsky who presented opening remarks and welcomed participants. All PICES member countries were present except China (*WG 21 Endnote 1*). On the first day, the agenda dealt with items 1 to 5, with the remainder being discussed on the second day. The agenda for the meeting can be found in *WG 21 Endnote 2*.

October 23, 2010

AGENDA ITEM 2
Reports on WG 21 activities in 2010

Demonstration Rapid Assessment Survey (RAS) workshop in Japan
A demonstration RAS workshop on "*An introduction to rapid assessment survey methodologies for application in developing countries*" was held July 13–15, 2010 at the Marine Station of the Center for Inland Seas on Awaji Island, Japan. The workshop was hosted by Professor Hiroshi Kawai of Kobe University (see PICES Press Vol. 19, No. 1, pp. 30–31). The goal of the workshop was to provide outreach to participants from developing Southeast Asian countries through training in survey techniques that are quick and inexpensive and can be used where monitoring for non-indigenous species (NIS) is limited and not conducted in a systematic manner. The RAS is a tool for small-scale surveys and is not a replacement for large-scale monitoring programs. Participants came from Malaysia, the Philippines, Indonesia, Singapore, and Thailand. They visited a number of sites around Osaka Bay where they were shown techniques to sample a variety of habitats. Specimens from the highly developed inner part of Osaka Bay and from the relatively pristine area outside of the Bay were collected and identified for comparisons. Based on the positive feedback received from the workshop in Japan, Dr. Thomas Therriault and Prof. Kawai are considering conducting a larger demonstration workshop next year.

RAS 2010 in Newport, Oregon, U.S.A.
The third WG 21 RAS was held at the Hatfield Marine Science Centre in Newport, Oregon, October 18–20, 2010. Twenty participants from Canada, Japan, Russia and the United States sampled intertidal and shallow subtidal habitats in Coos Bay and Yaquina Bay. Results of the Oregon RAS included identification of 191 taxa, most identified to the species level. Twenty-five species of polychaete represent the first records of these species in one or more of the sampled Oregon estuaries, and 8 species of polychaete represent new records in Oregon.

A significant advantage of these surveys is the opportunity for taxonomists to examine material from different areas and exchange ideas directly with other taxonomists of the same taxa and with other invasion ecologists. The participation of ascidian taxonomists in this survey allowed the identification of the second Pacific record of the introduced North Atlantic sea grape *Molgula citrina*, which was also the first Pacific record south of Alaska.

Two of the RAS participants, Graham Gillespie and Sylvia Behrens Yamada, contrasted Canadian and U.S. methods to trap European green crab *Carcinus maenas*, allowing a unique opportunity to inter-calibrate methods used among PICES member countries. Sylvia Behrens Yamada and colleagues have conducted trap surveys in Washington and Oregon estuaries for over a decade while Graham Gillespie and colleagues have conducted trap surveys in British Columbia for the last 5 years.

Gear types are standardized but the survey methodologies have subtle differences. In Washington and Oregon surveys are completely intertidal with traps set from shore during low tides, while in British Columbia surveys include inter- and sub-tidal habitat with traps set by boat. Catch rates (proxy for abundance) vary widely: generally less than 1 crab/trap-day in Washington and Oregon, while some sites in British Columbia have yielded over 30 crabs per trap-day. Therefore, it was desirable to trap a common area using both methods for inter-calibration.

Direct comparisons provisionally indicate that the two methods are comparable. Shore-based trapping is the most efficient means in large coastal estuaries as green crab populations are limited to the upper intertidal. The sample sizes were low and comparisons over a range of abundance would further increase confidence in these results.

Collector plates were deployed during 2010 in Canada in the ports of Vancouver and Victoria, Canada, in an effort to compare with the Ruiz group in San Francisco, U.S.A. Collector plates were also deployed in Osaka Bay, Japan, and the ports of Pusan, Pohang and Daesan in Korea. In the United States collectors were deployed in Oregon for the WG 21 RAS and in Seattle.

Non-indigenous species database project

Dr. Deborah Reusser installed the new version of the PICES NIS database on the laptop computers of participants at the meeting, and was able to resolve incompatibility issues resulting from different versions of Windows operating systems. The database contains a new feature which permits mapping of indigenous and non-indigenous species at a global scale using MEOW ecoregions. Another feature of the database is the ability to generate custom atlas reports.

Non-indigenous species in the North Pacific atlas

The draft atlas was presented to participants. The atlas now contains 631 non-native species and will be placed on a password protected site for review by WG 21 members and taxonomists who have participated in the RAS.

The long-term future of the database and atlas was also discussed. Funding from the Japanese Ministry of Agriculture, Fisheries and Forestry (MAFF) used to develop the database ends March 12, 2012. The United States Atlas Program has offered to host the database. Given PICES' limited resources for data management, this offer will be investigated as a long-term solution for the NIS database and atlas.

AGENDA ITEM 3

Country reports

Canada

Dr. Therriault reported that the Canadian Government has renewed funding for NIS. Fisheries and Oceans Canada is reviewing its marine and freshwater monitoring programs. The current Canadian Aquatic Invasive Species Research Network (CAISN) 5-year program will end March 31, 2011. A new 5-year network focusing on early detection, rapid response, climate change and management advice will succeed it. The new name is the NSERC Network on Aquatic Invasive Species and it will include an Arctic component, given the expectation that the Northwest Passage will be open to shipping in the relatively near future. Information on CAISN can be found at www.caisn.ca. The first record of the periwinkle *Litorina litorea* was reported in British Columbia.

China

No Chinese member was in attendance to provide a report.

Japan

Dr. Takeo Kurihara informed the meeting that Japan has begun a National Survey on the Natural Environment program. Under this program, organisms will be monitored for 100 years. The monitoring is focused on natural and well-preserved sites and will identify all organisms including NIS. Additional information on this survey can be found at:

- http://japan.wetlands.org/WetlandsInternationalJapanWIJ/tabid/1902/language/en-US/Default.aspx
- http://www2.restec.or.jp/geoss_web/pdf/0415/wg3/biodiversity/03.pdf

Korea

Dr. Jung-Hoon Kang gave a presentation on Port Environmental Risk Assessment Technology. Korea is conducting biological and environmental monitoring in 11 shipping ports. The biological monitoring includes NIS. The NIS monitoring includes deployment of the WG 21 collector plates. NIS will be classified based on risk. DNA probes are being developed to detect high-risk species. Korea is considering adding the NIS data from their port surveys to the PICES NIS database.

Russia

Dr. Radashevsky reported that Dr. Alexander Zvyagintsev of the Institute of Marine Biology, Vladivostok, has created a group working on NIS which has studied organisms in ballast water from two ships, one from Japan and one from China. A list of species found in the ballast water has been published. Many of the species were NIS. The publication is in Russian but has a list of the Latin names of species. Surveys are being conducted around Vladivostok Harbour to detect NIS.

United States of America

Dr. Mark Sytsma reported on a West Coast governors' agreement on ocean health. It is an ocean policy for the region with 7 elements, including one on NIS. There are two tasks related to NIS: standardizing ballast water regulations (Pacific ballast water group) and eradication of four species of invasive *Spartina*. The objective of the *Spartina* management plan is to eliminate it by 2018. The three West Coast states and British Columbia are involved in implementing the management plan.

Dr. Blake Feist reported that NOAA deployed collector plates at two stations around Seattle. The plates were modified to be attached to fixed structures. The plates have been collected and preserved, but not analysed. Additionally Dr. Andrew Cohen of NOAA has produced a paper on pathogens in ballast which can be accessed at the following URL:
http://bioinvasions.academia.edu/AndrewCohen/Papers/432605/Cohen_A.N._2010._Non-native_Bacterial_and_Viral_Pathogens_in_Ballast_Water_Potential_for_Impacts_to_ESA-listed_Species_under_NOAAs_Jurisdiction._A_report_prepared_for_the_National_Oceanic_and_Atmospheric_Administration_National_Marine_Fisheries_Service_Endangered_Species_Division_Silver_Spring_MD._Center_for_Research_on_Aquatic_Bioinvasions_CRAB_Richmond_CA

Dr. Henry Lee II reported that the Environmental Protection Agency is developing national ballast water standards and that Gregory Ruiz (Smithsonian Environmental Research Center) and Dr. Ian Davidson (Portland State University) are continuing extensive monitoring of hull fouling on ships at ports on the west coast of North America.

AGENDA ITEM 4

Other updates

RAS workshop in Thailand for the WESTPAC region

Dr. Apple Chavanich of Chulalongkorn University organized a Rapid Assessment Survey with WESTPAC funding. Dr. Therriault will share information and a proposal for a WG 21 event next year in Thailand.

Activities with ICES

Ms. Smith reported on the discussions by two ICES working groups (Working Group on Introduction and Transfer of Marine Organisms and the Working Group on Ballast and Other Ship Vectors) on possible collaboration between ICES and PICES. The two ICES working groups discussed the PICES NIS database but consider it too complex for immediate use. However, they still wish to continue to explore opportunities for collaboration with WG 21. A joint meeting between WG 21 and the ICES working groups is proposed concurrent with the 7th Marine Bioinvasions Conference in Barcelona, Spain, in August 2011.

Establishment of more formal linkages with NOWPAP

Dr. Sangjin Lee (NOWPAP) provided an update on NOWPAP NIS activities and indicated an interest in establishing linkages with PICES WG 21. NOWPAP is one of the UNEP Regional Seas Programs. NOWPAP has 4 member states, China, Japan, Korea, and Russia. One of Regional Activity Centres, DINRAC (Data and Information Network Regional Activity Centre), has established a database related to marine environment conservation on their website. DINRAC has compiled national reports prepared by national experts from member states on NIS and combined into a regional report. It includes current status, legislation, prevention, detection and management of MIS (marine invasive species), which is being implemented by each member state. More information on NOWPAP can be found at the following website: http://www.nowpap.org and http://dinrac.nowpap.org.

Scientific papers

Presentations on the following topics were given by the lead authors:

- Is it or isn't it? Taxonomic proficiency of North Pacific NIS polychaete assessments in the Northeast Pacific. Leslie H. Harris.
  Polychaete Section, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California, USA, 90007.
- Per capita invasion probabilities: A linear model to predict rates of invasion *via* ballast water. Deborah A. Reusser[1], Henry Lee II[2] and Melanie R. Frazier[2]
  [1] US Geological Survey, Western Fisheries Research Center and Oregon State University, 2111 NE Marine Science Dr., Newport, OR, 97365, USA. E-mail: dreusser@usgs.gov
  [2] US EPA, ORD, NHEERL, Western Ecology Division, 2111 NE Marine Science Dr., Newport, OR, 97365, USA
- Density matters: Comparison of approaches to developing ballast water discharge targets. Henry Lee II[1], Deborah A. Reusser[2] and Melanie R. Frazier[3]
  [1] U.S. EPA, Western Ecology Division, Pacific Coastal Ecology Branch, Newport, OR, 97365, USA. E-mail: lee.henry@epa.gov
  [2] USGS, Western Fisheries Research Center, Newport, OR, 97365, USA 3 U.S. EPA, Western Ecology Division, Pacific Coastal Ecology Branch, Newport, OR, 97365, USA
- Implications of the species area rule to human welfare
  John W. Chapman, Dept. Fisheries and Wildlife, Hatfield Marine Science Center, Newport Oregon, OR 97365, John.Chapman@OregonState.Edu

AGENDA ITEM 5

Long-term NIS activities in PICES

WG 21 is scheduled to complete its term at the PICES-2012 in Japan. A discussion was held among the 5 member countries present to assess interest in continuing work on NIS within PICES. Representatives from Canada and the U.S. agreed that NIS will continue to be a priority for them. Korean participants believe that NIS will continue to be a priority but that the focus of work should change and include climate change elements. Japanese participants indicated that NIS will continue to be an important issue, but that the focus should change to include indigenous and non-indigenous species in the context of climate change. The Russian participant concurred that it was important to continue the NIS work.

Discussions amongst WG 21 members during the meeting and at the PICES Opening Reception about this topic resulted in the following topics to be considered for continued PICES work on NIS:

- Climate change is expected to alter both indigenous and NIS species. Indigenous species may well change their ranges, especially in ecosystem boundary areas. Climate change may result in new vectors or change in the relative importance of existing vectors that introduce NIS. Climate change may also alter the severity of the impacts of NIS species and may result in indigenous species becoming problem species, as is the case with some species of jellyfish.

- Future PICES work could include study of the impacts of climate change on indigenous and NIS. The foundation work of WG 21, including the database and RAS/taxonomy initiatives, could be used to support this new focus. There could also be an opportunity to incorporate the work of the Section on *Harmful Algal Blooms* (HAB-S), as harmful algae will be affected by climate change just the same as the macro-organisms that WG 21 has focused on.

WG 21 members also discussed how current and future work must be relevant to the FUTURE program and its Advisory Panel on *Anthropogenic Influences on Coastal Ecosystems* (AP-AICE). Members believe that a new focus on climate change would be consistent with FUTURE.

October 24, 2010

AGENDA ITEM 6
WG 21 MAFF projects – Plans for 2011–12

Database and atlas
Discussion focused on the final entry of data. Dr. Lee II offered to enter data if it is sent him in an ordered format. WG 21 members and taxonomists who have worked on the RAS can submit data. Korea will consider entering the data from their port survey project. Deadline for comments on the database to Dr. Lee is due December 31, 2010. Dr. Reusser noted increasing difficulties being encountered with different versions of Windows and operating languages, and is working to resolve this issue.

Taxonomy project
Plans for a WG 21 RAS prior to PICES-2011 in Khabarovsk, Russia, were discussed. Khabarovsk is situated on the Amur River, some 700 km north of the Port of Vladivostok. Vladivostok, with its Institute of Marine Biology, was selected as the best location for the WG 21 RAS.

Continuation of collector plate surveys
Dr. Therriault sent collectors out this year and offered to ship collector plates to WG 21 members for the 2011 sampling year.

Demonstration workshop for countries in economic transition
The first RAS demonstration workshop was a successful start but a larger workshop is needed to reach more countries. Dr. Therriault and Prof. Kawai will work with Dr. Chavanich to develop a proposal to hold a second demonstration workshop in Puket, Thailand, during the summer of 2011, with support from WESTPAC. Target participants will be researchers and managers working on NIS.

Report to Japanese Fisheries Agency
A report of WG 21 and HAB activities conducted with the funding from MAFF will be presented to the Japanese Fisheries Agency. The WG 21 portion will include a summary of the RAS and the database and atlas development. The deadline for the report is October 31, 2010. The report is for bureaucrats and should highlight the successes and important results of the projects, for example, the confirmation that *Ulva pertusa*, which has been washing up in abundance in Oregon, is native to Asia and the documentation of *Mogula citrina*, a solitary tunicate from the North Atlantic.

AGENDA ITEM 7
Terms of reference

WG 21 reviewed its terms of reference and confirmed that it is on track for completion in October 2012.

AGENDA ITEM 8
Other business

Request for financial support
The organizers of the 7th International Conference on *Marine Bioinvasions* have requested financial support of $5000 from PICES. PICES has previously provided financial support at this level to fund travel for participants from PICES member countries. WG 21 members are supportive of this request.

Potential linkages between WG 21 and FUTURE
Dr. Therriault led the discussion on potential linkages between WG 21 and the FUTURE program, focusing on AP-AICE. WG 21 activities are consistent with FUTURE but are scheduled to terminate October 2012, leaving a short time period to develop links. A decision will be required to continue PICES work on NIS if longer-term links to FUTURE are to be established.

Suggestions for linking NIS with HAB-S or rolling WG-21 over into a section were made. A number of WG members indicated that their countries (Canada, Japan, Korea, U.S.) were interested in continuing with NIS. Climate change was proposed as a future focus of NIS activities.

WG 21 Endnote 1

WG 21 participation list

Members

Blake Feist (U.S.A.)
Graham Gillespie (Canada)
Jung-Hoon Kang (Korea)
Takeo Kurihara (Japan)
Henry Lee II (U.S.A.)
Yoon Lee (Korea)
Vasily Radashevsky (Russia, Co-Chairman)
Deborah Reusser (U.S.A.)
Darlene Smith (Canada, Co-Chair)
Mark Sytsma (U.S.A.)
Thomas Therriault (Canada)

Observers

Sangjin Lee (NOWPAP of UNEP)
John Chapman (U.S.A.)
Leslie Harris (U.S.A.)
Wang Qixiang (China)

WG 21 Endnote 2

WG 21 meeting agenda

October 23, 2010

1. Opening remarks and introductions (Smith and Radashevsky)
2. Reports on WG 21 activities in 2010
   - Demonstration Rapid Assessment Survey (RAS) Workshop in Japan (Therriault)
   - Newport Rapid Assessment Survey 2010 (Therriault and Chapman)
   - PICES NIS database project (Lee and Reusser)
   - Non-indigenous species in the North Pacific Atlas (Lee/Reusser)
   - Collector plate deployment in 2010 (Therriault and others)
3. National reports (All)
4. Other updates
   - RAS workshop in Thailand for the WESTPAC region (Smith)
   - Activities with ICES (Smith)
   - Establishment of more formal linkages with NOWPAP (Sangjin Lee)
5. Long term NIS activities in PICES

October 24, 2007

6. WG 21 MAFF Projects – Plans for 2011-12
   - Database and atlas (Reusser and Lee)
   - Taxonomy (Therriault)
   - Report to Japanese Fisheries Agency (Kurihara)
7. WG 21 terms of reference (All)
8. Other business (All)

PICES Twentieth Annual Meeting (PICES-2011)
October 14–23, 2011
Khabarovsk, Russia

Report of Working Group on *Non-indigenous Aquatic Species*

The Working Group on Non-indigenous Aquatic Species (hereafter WG 21) held its sixth meeting October 14–15, 2011 under the chairmanship of Ms. Darlene Smith who presented opening remarks and welcomed participants. WG 21 members from three PICES member countries (Canada, Japan and USA) and observers from the Northwest Pacific Action Plan (NOWPAP) and the IOC Sub-Commission for the Western Pacific (WESTPAC) were present (*WG 21 Endnote 1*). On the first day, the agenda dealt with items 1 to 4, with the remainder being discussed on the second day. The agenda for the meeting can be found in *WG 21 Endnote 2*.

AGENDA ITEM 2
Country and organization reports

Canada
The first Canadian Aquatic Invasive Species Network (CAISN), which was established in 2006, came to a close in 2011. The focus of the network was to identify and quantify the vectors and pathways by which aquatic invasive species enter Canada, determine factors that affect their colonization success, and develop risk assessment models for potential and existing aquatic invasive species. A report on CAISN is available at: http://www.caisn.ca/uploads/CAISN_FinalReport20112.pdf.

The Canadian Government has renewed funding for CAISN to address remaining information gaps. Future research will focus on four new core themes:

- Early Detection,
- Rapid Response,
- AIS as Part of Multiple Stressors,
- Reducing Uncertainty in Prediction and Management

More information can be found online http://www.caisn.ca/en/index.php.

Currently there are two research projects underway in the Pacific including: Characterizing effects of trophic interactions between native and non-native filter feeders on establishment and spread of aquatic invasive species, and evaluation of the efficacy of trap out efforts to control invasive European green crab: Lessons from Pipestem Inlet, BC.

Fisheries and Oceans Canada is also currently developing a national regulatory proposal to address the threat of aquatic invasive species.

Japan
A new species of non-colonial tunicate *Ascidiella aspersa*, first identified in Japan in 2009, has become widespread. It is causing serious damage to various cultured species, especially scallops. Work to confirm the validity of identification and origin of this species is ongoing.

Future funding from the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF), which has funded two WG 21 initiatives, will now focus on how to use coastal ecosystems sustainably and will not be directed specifically to non-indigenous species.

Russia

Dr. Alexi Gorodkov provided a summary of non-indigenous species in the Far East of Russia. There are currently 66 species listed that are in various stages of introduction. The species list can be found in the following paper: Non-indigenous species in the Far-Eastern seas of Russia. Zvyagintsev A.Yu., Radashevsky V.I., Ivin V.V., Kashin I.A. and Gorodkov A.N. 2011. *Russian Journal of Biological Invasions*. 2(2–3): 44–73.

Russia is considering ratification of the International Convention for the Control and Management of Ships' Ballast Water and Sediments. (N.B. Canada and Korea are the only two PICES member countries to have signed the convention.)

United States of America

The U.S. Fish and Wildlife Service (USFWS) is leading the North Pacific Landscape Conservation Cooperative (NPLCC), one of the many LCCs in a new national network aimed to address large-scale conservation issues like climate change and invasive NIS through a collaboration of natural resource agencies and universities. The NPLCC includes estuarine and coastal waters from Northern California to southeast Alaska. Although the NPLCC is still formulating its priorities and has not yet significantly addressed marine bioinvasions, it is anticipated that this will become a priority in the future.

As part of the National Fish Habitat Action Plan, USFWS and the National Oceanic and Atmospheric Administration (NOAA) are helping lead the formation of a new Pacific Marine and Estuarine Fish Habitat Partnership that will encompass California, Oregon, and Washington coastal waters. As with other fish habitat partnerships under this national program, this effort may be a source of additional resources for non-indigenous species monitoring and control.

The National Ocean Policy, established by Presidential Executive Order on July 19, 2010, includes nine National Priority Objectives that address pressing issues such as climate change and ocean acidification. A strategic action is being developed for each one of these objectives. (http://www.whitehouse.gov/administration/eop/oceans). Invasive species components are being incorporated into strategic action plans to:

- identify and prevent high-risk introductions of non-native species;
- increase research capacity to document economic and ecological impacts; and
- establish interagency partnerships to bring together expertise, strengths and resources to control existing populations.

NOAA has assisted in updating and revising the Hazard Analysis and Critical Control Point (HACCP) planning process to increase its benefit to preventing the spread of invasive species. The revised HACCP planning process includes a stronger emphasis on risk assessment in order to identify high-risk activities and focus attention on actions needed to reduce the movement of potential invasive species. NOAA will continue to offer HACCP training sessions to staff and grant recipients.

There is increased interest in non-indigenous tunicates in the Northeast Pacific since *Didemnum vexillum* was discovered last year on the Oregon coast and in Sitka, Alaska. In both cases, consideration of eradication opportunities were clouded by uncertainty about species range and the limited success of previous control efforts of this species and other non-indigenous tunicates in Puget Sound. There is also limited information available to help predict the ecological and economic implications of an invasive tunicate invasion in nearshore habitats. Citizen scientists were key to the discoveries in both Oregon and Alaska and continued to help with additional surveys in 2011 – illustrating the value in engaging nonprofessional groups in early detection of marine non-indigenous species.

The recent northward range expansion of *Undaria pinnatifida* into San Francisco Bay continues to raise concerns about its potential establishment in Oregon and Washington coastal waters. Currently there is no substantial effort to regularly survey for this macroalgae in the Northwest, nor is there much information available to estimate its potential impacts or plan for rapid response opportunities.

The West Coast Governor's Agreement on Ocean Health continues to support a Spartina Action Coordination Team and the associated goal of eradicating non-indigenous *Spartina* spp. from the West Coast by 2018.

Northwest Pacific Action Plan (NOWPAP)
Dr. Sangjin Lee provided an overview of NOWPAP activities related to aquatic invasive species. A regional report entitled "*Regional Overview and National Reports on the Marine Invasive Species of the NOWPAP Region*" has been produced. It contains information on current activities, threats and management, and information on current and ongoing research projects, and can be found at http://dinrac.nowpap.org.

IOC Sub-Commission for the Western Pacific (WESTPAC)
Dr. Suchanna Apple Chavanich gave an update on WESTPAC activities related to non-indigenous species conducted under the Project on Coastal Marine Biodiversity. The objectives of this project are to understand and provide the scientific basis for biodiversity management, to establish an effective management plan and monitoring programs for marine biodiversity among WESTPAC member countries and to encourage research collaboration and exchange of knowledge among WESTPAC countries.

Of note for 2011 was the IOC-WESTPAC/PICES joint workshop on "*Rapid Assessment Survey Methodologies for Detecting Marine Non-Indigenous Species*" held July 19–21. The purpose of the workshop was to provide a contextual perspective on why monitoring for non-indigenous species is important; to educate participants in RAS methodologies and demonstrate their application; and to provide participants with an overview of the PICES WG 21 database and how all can benefit from such an application. Twenty-nine participants from 9 countries (Canada, China, Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand and Vietnam) attended.

AGENDA ITEM 3
Reports on WG 21 inter-sessional activities in 2011

Demonstration Rapid Assessment Survey (RAS) in Thailand
As mentioned above, the second demonstration workshop was conducted July 19–21, 2011 in Puket, Thailand. Twenty-nine participants from 9 countries were provided with an overview of the rationale behind rapid assessments and the methods developed and used by WG 21. Two intertidal field sites were visited to collect scrapings and collector plates. A significant advantage of these methods is their low cost. It was noted that tropical waters have a high percentage of unknown species and taxonomy issues. Dr. Hiroshi Kawai (Kobe University, Japan) gave a presentation on molecular tools for species identification. Participants indicated that they were very satisfied with the workshop and that they intended to initiate rapid assessment projects in their home countries.

Seventh International Conference on Marine Bioinvasions
The Seventh International Conference on Marine Bioinvasions was held August 23–25 in Barcelona, Spain. Dr. Thomas Therriault served on the conference Scientific Steering Committee, representing WG 21. The theme of the conference was "*Advances and gaps in understanding marine bioinvasions*". PICES provided travel support to 8 graduate students and 4 postdoctoral fellows from PICES member countries to attend the conference. Additional information on the conference can be found at http://www.pices.int/publications/pices_press/volume20/v20_n1/pp_32-33_MBIC.pdf. The Eighth Conference on Marine Bioinvasions is to be held in 2013 on Canada's West Coast. This location was chosen to increase participation from Western Pacific countries.

RAS 2011 in Vostok Bay, Russia
The fourth WG 21 RAS was conducted from October 7–14, 2011, at the Vostok Marine Station. Most of the sampling was conducted in and around Vostok Bay in habitats that varied from small harbors to rocky shores and mud flats. Collector plates were deployed for 5 months. Two sets of these plates were recovered from Vostok Bay and one from the international harbor in Vladivostok. Participants from all PICES member

countries attended. Additional information on the Russian rapid assessment survey can be found at http://www.pices.int/publications/pices_press/volume20/v20_n1/pp_26-29_RAS-2011.pdf.

Database and atlas project
The framework for the NIS atlas and database was published in a peer reviewed journal. The citation for this paper is: Evolution of natural history information in the 21st Century – Developing an integrated framework for biological and geographical data. Reusser, Deborah A. and Lee II, Henry, J. 2011. *Journal of Biogeography* 38: 1225–1239 and can be found online at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2699.2011.02515.x/pdf

The Atlas of Non-indigenous Marine and Estuarine Species was peer reviewed. The Atlas is generated from the database and contains 700 species and is now 1800 pages long. For each taxa there is a two-page profile containing extensive information on habitat requirements, life history and distribution (native and non-native ranges). The Atlas also contains an extensive bibliography.

AGENDA ITEM 4
MAFF projects plans for 2012

Taxonomy project
A third and final demonstration RAS workshop is scheduled for February 8–9, 2012 in Nagasaki, Japan. The workshop will be held in collaboration with NOWPAP and IOC-WESTPAC and will be hosted by Dr. Takeo Kurihara of the Japanese Fisheries Research Agency at the Seikai National Fisheries Research Institute in Nagasaki.

Database and atlas project
The Atlas of Non-indigenous Marine and Estuarine Species generated from the PICES Non-indigenous Species Database will be published in electronic format. Development of a web application for the database, hosted by the U.S. National Atlas Program will continue.

Final reports on the two initiatives will be provided to MAFF.

AGENDA ITEM 5
WG 21 terms of reference

WG 21 is scheduled to complete its mandate with its last meeting at PICES-2012 in Hiroshima, Japan. The final report to meet the terms of reference will be prepared for review and revision at the Hiroshima meeting.

WG 21 Endnote 1

WG 21 participation list

Members

Blake Feist (USA)
Takeo Kurihara (Japan)
Henry Lee II (USA)
Debbie Reusser (U.S.A.)
Darlene Smith (Canada, Co-Chair)
Thomas Therriault (Canada)
Hisashi Yokoyama (Japan)

Observers

Suchanna (Apple) Chavanich (WESTPAC)
Alexi Gorodkov (Russia)
Sangjin Lee (NOWPAP of UNEP)

WG 21 Endnote 2

WG 21 meeting agenda

October 14, 2011 (Saturday, 9:00am–5:30pm)

1. Opening remarks and introductions
2. Country and organization updates
3. Reports on WG 21 inter-sessional activities in 2011
4. MAFF projects plans for 2012

October 15, 2011 (Sunday, 9:00am–12:30pm)

5. WG 21 terms of reference

PICES Twenty-first Annual Meeting (PICES-2012)
October 12–21, 2012
Hiroshima, Japan

The Working Group on *Non-indigenous Aquatic Species*

The Working Group on *Non-indigenous Aquatic Species* (hereafter WG 21) held its seventh meeting October 17, 2012 under the chairmanship of Ms. Darlene Smith who presented opening remarks and welcomed participants. WG 21 members from four PICES member countries (Canada, Japan, Korea and the United States) and observers from the Northwest Pacific Action Plan (NOWPAP) attended (*WG 21 Endnote 1*). The agenda for the meeting can be found in *WG 21 Endnote 2*.

AGENDA ITEM 2
NOWPAP alien species workshop

Dr. Sangjin Lee provided an overview of NOWPAP activities related to aquatic invasive species. NOWPAP has developed a Medium Interim Strategy 2012–2017 that comprises five areas of focus of which "biodiversity conservation" is of most relevance to WG 21. The biodiversity conservation focus includes:

- information sharing on current situation with biodiversity, including Marine Invasive Species (MIS) and
- application of international regulations for the prevention of alien species invasions.

NOWPAP has initiated a project to hold a regional workshop on "*MIS problems in northwest Pacific region*". The funding is from the Asia-Pacific Network for Global Change Research. The workshop will be held October 23–24, 2012, in Qingdao, China. Experts from China, Japan, Korea and Russia will participate. The workshop objectives are to:

- exchange information on MIS problems among officials and experts from NOWPAP member states;
- exchange experiences on the prevention and control of MIS problems among officials and experts from NOWPAP member states;
- analyze the needs for policies and measures on MIS problems and recommendations for NOWPAP member states.

Specific topics to be discussed are:

- the current situation of MIS problems in the NOWPAP region;
- experiences and good practices on the prevention and control of MIS problems;
- challenges in prevention and control of MIS problems;
- needs for policies and measures on MIS problems in NOWPAP member states; and
- necessity and ways of cooperation among NOWPAP member states for the prevention and control of MIS problems in NOWPAP region.

AGENDA ITEM 3
Ballast water monitoring in Korea

WG 21 member, Dr. Jung-Hoon Kang from the Korean Institute of Ocean Science and Technology (KIOST), provided a presentation on a Planning Project launched September 12, 2012. Under this project 12 ports are to be monitored for 5 years. The project's objectives are to obtain historical and current data required for risk analysis to control and reduce the hazardous effects of foreign species.

AGENDA ITEMS 4, 5 AND 6
MAFF-funded projects – final update

A final project report was submitted to the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF).

A brochure on the PICES Non-indigenous Species Information System, the Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific, and Rapid Assessment Survey Projects were also published.

Atlas and database
Dr. Deborah Reusser gave a demonstration of the PICES Non-indigenous Species Information System and the Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific. The database and atlas have been finalized and are available online at *the Coastal Biological Risk Analysis Tools (CBRAT)* website: https://cbrat.nationalatlas.gov/PICES_NISIS_download.html. The database and atlas can be accessed as follows:

<u>The PICES Non-indigenous Species Information System</u>
View the install instructions for the PICES_NISIS Database. The database is a .zip file. Once downloaded, you will need to unzip it and then follow the install instructions for the appropriate operating system. View the Users Guide and Metadata for the PICES_NISIS Database.

<u>The Atlas of Non-indigenous Marine and Estuarine Species in the North Pacific</u>
This atlas provides summary information on the species in the PICES_NISIS Database along with statistical analyses for the North Pacific regions on the distributions of nonindigenous species at the ecoregion and regional scale for the six North Pacific Marine Science Organization (PICES) member countries. Articles will be prepared for PICES Press to publicize the database and atlas. The metadata for the database and atlas will be entered into the TCODE information system. The data will be included in the Species at Risk to Multiple Climate Stressors (risk analysis tools) on the CBRAT website. It is anticipated that experts will be able to add additional NIS records in 2013 and that general public access will be available in 2014. Canada noted that it benefited greatly from information in the PICES NIS database to develop responses to non-indigenous species that arrived on debris resulting from the March 11, 2011 Tōhoku earthquake and tsunami.

Taxonomy project
The final Rapid Assessment Survey Demonstration Workshop was held February 8–9 at the Seikai National Fisheries Research Institute of the Fisheries Research Agency in Nagasaki, Japan. The workshop was co-convened by:

- Dr. Takeo Kurihara, Seikai National Fisheries Research Institute, Japan,
- Dr. Suchana (Apple) Chavanich, Chulalongkorn University, Thailand and WESTPAC,
- Dr. Sangjin Lee, NOWPAP,
- Dr. Thomas Therriault, Fisheries and Oceans Canada.

Approximately 25 participants from 7 countries (China, Indonesia, Japan, Korea, Philippines, Thailand and Vietnam) participated in the workshop.

AGENDA ITEM 7
Review of final WG 21 report

A draft of the final report was reviewed and suggestions made for completion. The revisions will be forwarded to all Working Group members for comment prior to finalization.

AGENDA ITEM 8
Discussion and recommendations for future NIS activities in PICES

Having completed its original mandate, WG 21 concluded that non-indigenous species (NIS) will continue to be an issue of significant concern for PICES members. Discussion considered various options for continuing work on NIS. Briefly, WG 21 recommends that PICES should utilize and build upon the NIS database and atlas tools to focus on how future global climate change and anthropogenic vectors will change the distribution of NIS in the North Pacific and to undertake risk identification to inform mitigation measures by PICES member countries. Revised terms of reference and further discussion of NIS activities can be found in *WG 21 Endnote 3*.

WG 21 Endnote 1

WG 21 participation list

<u>Members</u>

Blake Feist (USA – by correspondence)
Graham Gillespie (Canada)
Jung-Hoon Kang (Korea)
Takeo Kurihara (Japan)
Deborah Ann Reusser (U.S.A.)
Hajime Saito (Japan)
Kyoungsoon Shin (Korea)
Darlene Smith (Canada, Co-Chairman)
Thomas Therriault (Canada)

<u>Observer</u>

Sangjin Lee (NOWPAP of UNEP)

WG 21 Endnote 2

WG 21 meeting agenda

1. Opening remarks and introductions (Darlene Smith)
2. NOWPAP alien species workshop (Sangjin Lee)
3. Ballast water monitoring in Korea (Jung-Hoon Kang)
4. MAFF-funded projects – final update
5. Atlas and database (Deborah Reusser)
6. Taxonomy project (Therriault)
7. Review of final WG 21 report (All)
8. Discussion and recommendations for future NIS activities in PICES (All)

WG 21 Endnote 3

Terms of reference for a one-year extension of WG 21

1. Develop a proposal for continued NIS work that builds upon the work completed by WG 21 and that meets the objectives of FUTURE and the MEQ Action Plan and illustrates how it would integrate with other MEQ expert groups to achieve these objectives;
2. Publicize and promote the use of the NIS database and Atlas; and
3. Investigate and make recommendations for collaborations on NIS with other international marine science organizations including NOWPAP, WESTPAC and ICES.

Future of NIS activities within PICES

While WG 21 has successfully completed its terms of reference, this does not mean that the problem of marine NIS has been solved in the North Pacific. The natural next step is to build upon the database and accomplishments of this Working Group and move forward in the area of marine NIS interactions with marine ecosystems. With the completion of the comprehensive database on marine NIS distributions in the North Pacific, the database can now be utilized in the next logical step of gaining predictive insight to the changes and impacts of NIS. Of particular interest is how projected global climate change (GCC) will affect the introduction, spread and impacts of NIS. GCC and the associated decrease in Arctic ice cover and opening of new shipping routes also poses questions related to the introduction and spread of NIS. Interest has also been expressed in addressing specific taxa of common interest to many PICES member countries (*e.g.*, tunicates). Collaboration with other international organizations on NIS will be a benefit to PICES. NOWPAP, WESTPAC and ICES are of particular importance in this regard. The option of simply moving forward with annual or biennial topic sessions was proposed but without a formal group structure this would be difficult to sustain.

WG 21 developed the following options for continuing work on NIS within PICES:
1. Creation of a Section on Marine Biological Pollutants Focused on NIS,
2. Creation of a Working Group on NIS,
3. Creation of an Advisory Panel on NIS,
4. Amalgamation with S-HAB.

Each alternative is discussed in greater detail below.

1. *Creation of a new Section on Marine Pollutants*
   The NIS group could be the primary focus of biological pollution in North Pacific.

2. *Form a new Working Group on NIS with the following terms of reference:*
   The following draft terms of reference were prepared by Dr. Blake Feist who has indicated he is willing to co-chair a new working group on NIS.
   1. Review and summarize the current knowledge of pelagic marine NIS spatio-temporal distributions in the North Pacific;
   2. Collaborate with physical oceanographers to better understand the role of ocean circulation patterns in marine NIS range expansion and how that range expansion may be affected by GCC (Direct link with S-HAB);
   3. Use publicly available geospatial databases and the WG 21 NIS database to explore the relationship between biodiversity, anthropogenic forcing and NIS, particularly in coastal ecosystems (potential collaboration with NOAA Fisheries);
   4. Generate peer reviewed manuscript describing relative risks imposed by selected pelagic marine NIS proliferation in the North Pacific and how they alter ecosystem services;
   5. Plan and coordinate a symposium, workshop or an annual meeting session on the marine NIS.

What will set this new Working Group apart:
- It will explicitly integrate with other working groups and sections (S-HAB, WG 28, WG 24, *etc*.).
- It will produce peer reviewed papers as final products, which will better engage academics and provide focus for specific reference terms. This also reduces the risk of setting unobtainable goals.
- It will explicitly incorporate ecosystem level (ecosystem services, food web dynamics, community structure, trophic ecology, *etc*.) priorities that are more useful to PICES member countries.
- It will explicitly incorporate major forecasted shifts in ocean conditions (temperature, primary productivity, pH, hypoxia, upwelling, *etc*.) and how NIS may or may not respond differently from native species to these changes.

3. *Form a new Advisory Panel on NIS with the following terms of reference:*
    1. Focus on exchange of information related to changes to diversity, distribution, impacts, issues, mitigation, regulation among PICES member countries and between other international organizations (*e.g*., NOWPAP, WESTPAC and ICES);
    2. Provide recommendations on PICES NIS activities including linkages with other relevant working groups and sections;
    3. Develop and implement proposals for workshops and theme sessions at future PICES meetings;
    4. Develop and implement data, information, and technical standards for NIS in the NP (*e.g*., monitoring tools, risk assessment procedures, mitigation or control options, *etc*.);
    5. Model after ICES approach for annual reports from countries including updates of data to the PICES NISIS database.

4. *Amalgamate with S-HAB*

While the S-HAB has indicated an interest on focusing on climate change in their draft terms of reference, the Section intends to remain focused on phytoplankton. The NIS issue goes well beyond phytoplankton so if this was a desired direction, MEQ would need to clarify if a new Section would resemble the MAFF Project teams.

Relevance of continued NIS activities to FUTURE

WG 21 has developed tools that would allow FUTURE to use information on NIS as an index of a specific anthropogenic stressor. However, to implement this in the context of FUTURE (see below) it will be necessary to update this index as a time series for each ecoregion. This index could be included in the next NPESR. Further, a continued NIS expert group would allow exploration of climate change models on the most probable changes in NIS distributions around the North Pacific and to identify likely changes in NIS vectors (*e.g*., new shipping routes, expanding trade, *etc*.). The last component this new expert group could address is how PICES member countries have been affected by NIS and what community responses have occurred due to NIS incursions in the North Pacific.

FUTURE scientific priorities

- The effects of climate and climate change on physical, geochemical and biological processes at geographical scales ranging from the North Pacific basin and its marginal seas to the coastal regions of interest to PICES member countries;
- Direct and indirect effects of human activities, such as fishing, aquaculture, introduced species, habitat alteration, pollution, and greenhouse gas emissions and their consequences for member countries.

FUTURE research themes

1. How might changing physical, chemical and biological processes cause alterations to ecosystem structure and function?
2. What thresholds, buffers and amplifiers are associated with maintaining ecosystem resilience?
3. How has the important physical, chemical and biological processes changed, how are they changing, and how might they change as a result of climate change and human activities?
4. What factors might be mediating changes in the physical, chemical and biological processes?
5. How are human uses of marine resources affected by changes in ecosystem structure and function?
6. How do multiple anthropogenic stressors interact to alter the structure and function of the systems, and what are the cumulative effects?
7. What will be the consequences of projected coastal ecosystem changes and what is the predictability and uncertainty of forecasted changes?

PICES Twenty-second Annual Meeting (PICES-2013)
October 11–20, 2013
Nanaimo, Canada

Working Group on *Non-indigenous Aquatic Species*

The Working Group on *Non-indigenous Aquatic Species* (hereafter WG 21) held its eight meeting October 12, 2013 under the chairmanship of Ms. Darlene Smith who presented opening remarks and welcomed participants. WG 21 members from three PICES member countries (Canada, China and Korea) and observers from the Northwest Pacific Action Plan (NOWPAP) attended (*WG 21 Endnote 1*). The agenda for the meeting can be found in *WG 21 Endnote 2*.

Participants at the final meeting of WG 21 at PICES-2013 in Nanaimo, Canada. (Back, left to right) Hao Guo, Kyoungsoon Shin, Sangjin Lee, Graham Gillespie, Thomas Therriault, Keun-Hyung Choi, Anya Dunham. (Front) Jung-Hoon Kang, Darlene Smith.

AGENDA ITEM 2
Report on WG 21 related ICES activities

The International Council for the Exploration of the Sea (ICES) has launched the Strategic Initiative on Biodiversity Advice and Science (SIBAS) which has a key focus on aquatic invasive species, but also deals with ecological and biologically sensitive areas and marine protected areas. Information on SIBAS can be found on the ICES website: http://ices.dk/community/groups/Pages/SIBAS.aspx.

There will be a joint ICES/PICES theme session on marine biofouling at the ICES Annual Science Conference in A Coruña, Spain (September 15–19, 2014). WG 21 member, Dr. Thomas Therriault, will chair the session.

AGENDA ITEM 3
International Conference on Marine Bioinvasions

The 8th International Conference on Marine Bioinvasions was held in Vancouver, British Columbia, from August 20–22, 2013, and was co-sponsored by PICES. The conference's theme was "*Biological invasions in changing waters: Envelopes, estuaries, and evolution*". Approximately 125 researchers, policy makers, and managers from 13 countries in North America, South America, Europe, Australia/New Zealand, and Asia exchanged ideas and discussed the latest findings and progress in the global effort to understand and reduce the delivery, establishment, and spread of marine invasive species. Additional information on the Conference can be found in the PICES Press article (Vol. 22, No. 1): http://pices.int/publications/pices_press/volume22/v22-n1/pp_20-21_2013-MBIC.pdf.

Planning has begun for the 9th International Marine Bioinvasions Conference tentatively scheduled for January 2016 in Sydney, Australia, and the 10th International Marine Bioinvasions Conference tentatively scheduled for 2018 in Argentina.

AGENDA ITEM 4
NOWPAP Medium-Term Strategy

The Northwest Pacific Action Plan (NOWPAP) has adopted a Medium-Term Strategy for 2012–2017. Under this Strategy NOWPAP activities will focus on five priority areas:
1. Integrated coastal and river basin management;
2. Regular assessments of the state of the marine environment;
3. Pollution prevention and reduction, including harmful substances, hazardous waste and marine litter;
4. Biodiversity conservation (including marine invasive species); and
5. Climate change impacts.

NOWPAP will publish an Atlas of Marine Invasive Species in 2014.

Given the overlap of interests and membership, WG 21 members recognized the benefits of cooperation on marine non-indigenous species between PICES and NOWPAP.

AGENDA ITEM 5
Review of final WG 21 report

A draft of the final report was reviewed and suggestions made for completion.

AGENDA ITEM 6
Discussion and recommendations for future NIS activities in PICES

Having completed its original mandate, WG 21 concluded that non-indigenous species (NIS) will continue to be an issue of significant concern for PICES member countries. Discussion considered various options for continuing work on NIS. Briefly, WG 21 recommends two options for continuing NIS activities:
1. Create a section focused entirely on marine non-indigenous species; or
2. Create a Section on Conservation Focused on Drivers of Change in Biodiversity.

Proposed terms of reference for the two recommended options can be found in *WG 21 Endnote 3*.

WG 21 also recommends that PICES organize and support the following workshop/special sessions:
- Support a joint PICES/ICES theme session on "*The Increasing importance of biofouling for marine invasions: an ecosystem altering mechanism*" at the 2014 ICES Annual Science Conference in Spain;

- Mitigation and control measures to reduce the impacts of NIS on biodiversity;
- Range expansion of indigenous and non-indigenous species *vs*. human-mediated introductions;
- FAO workshop on identification of VMEs in the North Pacific Ocean;
- NPFC SWG meetings on identification of VMEs and development of encounter protocols.

WG 21 Endnote 1

WG 21 participation list

Members

Keun-Hyung Choi (Korea)
Graham Gillespie (Canada)
Hao Guo (China)
Jung-Hoon Kang (Korea)
Kyoungsoon Shin (Korea)
Darlene Smith (Canada, Co-Chairman)
Thomas Therriault (Canada)

Observers

Anya Dunham (Canada, FIS, AP-AICE)
Sangjin Lee (NOWPAP of UNEP)

WG 21 Endnote 2

WG 21 meeting agenda

1. Opening remarks and introductions (Darlene Smith)
2. Report on WG 21 related ICES activities (Thomas Therriault)
3. International Conference on Marine Bioinvasions (Thomas Therriault)
4. NOWPAP Medium-Term Strategy (Sangjin Lee)
5. Review of WG 21 final report (All)
6. Recommendations for future PICES activities on marine NIS (All)

WG 21 Endnote 3

Recommendations for future PICES activities on NIS

WG 21 makes the recommendations to Science Board on the following two options for continuing activities related to marine non-indigenous species:

Option 1 – Create a section focused entirely on marine non-indigenous species

Terms of reference

1. Continue to share information and taxonomic expertise and update the database and atlas on new introductions to ecoregions;
2. Evaluate how changes in patterns of trade affect pathways and vectors, and provide new species pools from donor regions (*e.g.*, in the potential opening of a north polar sea route, it is possible that NIS could spread between the North Atlantic and North Pacific);
3. Develop a protocol for sampling non-indigenous aquatic species in PICES member countries, including a method for sampling on polar sea route ships;
4. Develop a better understanding of changing distributions of NIS and vectors in the context of global climate change and its impacts on temperature, salinity, ocean acidification and deoxygenation;

5. Develop capacity for predicting changes in the distribution patterns of selected marine NIS among PICES member country ports over the next 100 years as global climate change leads to the opening of new pathways (*e.g.*, shipping in the Arctic);
6. Evaluate the risk of biofouling (hull fouling and tsunami debris) as a vector for the introduction of NIS. Additionally, evaluate the individual risks presented by species commonly encountered in biofouling vectors;
7. Investigate why some species establish over broad areas while some only establish restricted distributions. Compare widely distributed species (*e.g.*, green crab) with those of the same phyla with a narrow distribution. This information could be used in future risk assessments;
8. Changing vectors (*e.g.*, biofouling ships + tsunami debris (a novel vector) and understanding the risk of these species);
9. Plan workshops/special sessions, for example:
   - Support a joint PICES/ICES Theme Session on "*The increasing importance of biofouling for marine invasions: an ecosystem altering mechanism*" at the 2014 ICES Annual Science Conference in Spain;
   - Propose a workshop/session on mitigation and control measures to reduce the impacts on NIS on the marine environment;
   - Propose a workshop session on the role of global climate change in species' range expansion and human-mediated introductions.
10. Work with NOWPAP and ICES to accomplish the terms of reference;
11. Work with other PICES expert groups to accomplish the terms of reference;
12. Prepare a final report on accomplishments.

Option 2 – Create a Section on Conservation Focused on Drivers of Change in Biodiversity

Terms of reference

1. Partnerships:
   - Establish linkages with other intergovernmental organizations dealing with biodiversity issues (*e.g.*, ICES, NOWPAP, WESTPAC, NPFC, CBD, FAO);
   - Document and predict patterns in biodiversity:
     - Identify potential mechanisms to store and share information/data on biodiversity issues in the North Pacific (and beyond), *e.g.*, PICES atlas on NIS, NPFC SWG to build and update databases of the past and current distributions of key commercial and non-commercial species, including database of NIS, at the scale of ecoregions;
     - Identify areas that support high, rare, or unique biodiversity, including VMEs and EBSAs in collaboration with international organizations including CBD, FAO, NPFC, NOWPAP using international criteria (*e.g.*, CBD criteria for EBSA identification; FAO criteria for VME identification).

2. Understanding drivers of change in biodiversity:
   - Identify major drivers of change in biodiversity in the North Pacific Ocean, including non-indigenous marine species, climate change, fishing, and eutrophication, and develop pathways of effects models for related activities that describe the mechanisms of change, including interactions among multiple stressors;
   - Develop indicators to assess how drivers and biodiversity are changing over time and space (*e.g.*, ecosystem status index);
   - Develop models that relate changes in environmental (*e.g.*, climate-related changes in temperature, salinity, pH and O_2, human (*e.g.*, changes in the distribution of fishing effort, discharge of effluents), and ecological variables (*e.g.*, change in community structure) to changes in species distribution patterns, including changes in NIS distributions;
   - Develop models and predictions of change in biodiversity under alternative scenarios of climate change, NIS introductions, fishing patterns, eutrophication, or other key threats;

- Investigate impacts of NIS, fishing, climate change, contaminants (and other key threats) in areas that support high, rare, unique or endangered biodiversity;
- Identify how human societies around the North Pacific value marine biodiversity and how they benefit from naturally diverse marine ecosystems.

3. Provision of science advice:
   - Develop risk assessments for areas that support high, rare, unique or endangered biodiversity;
   - Review mechanisms to conserve biodiversity in the North Pacific, including development/ implementation of Ecologically and Biologically Significant Areas (EBSAs), identification of Vulnerable Marine Ecosystems (VMEs), Marine Protected Areas (MPAs), *etc*. and identify mechanisms to preserve endangered and threatened species in the North Pacific;
   - Respond to emerging issues related to biodiversity;
   - Prepare science advisory reports on key biodiversity issues;
   - Work with other PICES expert groups to accomplish the terms of reference.

4. Prepare a final report on accomplishments.

Appendix 7

PICES Press Articles Related to WG 21

Fifth International Conference on "*Marine Bioinvasions*" and a joint meeting of ICES, IOC, IMO and PICES working groups on invasive species

by Graham Gillespie

The 5th International Conference on "*Marine Bioinvasions*" was held May 21–24, 2007, at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, U.S.A., with more than 180 participants from 22 countries. The event was co-sponsored by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), the U.S. National Sea Grant Program and MIT Sea Grant College Program, with additional support from NOAA. The purpose of the conference was to examine marine bioinvasion vectors, patterns, distribution, ecological and evolutionary consequences, economic impacts, biosecurity approaches, and natural and invasion impacts on biodiversity.

Each day of the conference opened with an excellent plenary talk. Dr. Jeb Byers, University of New Hampshire, spoke on "upstream" dispersal of invasive species in advective environments. Dr. Janice Lawrence, University of New Brunswick, greatly expanded the awareness of the role of viruses in plankton dynamics. Dr. James Carlton, Williams College, gave an eloquent and entertaining presentation on the challenges associated with assessing the impacts of marine bioinvasions on ecological diversity, and thus the evolution, structure and functioning of natural communities. There were 22 topic sessions that ranged in subject matter from *Patterns in Time and Space*, *Impacts (Ecological, Economic, Risk Assessment, Strategies and Management Options)*, to *Shipping (Biofouling and Ballast Water)*, and *Phenotypic Responses, Molecular Tools and Information Management*.

While there were many papers documenting progress on invasive species issues, *e.g.*, models to identify potential invasive species, predict species dispersal and describe the possible range of introduced species, it was clear that there is yet much work to be done. In particular, general understanding and quantification of ecological and economic impacts need further development, as does the use of risk assessment principles to determine species with high potential to invade, to prioritize and direct research, and to identify high-risk vectors to management agencies.

The conference was followed by a joint meeting of the ICES Working Group on *Introductions and Transfers of Marine Organisms* (WGITMO), the ICES/IOC/IMO *Working Group on Ballast and Other Shipping Vectors* (WGBOSV), and PICES Working Group 21 on *Non-indigenous Aquatic Species*. It was convened by the Chairmen of the respective groups: Judith Pederson (MIT Sea Grant College Program, U.S.A., WGITMO), Anders Jelmert (IMR, Norway, WGBOSV), Darlene Smith (DFO, Canada, WG 21) and Vasily Radashevsky (Russian Academy of Sciences, WG 21). The participants briefly reviewed mandates and functions of each working group, then moved on to discuss issues of joint interest and how we might work together in the future.

Potential activities were discussed for the new PICES project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*", funded by the Government of Japan. A general lack of taxonomic expertise was cited as a limiting factor in exchange of information between the member nations of both ICES and PICES. Discussion focussed on a database that would bring together taxonomic information and a registry of taxonomic experts from PICES member countries, similar to DAISIE (**D**elivering **A**lien **I**nvasive **S**pecies **I**nventories for **E**urope).

Participants of a joint meeting of ICES, IOC (Intergovernmental Oceanographic Commission), IMO (International Maritime Organization), and PICES working groups on invasive species.

The participants discussed the development of an invasive species database similar to DAISIE or the Pacific Coast Estuarine Information System to collate information on alien invasive species (AIS) from PICES member countries. The database would be similar to the U.S. NISBASE (**N**on-**i**ndigenous **S**pecies Data**base**) and would contribute to the development of a global invasive species network. Database formats will be developed and tested on bivalve molluscs and reviewed at PICES XVI.

The group also discussed the importance of ballast water and biofouling as potential vectors for the introduction of invasive species. WGBOSV has nearly completed their ballast water sampling guidelines, and these will be distributed. The group proposed the presentation of member country reviews of ballast water issues and discussion of critical issues related to ballast water for a joint ICES/PICES meeting during PICES XVI. Several other topics included hull fouling and its role in introducing new species, identifying what is being done to prevent hull fouling, examining the ornamental fish trade as a potential source of introductions, and documenting the socio-economic impacts of non-indigenous species.

The final item of discussion was the role of ICES and PICES in advancing **E**arly **D**etection and **R**apid **R**esponse (EDRR) by governments, agencies and organizations to implement eradication or control measures for AIS. The group suggested documenting impacts, costs, successes and failures from world-wide examples, with the intent of providing evidence that success is possible, and examining the roles of governments and citizens in EDRR.

Graham Gillespie (gillespieg@pac.dfo-mpo.gc.ca) is a research biologist with Fisheries and Oceans Canada at the Pacific Biological Station in Nanaimo. His work is associated with inter-tidal bivalve fisheries and the dispersal and distribution of invasive species in the intertidal zone in British Columbia. He is a member of PICES' WG 21 on Non-indigenous Aquatic Species.

PICES WG 21 Meets in Busan, Korea: The Database Meeting

by Thomas Therriault

Non-indigenous species are a global concern because they are detrimental to native biodiversity and compromise ecosystem function. To better understand non-indigenous species in the North Pacific (and beyond), PICES established a Working Group (WG 21) on *Non-indigenous Aquatic Species* that had its inaugural meeting at PICES XV in October 2006, in Yokohama, Japan. In April 2007, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Research Agency (FRA) of Japan, provided a voluntary contribution to PICES for a project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*". This project is anticipated to run for five years (from April 1, 2007 to March 31, 2012), and has two distinct components: one on harmful algal blooms (HABs) and the other on marine non-indigenous species (MNIS). The intent of the funding is to develop international systems to collect, exchange and store relevant data, and to foster partnerships with non-PICES member countries and related international organizations, such as the International Council for the Exploration of the Sea (ICES). The contribution is from the Official Development Assistance (ODA) fund and thus, involvement of developing Pacific Rim countries is required in activities under this project. The project is conducted by two PICES expert groups under the Marine Environmental Quality Committee: Section on *Ecology of Harmful Algal Blooms in the North Pacific* (HAB Section) and WG 21. Each group oversees a specific sub-project. Within the non-indigenous species envelope, two specific initiatives have been identified. The first is the development of a comprehensive MNIS database, with Dr. Henry Lee II (U.S. Environment and Protection Agency) serving as the Principal Investigator. The second is a taxonomy initiative that includes rapid assessment surveys and associated collector surveys in PICES member countries, with Dr. Thomas Therriault (Fisheries and Oceans Canada) serving as the Principal Investigator.

Working Group 21, under the co-chairmanship of Ms. Darlene Smith (Canada) and Vasily Radashevsky (Russia) have focused recent efforts on the database initiative. Following initial discussions held at a joint meeting of PICES WG 21, ICES Working Group on *Introductions and Transfers of Marine Organisms* and ICES/IOC/IMO Working Group on *Ballast Waters and Other Ship Vectors* (May 25–26, 2007, in Cambridge, U.S.A., in conjunction with the 5th Conference on "*Marine Bioinvasions*"), a prototype MNIS database was developed by Dr. Henry Lee and Ms. Deborah Reusser based on the U.S. Environment and Protection Agency and the U.S. Geological Survey "Pacific Coast Ecosystem Information System" (PCEIS) spatial database. At a meeting of WG 21 convened during PICES XVI (October 26–27, 2007, in Victoria, Canada), it became evident that a subsequent meeting was required to beta-test the MNIS database and to develop standardized protocols. Dr. Yoon Lee (National Fisheries Research and Development Institute (NFRDI), Korea) graciously volunteered to host an inter-sessional meeting from March 3–5, 2008, at his institute in Busan. The purpose of the meeting was to reach an agreement on standards, data elements and data entry templates for the MNIS database that will be used to capture information on non-native species and allow sharing of this information, not only among PICES member countries, but more broadly with any community studying non-indigenous species. Species continue to be transported with increasing frequency to

Participants of the inter-sessional WG 21 database meeting (March 3–5, 2008, Busan, Korea).

new environments around the world, primarily *via* activities associated with international trade and commerce (*e.g.*, ballast waters, hull fouling, aquaculture, *etc*.), and once there, some impact ecosystem productivity and function, including local fisheries. Thus, it is critical to understand the distributions of these species in newly-invaded environments as well as in their native environments. This information is essential for undertaking risk assessments and will be a valuable tool to identify, and potentially mitigate, a variety of vectors and pathways.

Day 1 of the Busan meeting started with a round of introductions and opening remarks from our hosts. After reviewing the agenda and expected outcomes from this inter-sessional meeting, the participants quickly immersed themselves in the world of database structure and function. One of the initial discussions was on what scale the database should be developed and subsequently populated. Existing data on non-native species in PICES member countries has been collected at various scales; whereas some studies included latitude/longitude information for each non-indigenous species, others have focused at much larger spatial scales (*e.g*., embayments or basins). It was decided that for our purpose of understanding non-indigenous species patterns in the North Pacific, it would be most informative if we worked at a fairly large spatial scale (although the database will allow input at much smaller spatial scales, thereby meeting the needs of all member countries while ensuring seamless merging of country databases for joint, large-scale analyses). After a quick review of existing papers on potential spatial scales for the database, we agreed to use the eco-regions identified in a recent paper by Spalding *et al*. (2007; *Bioscience* **57**: 573–582) that defined Marine Eco-regions of the World. The key benefit of this paper for marine non-indigenous species is that the eco-regions are defined for the globe and, given that any species has the potential to be moved anywhere around the globe, researchers can clearly identify the eco-regions to which the species is native and those for which it has invaded. Further, this will allow our MNIS database to be populated by other groups working on characterizing and documenting the distribution of marine non-indigenous species (*e.g*., by ICES WGs).

Other issues discussed on the first day of the meeting centered on classification standards. When working on non-indigenous species, one needs to know that the species is not native to the ecosystem (eco-regions) where it has been identified. Several classification criteria were determined, including documentation within the database, in order to be able to classify a species as native or non-native. However, the participants did recognize that an increasing body of literature exists for a number of taxa, especially some of the more controversial ones, which suggests that for some species, we simply will not be able to resolve their invasion status, and these will need to be treated as cryptogenic (unknown origin). We also discussed how to identify if non-indigenous species have become established (self-sustaining population) compared to those that have not and represent "failed" introductions.

Graham Gillespie (Canada), Blake Feist (U.S.A.) and Evgeny Barabanshchikov (Russia) on an impromptu taxonomic survey at a Busan market.

Day 2 provided participants with some "alone time" with the database. After exploring the database by conducting hands-on data entry using our favorite non-indigenous species, we had a series of discussions on the pros and cons of including life history information for these species and on the level of detail that could be incorporated into the database. We also debated about who the end-users of the database likely would be and what their goals would be (*e.g.*, conducting risk assessments). By this point in the beta-testing it was very clear that with enough resources one could build the ultimate database that would include every potential bit of information a researcher could think of. However, it also became apparent that someone would need to serve as the gatekeeper for this database, and that databases do not simply remain error-free all by themselves. Thus, it was decided that, to the extent possible, we would include life history information into the database and that adequate documentation would need to be provided to implement this task. This is consistent with the necessity to add a citation for each species record in the database, thereby providing a mechanism to link an occurrence with a source for this information. After a visit to a local restaurant for lunch and a short stop at a local fish market, the group returned to NFRDI to continue their data entry quests. As expected, there were a number of minor issues identified and corrected with respect to the database itself, but considerable progress was made and the group was very satisfied with the beta-version. The key outstanding issue at the end of Day 2 was how to merge the individual country databases into a common database, or if the databases would be linked.

Day 3 allowed the group to refocus on the outstanding issues that had been identified during the previous two days of database beta-testing, discussions, and problem solving. Representatives from each country had an opportunity to provide input on their expectations of the final version of the database that WG 21 expects to have fully operational (if not fully populated) in time for the rapid assessment surveys to be conducted at two locations in China, prior to PICES XVII in Dalian. With an identified path forward that all attendees were comfortable with, including specific interim deliverables and associated timelines, the field trip portion of the meeting began. First, it was a boat tour of the port of Busan, arranged by Dr. Yoon Lee in conjunction with the local port authority. The group then proceeded on to Busan New Port which is currently under development and will greatly increase the shipping traffic in this part of the world once the expansion is complete. The day ended with the last group dinner associated with this inter-sessional meeting that allowed the participants to continue developing research collaborations and a better understanding of how non-indigenous species are impacting various PICES member countries.

Our meeting was a tremendous success thanks to Dr. Lee and his staff. Not only were meeting facilities extremely comfortable, the group meals every evening allowed participants to mingle in a less formal setting. In addition, we were able to sample a number of local delicacies (food and drink) and take in some of the sights this region has to offer. WG 21 continues to make significant advances towards better understanding non-indigenous marine species in the North Pacific and the dedication of its members will ensure that we are successful in all our endeavors, including completion of the database we beta-tested at our recent meeting in Busan.

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PICES WG 21 Rapid Assessment Surveys

by Thomas Therriault and Graham Gillespie

Since its inception in 2006, PICES' Working Group on *Non-indigenous Aquatic Species* (WG 21) has been advancing our understanding of marine non-indigenous species in the North Pacific Ocean. In 2007, the Japanese Government (Ministry of Agriculture, Forestry and Fisheries of Japan, through the Fisheries Agency of Japan) provided a voluntary contribution to PICES for a 5-year (2007–2012) project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" to develop international systems to collect, exchange and store relevant data, and to foster partnerships with non-PICES countries and international organizations. The project has two distinct components, one on harmful algal blooms carried out by the PICES Section on *Ecology of Harmful Algal Blooms in the North Pacific*, and the other on marine non-indigenous species conducted by WG 21. Two specific initiatives have been identified within the latter component. The first initiative is the development of a comprehensive database for non-indigenous species with Dr. Henry Lee II (U.S. Environment and Protection Agency, Lee.Henry@epa.gov) serving as the principal investigator. The second is a taxonomy initiative led by Dr. Thomas Therriault (Fisheries and Oceans Canada, Pacific Biological Station, Thomas.Therriault@dfo-mpo.gc.ca). The taxonomy initiative will focus on rapid assessment surveys for native and non-native species in a variety of habitats in commercial ports of PICES member countries, and on a collector survey to characterize the distribution of fouling organisms at a number of locations in each PICES member country. The rapid assessment survey will be discussed in this article, but look for future PICES Press articles on the much anticipated collector survey to be conducted in 2009!

In an ideal world, scientists would have the resources to maintain a vigilant watch for the arrival of non-indigenous species. However, the reality is that no country has the resources, financial or personnel, to do this. Thus, a rapid assessment survey (RAS) is one means to identify native, non-native and cryptogenic species present at a specific location at a specific time. By conducting RAS over time, an important baseline is developed which allows researchers to identify the arrival of new species. For the PICES project, we have elected to survey commercial ports in PICES member countries, as ports have a greater probability of containing non-indigenous species. Not only do these locations serve as a recipient environment for organisms transported by commercial shipping (ballast water, ballast sediment, hull fouling), they also often have high levels of secondary traffic (recreational or small craft, aquaculture transfers) and tend to be more disturbed than natural environments, a factor that could enhance invasion success. Although it may not be possible to characterize all habitat types within a port, our survey focuses on major ecosystem components, namely intertidal and subtidal habitats. Intertidal habitats are sampled using both a timed walk and quadrat/grab sampling methods, and subtidal habitats are sampled using (tunicate) collectors, trapping for macrofauna (primarily fish and crabs) and a survey of the fouling communities on floating docks and their associated structure. The intent of this qualitative survey (not a quantitative one) is to capture the species composition within each location surveyed, not characterize the abundance of any specific species. Population estimates can be made in subsequent surveys, if needed, but are not the principle reason for conducting a RAS. The assignment of native, non-native or cryptogenic status occurs following species identification based on literature accounts, general rules for classification of status, and discussion by WG 21 members.

Although many invertebrate species (not all) would be in greater abundances during the warmer, summer months, we decided it would be more informative for participants if sampling were carried out in conjunction with PICES Annual Meetings. Since many of the RAS participants also attend these meetings, logistical and economic benefits are also realized. Thus, our RAS will be conducted in the host PICES member country the week prior to the Annual Meeting (generally mid-October), as was the case with our first RAS in China. It is possible that some taxonomic groups might not be encountered or species missed, but this is expected and represents one limitation of these types of surveys. If the intent was to fully characterize a location, then sampling should be repeated during other seasons, but this significantly increases the resources needed and the number/type of species added is relatively minor.

The goal and success of this type of survey requires the participation of taxonomic experts with broad knowledge of their taxonomic group, in addition to the participation of taxonomic generalists who are able to help with sampling and species identification (primarily *via* the use of identification keys). Also, this type of survey can provide some training to taxonomic generalists, but more importantly can serve as a forum where taxonomic experts can discuss the organisms encountered. For example, experts with extensive knowledge from the North American side of the Pacific can discuss species found in Asian RAS with taxonomic experts familiar with these species there. It also provides an opportunity to highlight and potentially resolve taxonomic issues that can arise among countries, given differences in language and taxonomic advancements since the development of identification keys. For example, some taxa recently have been re-described based on either traditional morphological techniques or more modern genetic ones. Our RAS forum provides an opportunity for taxonomists to discuss these changes and/or advances. Given logistical constraints of

The 2008 PICES Rapid Assessment Survey team.

these types of surveys, our RAS uses members of WG 21 and as many taxonomic experts from the host country as possible. Participation of students is encouraged for logistical support and training. For some taxonomic groups experts might not exist in the host country, and so these "key" taxonomic experts are sought to participate. If you are a taxonomic expert wishing to be involved in our planned RAS in Korea in 2009, please feel free to contact Dr. Therriault about potential participation.

Taxonomy for some species will be controversial, and reference collections are important to document the occurrence of non-indigenous species, thus it is imperative that voucher specimens be maintained for future reference. Within our project, the host PICES member country is maintaining organisms encountered during the RAS in suitable archives. Further, all species records will be entered into the PICES WG 21 Non-indigenous Species Database.

PICES WG 21's first RAS was conducted in October 2008 in China, with two commercial ports targeted, Dalian on the Yellow Sea and Bayu Quan on the Bohai Sea. One unforeseen obstacle to sampling international ports was security concerns raised by port authorities. Thus, the port sampling was graciously co-ordinated by our Chinese hosts under the supervision of Dr. Lijun Wang from the National Marine Environmental Monitoring Center of the State Oceanic Administration (SOA). A total of 18 samples were collected according to the RAS sampling guidelines and preserved for identification by our international team of taxonomic experts. In addition to ourselves and Dr. Wang, this team consisted of Darlene Smith (National Headquarters, Fisheries and Oceans Canada), Zhisong Cui and Li Zheng (First Institute of Oceanography, SOA, China), Hiroshi Kawai (University of Kobe, Japan), Vasily Radashevsky, Eduard Titlyanov and Tamara Titlyanova (Institute of Marine Biology, FEB RAS, Russia), Liudmila Budnikova (Pacific Research Institute of Fisheries and Oceanography, Russia), Blake Feist (Northwest Fisheries Science Center, NMFS, U.S.A.) and Judith Pederson (MIT Sea Grant Program, U.S.A.). Further, Dr. Wang also provided our RAS team with laboratory space, equipment, and reference materials, at the brand new National Marine Environmental Monitoring Center facilities in Dalian, and his hospitality ensured the RAS team was happy and productive during our visit to China.

Preliminary results of the Dalian RAS include algae (45 taxa), arthropods and molluscs (25 taxa each), polychaetes (6 taxa), fish (5 taxa), bryozoans, cnidarians, echinoderms, platyhelminths and poriferans (2 taxa each) and one taxon each of hydrozoan, nemertine and tunicate. Most taxa were identified to the species level, although many are provisional identifications. Some taxa could only be identified to the genus, family or order levels until further investigation. However, we were able to classify three species as non-indigenous: shells were collected from the bivalve molluscs *Argopecten irradians*, *Mizuhopecten yessoensis* and *Mactra chinensis*. The former two species are actively cultured in China, and the latter is readily available in local markets. As only shells were collected, we cannot be certain whether these species have established viable populations in Dalian. It is possible that other non-indigenous species were encountered in some of the other taxonomic groups, notably algae, amphipods, and polychaetes, but identifications and classifications are pending. As our surveys continue, generating distributional data for a number of taxa among PICES member countries, it will be possible to better understand the extent of non-indigenous marine species in coastal waters of the North Pacific Ocean.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, BC. Tom is working on aquatic invasive species (research, monitoring, risk assessment, and rapid response planning) both within DFO and through the Canadian Aquatic Invasive Species Network (CAISN). He also conducts research on forage fishes, notably eulachon and Pacific herring, from conservation and ecosystem perspectives. Tom is a Principal Investigator on the Taxonomy Initiative of PICES' WG 21 on Non-indigenous Aquatic Species *that will include rapid assessment surveys for non-indigenous species in PICES member countries.*

Graham Gillespie (Graham.Gillespie@dfo-mpo.gc.ca) is a Research Biologist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, BC. Graham is the Head of the Intertidal Bivalve and Crab Programs, conducting stock assessments for commercially important species, providing scientific advice for the SARA-listed Olympia oyster and participating in ecosystem-level research involving these groups. He also coordinates an Aquatic Invasive Species project which examines distribution, dispersal and impacts of intertidal non-indigenous species on the Pacific coast of Canada. He is a member of PICES' WG 21 on Non-indigenous Aquatic Species.

2009 International Conference on "*Marine Bioinvasions*"

by Thomas Therriault

From August 24–27, 2009, about 200 bioinvasion biologists from around the globe descended on Portland, Oregon, U.S.A., to exchange ideas and information at the 6th International Conference on "*Marine Bioinvasions*". An additional meeting between PICES Working Group on *Non-indigenous Marine Species* and two ICES Working Groups on *Ballast Waters and Other Ship Vectors* and on *Introductions and Transfers of Marine Organisms* held immediately following this conference on August 28, allowed continued discussions about the role and impact of non-indigenous species world-wide, and how these two major regional scientific organizations could work together on this important topic.

The conference Scientific Steering Committee (SSC) was composed of: Jeb Byers (University of Georgia, U.S.A.), Jeff Crooks (Tijuana River National Estuarine Research Reserve, U.S.A.), Lisa Drake (Naval Research Laboratory, U.S.A.), Anders Jelmert (Institute of Marine Research, Norway), Yoon Lee (National Fisheries Research and Development Institute (NFRDI, Busan, Korea), Whitman Miller (Smithsonian Institution, U.S.A.), Henn Ojaveer (Estonian Marine Institute, Estonia), Gil Rilov (Oregon State University and University of Haifa, U.S.A./Israel), Mark Sytsma (Portland State University, U.S.A.), Thomas Therriault (Department Fisheries and Oceans, Canada), and Chela Zabin (Smithsonian Institution and University of California-Davis, U.S.A.). In addition, the SSC benefited from input of two advisors: Jim Carlton (Williams College, U.S.A.) and Judith Pederson (Massachusetts Institute of Technology Sea Grant College Program, U.S.A.).

The 6th International Conference on "Marine Bioinvasions" was held in Portland: downtown Portland across the Willamette River (left) and the Portland Classical Chinese Garden – place for the conference Welcome Reception (right). Located near the confluence of the Willamette and Columbia rivers, Portland has been referred to as the most environmentally friendly or "green" city in the United States, and the second most in the world. In October 2010, Portland will host the 2010 PICES Annual Meeting.

The conference was hosted by the Portland State University, with Mark Sytsma leading the local organizers. Sponsors for the conference were: the North Pacific Marine Science Organization (PICES), the International Council for the Exploration of the Sea (ICES), the Pacific States Marine Fisheries Commission (PSMFC), the Aquatic Bioinvasions Research and Policy Institute at the Portland State University, the U.S. National Sea Grant College Program, and the U.S. National Oceanic and Atmospheric Administration (NOAA).

ICES and PICES supported the three invited plenary speakers at this year's conference. These were: Dr. Anna Occhipinti-Ambrogi (University of Pavia, Italy), who spoke on alien species as an aspect of global change; Professor Sergej Olenin (Unifob AKSIS, Bergen, Norway and Coastal Research and Planning Institute, Klaipeda University, Lithuania), who summarized patterns and impacts of marine bioinvasions in Europe; and Professor Yoon Lee (NFRDI, Korea), who reviewed marine bioinvasions in Asia.

The conference agenda was an energetic one with two concurrent oral sessions on each of the four days (a total of 127 talks) and a poster session (24 presentations) required to accommodate the increased number of contributed papers over previous meetings. The number of increased contributions reflects increased research activities on non-indigenous marine species around the globe. The conference featured a nice mix of topics, with species–specific sessions focused on lionfish, spartina, and European green crab, vector/pathway specific sessions (*Propagule Pressure*, and *Measuring and/or Predicting Spread*), sessions on applied approaches to non-indigenous species (*Detection, Identification, and Tracking-to-Origin* [including *Advances in Detection*], *Predicting the Scale Diversity of Invasions*, and *Management, Rapid Response, Education, and Restoration*), and sessions that provided insights to broader patterns and implications of non-indigenous species (*Changing Global Conditions and Bioinvasions*, *Ecology and Evolution*, and *Invasion Patterns over Time and Space*).

In addition to these theme sessions, this year's conference hosted four workshops. The *Green Crab Management* Workshop benefited from input from green crab researchers from around the world to help consider options for management of this high profile invader. Similarly, the participants at the *Invasive Tunicate* Workshop provided input to Washington State's Action Plan to address invasive tunicates in Puget Sound. Workshops on *Spartina/Seaweeds and Shipping Activities* brought together conference participants working in these fields to formulate larger-scale research initiatives that can be conducted in future years. The addition of workshops to the program of the conference was valued by participants.

The Poster Session in front of the Hoffman Hall, Portland State University.

With such a full academic agenda it is important to have a balanced social agenda as well. Conference participants had many opportunities for informal discussions with colleagues and new friends. As with previous conferences on "*Marine Bioinvasions*", participants were provided breakfast and lunch on site, which allowed more discussion and less travel to seek restaurants off-site. Portland is a very easy town to get around with free public transportation in the downtown core that allows wider access to shopping, restaurants, and microbreweries. But the real highlight of the conference was the social evening hosted at the Chinese Gardens in the Chinatown District of downtown Portland. These gardens show what can happen when a small group of individuals come together to convert a vacant urban lot to a tranquil and relaxing environment. Participants were even more relaxed when they found out that snacks and drinks were included!

The conferences on "*Marine Bioinvasions*" have always been a place to showcase emerging research in this fast-paced field. Thus, conference organizers and sponsors encourage presentations by early career scientists. This year was no exception. Thanks to contributions from the co-sponsoring organizations, it was possible to provide travel support to all of the graduate students and postdoctoral fellows who requested it. PICES supported the travel of six graduate students (Heidi Gartner, Stephanie Green, Veronica Lo, Lisa Needles, Kimberly Peyton, and Cascade Sorte) and four post-docs (April Blakeslee, Jennifer Dijkstra, Anya Epelbaum, and Joshua Mackie) from Canada and U.S.A.

As a PICES representative on the conference SSC, I would like to express my thanks to the PICES Secretariat for their professional assistance on the conference planning stage, and especially to Julia Yazvenko (PICES Database and Web Administrator) for her valuable help on site.

Planning has already started on the 7th International Marine Bioinvasions Conference, so feel free to contact any of the Scientific Steering Committee members, especially your PICES representatives, and watch for further details in future issues of PICES Press.

2009 PICES Rapid Assessment Survey

by Graham Gillespie and Thomas Therriault

PICES Working Group on *Non-indigenous Aquatic Species* (WG 21) has been working to increase our understanding of marine non-indigenous species (MNIS) in the North Pacific since 2006. The taxonomy initiative is one of two key MNIS research activities within a 5-year (2007–2012) PICES project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" supported by a voluntary contribution from the Ministry of Agriculture, Forestry and Fisheries of Japan, through the Fisheries Agency of Japan. Under the supervision of Dr. Thomas Therriault (Fisheries and Oceans Canada), this initiative has evolved to include both rapid assessment surveys and collector surveys. The first PICES Rapid Assessment Survey (RAS) was carried out in October 2008, in conjunction with the PICES Annual Meeting in Dalian, China. This article discusses the second RAS conducted in October 2009, immediately prior to the PICES Annual Meeting in Jeju, Korea. The 2009 RAS was a tremendous success thanks to excellent logistical support and local knowledge supplied by our hosts, Drs. Kyoung Soon Shin and Jung-Hoon Kang (Korea Ocean Research and Development Institute, Geoje).

A rapid assessment survey provides the opportunity to catalogue native, non-indigenous and cryptogenic species at a given place and time. Repeated surveys over time generate important baseline information that allows researchers to, among other things, determine when new species arrive. Our surveys target commercial ports in PICES member countries, as ports have a greater probability of containing non-indigenous species. Not only do these locations serve as a recipient environment for organisms transported by commercial shipping (ballast water, ballast sediment, hull fouling), they often have high levels of secondary traffic (recreational or small craft, aquaculture transfers) and tend to be more disturbed than natural environments, a factor that could enhance invasion success. The PICES surveys focus on two major port ecosystem components, namely intertidal and subtidal habitats. Intertidal habitats are sampled using both a timed walk and quadrat/grab sampling methods, and subtidal habitats are sampled using fouling organism collectors, trapping for macrofauna (primarily fish and crabs) and a survey of the fouling communities on floating docks and their associated structures. These surveys are qualitative rather than quantitative and endeavour to capture species composition within each location surveyed, not characterize abundance of any specific species. Classification of species as native, non-native or cryptogenic occurs following species identification based on literature accounts, general rules for classification of status, and discussion by members of the RAS team.

2009 PICES Rapid Assessment Survey team.

Discussion of the 2009 PICES Rapid Assessment Survey results at the WG 21 meeting, October 23, 2009, Jeju, Korea.

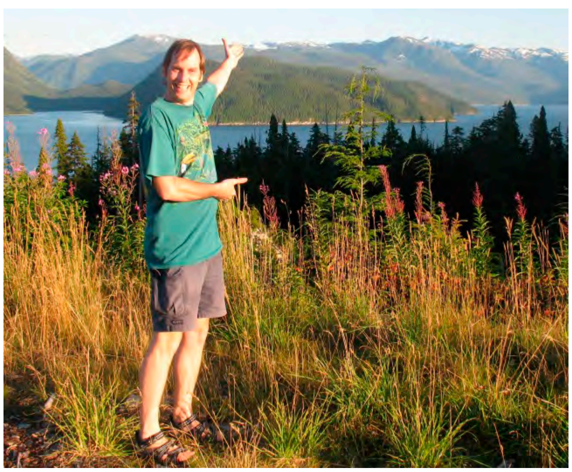
In addition to the authors of this article, the 2009 PICES RAS team consisted of Darlene Smith (National Headquarters, Fisheries and Oceans Canada); Masaya Katoh (Seikai National Fisheries Research Institute, Japan), Hisashi Yokoyama (National Research Institute of Aquaculture, Japan); Jin-Woo Choi, Jung-Hoon Kang, Kyoong-Soon Shin, Seungshic Yum (Korea Ocean Research and Development Institute, Korea); Sae-Heung Kim, Jong-Rak Lee and Eun-Young Yim (Jeju Biodiversity Research Institute, Korea); Eduard Titlyanov and Tamara Titlyanova (Institute of Marine Biology of RAS, Russia); Suchana Apple Chavanich (Chulalongkorn University, Thailand); John Chapman (Oregon State University, U.S.A.) and Judith Pederson (MIT Sea Grant Program, U.S.A.). Laboratory space, equipment, and reference material were graciously provided by the Jeju Biodiversity Research Institute (Jeju Hi-Tech Industry Development Institute, Seogwipo, Jeju, Korea).

During the summer of 2009, three collector plates were deployed at different locations within each of the following four ports: Busan, Masan, Jangmok, and Ulsan. These locations represented different levels of shipping and human-use activity that might suggest different patterns in non-indigenous species occurrence. The collector plates were subsequently processed in Jeju, the week prior to the

PICES Annual Meeting, by the assembled international team of participants. Further, since one of the goals of these surveys is to act as a conduit of knowledge, Korean RAS team members participated in hands-on field sampling in Jeju at Seogwipo Port and Sunrise Peak, Sungsan (UNESCO's World Nature Heritage Site). Seogwipo Port was typical of a multi-use commercial area, with sampling conducted in and around the port using a chartered fishing vessel. In addition, three baited traps were deployed at this location to sample more mobile fauna. The Sungsan location was selected to demonstrate sampling at an intertidal beach where a number of bivalve and algal species were found. Preliminary results of the 2009 RAS include 213 taxa from the following groups: crustaceans (58 taxa), algae (55 taxa), molluscs (54 taxa), polychaetes (37 taxa), ascidians (9 taxa), bryozoans (7 taxa), cnidarians and echinoderms (4 taxa each), porifera (3 taxa) and one taxon each of platyhelminth and fish. Most taxa were identified to the species level, although many are provisional identifications and will require further investigation. Also, some taxa could only be identified to higher taxonomic levels (genus, family or order). Currently, we are able to classify four species as non-indigenous: the bivalve mollusc *Mytilus galloprovincialis*, the cirriped *Balanus eburnus*, the amphipod *Podocerus cristata* and the polychaete *Hydroides norvegica*. A further 17 species were classified either as cryptogenic or status uncertain so it is possible that other non-indigenous species were encountered, but identifications and classifications are pending.

The 2008 RAS in Dalian, China, identified a total of 119 taxa, three of which (all bivalve molluscs) were classified as non-indigenous (PICES Press Vol. 17, No. 1, pp. 30–32). The larger species list in 2009 may be a reflection of the taxonomic expertise available for the Korean RAS or may be due to higher diversity at examined intertidal sites. Because several identifications remain provisional, both the total number of species and the number of non-indigenous species may increase for both the Chinese and Korean surveys.

As future surveys continue to gather distributional data for a number of taxa among PICES member countries, it will be possible to better understand the extent of non-indigenous marine species in coastal waters of the North Pacific Ocean.



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Graham Gillespie (Graham.Gillespie@dfo-mpo.gc.ca) is a Research Biologist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, BC. Graham is Head of the Intertidal Bivalve and Crab Programs, conducting stock assessments for commercially important species, providing scientific advice for the SARA-listed Olympia oyster and participating in ecosystem-level research involving these groups. He also coordinates an Aquatic Invasive Species project that examines distribution, dispersal and impacts of intertidal non-indigenous species on the Pacific Coast of Canada. He is a member of PICES WG 21 on Non-indigenous Aquatic Species and WG 24 on Environmental Interactions of Marine Aquaculture.

PICES 2010 Rapid Assessment Survey

by Graham Gillespie, John Chapman and Thomas Therriault

Status and trends of non-indigenous species (NIS) are of enormous interest in the North Pacific, but establishing extensive international cooperation required to investigate the problem has been difficult. In 2006, PICES Working Group 21 on *Non-indigenous Aquatic Species* was formed to increase understanding of marine non-indigenous species in the North Pacific. In 2007, two initiatives were started in a 5-year PICES project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" supported by a voluntary contribution from the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan. The first initiative, led by Dr. Henry Lee II (U.S. Environmental Protection Agency) was to develop a comprehensive database for non-indigenous species. The second was a taxonomy initiative that included rapid assessment and collector surveys in PICES member countries. Dr. Thomas Therriault (Fisheries and Oceans Canada) has served as the principal investigator of this initiative and organized rapid assessment surveys in 2008 in Dalian, China (see PICES Press 17(1): 30–32) and in 2009 in Jeju, Korea (see PICES Press 18(1): 38–40). The third rapid assessment survey was conducted in Oregon, U.S.A., just prior to the 2010 PICES Annual Meeting in Portland.

PICES Rapid Assessment Surveys (RAS) serve to collect initial baseline data and inter-calibrate species collection and identification methods that allow distinction of native, non-indigenous, and cryptogenic species. Standardized RAS data permit comparisons of invasions within and among countries and can reveal mechanisms and consequences of invasions. PICES RAS also support international cooperation that is critical for resolving NIS, their origins, mechanisms of dispersal, effects and impacts.

International ports are particularly important recipients of organisms associated with ballast water, ballast sediment or hull fouling, and often have high levels of secondary traffic (recreational or small craft, aquaculture transfers) to adjacent

Participants in the 2010 Oregon Rapid Assessment Survey of non-indigenous, cryptogenic and native species: Front row (left to right): Gayle Hansen, Gyo Itani, Thomas Therriault, Takeaki Hanyuda; middle row: Darlene Smith, Toshio Furota, in front of Katie Marko next to Leslie Harris, John Markham, Gretchen Lambert, Sylvia Yamada; back row: Vasily Radashevsky, Ralph Breitenstein, John Chapman, Graham Gillespie, Charles Lambert, Loren Curran. (Not shown: Donnelle Breitenstein, Jack Chapman, Ian Chun, Faith Cole, Caroline Emch-Wei, John Estabrook, Jeff Fischer, Brian Fodness, Bruce Hansen and Vallorie Hodges).

ports. International ports also tend to be more disturbed than other less urbanized estuaries and bays, possibly enhancing invasion success. New invasions, transoceanic transport mechanisms and vector pathways of dispersal are more readily identified and managed when they can be tracked among major ports. Before PICES-2010, intertidal and shallow subtidal habitats of two Oregon estuaries (Coos Bay and Yaquina Bay) were sampled using fouling plates (collectors), traps for macrofauna (primarily fish and crabs), scrapings of floats and pilings, and by diver collections. Additionally, a seawater reservoir tank at the Hatfield Marine Science Center in Yaquina Bay was drained and sampled for fouling organisms. These qualitative surveys measured species diversity within each location. Classification of species as native, non-native or cryptogenic occurred following species identification based on literature accounts and analyses by RAS team members.

The 2010 investigative team consisted of the authors of this article, Toshio Furota (Toho University, Japan), Gayle Hansen (Environmental Protection Agency, U.S.A.), Takeaki Hanyuda (Kobe University Research Center for Inland Seas, Japan), Leslie Harris (Natural History Museum of Los Angeles County, U.S.A.), Gyo Itani (Kochi University, Japan), Charles and Gretchen Lambert (University of Washington, Friday Harbor, U.S.A.), John Markham (Arch Cape Marine Laboratory, U.S.A.), Vasily Radashevsky (A.V. Zhirmunsky Institute of Marine Biology, Russia) and Sylvia Yamada (Oregon State University, Corvallis, U.S.A.). Volunteer divers and laboratory assistants included Donnelle and Ralph Breitenstein, Jack Chapman, Ian Chun, Faith Cole, Lorne Curran, Carolyn Emch-Wei, John Estabrook, Jeff Fischer, Brian Fodness, Bruce Hansen, Vallorie Hodges, Katie Marko, and Darlene Smith. Laboratory space, equipment, and reference material were graciously provided by the Hatfield Marine Science Center, Oregon State University, Newport, U.S.A. Additional funding and/or support was provided by Fisheries and Oceans Canada, Oregon Sea Grant, University of Guelph, U.S. Environmental Protection Agency, Ralph and Donnelle Breitenstein and Liu Xin (Oregon Oyster, Inc.).

On October 18, the team worked through samples provided to the Hatfield Science Center laboratory and was treated to a welcome reception at the Rogue Brewery in Newport. The reception featured microbrews and food provided by Oregon Oyster, Inc. Investigators and volunteers participated in a day-long field trip on October 19 that included collections from public and commercial boat docks in Charleston Harbor and the City of Coos Bay. Surface collections were supplemented with dive collections from low intertidal and subtidal zones and collection plates from Yaquina Bay. The team completed sample processing on October 20 and was then invited to a wrap-up social at the home of Henry Lee and Debbie Reusser.

Participants in the survey also contributed to presentations given at the WG 21 meeting and the Topic Session on "*Anthropogenic forcing in North Pacific coastal ecosystems: Understanding changes in ecosystem structure and function*" convened at PICES-2010. These talks and posters helped to facilitate cooperation and exchange between experts from PICES member countries. Topics included the WG 21 atlas of non-indigenous species in the North Pacific (Henry Lee II and Debbie Reusser); invasions, island biogeography and human welfare (John Chapman); propagule pressure in *Didemnum vexillum* (John Chapman *et al*.); *Didemnum* in New Zealand and other tunicate news (Gretchen and Charles Lambert); *Hediste* genetics (Toshio Furota and Hiroaki Toshuji); *Orthione griffensis* in Japan (Gyo Itani, Yukari Miyoshi and Hiroshi Kume); molecular elucidation of introduced seaweeds (Takeaki Hanyuda and Hiroshi Kawai); family Spionidae (Vasily Radashevsky); what makes better taxonomy (Leslie Harris); and green crab assessment in Yaquina Bay (Sylvia Yamada, Graham Gillespie and Katie Marko).

PICES RAS participants (left to right) Katie Marko, Graham Gillespie and Sylvia Yamada display non-indigenous European green crabs captured in Yaquina Bay.

Preliminary results of the Oregon RAS included 191 taxa from 400 sample lots. Nearly all taxa were identified to the species level, although many are provisional identifications and work is ongoing to resolve these. Twenty-five species of polychaete represent first records of these species in one or more of the sampled Oregon estuaries, and eight species of polychaete represent new records in Oregon. It is possible that other non-indigenous species were encountered but identifications and classifications are pending. In collaboration with the Barcode of Life Project, many incomplete identifications will be explored further using molecular methods.

A significant advantage of these surveys is the opportunity for taxonomists to examine material from different areas and exchange ideas directly with other taxonomists of the same taxa and with other invasion ecologists. The participation of ascidian taxonomists in our survey allowed the identification of the second Pacific record of the introduced North Atlantic sea grape *Molgula citrina*, which was also the first Pacific record south of Alaska. Another advantage is the comparison of collecting techniques and the development of standards. During this survey, Canadian and U.S. methods to trap European green crab *Carcinus maenas* were contrasted, allowing a unique opportunity to inter-calibrate methods used among PICES member countries. Other special projects examined the distribution of the invasive tunicate *Didemnum vexillum* in Coos and Yaquina Bays and the Umpqua triangle, genetic samples of the algae *Ulva* and the nereid worm *Hediste* to determine possible Asian or North American origins, and infection rates of bopyrid isopod parasites in the Eastern and Western North Pacific.

The 2008 rapid assessment survey in Dalian (China) identified a total of 119 taxa, three of which (all bivalve molluscs) were classified as non-indigenous. The 2009 survey in Jeju (Korea) identified 213 taxa with four (one bivalve mollusc, one cirriped, one amphipod and one polychaete) designated as non-indigenous. The Oregon survey yielded at least 14 species that were classified as non-indigenous: four algae, six ascidians, three polychaetes and one crustacean. Many identifications remain provisional; therefore, the total number of species and number of non-indigenous species may increase for all surveys.

Introductions reduce the wealth of every nation, and no country can deal with introductions alone. The PICES surveys provide critical information and a mechanism to foster the international cooperation needed for each nation to detect and manage its introduced species.



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John Chapman (John.Chapman@oregonstate.edu) is a marine biological invasions ecologist at the Hatfield Marine Science Center, in Newport, Oregon, U.S.A. In addition to the PICES surveys in 2009 and 2010, John's recent research has included the 1000 AD Viking species introductions across the North Atlantic, the systematics of shallow water gammaridean amphipod crustaceans of the northeast Pacific and the ecology of introduced and native bopyrid isopods on their burrowing shrimp hosts of the North Pacific. John also teaches lower and upper division Aquatic Biological Invasions through the departments of Biology and Fisheries and Wildlife at Oregon State University.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the Canadian Aquatic Invasive Species Network (CAISN). He is the Principal Investigator for the Taxonomy Initiative of PICES WG 21 on Non-indigenous Aquatic Species (under the project on "Development of the prevention systems for harmful organisms' expansion in the Pacific Rim" supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan) that includes rapid assessment surveys (RAS) for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and leads the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems (AICE). He is a member of the Marine Environmental Quality Committee (MEQ) and the P/ICES Study Group on Developing a Framework for Scientific Cooperation in the Northern Hemisphere.

PICES Workshop on "*An Introduction to Rapid Assessment Survey Methodologies for Application in Developing Countries*"

by Thomas Therriault

Since its inception in 2006, PICES Working Group 21 (http://www.pices.int/members/working_groups/wg21.aspx) has been advancing our understanding of marine non-indigenous species in the northern Pacific Ocean. Rapid Assessment Surveys (RAS) are one approach to quickly characterize the native, non-native, and cryptogenic species present in different locations. These qualitative surveys allow rapid depiction of the species composition within each location surveyed, not the abundance of any specific species. Quantitative surveys to estimate population sizes could be done subsequently, if needed, but are too time consuming for rapid assessments. Although specific methods vary slightly based on habitats being sampled or taxonomic groups being characterized, WG 21 has developed methodologies that have been used within PICES member countries to identify non-indigenous species in both inter-tidal and sub-tidal habitats. To date, RAS have been conducted in Dalian (China) in 2008, Jeju (Korea) in 2009, and most recently near Newport (Oregon, U.S.A.) in 2010 (*see related PICES Press article in this issue*). Data from each of these surveys have been archived in the PICES WG 21 database of marine and estuarine species. However, given the global nature of biological invasions, it is critical to engage researchers working on this important topic outside of PICES' six member countries, especially in locations adjacent to the PICES region where the potential transport of non-indigenous species is expected to be high. PICES WG 21 is working with other international organizations to share information on global invaders, but there remain fundamental gaps within developing countries. Thus, a demonstration workshop on "*An introduction to rapid assessment survey methodologies for application in developing countries*" was held to provide participants from developing countries with the tools to conduct their own surveys. In addition, the workshop provided a clear context to why this type of activity is essential both locally and globally, and how information on non-native species can be shared between developing and PICES member countries to benefit all. PICES co-sponsored this workshop with the Fisheries Research Agency (FRA) of Japan and Kobe University's Research Center for Inland Seas. The workshop was co-convened by Drs. Hiroshi Kawai (Kobe University, Japan), Hisashi Yokoyama (National Research Institute of Aquaculture, FRA) and Dr. Thomas Therriault (Fisheries and Oceans Canada), and focused on hands-on training of researchers from mostly developing Southeast Asian countries concerned about the potential introduction of non-indigenous marine species. From July 13–15, 2010, participants from Malaysia, Thailand, Singapore, Indonesia, Vietnam, the Philippines and Japan were invited to the Marine Station of Kobe University's Center for Inland Seas (Awaji Island, Hyogo Prefecture, Japan) to learn about PICES activities on non-indigenous marine species and to receive training in Rapid Assessment Survey techniques.

RAS workshop participants at the sampling site in the inner part of Osaka Bay, Japan: Front row (l-r): Dr. Tan Koh Siang (Singapore), Dr. Roike Montolalu (Indonesia), Dr. Hisashi Yokoyama (Japan), Takashi Nozawa (Japan) and Dr. Takeaki Hanyuda (Japan); middle row (l-r): Dr. Thomas Therriault (Canada), Dr. Teodora Bagarinao (Philippines) and Dr. Lim Phaik-Eem (Malaysia); back row (l-r): Dr. Akira Kurihara (Japan), Dr. Hiroshi Kawai (Japan), Dr. Takeo Kurihara (Japan), Dr. Paul Geraldina (Philippines), and Dr. Michio Otani (Japan); missing from the photograph: Dr. Suchana (Apple) Chavanich (Thailand).

RAS workshop participants getting ready to visit collection sites: Front row (l-r): Dr. Michio Otani (Japan), Dr. Lim Phaik-Eem (Malaysia), Dr. Tan Koh Siang (Singapore), Dr. Takeaki Hanyuda (Japan) and Dr. Takeo Kurihara (Japan); back row (l-r): Dr. Hisashi Yokoyama (Japan), Takashi Nozawa (Japan), Dr. Zhongmin Sun (China), Dr. Paul Geraldina (Philippines), Dr. Roike Montolalu (Indonesia), Dr. Thomas Therriault (Canada), Dr. Hiroshi Kawai (Japan), Dr. Teodora Bagarinao (Philippines); missing from the photograph: Dr. Suchana (Apple) Chavanich (Thailand) and Dr. Akira Kurihara (Japan).

RAS workshop participants at the Kobe University Marine Station sorting and identifying material collected from surveys on Awaji Island, Japan.

The workshop exposed participants to (1) a background about marine non-indigenous species and why vigilance is required, using a series of short lectures, (2) hands-on experience in making field collections in a variety of coastal environments, and (3) laboratory experience using keys and reference material to identify the organisms collected. Since the workshop focused on background and techniques, actual taxonomic experts were not utilized in this demonstration, but would play a critical role in actual RAS. Taxonomic experts have a broad knowledge of their taxonomic group amassed over time spent studying thousands of individuals from different geographical areas to resolve identifications – skills taxonomic generalists must develop to confidently resolve identifications (and potential invasion status). Further, given that taxonomy for some species will be controversial and that reference collections are important to document the occurrence of non-indigenous species, it is imperative that voucher specimens be maintained for future reference.

Workshop participants visited a number of sites around Osaka Bay where they were shown techniques to sample a variety of different habitats. On the first day, we visited a site on Awaji Island where participants made timed walk collections in two different inter-tidal habitats, one exposed directly to Osaka Bay with no development, and the other a small enclosed basin with shoreline development and small boat anchorages. These inter-tidal collections were supplemented with snorkelling collections made in the shallow sub-tidal environment directly adjacent to the shore, providing excellent specimens of crabs, bivalves, and tunicates. Loaded with bags of samples, participants returned to the Marine Station where they spent the afternoon identifying the treasures they had collected. On the second day, we focused on the application of collector plates to monitor for the introduction (and/or spread) of fouling organisms like algae, tunicates, and bryozoans that have received much attention in the invasion literature lately. Dr. Kawai and his colleagues have utilized these collectors to monitor changes in algae and invertebrate species in different parts of Osaka Bay over the past few years. Participants were able to observe first-hand differences in fouling communities between a study site in the inner part of Osaka Bay (highly developed) and another near the Marine Station on the outer part of the Bay (relatively pristine). Again, samples were collected and returned to the laboratory for further processing. As thunderstorms pounded the Marine Station on the third day, participants were introduced to the PICES WG 21 database on marine and estuarine species developed by Dr. Henry Lee II and Ms. Debbie Reusser. This hierarchical database, built on marine eco-regions of the world, can allow researchers from developing countries to archive their data in a systematic way that is then directly available both to them and to PICES member countries.

The positive feedback from workshop participants was overwhelming, with many participants eager to initiate aspects of RAS within their home countries. In fact, the feedback on this type of outreach and training activity was so encouraging that Drs. Therriault and Kawai are working with Dr. Apple Chavanich to host a larger demonstration workshop in 2011 in Bangkok, Thailand.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the Canadian Aquatic Invasive Species Network (CAISN). He is the Principal Investigator for the Taxonomy Initiative of PICES WG 21 on Non-indigenous Aquatic Species (under the project on "Development of the prevention systems for harmful organisms' expansion in the Pacific Rim" supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan) that includes rapid assessment surveys (RAS) for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and leads the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems (AICE). He is a member of the Marine Environmental Quality (MEQ) Committee and the P/ICES Study Group on Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science.

2011 PICES Rapid Assessment Survey

by Vasily Radashevsky, John Chapman, Leslie Harris and Thomas Therriault

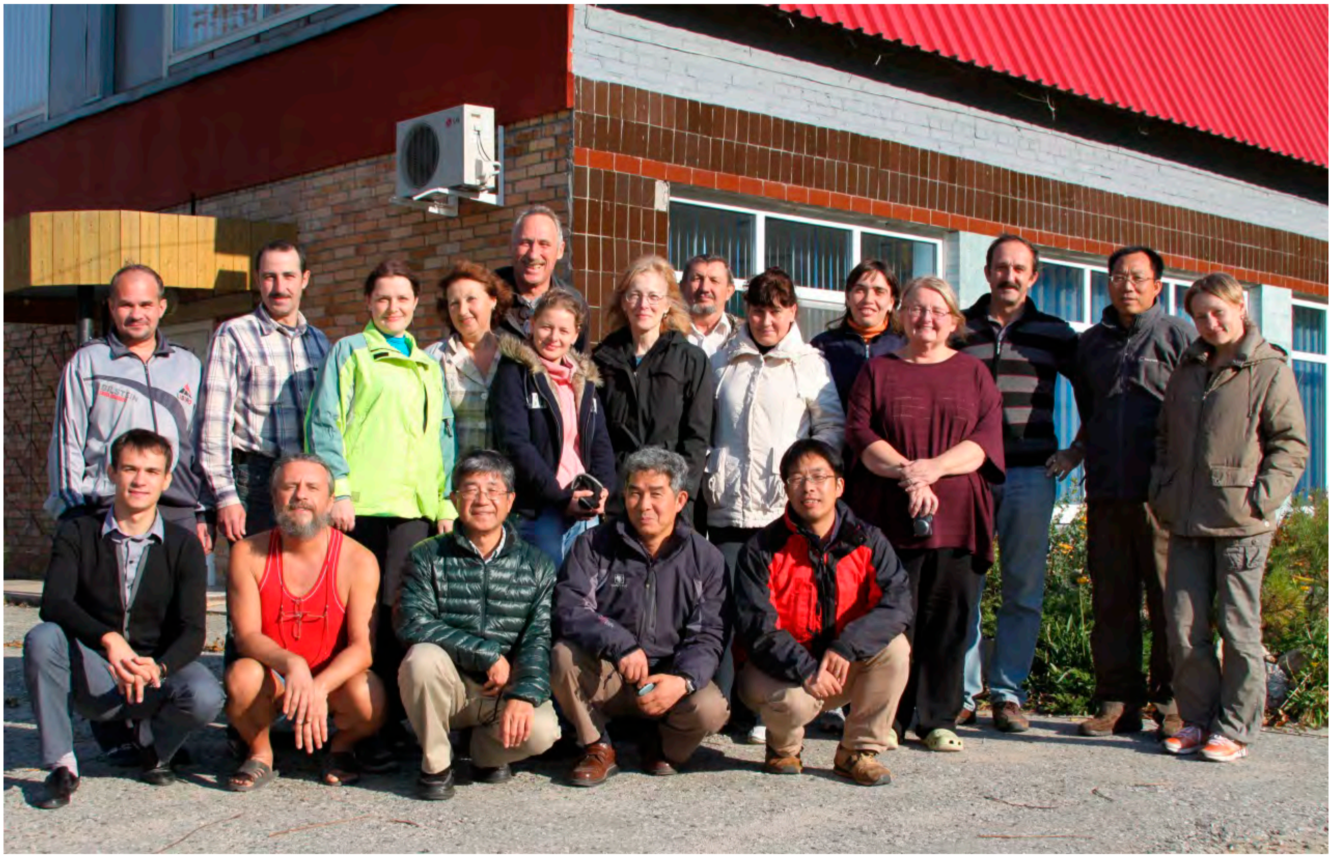
The central question to be answered by the PICES Working Group 21 (WG 21), since its formation in 2006, has been whether increasing invasions of non-indigenous species (NIS) threaten marine resources of North Pacific countries. In accordance with its mission to increase understanding of marine NIS in the PICES area, WG 21 began work in 2007 on the NIS component of a 5-year project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" supported by a voluntary contribution from the Ministry of Agriculture, Forestry and Fisheries of Japan, through the Fisheries Agency of Japan. This NIS component was further divided into two initiatives. Dr. Henry Lee II (U.S. Environmental Protection Agency; lee.henry@epa.gov) leads the first initiative, to develop a comprehensive database for non-indigenous North Pacific species. The second initiative, to conduct rapid assessment surveys (RAS) of PICES member countries, is being coordinated by Dr. Thomas Therriault (Fisheries and Oceans Canada; thomas.therriault@dfo-mpo.gc.ca). Both of these integrated initiatives have revealed: (1) significant and increasing threats to marine resources by NIS and (2) the critical importance of expanded international cooperation to resolve and manage them.

Responses to invasions are unlikely to be initiated or to be effective without understanding the problems they cause or collaborative efforts to manage them. Rapid assessment surveys are able to provide baseline data critical for measuring and limiting the rates and expansions of invasions among PICES member countries and are also indispensable for international calibration and standardization of both taxonomy and NIS detection. International ballast water traffic has been an especially important mechanism for transporting organisms into countries where high levels of secondary traffic (small craft and aquaculture) transfer these organisms to adjacent areas. The PICES surveys have been particularly useful for detecting and measuring invasions by all mechanisms.

The first PICES RAS was organized in Dalian, China, in 2008 (see PICES Press 17(1): 30–32). The second survey was conducted on Jeju Island, Korea, in 2009 (PICES Press 18(1): 38–40). The third one took place near Newport in central Oregon, U.S.A., in 2010 (PICES Press 19(1): 27–29). The 2011 survey described in this article was organized just prior to the 2011 PICES Annual Meeting in Khabarovsk, Russia.

The 2011 RAS was conducted in Peter the Great Bay, near Vladivostok and Nakhodka, the largest Far Eastern Region seaports of Russia. The survey was based at the *Vostok* Marine Biological Station of the A.V. Zhirmunsky Institute of Marine Biology (IMB) of the Far Eastern Branch of the Russian Academy of Sciences, which is located about 2 hours away in Vladivostok (see photo below). The *Vostok* Station, on the coast of Vostok Bay (an eastern extension of Peter the Great Bay), was established by the IMB in a comparatively clean area with diverse surrounding habitats to serve as an international base for marine studies. The biodiversity in the area has since become relatively well described due to continuous studies by scientists from all over the world.

Peter the Great Bay region, including Vladivostok, on the Muravyov-Amursky Peninsula and Vostok Bay to the east.



Participants in the 2011 PICES Rapid Assessment Survey of non-indigenous, cryptogenic and native species at the Vostok Marine Biological Station of the A.V. Zhirmunsky Institute of Marine Biology (taken by Leslie Harris). Front row (from left): Alexey Gorodkov, Alexander Rzhavsky, Hisashi Yokoyama, Jin-Woo Choi, Takeaki Hanyuda; back row: Evgeny Barabanshchikov, Ilia Korneichuk, Marina Nekrasova, Vera Radashevskaya, John Chapman, Oksana Belous, Gayle Hansen, Ivan Kashin Liudmila Budnikova, Natalia Demchenko Darlene Smith, Vasily Radashevsky, Xinzheng Li and Inna Alalykina (not in picture: Olga Golovan, Anastasia Mayorova and Leslie Harris).

As the previous year's RAS in Newport was particularly successful for polychaetes, small crustaceans, and marine algae, it was decided to focus on these groups again in 2011. A 7-member group, Leslie Harris (NHMLAC, U.S.A.), Vasily Radashevsky, Inna Alalykina and Marina Nekrasova (IMB), Alexander Rzhavsky (Severtsov Institute of Ecology and Evolution, RAS, Russia), Jin-Woo Choi (South Sea Research Institute, KORDI, Korea), and Hisashi Yokoyama (National Research Institute of Aquaculture, Japan), dealt with polychaetes. Another 7-member group, Liudmila Budnikova and, Evgeny Barabanshchikov and Ilia Korneichuk (TINRO-Center, Russia), John Chapman (Oregon State University, U.S.A.), Natalia Demchenko and Olga Golovan (IMB), and Xinzheng Li (Institute of Oceanology, CAS, China), surveyed crustaceans. Three participants, Oksana Belous (PIBOC, Russia), Gayle Hansen (Oregon State University, U.S.A.) and Takeaki Hanyuda (Kobe University Research Center for Inland Seas, Japan), worked with algae. Anastasia Mayorova (IMB) sampled for Sipunculida, and Evgeny Barabanshchikov did double duty, also surveying plankton. Alexey Gorodkov and Ivan Kashin (IMB) set the collector plates, and Darlene Smith (Fisheries and Oceans Canada) served as data manager. The entire survey was coordinated by Vasily Radashevsky.

The official survey took place from October 7–14. Several participants (Alalykina, Chapman, Demchenko, Hansen, Harris, Radashevsky and Rzhavsky) stayed on for another two weeks to maximize sampling efforts around the *Vostok* Station and to examine collections in Vladivostok. A seminar, with 10 reports on NIS research in the North Pacific, was organized at the station on October 13. Two additional lectures on introduced species issues were also delivered by Harris and Chapman at the Institute of Marine Biology in Vladivostok.

Most of the sampling was conducted in and around Vostok Bay in habitats that varied from small harbors to rocky points (see photo on next page) and mud flats. Collector plates (man-made attachment sites for species that prefer hard substrates) were deployed for about 5 months. Two sets of these plates were recovered from Vostok Bay harbors and one from the international harbor in Vladivostok.

The value of the PICES surveys depends on whether biological invasions affect marine ecosystems or human welfare, and whether managing or preventing these invasions can be cost effective. The surveys therefore focused on three relevant questions:

Participants of the PICES Rapid Assessment Survey on the rocky shore of Anna Bight, Anna Lighthouse Resort Point, near Vostok Bay, October 9, 2011.

(1) What are the patterns, magnitudes and processes of biological invasions?
(2) Can these invasions reduce food security, economic development or alter the ecological dynamics of natural ecosystems?
(3) Can biological invasions be managed or prevented?

All PICES member countries appear to be addressing *Question 3* but are hindered by the absence of quantitative measures or rigorous theory for measuring effects or designing and testing responses. International efforts depend on close collaborations such as those that the PICES surveys have produced. The accumulating discoveries of the PICES surveys have addressed *Questions 1* and *2* in particular, and thus *Question 3* as well. A sampling of PICES discoveries follows.

The most fundamental parameters of invasion ecology, the origins of species (native, ***N*** or introduced, ***I***) and their relative abundances (***R*** = ***I***/***N***) have proven elusive to measure in nearly all marine systems due to the large proportions of "cryptogenic species" (***C***), that cannot be confidently classified as ***I*** or ***N***. The unmeasured dependence of ***I*** and ***N*** on ***C*** has prevented confident measures of ***R***. Correlations between cryptogenic species with introductions but not with native species among sites and phyla were discovered in the PICES surveys. The majority of cryptogenic species are likely to be introduced and therefore, can be included among introduced species for estimates of ***R***. Preliminary analyses of other surveys around the world indicate a nearly universal association of cryptogenic species with introductions.

Another fundamental question has been whether the recently found invasions are due predominantly to rapidly increasing new mechanisms or to long-standing gradual increases only recently discovered. Comparisons of the dates of species descriptions with their dates of discovery in Peter the Great Bay revealed that most introduced species of the region were known more than 100 years before they were discovered in the bay. The majority of native macroscopic invertebrates, algae and plants recovered in recent surveys of Peter the Great Bay were also previously known. These discoveries of introduced species were therefore, not likely to have been overlooked among previously unreported species. More probable, these invasions are due to recent arrivals rather than to increases in research.

The PICES surveys permit analyses of climate effects on the rates and patterns of invasions. Nearly all of the introduced species discovered in Peter the Great Bay since 2009 were previously known from southern East Asian countries (Zvyagintsev *et al*. 2009, 2011). The restricted ranges and summer occurrences for most of these species are consistent with expanding southern populations or northern migration (Zvyagintsev *et al*. 2009, 2011). The recent invasions of Russia found in the PICES survey appear also to be northern shifts or expanding ranges of warm water species. The introduced and cryptogenic species found in the relatively pristine Vostok Bay area also indicate that they are not restricted to harbors and thus have broad distributions on the Russian coast, with significant potential to interact with valuable native populations.

Relative to whether marine invasions can threaten human welfare: none of the human-borne introduced species found in the October 2011 and earlier surveys (Zvyagintsev *et al*. 2009, 2011) are of economic value to Russia. Since all of these species have the potential to displace or replace economically valuable native species, the common introduced species to Russia thus appear more likely to be harmful than useful and also unlikely to make positive contributions to the native biota.

Population extinctions and displacement of native species coincident with introduced biological invasions are occurring in North America (Chapman *et al*., in press), as species equilibrium models have predicted. Although invasions of the Russian coasts seem to be less intense than in North America, their rapid increases appear likely to soon bring them to North American intensities. The PICES surveys provide critical information and a mechanism to foster the international cooperation needed for each member country to detect and manage introduced species. International collaborations through PICES are thus increasing the quality and resolution of taxonomic research on Asian coasts, increasing the resolution of invasion patterns and opening communications needed to permit relevant, cooperative responses to begin.

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Dr. Vasily Radashevsky (radashevsky@gmail.com; left photo) is a Research Scientist at the A.V. Zhirmunsky Institute of Marine Biology (IMB) of the Far Eastern Branch of the Russian Academy of Sciences in Vladivostok, Russia. Vasily studies the morphology, ecology, reproductive biology and phylogeny of marine worms of the family Spionidae (Annelida) which easily survive in ballast waters and are transported worldwide. He co-chairs PICES Working Group 21 on Non-indigenous Aquatic Species.

Dr. John Chapman (John.Chapman@oregonstate.edu; center photo, with Natalia Demchenko [amphipod taxonomist and ecologist at IMB]) is the Head of the Marine Biological Invasions Laboratory at the Hatfield Marine Science Center, in Newport, Oregon, U.S.A. In addition to the PICES rapid assessment surveys in 2009, 2010 and 2011, his research includes shallow water amphipod crustacean systematics and the parasite-host ecology of introduced and native bopyrid isopods and their host shrimps. John also teaches lower and upper division Aquatic Biological Invasions through the Departments of Biology and Fisheries and Wildlife at Oregon State University.

Leslie Harris (exogone@hotmail.com; left in right photo, reviewing North Pacific polychaete taxonomy with Inna Alalykina [polychaete taxonomist and ecologist at IMB]) is the Polychaete Collection Manager at the Natural History Museum of Los Angeles County, U.S.A. She has over 30 years of experience in identifying polychaetes from the Arctic to the Antarctic and points in between, with particular emphasis on the North Pacific fauna. A veteran of non-indigenous species surveys since 1998, Leslie was also a participant in the 2010 PICES rapid assessment survey. Her research focuses on taxonomic issues, distribution patterns, and resolution of introduction status of marine organisms, in general, and polychaete worms, in particular.

Dr. Thomas Therriault (Tom's photo can be seen in the next article; Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the second Canadian Aquatic Invasive Species Network (CAISN II). He is the Principal Investigator for the Taxonomy Initiative of PICES Working Group 21 on Non-indigenous Aquatic Species (under the project on "Development of the prevention systems for harmful organisms' expansion in the Pacific Rim" supported by the Ministry of Agriculture, Forestry and Fisheries of Japan) that includes rapid assessment surveys for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and Chairman of the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems. He is a member of the Marine Environmental Quality Committee and the PICES/ICES Study Group on Developing a Framework for Scientific Cooperation in the Northern Hemisphere Marine Science.

Introduction to Rapid Assessment Survey Methodologies for Detecting Non-indigenous Marine Species

by Thomas Therriault

Thanks to a contribution from the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), funding for a PICES project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" has allowed Working Group 21 (http://www.pices.int/members/working_groups/wg21.aspx) to advance its understanding of non-indigenous marine species in the North Pacific. As highlighted in previous PICES Press articles, WG 21 has employed Rapid Assessment Surveys (RAS) to quickly characterize the native, non-native, and cryptogenic species present in coastal areas of different PICES member countries. To date, RAS have been conducted in 2008 in Dalian (People's Republic of China), in 2009 in Jeju (Republic of Korea), in 2010 in Newport (U.S.A.), and most recently near Vladivostok, Russia, in 2011 (*see related PICES Press article in this issue*). In addition, this funding has allowed for capacity building in non-PICES member countries. In July 2010, a pilot workshop was held at the Marine Station of Kobe University's Center for Inland Seas (Awaji Island, Japan) to provide participants from developing countries with the tools to conduct RAS in their own waters (PICES Press, 2011, Vol. 19, No. 1, pp. 30–31).

The positive feedback from workshop participants was so overwhelming that Drs. Thomas Therriault (Pacific Biological Station, Fisheries and Oceans Canada) and Hiroshi Kawai (Kobe University, Japan) started planning for a larger RAS demonstration workshop for 2011. Given the global nature of biological invasions, it was critical to engage researchers working on this important topic outside the six PICES member countries, especially those locations adjacent to the PICES region where the potential transport of non-indigenous species is expected to be high. The Intergovernmental Oceanographic Commission's Sub-Commission for the Western Pacific (WESTPAC) has been assisting their member countries in studying marine non-indigenous species since 2009, with a focus in Southeast Asia, and the shared interests of the two organizations represented an excellent opportunity to collaborate on marine non-indigenous species issues. Dr. Apple Chavanich offered to host the joint workshop in Thailand, given its logistical benefits.

Although specific methods vary slightly, based on habitats being sampled or taxonomic groups being characterized, WG 21 has developed methodologies that have been used within PICES member countries to identify non-indigenous species in both intertidal and subtidal habitats. In addition, data from each of these surveys have been archived in the WG 21 database, thereby making it more broadly available. Thus, the objectives of the demonstration workshop on "*Rapid Assessment Survey methodologies for detecting non-indigenous marine species*" were to:

(1) provide hands-on training to researchers from developing Southeast Asian countries concerned about the potential introduction of non-indigenous marine species;
(2) introduce the PICES WG 21 database on non-indigenous marine species; and
(3) foster collaboration between PICES and WESTPAC.

Workshop participants explore the intertidal zone near the Phuket Marine Biological Center.

Workshop participants engaged in sample processing and species identifications.

The workshop was held July 19–21, 2011, at the Marine Biological Center, Phuket, Thailand, with more than 25 participants from the People's Republic of China, Hong Kong, Indonesia, Malaysia, the Philippines, Republic of Korea, Singapore, Thailand, and Vietnam. The workshop was supported by PICES, WESTPAC and the Phuket Marine Biological Center, and co-convened by Drs. Apple Chavanich (WESTPAC), Hiroshi Kawai (PICES), and Thomas Therriault (PICES).

The workshop kicked off on Day 1 with a warm welcome from the Director of the Phuket Marine Biological Center, Mr. Wannakiat Thubthimsang. Following an introduction from the co-convenors and with participants providing a bit of background about themselves, information about PICES and WESTPAC initiatives on non-indigenous marine species were discussed. However, with the Marine Biological Center positioned right on the Andaman Sea, it did not take long to get to the hands-on part of the workshop, and participants visited a number of intertidal sites around the Center and the dock where a Thai research vessel was tied up. Thus, participants were exposed to techniques for sampling a variety of different habitats and organisms. Dr. Kawai supplemented algal collections by snorkelling in the warm (but murky) nearshore waters. Loaded down with bags full of live samples, participants returned to the Marine Biological Center where they spent time identifying the various organisms they had collected. On the second day the workshop shifted towards data collection and data sharing. Dr. Therriault introduced the PICES WG 21 database on non-indigenous marine species developed by Drs. Henry Lee and Debbie Reusser. This hierarchical database, based on marine eco-regions of the world, will allow participants from developing countries to archive their data in a systematic way that is then directly available both to them and to scientists from PICES member countries. The afternoon saw a bit of free time emerge, and most participants visited the nearby Phuket Aquarium before regrouping for a wonderful all-you-can-eat seafood buffet. The last day included a special lecture on how genetic techniques can be used to resolve invasion patterns in marine systems, and workshop attendees each provided an overview of the types of research they are conducting with respect to non-indigenous species.

Overall, this workshop exposed participants to a background about marine non-indigenous species and why vigilance is required, using a series of short lectures, hands-on experience in making field collections in a variety of coastal environments, and laboratory experience using keys and reference material to identify organisms collected. Since this workshop focused on background and techniques, actual taxonomic experts were not utilized in this demonstration but would play a critical role in actual RAS. Taxonomic experts have a broad knowledge of their taxonomic group amassed over time spent studying thousands of individuals from different geographical areas to resolve identifications – skills taxonomic generalists must develop to confidently resolve identifications (and potential invasion status). Further, given that taxonomy for some species will be controversial and that reference collections are important to document the occurrence of non-indigenous species, it is imperative that voucher specimens be maintained for future reference.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the second Canadian Aquatic Invasive Species Network (CAISN II). He is the Principal Investigator for the Taxonomy Initiative of PICES Working Group 21 on Non-indigenous Aquatic Species that includes rapid assessment surveys (RAS) for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and Chairman of the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems. He is a member of the Marine Environmental Quality Committee and the PICES/ICES Study Group on Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science.

The 7th International Conference on Marine Bioinvasions

by Lisa Drake and Thomas Therriault

From August 23–25, 2011, the 7th International Conference on Marine Bioinvasions—the first held in Europe—was convened in Barcelona, Spain. Approximately 150 scientists, policy makers, and regulators from 20 countries in North America, Europe, Africa, Asia, and Australia and New Zealand arrived in Barcelona to exchange ideas and discuss the latest findings and progress in the global effort to understand and reduce the delivery, establishment, and spread of marine invasive species.

The Scientific Steering Committee (SSC) for the conference was composed of researchers from the international community: Jeb Byers (University of Georgia, U.S.A.), Jeff Crooks (Tijuana River NERR, U.S.A.), Lisa Drake (SSC Co-Chair; Naval Research Laboratory, U.S.A.), Graeme Inglis (National Institute of Water and Atmospheric Research, New Zealand), Anders Jelmert (Institute of Marine Research, Norway), Emma Johnston (University of New South Wales, Australia), Whitman Miller (Smithsonian Institution, U.S.A.), Henn Ojaveer (Estonian Marine Institute, Estonia), Gil Rilov (National Institute of Oceanography, Israel Oceanographic and Limnological Research, Israel), Gemma Quílez-Badia (SSC Co-Chair and local host; World Wildlife Fund, Spain), Thomas Therriault (Fisheries and Oceans Canada), and Chela Zabin (Smithsonian Institution and University of California-Davis, U.S.A.). Also, two technical advisors provided helpful input in preparing the conference: Jim Carlton (Williams College, U.S.A.) and Judith Pederson (MIT Sea Grant College Program, U.S.A.).

The SSC benefited greatly from the work of the Local Organizing Committee, which was very capably led by Gemma Quílez-Badia and included: Ernesto Azzurro and Pep Gasol (Marine Science Institute of Barcelona, Spanish Council for Scientific Research), Xavier Turon (Centre for Advanced Studies of Blanes, Spanish Council for Scientific Research), and Luis Valdés (Intergovernmental Oceanographic Commission of UNESCO, Paris).

In addition to the efforts by the SSC and its advisors, the Local Organizing Committee, and three student interns, the conference received generous support from the North Pacific Marine Science Organization (PICES), the National Oceanic and Atmospheric Administration (NOAA), CosmoCaixa (Barcelona) and "La Caixa" (Barcelona). Fittingly, the conference was held at the sleek and modern CosmoCaixa, a state-of-the art science museum.

The three invited plenary speakers began each day with timely and novel approaches to issues of invasive species research. Bella Galil (National Institute of Oceanography, Israel Oceanographic and Limnological Research, Israel) opened the conference by discussing the history of invasions to the Mediterranean Sea as well as gaps in our knowledge in this region. Fabio Bulleri (Dipartimento di Scienze Botaniche Ecologiche e Geologiche, Università di Sassari, Italy) gave a thought-provoking talk suggesting that invasive species researchers should consider potential positive species interactions that can occur due to some invasions and how these relationships might be included in invasion models. Lastly, Graeme Inglis (National Institute of Water and Atmospheric Research, New Zealand) provided insight into the dynamics of transporting species by shipping and the role of initial population size in successful colonization. All plenary presentations were well received and became a starting point for continued discussion during coffee breaks, meals and especially over drinks.

The Marine Bioinvasions Conference series continues to grow in popularity. This year's conference theme was "*Advances and gaps in understanding marine bioinvasions*" and, due to the many submissions for oral presentations (almost all of which were accommodated), the days were long with talks organized in two concurrent sessions. Oral presentations were 15 minutes followed by five minutes for questions, which delegates felt was a good format, as it allowed conference participants to actively interact with speakers during the sessions. In addition to general sessions, several special topic sessions were organized including: region-specific invasion research (this year, the Mediterranean Sea), application of new genetic tools for reconstructing invasion histories, ship biofouling as an understudied invasion vector, factors promoting the establishment and spread of invasive species, and management and eradication efforts. In addition, a poster session that included approximately 40 posters was held at the museum on the first evening, and allowed presenters and attendees to mingle and learn about the latest findings in a relaxed atmosphere that included food and drinks (always a good motivator for discussions).

An important part of conferences is the opportunity to informally discuss presentations, meet new colleagues, and forge new collaborations. The breakfasts, coffee breaks, and lunches (held on site and consisting of traditional Spanish foods), allowed these happy interactions to proceed. On the second evening of the conference, a reception was held on the museum grounds as the sun was setting. Conference delegates were free to explore the museum during the day and were able to sightsee or go clubbing around the fabulous city of Barcelona at night.

The input and participation of early-career scientists historically has been an important aspect of the Marine

Recipients of PICES travel grants for the 7th International Conference on Marine Bioinvasions, left to right: Amy Fowler (U.S.A.), April Blakeslee (U.S.A.), Joao Canning Clode (U.S.A.), Paul Edwards (Canada), Sam Collin (Canada), Catherine Clarke Murray (Canada), Gail Ashton (U.S.A.) and Francis Choi (Canada). Missing from photo: Michael MacGillvary and Anais Lacousière-Roussel (Canada); Max Castorani and Annick Drouin (U.S.A.).

Bioinvasions Conferences. Indeed, this conference was no different. Thanks to contributions from the sponsoring organizations, it was possible to provide travel support to 22 graduate students and postdoctoral fellows who applied. PICES supported the travel of eight graduate students (Max Castorani, Francis Choi, Catherine Clarke Murray, Samuel Collin, Annick Drouin, Paul Edwards, Anais Lacousière-Roussel and Michael MacGillivary) and four postdoctoral fellows (Gail Ashton, April Blakeslee, Joao Canning Clode and Amy Fowler).

In summary, the plenary talks, along with all of the presentations—approximately 140 papers and posters—engendered lively discussions during the sessions, the breaks, and the social events. The topics of the presentations were impressive: new ideas and approaches to invasion biology, clever field studies to address emerging hypotheses, and research results used to inform international policy. This clearly illustrates how the field of invasion biology has advanced since the first conference in 1999, owing largely to the researchers and policy makers who attend these conferences!

In Barcelona, the SSC members developed a strategic plan for future conferences. Our goals are to increase the geographic breadth of these meetings (since all but two of seven conferences have been held in the United States) and to encourage participation by researchers and decision makers from areas typically underrepresented at this forum: Asia, Central America, South America and Africa. To that end, we devised the following schedule of conference locations: 2013 – Canada, 2015 – Australia, and 2017 – South America. We are excited about the upcoming conferences and are confident they will strengthen existing collaborations and promote new ones. In fact, planning has begun for the 8th International Conference on Marine Bioinvasions, tentatively scheduled for the summer of 2013 in Vancouver, Canada, so feel free to contact any of the SSC members, especially your PICES representatives, and keep an eye out for further details in future issues of PICES Press.

Dr. Lisa Drake is a Physical Scientist at the U.S. Naval Research Laboratory in Key West, Florida. She is a biological oceanographer and leads a team of biological and physical scientists, engineers, and a statistician who develop procedures and methods used in testing ballast water management systems. Specifically, the biology group is developing robust, automated analyses to determine protist and zooplankton viability.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the second Canadian Aquatic Invasive Species Network (CAISN II). He is the Principal Investigator for the Taxonomy Initiative of PICES Working Group 21 on Non-indigenous Aquatic Species that includes rapid assessment surveys (RAS) for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and Chairman of the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems. He is a member of the Marine Environmental Quality Committee and the PICES/ICES Study Group on Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science.

The 8th International Conference on Marine Bioinvasions

by Thomas Therriault and Lisa Drake

From August 20–22, 2013, the 8th International Conference on Marine Bioinvasions—the first held in Canada—was convened in Vancouver, British Columbia. Approximately 125 researchers, policy makers, and managers from 13 countries in North America, South America, Europe, Australia/New Zealand, and Asia arrived in Vancouver to exchange ideas and discuss the latest findings and progress in the global effort to understand and reduce the delivery, establishment, and spread of marine invasive species. This conference's theme, "*Biological Invasions in Changing Waters: Envelopes, Estuaries, and Evolution*", solicited papers on a variety of topics, including the role of some invasive species as ecosystem engineers, the intersection between invasive species and climate change, and the increasing use of molecular tools in invasive species studies. In addition, a poster session was held on the first evening that allowed presenters and attendees to mingle and learn about the latest findings in a relaxed atmosphere that included pizza and drinks (always helpful for breaking the ice!). A social gathering on the second night allowed continued discussion over snacks and drinks at the beautiful University of British Columbia gardens. An important part of this conference is the opportunity to informally discuss presentations, meet new colleagues, and forge new contacts. To this end, coffee breaks and meals hosted on site allowed these happy interactions to take place in a relaxed and inviting setting. On the last day conference delegates were free to explore the famed Beaty Biodiversity Museum on campus and each evening participants were able to sightsee or tour around Vancouver.

The conference co-chairs (and co-authors of this article), Thomas Therriault (Fisheries and Oceans Canada) and Lisa Drake (Naval Research Laboratory, USA), were supported by a diverse, international Scientific Steering Committee (SSC) and an extremely productive Local Organizing Committee (LOC) headed by Cathryn Clarke Murray (World Wildlife Fund/University of British Columbia). In addition to the efforts by the SSC and its advisors, the LOC, and three student interns, the conference received generous financial support from the North Pacific Marine Science Organization (PICES), the Second Canadian Aquatic Invasive Species Network (CAISN II), the National Oceanic and Atmospheric Administration (NOAA), the World Wildlife Fund (WWF), and the University of British Columbia (UBC). The conference was held at the main campus of UBC in Vancouver which allowed easy access to the botanical gardens and the Beaty Biodiversity Museum.

Dr. Thomas Therriault with the PICES-supported early career scientists at the 8th International Conference on Marine Bioinvasion.

The three invited plenary speakers began each day with timely and novel approaches to issues of invasive species research. Emma Johnston (University of New South Wales, Sydney, Australia) opened the conference by discussing how marine ecosystems are under pressure from a wide variety of stressors, including invasive species, and that research needs to consider how invasive species interact with these other stressors, particularly the cumulative effects which are much less predictable. James Carlton (Williams College – Mystic Seaport, USA) provided a moving and thought-provoking plenary about the potential introduction of invasive species associated with Japanese tsunami debris from the catastrophic magnitude 9.0 earthquake that hit off the coast of Japan in March 2011. Lastly, Thomas Therriault (Fisheries and Oceans Canada, Nanaimo) provided an overview of CAISN II and highlighted advancements on better understanding European green crab invasion dynamics in British Columbia. All presentations were well received and provided a starting point for continued discussion during coffee breaks, meals and especially over drinks. Plenary talks were followed by two concurrent sessions on each day and included topic sessions on: management of invaders, factors affecting invasion success, invasion vectors, invasion niche, invasion impacts, applying molecular tools, fish invasions, tunicate invasions, and crab invasions.

The input and participation of early career scientists historically has been an important aspect of the Marine Bioinvasions Conferences, both due to the contributions of early career scientists and the benefits to their professional development by participating in such events. Indeed, this conference was no different. Thanks to funding from PICES, it was possible to provide travel support to 14 of the 34 graduate students and postdoctoral fellows who applied. PICES offered travel support to two undergraduate students (Stephanie Hall and Katherine Rolheiser), eight graduate students (Johanna Bradie, Farra Chan, Elizabeth Sheets, Darragh Clancy, Brian Turner, Max Castorani, Carolyn Tepolt, and Brian Cheng), and four postdoctoral fellows (Emily Brown, Amy Fowler, Christine McLaughlin, and Amanda Kelley). Many of these award recipients were captured in a group photo.

In summary, the plenary talks, along with all of the presentations—approximately 110 papers and posters—engendered lively discussions during the sessions, the breaks, and the social events. The topics of the presentations were impressive: new ideas and approaches to invasion biology, clever field studies to address emerging hypotheses, and research results used to inform national and international policy. This clearly illustrates how the field of invasion biology has advanced since the first conference in 1999, owing largely to the researchers and policy makers who attend these conferences!

Planning has begun for the 9th International Marine Bioinvasions Conference tentatively scheduled for January 2016 in Sydney, Australia, and the 10th International Marine Bioinvasions Conference tentatively scheduled for 2018 in Argentina, so keep an eye out for further details in future issues of PICES Press.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the second Canadian Aquatic Invasive Species Network (CAISN II). He was the Principal Investigator for the Taxonomy Initiative of PICES Working Group 21 on Non-indigenous Aquatic Species that includes rapid assessment surveys for non-indigenous species. Within PICES, Tom now serves as Chairman of Science Board (see p. 43 for more details).

Dr. Lisa Drake is a Physical Scientist at the U.S. Naval Research Laboratory in Key West, Florida. She is a biological oceanographer and leads a team of biological and physical scientists, engineers, and a statistician who develop procedures and methods used in testing ballast water management systems. Specifically, the biology group is developing robust, automated analyses to determine protist and zooplankton viability.

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PICES PUBLICATIONS

The North Pacific Marine Science Organization (PICES) was established by an international convention in 1992 to promote international cooperative research efforts to solve key scientific problems in the North Pacific Ocean.

PICES regularly publishes various types of general, scientific, and technical information in the following publications:

PICES ANNUAL REPORTS – are major products of PICES Annual Meetings which document the administrative and scientific activities of the Organization, and its formal decisions, by calendar year.

PICES SCIENTIFIC REPORTS – include proceedings of PICES workshops, final reports of PICES expert groups, data reports and planning reports.

PICES TECHNICAL REPORTS – are on-line reports published on data/monitoring activities that require frequent updates.

SPECIAL PUBLICATIONS – are products that are destined for general or specific audiences.

JOURNAL SPECIAL ISSUES – are peer-reviewed publications resulting from symposia and Annual Meeting scientific sessions and workshops that are published in conjunction with commercial scientific journals.

BOOKS – are peer-reviewed, journal-quality publications of broad interest.

PICES PRESS – is a semi-annual newsletter providing timely updates on the state of the ocean/climate in the North Pacific, with highlights of current research and associated activities of PICES.

ABSTRACT BOOKS – are prepared for PICES Annual Meetings and symposia (co-)organized by PICES.

For further information on our publications, visit PICES at www.pices.int.

Front cover figure

Didemnum vexillum (a colonial tunicate invader) smothering Pacific oyster (*Crassostrea gigas*) cultivated in British Columbia and an example of the hierarchical biogeographical classification system used for WG 21's database and *Atlas* (Lee II, H. and Reusser, D.A., 2012) that allows a quick visualization of global invasion status. The example shows the spread of the tunicate *Molgula manhattensis*, native to the Northeast Atlantic, to the eastern and western sides of the North Pacific.