ICMBIX 2016
Sydney, Australia

ABSTRACT BOOK

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ICMBIX2016
Sydney, Australia

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9th International Conference on Marine BioInvasions

ICMB2016

19th-21st January 2015

Welcome!

Dear Conference Participant On behalf of the Scientific Steering Committee (SSC) and our sponsorswe would like to welcome you to Sydney for the 9th International Conference on Marine Bioinvasions (ICMB-IX). Sydney is one of the world's iconic harbour cities with picturesque beaches and national parks to explore and well known attractions including the Sydney Harbour Bridge and Opera House to visit. There is great diving at North Head and snorkelling in many parts of the outer harbour. We hope you will take some time to explore all that the city and its surroundings have to offer. We are grateful for the terrific efforts of our local organizing committee as well as for the generous support of:

- Cawthon Institute
- Centre of Excellence for Biosecurity Risk Analysis (CEBRA)
- NSW Department of Primary Industries
- New Zealand Ministry for Primary Industries
- North Pacific Marine Science Organization (PICES)
- National Institute of Water & Atmospheric Research Ltd (NIWA)

and the local hosts:

- University of New South Wales
- Sydney Institute of Marine Sciences (SIMS)

Above all else we are grateful for your participation and willingness to discuss your ideas latest research results and vision. Among the papers, posters, and plenary presentations that comprise the conference we hope you will find many opportunities for discussion and new collaborations. Finally we hope this summation of the state of the field will provide solutions to the problems of marine invasive species as well as generate new research directions.

Once again welcome to the 9th International Conference on Marine Bioinvasions and we look forward to a fun and thought-provoking event!

Conference Co-Chairs; Prof Emma Johnston UNSW and Dr Graeme Inglis NIWA

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Abstracts

Corridors for aliens but not for natives: Challenges and opportunities of an ecologically based design of marine infrastructure

Airoldi, Laura[1];

[1]University of Bologna

Urban sprawl has dramatically expanded across marine seascapes. Throughout history, marine infrastructures have expanded, shorelines have been developed and intertidal and shallow subtidal areas have been reclaimed and armored to meet the growing societal needs of burgeoning coastal populations, and respond to greater threats from climate change, storm surges and sea level rise. These habitat modifications have altered the local to regional distribution of a number of species, including numerous aliens, which can thrive on these anthropogenic surfaces. Recent work has shown that artificial habitats can act as regional corridors for non-indigenous species, while not representing adequate substrata for many native species. I will discuss the structural and environmental factors promoting the colonisation of marine infrastructures by non-indigenous species, the seascape connections between artificial and natural habitats, and the potential of ecological engineering to mitigate some of these impacts. I will show that adequate substrates, transplantation techniques and sound management can be combined to design better constructions that favour the preferential use by native species over non-indigenous ones. I will also discuss the need to incorporate marine habitat enhancement in modern planning, policy and design of cities and waterfronts, where people would directly benefit from the ecological services provided by healthy marine ecosystems, and will introduce a conceptual framework for designing marine developments that provide multifunctional outcomes for the society.

Presenting author is Laura Airoldi laura.airoldi@unibo.it

Good partnerships bring centuries - working with stakeholders to protect Western Australia from marine pests

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For me, it's important to build good partnerships rather than score centuries. Once, you have those partnerships, you will also get centuries. (M. S. Dhoni, cricket legend.) Focusing on developing strong stakeholder partnerships is enabling the Department of Fisheries to score centuries in the form of improved biosecurity outcomes for WA. WAs pristine marine environment is an integral part of WAs lifestyle, and fisheries, aquaculture and marine tourism are worth well over AU$1 billion annually to the WA economy. Half the nations shipping volume comes through WA ports, and vessels are the primary vector for moving marine pests into the WA marine environment. The Departments management approach is to focus resources where they will have the most impact; on prevention, and early detection of pests to provide the best chance of eradication. To do this effectively the Department works in partnership with its stakeholders. An example of where this approach has paid off was the 2012 detection of three Asian paddle crabs (Charybdis japonica) by recreational crabbers in the Swan River, after extensive awareness raising efforts by the Department and searching by many river users. People do care about these issues, they genuinely want to be involved, they can bring local knowledge and provide a huge capacity boost to biosecurity surveillance. This approach is also used when the Department holds annual workshops where resource company representatives and experts discuss the management of marine pests moved by vessels. They have helped identify the need for, and requirements of, a standard biofouling risk assessment tool, Vessel Check, which is now the WA standard. The Department aims to continue scoring centuries through the fostering of strong partnerships with both industry and the community, in order to protect our aquatic biodiversity and associated resources, now and into the future.

Presenting author is Victoria Aitken victoria.aitken@fish.wa.gov.au

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Early phase of the invasion of Balanus glandula along the coast of Eastern Hokkaido: changes in abundance, distribution, and recruitment

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To understand the patterns and processes associated with the population dynamics of Balanus glandula during the early phase of invasion along the Pacific coast of eastern Hokkaido, population surveys were conducted from 2002 to 2011 at five shores, each consisting of five paired plots (scraped recruitment plot and unscraped establishment plot), along 49 km of coastline located 144 km east of the eastern front of the invasion of this species in 2000. Larval recruitment was first detected in 2004, but the establishment of a population was not observed until 2 years later at the westernmost shore of the study area. Occurrence increased from non-native barnacle present in 4 % of plots in 2006 to 100 % in 2011, but mean coverage remained low (<5 %) in 2011. Most local population coverage fluctuated without indicating clear temporal trends, but coverage in one plot showed a consistent pattern of rapid increase. Local extinctions occurred, but rates of local extinction decreased with time as larval recruitment increased. Lag times between recruitment and establishment occurred for 64 % of the paired plots and ranged from 1 to 4 years. Lag times decreased after 5 years, when larval recruitment increased. These findings suggest that the intensity of larval recruitment determined invasion dynamics during this early phase of the invasion, and the monitoring of recruitment is therefore essential for early detection of invasions by sessile marine organisms and prediction of their range expansion.

Presenting author is A.K.M. Rashidul Alam akmrashidulalam@yahoo.com

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An experimental evaluation of the direct and indirect effects of endemic seaweeds, barnacles, and invertebrate predators on the abundance of the introduced rocky intertidal barnacle Balanus glandula

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The barnacle, Balanus glandula has recently invaded along the Pacific coast of eastern Hokkaido, Japan. To evaluate the direct and indirect effects of endemic seaweeds, barnacles, and invertebrate predators on the abundance of B. glandula on the rocky intertidal coast of eastern Hokkaido, we conducted a field experiment from June 2011 to October 2012 in which we manipulated the presence or absence of these factors. Seaweeds showed no significant effect on the abundance of B. glandula. The endemic barnacle Chthamalus dalli and the invertebrate predator Nucella lima reduced the abundance of B. glandula. However, the simultaneous effect of C. dalli and N. lima was compensative rather than additive, presumably due to keystone predation. These findings suggest that competition by the endemic barnacle C.

dalli and predation by the invertebrate predator N. lima decreased the abundance of B. glandula, but that N. lima predation on C. dalli weakened the negative influence of C. dalli on B. glandula. The implications of these findings are twofold: the endemic competitor and invertebrate predator may have played important roles in decreasing the abundance of B. glandula in natural habitats, and conservation of endemic invertebrate predators may be crucial to impede the establishment and survival of introduced barnacles in rocky intertidal habitats.

Presenting author is A.K.M. Rashidul Alam akmrashidulalam@yahoo.com

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Use of Sodium Hypochlorite as a control method for non-indigenous corals: The case of Tubastraea coccinea Lesson, 1829

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The scleractinian coral Tubastraea coccinea is native from the Pacific Ocean and it is the first documented hard coral to have invaded the Western Atlantic. In the Brazilian Coast this species was registered in late 80s in artificial substrates, but nowadays T. coccinea is also observed in natural environment. Previous studies reported that T. coccinea can alter the structure of the native community and cause social and economic impacts. However, relatively few information is available about methods and control strategies focusing on this coral as target species. This study aims to evaluate the effectiveness of Sodium Hypoclorite (NaClO) on T. coccinea colonies mortality and to set the lowest concentration required to kill this species. The experiments were carried out in controlled laboratory conditions. Colonies (N = 15/ treatment) were exposed to NaClO solution (2,5 % active chlorine) at concentrations of 2, 20, 50, 100, 150 and 200 ppm. The control condition was kept in seawater. Colonies were monitored by seven days or until the death of the colonies. They were considered dead when there was no response to tactile stimulation and presented tissue degradation. Concentrations equal or higher than 20 ppm were harmful to T. coccinea, causing several damages and, at last, mortality of the colonies. The time needed to kill all the colonies was 108 hours in 20 ppm, 72 hours in 50 and 100 ppm, 5 hours in 150 ppm and 3 hours in 200 ppm. Our results showed that NaClO solution was effective to kill T. coccinea colonies. In addition, it is considered a low toxicity chemical substance and, therefore, could be applied in the management and control of this invasive coral in restricted areas, in both artificial and natural substrates.

Presenting author is Luciana Altvater lual81bio@gmail.com

Toxicity and antifouling activity from the non-indigenous octocoral Stragulum bicolor Van Ofwegen & Haddad, 2011

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The octocoral Stragulum bicolor (Octocorallia: Alcyonacea: Clavulariidae) was probably introduced in Brazil by the year 2000. Since then, this species has been registered in artificial and natural substrates and has expanded its distribution along the Brazilian coast. Paranagu Bay is one of the first sites where this species was recorded. This estuarine system has the two major ports of Paran state, and one of the main ports of Brazil. Alcyonaceans are rich in secondary metabolites, that act in different biological interactions as reproduction and chemical defense against predators, epibionts and competitors, enhancing the invasiveness of some species. This study aims to verify the antifouling activity and toxicity of the crude extract of S. bicolor on marine invertebrate larvae. Colonies of S. bicolor collected in Paranagua Bay were frozen, lyophilized and used to obtain the organic extract in dichloromethane. The crude extract was applied in antifouling and toxicity tests against larvae of the bryozoan Bugula neritina and the barnacle Amphibalanus amphitrite at different concentrations (100 %, 50 %, 10 % and 1 % of the natural concentration). Larval settlement and mortality were recorded and compared between the treatments: (1) with extract; (2) control with dichloromethane; and (3) null control (only filtered seawater) using, respectively, Repeated Measures ANOVA and One-Way ANOVA. In all tested concentrations, the crude extract of S. bicolor inhibited the settlement of B. neritina and A. amphitrite, and was toxic to both species. The dichloromethane had no influence on settlement and mortality. Our results indicate that the success of S. bicolor in colonizing and establishing into new regions may be related to the chemical defenses production.

Presenting author is Luciana Altvater lual81bio@gmail.com

Green vs. blue mussel: The space race

Atalah, Javier[1]; Rabel, Hayden[2]; Forrest, Barrie[3];
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The green-lipped mussel, Perna canaliculus, forms the backbone of the New Zealand aquaculture industry, with annual export earnings of >$218M. Crops are susceptible to the detrimental effects of fouling pests, including pre-emption of space, overgrowth and dislodgement of crops, and food competition. The blue mussel (Mytilus galloprovincialis) is one of the greatest threats, with over-settlement of Mytilus onto Perna spat or grow-out lines in the Marlborough Sounds region often resulting in considerable crop losses. The Marine Farming Association (MFA) has been monitoring settlement of Perna and Mytilus spat throughout the region for almost 40 years. Here we use these data to describe how spatial and temporal patterns in the distribution of these species that could be exploited, both to

maximise the settlement of Perna and to avoid over-settlement by Mytilus. Large inter-annual and spatial variability in the settlement of both species was observed, with distinct seasonal and depth patterns. Settlement was modelled in response to a number of environmental conditions (e.g. water temperature, salinity, primary productivity, Southern Oscillation Index) using spatio-temporal Bayesian approaches. A web application displaying the dataset and providing a forecasting tool for Perna and Mytilus (https://cawthron.shinyapps.io/BMOP/) will be incorporated into the MFA website. In addition to identifying seasons and growing areas less prone to blue mussel over-settlement, this work will also identify new sites appropriate for green-lipped mussel spat collection.

Presenting author is Javier Atalah javier.atalah@cawthron.org.nz

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Spatial and temporal distribution patterns of the invasive European shore crab Carcinus maenas in nearshore habitats of Gulf St. Vincent, South Australia

Baring, Ryan[1]; Campbell, Rene[1]; Evans-Sanchez, Katherine[1]; Dittmann, Sabine[1];
[1]Flinders University

Carcinus maenas is listed among the top 100 of the IUCNs most invasive species in the world with a broad invasion risk. It was first recorded in South Australia in 1976, and abundances have been variable since then. We have investigated the distribution and abundance of C. maenas since 2012, coinciding with an overall increase of the population along the Adelaide metropolitan coastline. In 2015 we also studied the population structure of C. maenas, its predation pressure on native benthic fauna, and the influence of tides on abundance and activity patterns. At a large spatial scale, C. maenas was rare or mostly absent from small estuaries and rocky shores south of Adelaide, with the occurrence concentrated in the estuary and mangroves north of Adelaide. At a medium spatial scale, abundances were higher in the mangroves compared to sites in the Port River. At a fine spatial scale, abundances increased in the mangroves from the upper edge of the mangroves to the shallow subtidal seagrass beds. Temporal patterns in abundance were recorded with higher catches in the cooler winter months. The total catch of C. maenas varied over the winter months of three consecutive years, with highest catches in 2014. Catches of C. maenas also revealed a finer temporal scale related to the lunar and tidal activity rhythms of this species, with highest catches at new or full moon compared to the first and last quarter of the lunar cycle. Findings from our investigations give insight into the adaptation of C. maenas to a warm temperate habitat with mixed tidal rhythms. The spatial and temporal patterns revealed in this study have further implications for the future sampling design of any studies on the occurrence and abundance of this invasive crab.

Presenting author is Ryan Baring ryan.baring@flinders.edu.au

Development of an expert-based model for improved biofouling risk assessment

Barry, Simon[1]; Caley, Peter[1]; Liu, Shuang[1]; Dean, Paini[1]; Carey, Jan[2]; Clark, Graeme[3];

[1]CSIRO [2]University of Melbourne [3]University of New South Wales

This talk describes the use of scenario-based calibration as a holistic method for estimating risk using expert opinion. The risk endpoint on interest was the establishment of an exotic pest species arising from hull biofouling. In summary, scenarios were constructed and experts provide their views about the risks. These views were summarised statistically across the sample of experts. A model emulator was built relating the establishment risk to the attributes of the scenario, in this case the vessel and voyage characteristics, and the environmental features of donor and recipient ports. A novel component of this analysis was use of relative assessments. The risk of translocation of species is very low on a per vessel basis. Initial discussion of this with experts identified that they would firstly not be particularly good at this, and secondly would find it very uncomfortable. To address this problem we modified the elicitation to consider the relative risk of journeys. The resulting emulator was able to explain a considerable proportion of the variation in expert assessments.

Presenting author is Simon Barry peter.caley@csiro.au

Reproduction of Green Crab, Carcinus maenas, in Placentia Bay and Juvenile Targeted Mitigation to Prevent Mussel Aquaculture as a Vector for Introduction and Spread

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[1]Marine Institute of Memorial University of Newfoundland [2]Science Branch Fisheries and Oceans Canada, St. John's, NL

The reproductive strategies of green crab (Carcinus maenas) in recently invaded cold-tolerant populations in Newfoundland were investigated to determine the physiological maturity, timing of mating behavior, egg development and larval release. Non-native green crab populations in Atlantic Canada were compared to determine if strategic adaptations had been made at the extreme northern Atlantic range of their distribution. This information was used in targeting high risk green crab life stages in the movement of aquaculture mussel seed from invaded areas. Mitigation studies focused on a series of trials where green crab juveniles were subjected to a series of heated salt water immersion where it was determined that heated salt water for no longer than 1 minute at 45C is sufficient to cull the crab. This method which in practice will treat the mussels that green crabs may take shelter in did not cause any significant physiological stress to the mussel seed. This information and subsequent control measures are valuable to the mussel aquaculture industry and to designing plans for future control of this invasive species.

Presenting author is Kiley Best kiley.best@mi.mun.ca

Opportunities and challenges of managing marine invasion pathways within New Zealand

Bird, Rosemary[1];

[1]Ministry for Primary Industries

The Ministry for Primary Industries (MPI) is the lead agency for the management of invasive marine species within New Zealand, which has (up until recently) been largely focused on species and site led management. With an increasing number of established marine pests invading new areas of New Zealand via largely unmanaged pathways, new regulatory tools were established to manage domestic invasion pathways, enabling a more proactive focus for both national and regional management. This required information on the marine invasion pathways that facilitate domestic spread of established species and practical options to reduce the risk on these pathways. In 2012, MPI commissioned NIWA and the Cawthron Institute to produce two reports to summarise operational tools and assess regulatory options for marine pathway management. I will present the outcome of the reports and discuss how MPI is using this information to develop a strategy for improving domestic marine pathway management. I will discuss the factors influencing our ability to implement national marine invasion pathway management, regional developments and our implementation with development approach. The presentation will provide an overview of the process underway to build the case for change and a collective understanding of where to invest our limited resources to get the greatest risk reduction.

Presenting author is Rosemary Bird Rosemary.Bird@mpi.govt.nz

Trematode infection does little to hinder invasive green crabs in eastern North America

Blakeslee, April[1]; Keogh, Carolyn[2]; Fowler, Amy[3]; Griffen, Blaine[4];

[1]East Carolina University [2]University of Georgia [3]South Carolina Department of Natural Resources [4]University of South Carolina

A common signature of marine invasions worldwide is a significant loss of parasites (= parasite escape) in non-native host populations, which may confer a release from some of the harmful effects of parasitism (e.g., castration, energy extraction, immune activation, behavioral manipulation) and possibly enhance the success of non-indigenous species. In eastern North America, the notorious invader Carcinus maenas (European green crab) has escaped more than two-thirds its native parasite load. However, one of its parasites, a trematode (Microphallus similis), can be highly prevalent in the non-native region; yet little is known about its potential impacts. We employed a series of laboratory experiments to determine whether and how M. similis infection intensity influences C. maenas, focusing on physiological assays of body mass index, energy storage, and immune activation, as well as behavioral analyses of foraging, shelter utilization, and conspicuousness. We found little evidence

for enduring physiological or behavioral impacts four weeks after experimental infection, with the exception of mussel handling time which positively correlated with cyst intensity. However, we did find evidence for a short-term effect of M. similis infection during early stages of infection (soon after cercarial penetration) via a significant drop in circulating immune cells, and a significant increase in the crabs' righting response time. Considering M. similis is the only common parasite infecting C. maenas in eastern North America, our results for minimal lasting effects of the trematode on the crab's physiology and behavior may help explain its continued prominence as a strong predator and competitor in the region.

Presenting author is April Blakeslee blakesleeap14@ecu.edu

Invasive Species and Plankton Dynamics of the Columbia River Estuary

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[1]Washington State University [2]University of Washington

We have been investigating the plankton dynamics of the Columbia River Estuary (CRE), with special emphasis on invasive species, for more than a decade. Several important findings have emerged from our field and experimental studies. First, that several species of Asian copepods have invaded the CRE, with one species in particular, the calanoid copepod Pseudodiaptomus forbesi, becoming extremely widespread (penetrating several hundred kilometers upriver) and very abundant in late summer and early autumn (it is the overwhelming dominant mesozooplankter at this time of the year). Second, P. forbesi feeds on diatoms, ciliates, flagellates, and dinoflagellates, and exhibits a general preference for diatoms and ciliates (which suggests potential competition with native copepods), and an avoidance of chlorophytes and cyanobacteria. Third, that P. forbesi can be preyed upon by a range of native CRE predators, including juvenile chinook salmon, three-spined stickleback, northern pikeminnow, and mysids, and that some (but not all) of these native predators select for native zooplankton over P. forbesi. Fourth, that an invasive Asian clam, Corbicula fluminea, is also extremely widespread and abundant. Fifth, that dreissenid (quagga and zebra) mussels have not yet (to our knowledge) invaded the Columbia River Basin, but that these mussels represent a major threat for future invasion. These results will be presented and discussed in the context of food web impacts and potential climate change effects.

Presenting author is Stephen Bollens sbollens@wsu.edu

Marine invasive species in Gippsland Lakes, Victoria, Australia

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[1]RMIT University [2]CSIRO [3]San Jose State University [4]Museum and Art Gallery of the Northern Territory [5]Deakin University

We undertook a survey of marine invasive species (MIS) in the fragile Gippsland Lakes, eastern Victoria, by undertaking a baseline survey and risk assessment for the entire system. Nearby Port Phillip Bay is one of the most heavily infested ports in the world highlighting the importance to understanding the threat posed by MIS. We undertook an assessment of the current status of MIS in the Gippsland Lakes by undertaking a targeted survey throughout 2015. Potential vector nodes were surveyed using visual inspection (SCUBA diving), grab and dredge sampling, and deployment of settlement plates. Suspected MIS organisms were identified via a combination of molecular and morphological methods. Environmental samples (plankton, sediments and biofouling) were analysed via the use of metabarcoding next generation sequencing techniques. Seasonal zooplankton sampling was undertaken to identify seasonal patterns in the presence of MIS larvae/propagules in the water column. Notable MIS identified to date include European Green Crab, Carcinus maenas, Asian Bag mussel, Arcuatula senhousia and Pacific oyster, Crassostrea gigas. The identification of potential vectors of MIS introduction as well as a framework for on-going surveillance and management strategies will be discussed.

Presenting author is Nathan Bott nathan.bott@rmit.edu.au

The Adaptation Genomics of Three Globally-Distributed Marine Invaders

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[1]University of Southampton

It has long been a goal of evolutionary biology to elucidate the effects of localised adaptation on the genome- especially under the threat of a changing environment. Invasive species provide an intriguing model for studying these effects due to their evolution occurring on timescales contemporaneous to humans. Here I will introduce my PhD project focusing on investigating the adaptation genomics of three prolific ascidian invaders: Ciona intestinalis, Ciona robusta and Microcosmus squamiger. Populations of the three ascidians will be sampled along abiotic gradients across their native and invasive ranges, and next-generation sequencing technology will be used to identify regions of local adaptation in their genomes. This technology will enable the disentanglement of positive and neutral processes underlying their evolution, and will also allow the investigation of demographic changes in their evolutionary history. This comprehensive genomic study will offer thorough insights into the past, present and future of these marine invaders, and will contribute answers towards fundamental questions in evolutionary and invasion biology.

Presenting author is Steven Bourne s.bourne@soton.ac.uk

Characterizing the generality and shape of the relationship between propagule pressure and establishment probability for species invasions.

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[1]University of Minnesota Duluth [2]Northeast Midwest Institute [3]University of Wisconsin Superior

Understanding how inoculation characteristics (propagule pressure) affect establishment probability of an invading species in the context of abiotic and biotic factors is a recent area of emphasis in ecology given an urgent need to prevent and manage invasive species globally. Currently, propagule pressure, defined as the number and frequency of arriving organisms during an invasion event, drives many predictive models of invasion. However, there are few empirical data to define the shape and generality of relationships between propagule pressure and establishment success across gradients in niche space for an organism. This project summarizes the risk-release relationship for three different aquatic invader species utilizing mesocosm based experiments. The following invader species Melosira varians (photosynthetic protist), Daphnia magna (herbivorous crustacean), and Bythotrephes longimanus (carnivorous crustacean) were added at target inoculation levels that ranged from 1 to 100 cells/mL, 1 to 4 individuals/ 200 L, and 1 to 40 individuals/1000 L, respectively. These inoculation levels were chosen because they bracketed the International Maritime Organization ballast water discharge standards for organisms 10-50 or greater than 50 microns in minimum dimension. All experiments were conducted with ambient water drawn from a Laurentian Great Lakes harbor (Duluth-Superior) at different times of year providing a range of starting conditions. Results indicate strong interaction between propagule pressure, abiotic and biotic factors of the receiving environment and the probability of establishment. The results from these three distinct species will be discussed in the context of our emerging understanding of the risk-release relationship.

Presenting author is Donn Branstrator dbranstr@d.umn.edu

An invader and the receiving assemblage: a love story

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The invasive biology of the isopod Cirolana harfordi was investigated in Sydney, Australia. This species is of particular interest because it reaches great abundances in estuaries in the area (up to (up to 900 individuals/m2). The impacts of C. harfordi on the assemblages in oyster-beds were evaluated using observational and manipulative studies. These experiments did not show any effects of C. harfordi on the receiving assemblages. On the other hand, colonisation of oyster-beds by non-indigenous species can be affected by the receiving assemblage, and these effects can be modified by environmental conditions. I used experimental oysters-beds in mesocosms to evaluate the effect of the receiving assemblage and disturbance on NIS colonization. C. harfordi was found in greater abundances in patches with assemblage (disturbed or undisturbed) than in patches without assemblage. Hence, the organisms in the receiving assemblage facilitated colonisation. In addition, C. harfordi was found in greater abundances in patches with a disturbed assemblage than in patches with undisturbed assemblage, suggesting the possibility of weak biotic resistance and an interaction between disturbance and invasion success.

Presenting author is Ana Bugnot a.bugnot@unsw.edu.au

The science of expert judgement for biosecurity

Burgman, Mark[1];
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Decisions about the management of exposure pathways are characterised by poor data and imminent decisions with substantial ramifications. Expert judgement is an integral part of decision making, yet most procedures for acquiring estimates are rudimentary and prey to a host of contextual biases and psychological frailties. They stand in stark contrast to a suite of new methods in psychology, philosophy and mathematics that could revolutionise the quality and reliability of expert judgements. This presentation outlines some of these new approaches and illustrates their performance on case studies. It identifies areas where both the reasoning that contributes to judgements and the methods used to interact with experts and combine judgements could lead to improved biosecurity outcomes. It illustrates these issues with questions about invasive species including Acanthaster planci and Caulerpa taxifolia.

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Is the Invasive European shore crab, Carcinus maenas, a potential predator on native bivalves in South Australia?

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Invasive marine species threaten native biodiversity and marine industries, with approximately 250 invasive marine and estuarine species identified in Australia alone. The European shore crab, Carcinus maenas, is a global invader and listed among the top 100 of the IUCNs most invasive alien species in the world. These crabs have been known to feed extensively on a variety of mollusc species, which can impact on commercially important bivalve fisheries. We investigated the potential predation pressure these crabs may exert on two commercially and ecologically important native bivalves: the thin-shelled mussel, Xenostrobus inconstans, and the thick-shelled mud cockle Katelysia spp. The crabs' shell breaking behaviour dominated among the thin shelled mussels in both choice and isolation field experiments, but thick-shelled cockles were not fed on in any circumstance. The shell-breaking force for Katelysia was found to be much higher than the range exerted by adult crabs, however significantly lower shell-breaking forces for X. inconstans make them viable prey. Sex did not influence the prey choice of C. maenas, with all bivalves eaten evenly. These findings provide some insight into C. maenas predation on benthic species in a southern temperate habitat, and their potential impacts on a commercially exploited cockle species and an important ecological engineer. Our study raised further questions about the crabs' predation effect on other native bivalve species, and if the spread of this invader may impact on bivalve fisheries elsewhere in South Australia.

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A mesocosm-based method to quantify the risk-release relationship relevant to ballast water discharge standards.

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The transportation of aquatic species by ships ballast water is one of the principal means by which new aquatic invasive species are introduced to new aquatic ecosystems around the world. The desire to set scientifically-based ballast water discharge standards for live organisms to reduce ship mediated AIS, drives interest in quantitative estimation of the relationship between discharge quantities over time, and probability of establishment of new populations in receiving systems (risk-release relationship). A National Research Council report found "a profound lack of data" currently prevents scientific understanding of the risk-release relationship. This study developed methods used for indoor 1000 L mesocosms (n=22) to quantify the

risk-release relationship of a Laurentian Great Lakes relevant zooplankton invader, Bythotrephes longimanus. B. longimanus has an asexual reproductive strategy and rapid developmental timeline making it a worse-case invader. Methods include uniform filling, optimized collection of target and background species, and a positive-growth control for the zooplankton invader. Inoculation levels tested bracketed the International Maritime Organization ballast water discharge standard for organisms greater than 50 microns in minimum dimension. Inoculation levels of 1, 5, 10, 20, or 40 per 1000 L of the zooplankton invader were added to ambient harbor water (fish predators were excluded) at the beginning of a series of two-week trials. Environmental factors were monitored throughout the experiment. Assessments of environmental factors and tank volumes indicate we were able to minimize variation across replicate tanks and inoculation levels during each fill. B. longimanus was able to successfully reproduce at all inoculation levels. The relationship between B. longimanus final densities versus inoculation densities will be presented and discussed in context of ballast water discharge policy.

Presenting author is Matthew TenEyck mteneyck@uwsuper.edu

Poleward Creep Punctuated by Set Backs and Surges: Refining Climate Change Scenarios for Marine Non-Indigenous Species

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Invasion dynamics are sensitive to global scale changes. New marine invasions have been recorded in dramatically increasing numbers along the world's coasts, due, in part, to the global warming of the oceans and the ability of many successful invasive marine species to tolerate a broader thermal range than similar native species. Several studies worldwide have investigated the interplay between bioinvasions and climate change. As a response to this recent warming of the oceans, a poleward movement of numerous species has been observed in many biogeographic regions. In the Northwest Atlantic Ocean the poleward expansion of Caribbean and Bahamian species into the southern and mid-Atlantic coasts of the United States has been termed

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The Invasion Process Model and the Long-Distance Transoceanic Dispersal of Coastal Marine Organisms by Japanese Tsunami Marine Debris

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The arrival onto the shores of North America and Hawaii of a vast flotilla of materials (ranging from small buoys to vessels to large docks) generated on March 11, 2011 by the Great East Japan Earthquake offers a rare opportunity to pose fundamental hypotheses and questions that address the processes by which coastal (neritic) organisms are engaged, transported and survive passive long-distance transoceanic dispersal (LDTD) events. LDTD is a phenomenon so commonly invoked that the conclusion

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Linking integrative molecular and morphological taxonomy with community ecology: diversity and distribution of littoral native and invasive gastropods and crabs in British Columbia, Canada

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Invasion impacts on indigenous biodiversity are poorly understood, in part because ecosystem dynamics depend on complex and often unresolved networks of interacting species. Improved understanding of these systems and the impacts of invasive species requires novel synthetic approaches to biodiversity and ecology assessments that would, ideally, capture the entire diversity of species in a given community and their dynamics and relationships. Here we present and apply an integrative approach that links high-throughput biodiversity assessments with community ecology. A total of 1,195 specimens of native and invasive shelled gastropods and brachyuran crabs were collected across 700 km of coastline in southern British Columbia (BC), Canada. We used molecular (DNA sequence) and morphological evidence to generate fast and accurate species hypotheses and used this critical species identification assessment to investigate community structure with respect to ecological null models. To date, 57 species have been delineated, including invasive and native species, many of which that are not easily distinguished in the field, which has implications for range determination and invasive species surveillance. Nonrandom species co-occurrence patterns indicative of ecological relationships or habitat preferences were observed for grazer gastropods whereas assemblages of opportunistic omnivorous gastropods and crabs appeared influenced by random processes. Overall, the four habitat-types analyzed contained distinct species assemblages and invasive species

occurred on sites depleted of native biodiversity including abandoned oyster farms, sites with high urban-activity or sites naturally characterized by low evenness, such as mudflats. The high-throughput taxonomic approach used here provides new opportunities for understanding ecosystem-level impacts of invasive species.

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Diffuse copper tolerance facilitates marine bioinvasion

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Tolerance to anthropogenic contaminants is a trait critical to the success of many species, particularly in highly contaminated areas. Most research has focused on localised tolerance, but mechanisms now exist for the evolution of diffuse, global-scale tolerance, with fundamentally different properties. Vessels coated in copper anti-fouling paint act as numerous mobile, heavily contaminated sites for marine epibiota, selectively transporting copper-tolerant species between contaminated port and harbours. We examined how diffuse (non-localised) tolerance may contribute to bioinvasion by testing the relationship between copper tolerance and marine bioinvasion at a regional scale (99 sites over 7 estuaries). Invader abundance and diversity were positively correlated with environmental copper, and invaders were 60% less sensitive to copper than native or cryptogenic species. Tolerance of a dominant invader (Watersipora subtorquata) increased with environmental copper, suggesting regulation of tolerance. We then used a simulation model to explore the basic properties of diffuse tolerance, and discover how its evolution and consequences intrinsically differ from those of localised tolerance.

Presenting author is Graeme Clark g.clark@unsw.edu.au

Effects of marine debris caused by the Great Tsunami of 2011

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The Great Tohoku Earthquake of 2011 created a massive tsunami which washed an estimated five million tons of debris into the Pacific Ocean. In response to this unprecedented event, the North Pacific Marine Science Organization (PICES) ADRIFT project was launched, funded by the Ministry of the Environment of Japan (MoE). The primary goal of this project is to assess and forecast the effects of debris generated by this tsunami, especially those related to non-indigenous species (NIS), on ecosystem structure and function of communities on the west coast of North

America and Hawaii. The project focuses on three main areas of research: (1) modeling movement of marine debris in the North Pacific, (2) surveillance and monitoring of tsunami-generated marine debris landfall, and (3) assessing risk from potentially invasive species to coastal ecosystems. A suite of general circulation models was used to simulate movement of marine debris arising from the tsunami. Surveillance and monitoring research has characterized the temporal and spatial variability in debris landfall. Aerial photographic surveys were conducted for the exposed coastlines of British Columbia, Alaska and the Hawaiian Islands to search for large debris items and identify debris accumulation hotspots. The invasive species team continues to characterize the invasion potential of NIS associated with tsunami debris. Over 400 items attributed to the tsunami have been intercepted, and from these over 300 species of algae, invertebrates and fish have been identified. Some of these species are well-known global invaders, such as the large pink barnacle Megabalanus rosa, the bryozoan Tricellaria inopinata, the seaweed Undaria pinnatifida, and the serpulid tube worm Hydroides ezoensis. Others could be high risk species and thus screening level risk assessments are underway. To understand how the tsunami debris vector compares to other better studied ones a pathway risk assessment is being conducted.

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How will introduced mussels influence native biodiversity?

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It is predicted that ecological interactions between non-native and native species will be affected by future climate change. The native hairy mussel, Trichomya hirsuta, and introduced mussel, Mytilus galloprovincialis, are present in Sydney Harbour. Mussels are important ecosystem engineers that provide habitat for diverse assemblages of infauna. Along with the mussels, the infaunal species living within mussel beds will also be faced with an increasingly stressful environment. Using novel mesocosm experiments, manipulating temperature and pCO2, this research investigated how native and introduced mussels, and the invertebrates colonising mussel beds will respond to future climate change. Preliminary findings have shown that clearance rates, metabolic rates, and subsequent rates of growth of mussels, were influenced by ocean acidification, temperature, and the presence of the other mussel species. Although the introduced mussel, M. galloprovincialis, showed little response to elevated pCO2, the native mussel, T. hirsuta, had a negative response to pCO2. Moreover, under elevated pCO2, the effect of M. galloprovincalis as a superior competitor over T. hirsuta was much greater. In addition to ocean acidification influencing interactions between native and non-native mussels, it also affected the role of each of these species as ecosystem engineers. Investigation of the response of different groups of infaunal species to ocean acidification and the presence of native or non-native mussels influenced overall abundances of infauna and their small-scale behaviour. There were greater abundances of polychaetes colonising mussels under elevated pCO2, and they actively chose to be associated with T. hirusta and actively

avoided M. galloprovincialis. These findings have implications for how future climate change and the presence of non-native species will influence native biodiversity.

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Temporal modeling of ballast water discharge and ship-mediated invasion risk to Australia

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Biological invasions have the potential to cause extensive ecological and economic damage. Maritime trade facilitates biological invasions by transferring species in ballast water, and on ships' hulls. With volumes of maritime trade increasing globally, efforts to prevent these biological invasions are of significant importance. In this study, we characterized the spatial and temporal trends in international shipping traffic into Australia, and integrated shipping network and specific empirical ballast discharge data, including the source of discharged ballast water, to highlight potential ballast-mediated invasion hotspots in Australia. Models for the transfer of ballast water into Australian waters were constructed based on historic ballast survey data. We used these models to hindcast ballast water discharge over all vessels that arrived in Australian waters between 1999-2012. We used models for propagule survival to compare the risk of ballast-mediated propagule transport between ecoregions. We found that total annual ballast discharge volume into Australia more than doubled over the study period, with the vast majority of ballast water discharge and propagule pressure associated with bulk carrier traffic. As such, the ecoregions suffering the greatest risk are those associated with the export of mining commodities. Our approach demonstrates a biosecurity case study for ballast-water-mediated invasion risk, and similar techniques could be applied in other countries when relevant data are available. As global marine trade continues to increase, effective monitoring and biosecurity policy will remain critical to mitigating the risk of future marine invasion events.

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Using local and scientific perspectives to understand factors affecting the distribution of invasive Green Crab (Carcinus maenas L.)

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Understanding the nature of species' spatial distributions is central to many management regimes, including predicting invasion risk, wildlife conservation and fisheries planning. If there is knowledge of which environmental factors affect species distributions, and how, this may be used to make inferences about distributions within a specific region or scenario. While scientific knowledge has often been used to this purpose, there is increasing support for the incorporation of other knowledge types. As individuals with extensive exposure to their environment, local knowledge holders often have considerable understanding concerning observed distributions of species as well as the factors associated with these distributions. Consequently, multiple knowledge sources may be implemented to improve our understanding of species' distributions. In this research, we explored the environmental factors driving local-scale distributions of invasive European green crab (Carcinus maenas), using both local and scientific knowledge sources. Information was gathered through 1) extensive review of the scientific literature and 2) interviews with locals who have experience with C. maenas. The most strongly supported environmental factors and conditions were noted, as well as interacting variables (e.g. temporal changes and internal population characteristics). Geographic regions for studies were also noted, as there is some evidence that behavioural differences exist among different genotypes of this species. Our poster will briefly review the rationale behind, methodology for and results of this study, noting key points of agreement as well as incongruences among our knowledge sources. The implications of these findings will also be discussed, such as the potential benefits and limitations of incorporating disparate knowledge sources into management practices.

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Comparing introduced, invasive and all marine species using WRIMS

Costello, Mark[1]; Pagad, Shyama[2]; Dekeyzer, Stefanie[3]; Vandepitte, Leen[3];
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Data on alien and invasive alien species (IAS) is repeatedly re-compiled as part of national biosecurity risk assessments. This includes checking species' taxonomy and alternative names, their native and introduced ranges, species impacts, pathways and vectors of introduction and spread. These costs will now be reduced by the establishment of the World Register of Introduced Marine Species (WRIMS) within the World Register of Marine Species (WoRMS). The species taxonomy and related

information are managed by WoRMS taxonomic experts. WRIMS editors manage additional species information, including literature references, geographic distribution, invasiveness, pathway, and vector of the over 1,600 currently listed species. The Editorial team is also focused on expanding the database so it is geographically and taxonomically comprehensive. This is the first IAS database integrated with a global all-taxon database that is dynamically updated. This talk will introduce WRIMS and test the null hypothesis that IAS are a random sample of all marine species. The results will help predict which taxa are more likely to have species that are introduced and/or become invasive.

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Invasion of the Pacific Oyster, Crassostrea gigas, into Southern California, USA

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The Pacific Oyster, Crassostrea gigas, is becoming one of the most successful, and transformative, of marine invaders. Although the oyster was first intentionally introduced into the estuaries of Southern California in the 1930's, it was not until seventy years later that wild individuals began to be routinely reported. In 2005, we began documenting the presence of C. gigas in the bays and lagoons of San Diego County. Since that time, we have found this non-native oyster in virtually every suitable system along the stretch of coastline. In some locations, such as parts of San Diego Bay, the oyster now represents the most conspicuous of intertidal fauna. Ongoing work on the effects of the oyster are consistent with impacts observed elsewhere, as well as with patterns seen for other invasive ecosystem engineers. The invasion of this oyster has the potential to re-shape intertidal landscapes of the region, as well as the way we manage them. Of particular interest is the potential impact on efforts to restore the native oyster, Ostrea lurida, in the region, as well as the role of oysters in creating "living shorelines" as a climate change adaptation strategy. Because of the considerable interest this invasion is likely to generate, the Pacific Oyster should also provide opportunities for education and outreach that emphasize often-hidden changes occurring in the sea.

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Fiordland Marine Biosecurity and the Development of a Marine Pest Pathways Plan

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A number of non-native marine species incursions have occurred throughout New Zealand requiring intensive resources to manage. Fiordland is no exception, and in April 2010 the invasive seaweed Undaria pinnatifida was detected in the isolated Sunday Cove in Breaksea Sound. Such incursions are alarming as Fiordlands remoteness, unique marine ecology and productive fisheries give the area enormous importance. The establishment of U. pinnatifida initiated a joint agency eradication response in June 2010 involving; Environment Southland, Ministry for Primary Industries, Department of Conservation and the Fiordland Marine Guardians. The eradication of U. pinnatifida from Fiordland is looking promising, however, the program is still ongoing today. This instance of U. pinnatifida is not the only threat, the ecological state and quality of the Fiordland Marine Area is constantly at risk to invasives introduced via human-mediated pathways. To help prevent pest establishment, the government implemented its marine biosecurity pathway policy by introducing Pathway Management Plans as an amendment to the Biosecurity Act 1993. The pathways approach is proactive, and provides an opportunity to focus greater efforts on the vectors pests may take to reach a new destination such as vessels and fishing/recreational gear. Because Fiordland is such a difficult and costly area to survey and respond, an effective pathways focused management is of the upmost importance and will be a great tool to manage this unique marine environment. The process of implementing the Fiordland Marine Pathways Plan will involve a number of different components, and this is nearing the end of development. For the plan to be successful and effective, it is essential to get buy in from Fiordlands many users. Communication and consultation is therefore a major component in the implementation of the plan. Here, Fiordlands marine biosecurity issues and the pathways approach we are taking will be discussed.

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Pathway to invasion: from artificial structure to rocky reef

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Artificial structures are introduced into the marine environment for various purposes including defence (e.g. seawalls, breakwaters), boating (e.g. jetties, pontoons) and fisheries (e.g. artificial reefs). These structures differ from natural rocky reefs due to their physical characteristics and have the potential to provide stepping stones for invasive species spread. We investigated the abundance and identity of invasive species on pilings, pontoons, artificial reefs and natural reefs at multiple locations in Sydney Harbour and Port Phillip Bay, Australia. We found greater non-indigenous diversity and dominance on piers and pilings relative to rocky reef. Manipulative experiments suggested that shading boating structures reduces competition from many native algal species and allows the development of assemblages dominated by invasive sessile invertebrates. Artificial reef balls tended to be dominated by native turfing algal assemblages, but we also identified large populations of the invasive fanworm Sabella spallanzanii on the reef balls. Sabella spallanzanii is a priority pest in Australia due to potential ecological and economic impacts and the potential for artificial reef deployments to provide habitat for this species requires further investigation.

Presenting author is Katherine Dafforn k.dafforn@unsw.edu.au

Optimal Treatment Regimes from Productivity and Economic Standpoints: The Management of Suspended Mussel Lines Using High Pressure Water Treatment for the Vase Tunicate, Ciona intestinalis

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The invasive tunicate Ciona intestinalis (L., 1767) had an economic impact on the aquaculture of the blue mussel Mytilus edulis (L., 1758) in Prince Edward Island (PEI), Canada and other areas. This tunicate fouls mussel socks suspended on long lines in the water, increasing the weight of the lines and reducing the weight and number of mussels, decreasing overall productivity and profitability. This study determined the relative effects of high pressure water treatment schedules over a 4 month period on two representative sites located in Murray and Brudenell Rivers on PEI. Results indicated that initiating treatment early in the season (July) and treating another 2 or 3 times on a monthly basis had the greatest effect on reducing tunicate numbers and size and enabling greater mussel productivity and farm profitability. While the most effective treatment may ultimately be site-specific, the two sites in this study support the notion that beginning treatment when tunicates are

small is one of the most significant parts of a treatment strategy. The optimal treatment strategy needs to be balanced with the most cost effective regime to maintain or improve the economic potential of a mussel farm. Results show that a treatment regime that includes three or four treatments consistently results in an economic advantage over treating two times. If treating mussel socks only two times, treating them early also shows substantial economic advantage.

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Shifting assemblages: the invasion of northern New Zealand by the ascidian Pyura doppelgangera n sp.

Davis, Andy[1]; Walls, Kathy[2]; Jeffs, Andrew[3];

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Green-lipped mussels, Perna canaliculus, dominate wave-exposed rocky shores in northern New Zealand. The recent appearance of an invasive ecosystem engineer, the ascidian Pyura doppelgangera, at the very northern tip of New Zealand now threatens to exclude these bivalves from this habitat. Here we chronicle the invasion of new sites and report major shifts in assemblages associated with the invader. We examined epibiota associated with clumps of mussels and clumps of Pyura from within pools and on emergent rocky substrata at two locations. We did not detect differences in species richness but rejected the hypothesis that the species composition of epibiota was the same. We observed a dramatic shift from a gastropod and crustacean dominated fauna within mussels to a polychaete dominated fauna associated with the ascidian. The other factors we explored were not significant. The broader implications of these faunal shifts to local and regional patterns of biodiversity as well as ecosystem function remain unclear, but deserve further attention.

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Effect of invasive corals (Tubastraea spp.) on native community structure

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Corals are not frequently reported as invaders, but two Tubastraea species were introduced onto South Atlantic tropical rocky shores and are expanding their range along the Brazilian coast where they cause negative ecological and economic impacts. The aim of the current study was to investigate community level change in the invaded benthic community. We sought to establish whether the invasive corals Tubastraea coccinea and T. tagusensis restricted the habitat for native species by

determining the community response over time to the elimination of the competitive interactions involving these invasive species. The manipulative experiment was performed over one year in the shallow subtidal at Ilha Grande Bay, tropical southwestern Atlantic. Areas where the corals were established were manipulated with four treatments: control; removal by scraping of all benthos; single removal of invasive corals; repeated removal of invasive corals. Periodically we estimated the density of the corals by counting recruits/colonies and the cover of the benthos to species level where possible. Changes were analyzed using ANOVA and non-parametric multidimensional scaling to explore similarity between assemblages under different treatments over time. Both species of Tubastraea showed a peak of recruitment from April to July with average recruitment of 133 recruits.0.16 m2 for T. coccinea and 173 recruits.0.16 m2 for T. tagusensis. Recruitment (and thus density) of the corals was enhanced by removal. Removal resulted in increased cover of native macroalgae, sponges and the zoanthid Palythoa caribaeorum. Communities which developed after removal by scraping of all benthos or single removal of invasive corals initially differed from controls but over time re-approximated them as the invasive corals re-established. Communities which developed under repeated removal of invasive corals remained quite different indicating the invasion has caused a resilient alternative stable state.

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Aquatic disease biosecurity: moving away from an approach based on pathogens

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Approaches for management of disease risks in aquatic commodity trade are based on terrestrial models, despite fisheries and aquaculture production encompassing many more taxa and species, lower levels of knowledge about aquatic hosts and their pathogens, far more frequent emergence of undescribed diseases, a much lower likelihood of containment or eradication of established aquatic diseases and ongoing economic loss and environmental degradation associated with disease establishment in open systems. The complexity and uncertainty associated with diseases of aquatic organisms make dependence on risk assessment of specific pathogens, as used for terrestrial based commodities, risky at best, and in the worst case, worse than no management. International transboundary spread of aquatic animal diseases is been common, although the relative lack of effort in applying controls may be as responsible for this as the underestimation of risks associated with trade in aquatic commodities compared to their terrestrial counterparts. Here, we present an alternative approach using a simple risk scoring method, to assess risks associated with a range of aquatic animal product types generically (i.e. not on a pathogen specific basis) with recommended best practice guidelines to complement existing pathogen based IRA processes in the international standards.

Presenting author is Marty Deveney marty.deveney@sa.gov.au

Invasion by a structurally complex macroalga alters habitat usage and trophic interactions among native mudflat fauna

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Exotic producers can have complex effects on invaded ecosystems, especially where invasion transforms the physical structure of affected environments. One invader that may have such effects is the macroalga Gracilaria vermiculophylla, which has significantly altered the structure and productivity of the estuarine mudflats of the southeastern United States; habitats which were previously largely devoid of macrophytes. However, the nature of these effects will be influenced by whether resident organisms select for invaded patches, as well as how Gracilaria alters their performance. In intertidal habitats, the consequences of these choices are more complex, as both habitat preferences as well as the invaders effect on species performance may vary depending on whether the mudflat is exposed or inundated. We determined how Gracilaria affects habitat usage of benthic invertebrates during both high and low tide by seasonally manipulating the presence of this invasive macroalga within study plots at four sites. Samples were collected the following day through the use of lift baskets (high tide) and by scraping exposed plots (low tide). Field and lab trials then tested the effect of Gracilaria on the survival of resident species during each tidal stage. We found that both immigration and retention during tidal drop was higher in plots with Gracilaria for invertebrates such as amphipods, shrimp, and crabs. Though predator densities and predaceous shrimp survival were higher in plots with Gracilaria, amphipod survival also increased in invaded plots, likely due to the quality of the refuge provided by the complex algal structure. Gracilaria therefore influences native species both through effects arising from small-scale habitat selection (i.e. invaded vs. uninvaded patches) as well as more large-scale alterations in habitat usage (i.e. suppression of intertidal migration patterns during tidal drop), both of which have cascading trophic implications.

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Establishment and future applications of an invasive marine species reference collection in Australia

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The introduction of invasive species is particularly worrying in the marine environment as the majority of these can spread quickly through planktonic stages, facing few boundaries. Examples of successful eradication of invasive marine species (IMS) worldwide are few, expensive and feasible only at the early stages of introduction. Therefore, marine biosecurity operations worldwide focus on the early detection of IMS in order to prevent their establishment. In Australia, increased detections of IMS during the 90's led to the establishment of the National System for Prevention and Management of Introduced Marine Pest Incursions, which sets out standards for monitoring programmes, including lists of target species. A collection of reference specimens of species found on the national pest species monitoring list, has recently been built at the Department of Fisheries Western Australia. The main objective of this collection is to facilitate the future identification of target IMS using both taxonomic and molecular methods. Vouchered specimens are kept alongside a subsample of tissue from which species-specific DNA barcodes can be obtained. DNA barcoding offers a reliable, cost-effective and relatively fast alternative to routine taxonomic identification of previously characterised organisms. The reference collection is also essential to developing further molecular methodologies for improved detection of target IMS such as species-specific real-time PCR or metabarcoding based on High Throughput Sequencing (HTS) technologies. HTS-metabarcoding allows for the sequencing of multiple species present in pooled or complex environmental samples. The application of this technique is dependent on the development of general primers able to simultaneously amplify multiple target IMS as well as a priori knowledge of their barcodes. The collation of the reference collection is a fundamental step in validating new methods for the specific and efficient early detection of IMS.

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The Efficacy and Practicability of Combining Ballast Water Exchange with Treatment: Shipboard Trials

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In the US, both the US Coast Guard (USCG) and Environmental Protection Agency (EPA) are responsible for regulating ballast water discharges. Compared to the USCG ballast water regulations, the EPA Vessel General Permit (VGP) includes additional requirements for vessels entering the Great Lakes through the St. Lawrence Seaway System if they have (1) operated outside the Exclusive Economic Zone (EEZ, nominally 200 nm offshore) and >200 nm from any shore, and (2) taken on ballast water with a salinity of <18 ppt within the previous 30 days. If both of these qualifications are met, once a vessel is required to meet the numeric discharge standardlikely by treating the ballast water with a ballast water management system (BWMS)it must also conduct ballast water exchange or saltwater flushing. Here, this practice is defined as an exchange in the mid ocean (typically >200 nm from shore in waters >200 m), which may be conducted either by emptying and refilling tanks or by overflowing tanks with a volume of water equivalent to three times the volume of the tanks. This work is investigating the efficacy and practicability of combining exchange with ballast water treatment to reduce the transport and delivery of potentially invasive species. Central to this effort are shipboard experiments aboard commercial vessels to compare ballast water that has been treated by a BWMS to ballast water that has undergone exchange plus treatment with the BWMS. Using vessels of opportunity, ballast water discharges will be sampled using a shipboard filter skid, and they will be analyzed for parameters prescribed by the US Environmental Technology Verification (ETV) Generic Protocol for the Verification of Ballast Water Treatment Technology. The study plan, filter skid installation, and preliminary data will be discussed.

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Optimizing screening protocols for non-indigenous species risk assessment tools: are they over-parameterized?

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Invasive species are a serious ecological and economic problem. Thus, a variety of tools (screening procedures) have been developed to predict which non-indigenous species (NIS) can become invasive in a particular area by examining multiple factors suspected to influence a species success outside of its native range. Scoring system screening procedures for NIS generally ask a series of questions to assign risk scores to allow species to be ranked in terms of relative risk they pose and priority lists to be created. Few scoring systems have been calibrated and tested and many risk assessment tools for invasive species may be over-parameterized. We analyzed the contribution of each question in a new screening-level risk assessment scoring system (CMIST) for non-indigenous marine invertebrates in three Canadian marine ecoregions to tool accuracy (correspondence of scores with expert opinion on realized impacts). We then optimize the tool by removing questions that did not contribute to accuracy and deriving weights for each question. Most questions (9/17) contributed positively to the fit between CMIST and expert opinion scores when all species were included but the accuracy of CMIST was greater if the remaining eight questions were ignored. Weighting questions further increased CMIST accuracy.

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Trapping as a method to control European green crab, Carcinus maenas: a test at Pipestem Inlet, British Columbia, Canada

Duncombe, Lynda[1]; Therriault, Thomas[2];
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The invasive European green crab, Carcinus maenas, has been present on the west coast of Vancouver Island since 1998. Trapping was conducted between 2010 and 2015 at Pipestem Inlet, British Columbia, Canada in an effort to evaluate if depletion via trapping can serve as a mechanism to eradicate or control established green crab populations. Although catch per unit effort decreased over the duration of specific trapping events, suggesting depletion efforts may be reducing the localized population, this trend is was not apparent between years suggesting control measures may be of limited utility over the longer term. For example, there was a drastic increase in population size from 2010 to 2012 despite depletion efforts, but population size has gradually decreased since 2012. However, the relative contribution of removals due to depletion compared to changes in recruitment or survival rates are unknown. Also, average carapace width declined within each trapping event, and from year to year, most notably from 2010 to 2011 suggesting larger, older crabs were effectively removed from the population via trapping. In 2010, 2012 and 2013, catch rates showed a bias towards female crabs (2011 showed a slight male bias); suggesting depletion efforts had affected population structure even when impacts on abundance were less clear. Overall these intensive trapping events have significantly altered the demographics of the green crab population in Pipestem Inlet, but the effects on population size (and hence potential impacts) are less apparent, especially over time. Thus, implications for management options will be discussed.

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A risk analysis of Australia's marine ornamental value chain focusing on biosecurity (diseases and pathogens) concerns

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This presentation shows the outcome of PhD research focusing on the management and risk prevention efforts that Australia is implementing to insure imported marine ornamental animals do not establish a permanent while foothold within Australia. Additionally, consideration and monitoring of these imported organisms as pathways of foreign disease transmission was carried out. Supply/value chain analysis was used to establish an Australian current practices baseline for the marine aquarium trade. This occurred via a survey of the marine ornamental organisms that are available in Australia to identify the species that are non-native. Determination of the marine species status (native, introduced or cryptogenic) occurred using an established protocol. From there, the methods of how these imported species enter the country were investigated and the importers current biosecurity measures are recorded. These imported organisms were then followed to the distributor who sent them to various stores around Australia who then sold them on to individual hobbyists. While the organisms were being followed, they were monitored for potential diseases and parasites that may have been imported with them, or that they may have been exposed to when they were in quarantine or retail facilities.

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Quantifying the risk of fouling of non-indigenous species and spread by recreational boats using fuzzy logic: a case study from Italy

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In the Mediterranean Sea, recreational boating is an underestimated and unregulated vector of non-indigenous species (NIS) introduction and spread. Furthermore, travel and hull maintenance (e.g. cleaning) habits of recreational boaters are largely unknown. In order to quantify the risk of fouling by NIS and consequent spreading of caused by recreational vessels, a two-levels model based on the fuzzy logic approach was developed and tested on a sample of about 200 Italian boaters. The first level of the fuzzy system separately assesses the risk of hull fouling and the risk of spreading of NIS; the second level combines the two risks into an overall index, ranging from 0 (very-low risk) to 100 (very-high risk). The input variables of the model were defined

after a thorough literature survey; they are: type of vessel, frequency of antifouling painting, hull cleaning and hauling out, and time of permanence at sea after an antifouling treatment (fouling risk model); journey length and journey frequency (spread model). Input data were collected by means of questionnaires submitted to boaters face-to-face and online; at the same time, the questionnaires allowed to gather data about the awareness of boat owners on NIS in marine environments. The results of this study showed that 53.9% of the respondents fell into the very-low and low risk categories, and 46.1% into the medium, high and very-high risk categories. Most of them knew about non-indigenous species along the Italian coast, but were not aware that recreational boats can play the role of vectors increasing their dispersal. In a context of prevention and management programs on NIS introduced by recreational vessels, the fuzzy analysis of data obtained by questionnaires proved to be a cost-effective and rapid method to estimate the magnitude of the risk posed by infected boats. Further testing and validation of the proposed model are needed before its routine use in implementing mitigation measures.

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Compliance tools to rapidly detect living microorganisms in ballast water: How do they compare to traditional microscope counts?

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Ballast water has long been recognized as a vector for transporting organisms, and regional, national, and international limits on the concentrations of organisms discharged from ships seek to reduce the risk of bioinvasions. Several commercially available instruments have been developed to rapidly assess ballast water, allowing for shipboard analysis to determine the likelihood that the discharge water complies with the numerical limits. A comprehensive evaluation of such compliance tools is underway. In the initial phase of the project, the first set of compliance tools all measure the variable fluorescence of chlorophyll at the core of their approach. These compliance tools were tested in a series of laboratory trials, which presented the instruments with samples of cultured microalgae along a range of concentrations. Laboratory trials also included samples prepared to simulate a ballast water treatment (hypochlorite) as well as samples prepared with high concentrations of dissolved and particulate matter. Field trialsmeasuring natural assemblages of microorganisms at freshwater, estuarine, and marine locationsare currently underway. These multi-latitudinal field tests include ambient water diluted or concentrated to yield concentrations of organisms below, near, and above the discharge standard for organisms ?10 m and <50 m: 10 living organisms mL-1. For all laboratory and field

trials, the readings of the compliance tools were or will be compared to a standard approach using direct microscope counts of organisms labeled with fluorophores. Trials began in June 2015; the initial results and evaluation of these tools will be reported.

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Assessing the efficacy of management campaigns to reduce the spread of invasive species within transport networks: why targeting only the worst offenders can fail to succeed

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The spread of invasive species within transportation networks is influenced by a range of biological, environmental and anthropogenic factors. The human dimension of transport pathways is an important contributor to variation in vector risks. We modelled the efficacy of management campaigns that aim to reduce the spread of invasive biofouling organisms by improving the antifouling behaviour of a domestic boater population. We examined the influence of three factors on the effectiveness of the campaigns: (1) the proportion of the vessel population that is targeted by the measure, (2) the average amount of change in behaviour made by individual boaters, and (3) the rate of uptake of the measure by the targeted population. The modelled campaigns reduced the spread of an invasive species within a domestic boating network by 0 to 56 % over a 10-year period. The outcome depended strongly on the combination of the three factors examined. Strategies that targeted only the "worst offenders" caused relatively little reduction in spread unless there was very high uptake of the measure and a larger shift from current practice than could reasonably be expected. In comparison, a strategy that utilised a lower threshold for"risky behaviour" and targeted a larger proportion of boaters was three times more effective, even for modest changes in behaviour. Our study shows that vector management can be effective in reducing the spread of a marine invader, but campaigns need to be well designed if they are to be effective. Greatest gains are likely when measures are targeted at critical transition points, where relatively small changes in behaviour lead to a considerable reduction in risk. Combined "carrot and stick" approaches that incorporate incentives for compliance are likely to be most effective at eliciting meaningful levels of change.

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An introduced species meets the local fauna: predatory behavior of the crab Rhithropanopeus harrisii in the Northern Baltic Sea

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Crabs are some of the most successful introduced species among marine organisms, and they can be an important structuring force in marine communities. Recently, the North American white-fingered mud crab, Rhithropanopeus harrisii, has invaded the Northern Baltic Sea. This is an area where no native crab species exist, and the addition of a novel functional species to the low species diversity of the Baltic Sea could have large community-level impacts i.e. modifying biotic interactions and/or altering ecosystem functioning. We examined the predatory behavior of introduced R. harrisii both in the laboratory and field focusing in shallow, hard bottom habitats dominated by the alga Fucus vesiculosus. In the laboratory environment, R. harrisii was an effective predator of littoral grazers, readily consuming both sessile fauna (Mytilus trossulus) and also mobile species such as isopods (Idotea balthica) and gammarid amphipods (Gammarus sp.). When studying the predation of different sized prey items, R. harrisii preyed upon small and medium sized prey of both mobile and sessile species. However, in the field experiment with the native faunal community associated with F. vesiculosus, R. harrisii negatively impacted only the abundance of the snail Theodoxus fluviatilis, possibly through indirect effects. Nevertheless, R. harrisii significantly decreased both the prey species richness and diversity but not the total number of potential prey individuals associated with F. vesiculosus. In conclusion, predatory behavior of this novel crab has the potential to impact the native macroinvertebrate littoral community, but the realized predation pressure in the field is lower than could be expected from laboratory experiments.

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The impacts of an invasive crab (Hemigrapsus sanguineus) on estuarine fouling communities.

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Interactions between anthropogenic disturbances and invasive and native species can shift ecological communities, potentially leading to the successful establishment of additional invasive species. Since 1988, the Asian shore crab (Hemigrapsus sanguineus) has successively invaded estuarine habitats in eastern North America and become highly abundant in the region. H. sanguineus occupies similar habitats to native, panopeid mud crabs (e.g., Panopeus herbstii and Eurypanopeus depressus). These crabs and a variety of fouling organisms (both invasive and native) are often

found in habitats created by man-made substrates (like piers and riprap) and anthropogenic debris in estuaries. In a series of in situ experiments at a closed dock in southwestern Long Island (New York, USA), we documented the impacts of these native and invasive crabs on hard-substrate fouling communities. We found that while the presence of native mud crabs did not significantly influence the succession of fouling communities compared to caged and uncaged controls, the presence of invasive H. sanguineus reduced the biomass of native tunicates (particularly Molgula manhattensis), relative to caged controls. Moreover, the presence of H. sanguineus appeared to favor fouling communities dominated by invasive tunicates (Botrylloides violaceous and Diplosoma listerianum). Altogether, our results suggest that H. sanguineus could help facilitate invasive fouling tunicates in the region, particularly in locations where additional solid substrates have created novel habitats.

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The enlargement of Suez Canal: Bioinvasions and Conservation in the Mediterranean Sea

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Symptoms of complex and fundamental alterations to the Mediterranean Seas ecosystems proliferate, including increases in non indigenous species (NIS). The Suez Canal is the primary corridor for marine bioinvasions into the Mediterranean. There is much concern that the recently inaugurated enlarged New Suez Canal may result in increasing the number of invasions from the Red Sea with a diverse range of injurious effects on biological diversity, ecosystem structure and functioning, together with implications to services it provides for humans. MPAs, created, in part, to conserve natural diversity of native species in their habitats, are meant to offer an ecosystem-based approach to conservation, and provide protection to habitats, biodiversity and ecosystem services, and insurance against environmental or management uncertainty. It is, however, questionable whether MPAs, or even networks of MPAs, provide adequate protection from NIS impact. We examine evidence of the role of MPAs in protecting native biodiversity under high pressure of NIS in the Mediterranean Sea. We propose that MPAs with dense populations of NIS may serve as seed banks inducing spill-over effect to adjacent areas, and as dispersal hubs for secondary dispersal by natural or anthropogenic vectors. Considering the highly connected nature of the sea, a MPA, even a network of MPAs (except for the very large and isolated ones - unfeasible in the Mediterranean Sea) will not be free of NIS, unless embedded in an integrated ecosystem management regime. The success in controlling pathways and vectors is key to achieving the long term objectives of MPAs. If not acted upon with alacrity, MPAs under high propagule pressure of NIS, especially those located along the Levant coast, near ports, marinas, fish and shellfish farms, may serve as invasion hot spots and hubs rather than valued tools for native biodiversity conservation.

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Antipode marine fauna in ports of temperate regions: a pilot survey in north Iberia.

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Ports are gateways for many unwanted stowaways - marine organisms transported by ships worldwide. The origin of non-indigenous organisms in a port expectedly reflects the major marine routes operating in the region. The number and frequency of new arrivals, on the other hand, correspond to the propagule pressure - the number of viable propagules transported from the source ecosystem and released into a recipient ecosystem. Thus, for unintentionally transported organisms, the survival and consequently propagule pressure should negatively correlate with the distance from the donor area. The longest travel a marine organism can accidentally undertake corresponds to Antipode transfers by ships. In this study carried out in North Iberian ports (Cantabrian Sea, Bay of Biscay) we have observed a high proportion of Antipode invertebrate species, and some of them exhibited clear signs of invasiveness. Based on the phylogenetic screening, introductions from multiple source populations (including the native one in Oceania) are suspected. Similar environmental conditions in temperate antipode regions, as well as selection for wider tolerance ranges during the long and ordeal travel, may explain these results. More insight on the propagule survival on the transport vector and possible mechanisms of adaptation is desirable for a better pathway management.

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Combined evidence indicates that Perna indica Kuriakose and Nair 1976 is Perna perna (Linnaeus, 1758) from the Oman region introduced into southern India more than 100 years ago

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The specific status of the brown mussel, Perna indica, in southern India has long been questioned. Its limited geographical distribution within the extensive range of the Asian green mussel, P. viridis, and its morphometric similarity to the African brown mussel, P. perna, have led several authorities to suggest that P. indica is in fact introduced P. perna. Analysis of DNA sequences for nuclear ITS and mitochondrial COI from newly collected mussels from southern India examined in the context of DNA sequence data from GenBank for mussels of the genus Perna reveals that P. indica is indeed P. perna from the Oman region. Literature review indicates that P. indica has been established in southern India for at least 100 years. P. perna forms high density populations that have long been fished by local coastal communities and recently the fishery for P. perna has expanded to markets beyond the coastal area. Eradication of the introduced P. perna is not feasible and is not desirable given its important role as a source of protein and revenue for the local community. Because no monitoring of the range of P. perna in southern India occurs it is not possible to know if this species is increasing its area of distribution, but a qualitative assessment of ongoing range expansion is made based on limited evidence from published reports. The possibility exists for inter-specific hybridisation between P. viridis and P. perna and we recommend that testing commence to check for this. This research highlights the value of a detailed understanding of the genetic structure (four different clades) of the genus Perna, without which the status of P. indica as P. perna from Oman in southern India could not have been made.

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Putative Predators of Carcinus maenas in Eastern Australia

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Following the arrival of non-native species into suitable environments, interactions with native biota can influence non-native species proliferation and spread. The European shore crab, Carcinus maenas, is a global invader for which top-down control by predators has been implicated in limiting range expansion in its North American range. Little is known, however, about predators of this non-native species within its Australian distribution. We conducted quarterly trapping over 2 years in ten Australian estuaries to assess relationships between the abundance of C. maenas

and native predators. Feeding assays between C. maenas and putative predators, identified from negative associations in occurrence, assessed the ability of putative predators to recognise C. maenas as prey. Six taxa were negatively correlated with C. maenas' abundance and capable of eating the non-native crab. These were the blue swimmer crab (Portunus pelagicus), octopods (Octopus spp.), leatherjackets (Monocanthidae), yellowfin bream (Acanthopagrus australis), toadfish (Tetraodontidae) and the eastern fiddler ray (Trygonorrhina fasciata). Octopus spp. were rare in and blue swimmer crabs absent from mangroves; the habitat in which C. maenas was most abundant. A tethering experiment confirmed that Octopus spp. eat C. maenas in the field, with greater rates of mortality of the crab close to than away from the Octopus spp. lairs. Overall, our study indicates that a diverse assemblage of predators may prey upon C. maenas in southeastern Australia. Further studies assessing relative rates of predation by these predators on C. maenas are needed to assess whether they are exerting significant top-down control.

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DNA barcode and metagenetic approaches for monitoring and surveillance of marine invasive species in North American waters, with focus on 2011 Japanese Tsunami Marine Debris-associated species

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New technologies continue to reduce the cost and increase the throughput of genetic analyses, which become efficient alternatives to traditional morphological analysis for identification, monitoring and surveillance of marine invasive species. Using next-generation sequencing of mitochondrial Cytochrome c oxidase subunit I (COI) and nuclear large subunit ribosomal RNA (LSU), we analyzed over 15,000 individual marine invertebrates collected in Californian waters; here we present our analytical pipeline and compare performance of morphological and genetic taxonomic assignments. The Great East Japan Earthquake of March 11, 2011 ejected uncounted tons of debris into the Pacific Ocean that have served as substrate for rafting by coastal Japanese marine organisms. Examination of over 400 tsunami-associated objects has revealed more than 300 species, many not previously known in North America but presenting potential to establish as invasive species. We have created COI and LSU sequence databases of tsunami-related species to assist in molecular identification and surveillance in North American and Hawaiian waters. Conventional sample collection and processing is laborious, slow and costly, and may require considerable taxonomic expertise requiring detailed time-consuming microscopic study of multiple specimens. These factors in concert limit the volume of biomass that can be searched for introduced species. Metagenetics, the next-generation sequencing of

environmental samples with comparison to DNA sequence databases, is a faster and cost-effective alternative. We have sequenced COI and LSU from biomass collected from JTMD objects, plankton, and settling plates collected in North America, and used our introduced species database to create species lists; representative examples are presented here.

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Impact of rafting marine debris and non-indigenous species in the marine protected areas of the Madeira archipelago (NE Atlantic)

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Nowadays, oceans are facing severe pressures resulting from multiple human activities. For example, biological invasions together with habitat destruction are for long considered major causes of biodiversity loss worldwide. In addition, a considerable amount of plastics, metals, rubber, paper, textiles and fishing gear are discarded into the marine environment every day. This makes anthropogenic marine debris (AMD) a major threat to marine life for several reasons: ingestion of plastic debris, entanglement, transport of fouling non-indigenous species (NIS) at a global scale, or acting as vector for pollutants. Island ecosystems are particularly vulnerable to human degradation and ubiquity of plastic debris in ocean waters makes on-debris transport of fouling species a matter of particular concern in marine protected areas (MPAs). On a first stage, we are carrying out monitoring surveys along the coast of Madeira island, Portugal, located in the Northeast Atlantic, to sample marine debris and quantify their capacity to transport hitch-hiking species. Ongoing surveys in collaboration with local nautical companies are confirming AMD as a potential introduction vector for NIS arrivals in Madeira Island. The present study reports preliminary results from a pilot study conducted in a MPA of Madeira Island. We conducted a manipulative field experiment with fouling communities from the MPA of Garajau, at the south coast of Madeira. After an initial 6-month colonization period at the MPA, 10 PVC settling plates were transferred to Funchal marina to be exposed to high levels of NIS propagule pressure. Fouling communities from the MPA, Funchal marina and bare plates were combined in four different PVC plate treatments. By implementing this design, we aim to evaluate how MPA communities will be affected by settlement and/or expansion of NIS. Preliminary results indicate structure and composition of communities from the MPA differed from those collected in the marina.

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All aboard! Marine vessels as a vector for non-indigenous ascidians dispersal in the Mediterranean Sea

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Ascidians (Phylum: Chordata, Sub-phylum: Tunicata) are considered as highly successful invaders, exploiting marine vessels as their main path of introduction. Non-indigenous ascidians are now commonplace in both tropical and temperate waters, with a major impact on natural fauna, aquaculture and marine infrastructures. The main goal of our work is to acquire better understanding of the role of marine vessels in alien ascidians' dispersal in the Mediterranean Sea. We have monitored recreational, commercial and military vessels dry-docked in five Israeli shipyards. To date forty-four marine vessels have been examined. Crafts usage, size, home port, sailing trails, and duration in water were recorded, as well as ascidians detected and their location on the craft (hull, propeller, rudder and sea chest). Samples were taken to the laboratory for morphological and molecular identification. Alien ascidians were detected on 52% of the vessels, two species recorded for the first time in the Israeli waters. Military vessels carried ascidians in 90% of the cases, commercial in 55% and recreational in only 35%. In many cases ascidians were located in the protected area of the sea chest and the propeller, despite constant movement and good maintenance of the vessel. Ship-mediated introductions have been only incidentally documented in the Mediterranean. Moreover, it is the first time that military vessels are examined for this purpose. The current research verifies that marine vessels are a vector for non-indigenous ascidians. It emphasizes the need for specific maintenance and monitoring of vessels and areas with high bio-security risk, e. g. military crafts, the sea chest and the propeller. In addition, the results of our research raise the possibility that marine vessels monitoring will provide an early detection tool which will enable a rapid response once nuisance ascidians are observed.

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Time to rethink invasive species research and management?

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There have been many great advances in our understanding of invasive marine species over the last few decades. There have also been improvements to the way we manage these species, but, with some exceptions, our general approach has not changed greatly over the last 20 years. There are now numerous case studies of marine invasions which provide us with information about vectors, efficacy of surveillance and control, and levels of impact. I will discuss some of what we have learned and question whether we are applying all that knowledge to the way we think about

invasive species management and research.

Presenting author is Tim Glasby tim.glasby@dpi.nsw.gov.au

Modelling present and future habitat suitability of aquatic invasive species in the Canadian Arctic

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Increases in temperature in recent years have made coasts in high-latitude areas more susceptible to changes in climate, hydrography and ecology. This together with increases in Arctic shipping activity resulting from global warming and resource exploitation is expected to increase the risk of aquatic invasive species (AIS) introductions in the region. We examined potential for future AIS incursions as a result of climate change and shipping at a Canadian Arctic regional scale by modelling habitat suitability for a subset of higher risk AIS under current environmental conditions and future climate change scenarios. Eight invaders (Amphibalanus improvisus, Botrylloides violaceus, Caprella mutica, Carcinus maenas, Littorina littorea, Membranipora membranacea, Mya arenaria and Paralithodes camtschaticus) with potential for introduction to the Canadian Arctic were identified. Habitat suitability in this region was modelled using MaxEnt based on global known native and non-native occurrence records and environmental ranges. Modelling under current environmental conditions predicted that the habitat is suitable under current environmental conditions in the Hudson Complex and Beaufort Sea regions of the Canadian Arctic for P. camtschaticus, M. arenaria and L. littorea. Under the future climate change scenario, suitable habitat in the Canadian Arctic was predicted for the complete suite of species modelled. The utilization of these models will help in understanding potential risks of future AIS incursions as a result of climate change and shipping at large spatial scales. These approaches will aid in the identification of high risk regions and species to allow for more focused AIS monitoring and research efforts in response to climate change.

Presenting author is Kimberly Howland kimberly.howland@dfo-mpo.gc.ca

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Developing an aquatic pest risk management system for South Australia: hurdles, breakthroughs and a proposed framework

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It is not difficult to predict that human-mediated aquatic invasions will continue to occur, as long as vessels ply the world's oceans (transporting ballast water and biofouling) and anthropogenic activities continue in marine and freshwater environments. What is challenging, however, is to predict which species will arrive into a donor region, their likely impact and when it is feasible to invest in response or control activities. Determining an appropriate course of management for potential and established aquatic pests requires evaluation of the risks that they pose to the environment and resources, and the feasibility of their control or eradication. Risk management systems have been used to achieve this evaluation and provide a robust and consistent decision making framework. The state government of South Australia through the Department of Primary Industries and Regions SA (PIRSA) is developing a tool to prioritise marine and freshwater pest species for management actions, based on their future risk to the state's waterways and their feasibility of control. The tool is intended to have multiple purposes, from assisting with relative risk prioritization of aquatic pests, to informing response and control effort for existing and emerging aquatic invaders. It is envisaged that the tool will be used by government and other organisations at state and regional levels to guide decision-making for actions to address aquatic pest issues in specified donor (or recipient) regions.

Presenting author is Sonia Gorgula Sonia.gorgula@agriculture.gov.au

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Phylogeography of the invasive marine green macroalga Caulerpa cylindracea Sonder in Australia

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Caulerpa cylindracea is a benthic green marine macroalga that is invasive in the Mediterranean Sea and Canary Islands, usually in association with its notorious invasive congener C. taxifolia. In Australia, C. cylindracea is native in tropical regions and sub-tropical to temperate coastal reefs of Western Australia. In South Australia, a population of this species was discovered in 2001. I assessed if application of the universal chloroplast primers of the rpl16-rps3 region described by Provan et al. (2004) and subsequent sequence analysis show enough variation in Caulerpa cylindracea to differentiate populations, and if the variation in C. cylindracea UCP6 data can identify if natural or anthropogenic dispersal was responsible for the establishment of C. cylindracea in SA. Strong genetic differentiation associated with haplotype fixation between tropical and temperate native populations was detected

(Fst = 0.8, Gst = 0.21). Native temperate populations displayed the highest genetic diversity (Hd = 0.508, ? = 1.43x10-3), followed by the South Australian population (Hd = 0.107, ? = 2.8x10-4) and the tropical populations (Hd = 0.0, ? = 0.0). South Australian populations comprise algae with temperate or tropical haplotypes, but none were detected with both haplotypes, suggesting a single introduction of C. cylindracea with a mixed geographic origin, or multiple introductions from more than one source region. Lack of support for natural dispersal indicates that SA populations of C. cylindracea were introduced by anthropogenic translocation and should be considered invasive.

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Do changes in parasite loads and/or habitat-traits explain higher abundances of a crab in its invaded compared to native range?

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Several mechanisms explain the sometimes higher abundance of invasive species in their non-native compared to native ranges. Prominent among these is an escape from natural enemies (e.g. parasites). In addition, where an invader has specific habitat requirements, increases in habitat-availability may lead to higher abundances in the invaded range. The porcelain crab Petrolisthes elongatus has invaded Tasmania from its native New Zealand; in both the native and invasive ranges it is found under rocks on intertidal rocky shores. In this study we tested the hypotheses that reduced parasite loads and/or changes in habitat attributes explain the higher abundances of Petrolisthes in Tasmania compared to New Zealand. Biogeographic surveys conducted throughout Tasmania and New Zealand confirmed higher abundances of Petrolisthes in its invaded compared to native ranges, but the higher abundances were unrelated to parasite loads and key habitat attributes (amount of rock cover, maximum rock size or number of rocks in quadrats), which did not differ between native and invasive ranges. Instead, higher abundances of Petrolisthes in Tasmania appears related to a high cover of the tube-building serpulid Galeolaria caespitose on the underside of rocks; this species was largely absent from rocks in New Zealand. Overall our results suggest that the presence of a novel habitat in our case a complex tube matrix provided by a native habitat-forming ecosystem engineer may be an important mechanism facilitating a higher abundance of invasive species in their non-native ranges.

Presenting author is Paul Gribben p.gribben@unsw.edu.au

Management failure and the hydra effect: overcompensation following intensive removal of the invasive European green crab

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Well known population dynamics models show that harvesting can paradoxically increase the equilibrium level of a population relative to non-harvest under some conditions. Formally known as overcompensation, this phenomenon of has been called the hydra effect, has been documented in a variety of systems, but it has rarely been documented in the context of reduction of an invasive species and never in a marine system. We documented a dramatic population explosion of the invasive European green crab (Carcinus maenas) in a California estuary following five years of intensive removal efforts. After a >90% removal of the adult population from 2009-2013, we recorded a 30-fold increase in population size in 2014 relative to the previous year, which was 3-fold greater than the pre-removal population size in 2009. We show that this is the result of overcompensation due to the loss of adult control of recruitment following intensive removal efforts. We find rates of size dependent cannibalism, as well as rates of change in maturation rates that are consistent that are consistent with model predictions that would produce these unusual population dynamics. Our results suggest that this unfortunate outcome could occur in other systems with similar demographics and we use these results to create a framework for predicting potential overcompensation in other systems. These results suggest that there are fundamental population dynamics that need to be carefully considered before engaging in invasive species management programs.

Presenting author is Edwin Grosholz tedgrosholz@ucdavis.edu

In-water vessel decontamination: challenges, solutions and lessons from an incursion response on a complex vessel.

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An inspection of a 98m high speed aluminium catamaran with an international voyage history detected a high priority invasive marine species (Amphibalanus improvisus Darwin 1854). These barnacles are not known to be established in Australian waters yet, but were detected on a vessel after it had remained moored for a year in Tasmania's Derwent estuary. Detected specimens were large, sexual mature and are highly likely to have spawned during the preceding year. Since it was not practical to remove the vessel from the water, in-water decontamination was undertaken using a number of techniques. Descaler treatment of internal seawater systems and sea chests was undertaken, while accessible hull areas were cleaned via diver hand-scraping with specimen collection in a purpose built net. Inaccessible niche areas

were treated via a novel partial vessel encapsulation technique incorporating biocidal chemical treatments. Native proxy organisms (Mytilus galloprovincialis and Austrominius modestus) were used as surrogates to determine efficacy of biocidal treatments with grow-out periods used to confirm LC100 values. Legislative and practical challenges of the operation and lessons learnt from trials of readily available biocidal chemicals will be addressed during the presentation.

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Marine Algae arriving on Japanese Tsunami Marine Debris (JTMD) and their invasion threat to the coasts of Oregon and Washington, USA

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Carried across the North Pacific on currents from Japan, recognizable debris from the 2011 Great T?hoku Earthquake and Tsunami has been arriving in Oregon and Washington since June 2012. The debris items are often laden with healthy Japanese marine algae that could recruit to invade NE Pacific shores. On 24 of the most heavily colonized items, we identified 62 marine macroalgal species. Of these species, 32% species were found on only 1 debris item, and only 8% occurred on >10 debris items. More than 80% of the species were fertile bearing mature reproductive structures. The majority of the species were ephemeral (53%) and/or early successional (76%) forms capable of reproducing multiple times during a single year and quickly invading new habitats. More than half of the species on JTMD have already been reported to occur in the NE Pacific. These include widespread species, native species common to both the NW and NE Pacific, and also non-indigenous species by earlier introductions. Currently, we are using multiple genetic markers to analyze the JTMD specimens and determine their relatedness to native populations in the NW and NE Pacific. Our comparative studies are also revealing new cryptic species in populations on both coasts. Well-known global invaders on JTMD include: Undaria pinnatifida, Codium fragile subsp. fragile, Grateloupia turuturu, Antithamnion nipponicum, Polysiphonia morrowii, and Saccharina japonica. New populations of these species have not yet been found in Oregon or Washington. However, if they do recruit and become invasive here, they could dramatically impact the marine environment.

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Detecting non-indigenous species: the importance of biological dispersal trait and collection method

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Early detection of non-indigenous species (NIS) is a critical preliminary step to protecting coastal ecosystems and economies from the spread of harmful organisms. Directly monitoring natural habitat for a host of potentially invasive species along Canada's extensive coastline is unrealistic, so surveillance efforts justifiably focus on ports, harbours and aquaculture facilities, where NIS are most likely to be introduced and then spread to the surrounding region. Larval recruitment plates are rapidly becoming standard tools for detecting biofouling species. This method is cheap, fast and easy; however, there is a risk that recruitment plates may only reflect larval dispersal potential without matching actual species establishment to benthic habitats. Inside a highly invaded marina on Canada's Pacific coast, we assessed the local abundances of 17 established NIS biofouling invertebrates. Using two collection methods, we measured the distribution of each species surrounding this local introduction site. We deployed two seasonal sets of recruitment plates radiating from the marina out to three kilometers, and we used SCUBA dive transects to survey suitable natural habitat in the study area. For NIS with low larval dispersal ability (i.e., Botryllid tunicates), the density of recruits on plates was highest in the direct vicinity of the marina, but the pattern was not common to species with greater dispersal potential (e.g., molluscs, crustaceans). Detection patterns differed between collection methods. Half of the NIS were detected outside of the marina using one or both methods; of these, four species were detected only on plates, and one species, Didemnum vexillum, was never detected on plates yet was abundant along one transect. The difference in species detection between techniques underscores the importance of considering key dispersal traits of NIS and methodological biases when designing surveillance programs.

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The intrinsic parameters of propagule pressure: implications for bioinvasion

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The role of propagule pressure is now recognised as a fundamental driver of species establishment and colonisation. This is particularly evident in terrestrial plants, ungulates, birds and mammals. Propagule pressure effects in marine sub-tidal systems have, however, received little experimental attention. This is perhaps due to the small intractable nature of marine larvae. Some workers have stressed the need to

elucidate dose-response curves between the number of arriving larvae and species colonisation in order to predict marine invasion. I argue that this line of thinking is overly simplistic and fails to account for the intrinsic parameters of propagule pressure. I outline several investigations of propagule pressure effects in the marine subtidal using a combination of experimental and modelling methods. These studies highlight the need to examine not only the numerical size of arriving larvae, but also the rates of arrival and the genetic richness of larval cohorts. These parameters are shown to interact with each and were far better at predicting colonisation/invasion together, rather than in isolation.

Presenting author is Luke Hedge l.hedge@unsw.edu.au

Why hasn't Asian Green Mussel established in Australia?

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Perna viridis (Asian green mussel - AGM) is an invasive marine pest, which can cause significant ecological and economic damage, and there has been significant concern for this species invading Australia. However, apart from one small population that established (and was eradicated) in Cairns in 2001, this species has never established in Australia. Given this, we attempt to answer two key questions; 1. Can AGM establish in Australia? and 2. What is the likelihood of this happening? We answer these questions using a two stage Bayesian model, which incorporates a temperature based species distribution model and the current approach rate for AGM on fouled vessels into Australia (propagule pressure). We show the species distribution model indicates that ports in the northern half of Australia are suitable for AGM, and the propagule pressure for AGM is high with tens to hundreds of fouled vessels entering Australian ports each year. Despite this high propagule pressure, no significant AGM populations have established in Australia. Given this, we show that the probability of establishment in Australia is low and discuss the possible reasons for this.

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Sampling effort and density of live zooplankton in ballast water

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The International Maritime Organization (IMO) has proposed a performance standard known as IMO D-2, establishing a numerical limit for viable zooplankton-sized organisms of <10 organisms m-3. In response, manufacturers have developed technology devices or treatment processes that once applied will make it possible to achieve the performance standard. Because the standard is difficult to assess in the field and no field-based validation procedure has been widely accepted, certification centers are used to evaluate devices or treatments. Certification centres are located in ports worldwide and operate by filling and emptying small model tanks. These microcosm-like testing approaches are simplified models. The common method for live zooplankton assessment involves sampling and visual determination of live and dead organisms using microscopy. Adequate sampling is difficult in the field, because access to all tanks is not possible on working vessels. Here we test a variety of sampling efforts on a real ballast tank, with samples taken post-ballast water exchange on a vessel operating on the North Atlantic Ocean. Our tests encompassed four seasonal trials, with three sampling intakes and five different sample volumes. We hypothesise that low volumes will exhibit larger variation in organisms captured, while large volumes will have greater precision. Our results support this; however, variation is also affected by initial organism density as summer trials exhibited large variation and highest average abundance, while winter samples had low variation and low mean density. Our data was used to generate a model that simulates different levels of sampling effort. It is apparent that the Negative Binomial distribution fit field data better than the Poisson for four of five volumes tested. This study provides a first test of alternative sampling strategies (i.e. single large versus several small samples) for onboard validation processes to meet the IMO D-2 standard.

Presenting author is Marco Hernandez hernand2@uwindsor.ca

Categorising Non-Indigenous Species Impacts: what, why and wherefore

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Non-indigenous species (NIS) concerns typically relate to their ecological, economic and societal impacts. Yet what constitutes a sufficient level of impact to warrant response is increasingly being questioned. Recent debate, largely derived from the community of terrestrial plant ecologists, has questioned the need to manage all

invasions, and suggested that public monies might best be reserved for those species demonstrably invasive. At the core of this discussion is the role that precaution plays in determining level of impact and who should be responsible for developing the underpinning knowledge base for determination. On the one hand, an environmentally-focussed precautionary approach would suggest that unless proven otherwise, all NIS present a level of threat warranting response (equivalent to a guilty until proven innocent approach). On the other hand the argument that we should only pay attention to high profile species with demonstrated impact is equivalent to an innocent until proven guilty approach. In this presentation we discuss the theoretical and practical implications of how and why we classify impacts of NIS and provide examples of both the rationale and processes for implementation, comparing terrestrial versus marine systems.

Presenting author is Chad L Hewitt chewitt@waikato.ac.nz

Range expansion of Asterias amurensis along the east coast of Victoria, Australia, via larval dispersal

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The Northern Pacific seastar (Asterias amurensis) is an introduced marine pest, native to the NW Pacific, and likely to have been first introduced to SE Tasmania from Japan via ballast water in the 1980s, and subsequently to Port Phillip Bay, Victoria from Tasmania in the mid-1990s. Populations of A. amurensis have subsequently been recorded along the east coast of Victoria. It is unclear whether these outbreaks represent a natural range expansion of the population within Victorian waters, facilitated by planktonic larval dispersal, or are the product of physical translocation of larval and adult seastars by anthropogenic vectors. This study used a combination of plankton surveys and hydrodynamic modelling to examine the distribution of A. amurenis larvae in coastal waters between Port Phillip Bay and Port Welshpool in eastern Victoria. The source of A. amurensis populations at Tidal River and San Remo was identified using polymorphic microsatellite markers collected from potential source populations in Port Phillip Bay, SE Tasmania and Japan. A. amurensis larvae were detected in coastal waters between Port Phillip Bay and Wilsons Promontory consistent with hydrodynamic modelling of buoyant particles simulating the behaviour of larvae exported from the bay. New populations along the east coast of Victoria were most closely related to A. amurensis populations in Port Phillip Bay consistent with the hypothesis that outbreaks of A. amurensis originated from larvae exported from the bay, and subsequently dispersed eastwards along the coast by prevailing currents in Bass Strait. The pattern of A. amurensis incursions along the east coast of Victoria is therefore entirely consistent with natural range expansion via larval dispersal; with Port Phillip Bay as the main source of larvae in the region.

Presenting author is Alastair Hirst a.hirst@deakin.edu.au

It's a wrap: operational tools to manage biosecurity risks from fouled vessels and marine infrastructure

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There is no arguing that biosecurity agencies need bigger toolboxes to manage the ever-growing list of marine pests. We also require robust operational guidelines for the tools that we use so that they are applied successfully. In New Zealand, risks posed by vessel biofouling have been successfully managed by a range of tools, including two very simple approaches: (i) smothering biofouling in plastic wrap (encapsulation), sometimes with the addition of chemicals (e.g. acetic acid, chlorine), and (ii) prolonged air exposure. To support the development of operational guidance and protocols for wide use of these approaches, factors influencing their efficacy on adults and early life-stages of temperate biofouling species were explored during laboratory and field based trials. Total mortality took up to 10 d for mature biofouling communities encapsulated in plastic without chemicals. By contrast, biofouling was reduced to around 5% after 1 h and total mortality achieved within 48 h when acetic acid was injected into the encapsulated water. Desiccation tolerance of taxonomic groups varied considerably; the ascidian Ciona spp. died within 24 h under both laboratory and "realistic" settings, whereas hard bodied organisms, such as the bivalves Mytilus galloprovincialis and Crassostrea gigas, were more tolerant to desiccation stress (up to 7 and 16 d in the field, respectively). While it is acknowledged that further testing is required, involving a wider range of taxonomic groups and climatic regimes, we draw upon this study and real-world examples to provide preliminary operational guidance on these two techniques.

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Emergency response to an incursion of Northern Pacific Seastar at Tidal River, Victoria - applied science on the run.

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On 16 May 2012, the Northern Pacific Seastar (Asterias amurensis) was first recorded in Tidal River in Wilsons Promontory National Park, adjacent to Wilsons Promontory Marine National Park, in Victoria, Australia. Marine pests have been identified as one of the biggest threats to natural values in Victorias Marine Protected Areas, while Asterias is considered one of the ten most damaging marine pests in Australia, based on overall environmental and economic impacts.The Asterias incursion was treated as a marine pest emergency triggering the establishment of an Incident

Management Team (IMT) and initiation of a targeted science program designed to inform the response and control effort. The science program involved a large number of partnerships with various government departments and agencies, and Deakin and Melbourne Universities, as well as expert consultants. The program involved a range of approaches and methods including 1) water quality monitoring and sidescan sonar mapping to determine potential Asterias habitat, 2) seastar surveys using a range of methods targeting various stages of the life cycle to assess the extent of the infestation and effectiveness of the control program, 3) assessment of seastar detection rates and modelling of numbers remaining in Tidal River, and 4) plankton tow surveys, hydrodynamic modelling and genetic analysis of seastars to help determine the possible source population. The collective results of the science program were evaluated and integrated into management options by a Technical Advisory Group, which was established when the IMT was scaled down as the response transitioned to a longer term management issue for Parks Victoria. Ultimately the science program formed the basis of a comprehensive evidence based approach to management of the Asterias outbreak in Tidal River. The practical applied science which was used in the response achieved several "firsts" for Victoria in terms of marine pest management.

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Does transport on ship hulls mitigate the risk of establishment in Asian green mussels Perna viridis?

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The Asian green mussel Perna viridis is a successful marine invader in the subtropical and tropical world. Its native range stretches from the Persian Gulf to the western part of Indonesia and comprises coastal areas of, i.a. India, Thailand, Malaysia and the Philippines. However, since the 1970s, when P. viridis started to be introduced for aquaculture purposes, this species further established at several Pacific and Caribbean islands. Ballast water and fouling of ship hulls are also discussed as important vectors for numerous incursions and introductions of this species worldwide. In the Mollucas, within the eastern, non-native range of P. viridis in Indonesia, we found this species fouling the hulls of two passenger ferries. We examined the mussels' body condition index (BCI) in order to obtain information on their physical condition and compared it to the BCIs of mussels from four different coastal habitats in Indonesia. Additionally, we conducted hypoxia tests in the laboratory and compared the survival under 0.5 and 1.0 mg/l dissolved oxygen between mussels collected from the ferry and from two habitats in the western, native range in Indonesia. We found a strong correlation between the BCIs and the hypoxia tolerance, with mussels collected directly from the ferry having the lowest BCIs and hypoxia tolerance. This suggests that the risk of establishment of P. viridis, when transported as hull

fouling, is relatively low, unless environmental conditions in the introduced area are highly preferable for the species, i.e. eutrophic with rich phytoplankton availability. This might explain why past P. viridis introductions for aquaculture purposes often, whereas introductions via hull fouling rarely led to the establishment of the species. We explain this assumption by the lack of food availability on open ocean voyages and discuss its relevance for future prevention and management of P. viridis in the non-indigenous range.

Presenting author is Mareike Huhn mhuhn@geomar.de

Undaria in Northern New Zealand: population ecology, vectors and genetics

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Understanding the potential impacts of the invasive kelp Undaria pinnatifida in the Hauraki Gulf Marine Park, northern New Zealand, is vital to informing conservation and management decisions. This work provides an overview of the population ecology, spread via mussel aquaculture and genetic diversity of Undaria in this region. Monitoring over a three year period confirmed a winter annual population cycle in the Hauraki Gulf, although populations on artificial structures were larger, and more seasonally and reproductively persistent, compared to a native reef population. Surveys throughout the Hauraki Gulf found Undaria to be prolific at all mussel aquaculture sites investigated but relatively rare on adjacent reef sites. Abundance of Undaria on mussel farms was related to the size of mussels present but the spread of Undaria from mussel farms to native reefs did not relate directly to different spatial attributes of farms (wave exposure, turbidity, size of farm, or distance from shore). Mussel farms can act as year-round source populations of Undaria and management strategies must consider that mussel farms of any size or position relative to shore increase the risk of introducing Undaria to native habitats. Genetic analysis confirmed all samples from the Hauraki Gulf (n=32) to be the same strain, further implicating the secondary spread of Undaria via aquaculture transfers.

Presenting author is Kate James kjam015@aucklanduni.ac.nz

Relative effect of invasions on native species richness and community structure across habitats in in a highly invaded estuary

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San Francisco Bay is known worldwide as a highly invaded estuary, where the invasions have increased dramatically in recent years. The majority of studies have reported non-native species on hard-substrates, including artificial structures at docks and marinas, but less is known about the adjacent habitats. The goal of this study is to efficiently characterize native and non-native species diversity, species composition and their distribution in order to test for differences across different habitats. We hypothesize that not all habitats are equally susceptible to invasions. We report initial results from a multiple-year survey of the hard-bottoms and soft-sediment invertebrate communities in high salinity (8 sites) and low salinity (5 sites) areas of the Bay. We sampled benthic sessile communities on PVC panel plates and macrofauna using sediment grabs. All the individuals were taxonomically identified and vouchers for DNA identification were also taken. Of 154 and 87 morphotypes were recorded on hard-substrates and soft-sediments, respectively, 18 species were common to both habitats, mostly from the phylum of Arthropoda and Amphipoda. Both communities were dominated numerically by non-native species. Non-native species comprised a higher proportion of total species richness in the hard-bottom than soft-sediment community in our surveys. We will explore the relative strength, history, and ecological significance of invasions in these habitats for San Francisco Bay and more broadly.

Presenting author is Haizea Jimenez jimenezh@si.edu

The invasion mudcrab enforces a major shift in a rocky littoral invertebrate community of the Baltic Sea

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In rocky littoral communities, intense herbivory allows for the occurrence of trophic cascades where higher trophic levels influence producer communities. Invasive predators can be especially effective in imposing trophic cascades. The North American mudcrab Rhithropanopeus harrisii is a recent invader in the Baltic Sea, with an expanding distribution range. Here, we document the effects of mudcrabs on the native invertebrate community associated with the key foundation species Fucus vesiculosus. During the initial three years of invasion, mudcrab abundance in F. vesiculosus increased from 2 % to about 25 %. Simultaneously, the invertebrate community underwent a major transition: species richness and diversity dropped as a consequence of decreasing abundance and the loss of certain taxa. The abundance

of gastropods decreased by 99 % and that of crustaceans by 75 %, while chironomids completely disappeared. Consequently, the community dominated earlier by herbivorous and periphyton-grazing gastropods and crustaceans shifted to a mussel-dominated community with overall low abundances of invertebrates. We suggest that this shift in the invertebrate community may have far reaching consequences on ecosystem functioning. These arise through changes in the strength of producer - herbivore interaction, caused by mud crab predation on the dominating grazer taxa. This interaction is a major determinant of ecological function of ecosystems, i.e. productivity and energy flow to higher trophic levels. Therefore, the decrease in herbivory can be expected to have a major structuring role in producer communities of the rocky littoral macroalgal assemblages.

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Are small boats local vectors of dispersal of encrusting macrofauna?

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Once introduced, species are then subject to secondary (local or regional) dispersal or transport. An important vector of secondary transport are small fishing and recreational boats that have hulls encrusted with both native and introduced species. Differential transport may occur, as a consequence of resistance of the species to both, drag forces generated by different velocities to which they will be subjected during transport, and dessication. The first experiment comprised experimental plates that were colonized during four months, after which they were placed on the hull of a recreational boat and dragged for 20 min at each of three speeds (9, 27 and 36 km/h). A second experiment tested the effect of desiccation (in southern Brazil it is a common practice to haul boats out of the water daily). Again, plates that had been colonized during four months were then taken from the water and exposed to air for 3 - 132 hours. After each trial, plates were examined for the presence of living organisms. Thirty five taxa remained alive after treatments, including known introduced species in south Brazil: the barnacles Amphibalanus amphitrite, Amphibalanus reticulatus and the octocoral Stragulum bicolor. The drag experiment demonstrated that all species were resistant to the speeds tested. In the desiccation experiment, most species survived for more than six hours of air exposure (= one tide cycle). Our results support the prediction that small boats can be important vectors and can carry species over regional scales under typical conditions to which they are commonly exposed. Additionally, simply removing the boats from the water will not be an effective barrier to transport unless it is accompanied by active hull cleaning.

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First appearance of the invasive jellyfish, Cassiopea, from New South Wales, Australia

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The sudden, recent appearance of medusae of the invasive jellyfish Cassiopea is reported from two coastal lakes on the central east coast of New South Wales: Wallis Lake (3211'45"S 15229'56"E, during 2009 and again in 2014 and 2015) and Lake Illawarra (34 31'36"S 15051'53"E, during 2013). These instances represent new records for Australia extending the known east coast distribution of the genus southwards by 600 to 900 kilometres. The taxonomy of the specimens, ecological and economic significance, and possible mechanisms leading to these occurrences is discussed.

Presenting author is Shane Ahyong stephen.keable@austmus.gov.au

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Introduced species risks of marine traffic arriving to the Galapagos Marine Reserve (GMR)

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The Galapagos Marine Reserve (GMR) is located in the Eastern Tropical Pacific (ETP) 1,000 km off the coast of Ecuador and 1,500 km from the Panama Canal. Since the Galapagos Archipelago was discovered in 1535, the islands have received vessels from around the world and as tourism, trade and transport increases due to global growth, the amount of marine traffic that enters the GMR has increased as well. Cargo ships, private yachts, illegal fishing boats, research vessels and patrol boats are the main example of the types of vessels that enter the GMR on a weekly, monthly or yearly basis. To add to this there is a large amount of marine traffic that navigates on a daily basis within the limits of the GMR. This paper aims to present the risk of human mediated transport of non-native species due to the increase of marine traffic towards and within the GMR and discuss management strategies to minimize impact on the native biodiversity. A dataset of all continental Ecuadorian and foreign vessels was used to produce introduced species lists of all possible non-native species that could be transported into the GMR. A hub and spoke model was then used to derive a measure of risk posed by local marine traffic transporting non-native species from primary introduction nodes to the main ports of the archipelago.

Presenting author is Marnie Campbell inti.keith@fcdarwin.org.ec

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Is marine debris a dispersal vector for Sabella spallanzanii?

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Species have the ability to reach new habitats via rafting on marine debris that can be dispersed with the currents. Of concern is that there has been a significant increase in plastic pollution in the marine environment, and plastics are extremely buoyant and slow to degrade. When coupled with the fact that non-indigenous marine species (NIMS) have a propensity to foul artificial substrates, plastics become an ideal mechanism that can facilitate long-distance dispersal of organisms. The European fanworm, Sabella spallanzanii, was first discovered in New Zealand in 2008. This species has slowly spread to a number of locations via jump dispersals. Unfortunately, Sabella fouls aquaculture facilities with the potential of poor quarantine practice aiding the further spread of this organism. Of concern is that many aquaculture leases create plastic debris that ends up on local beaches and these facilities are within high value tourist locations, such as the Coromandel Peninsular. Thus, there is a potential threat that Sabella may spread from aquaculture facilities to the rocky rip-rap along the western Coromandel coastline. This project will examine the secondary spread of Sabella from marine farms to the natural coastline (rocky rip-rap) via rafting on marine debris that originates from aquaculture facilities. The standing crop of marine debris on local beaches will be determined. The level of fouling on natural and artificial debris at these beaches will then be examined to establish if Sabella has a propensity to foul one type of debris material over others.

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Understanding invasive polychaetes: integrative taxonomy to the rescue

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According to a recent study, 292 polychaete species from 164 genera and 39 families have been transported around the world with human-mediated assistance. Alien species can be grouped into three categories: established (non-natives with self-maintaining populations), questionable (with uncertain taxonomic status), and cryptogenic (with no definite evidence of their native or introduced status). Invasive species are established aliens that expand their ranges impacting invaded habitats. Here we discuss studies revealing taxonomic uncertainties for several reportedly invasive polychaetes. Sabella spallanzanii (Sabellidae) from the Mediterranean is an established alien in Australia with demonstrated ecological impact. Serpulids Hydroides ezoensis from Japan and H. diramphus from the Caribbean are established aliens having wide distribution being ship-transported. Hydroides elegans described from Sydney is a ship-transported serpulid established in subtropical areas

world-wide, but its Australian origin is doubtful (= cryptogenic species). Hydroides brachyacanthus described from Mexico and reported from many localities is a species complex. In Australia this questionable group includes two species morphologically and genetically distinct from H. brachyacanthus. Hydroides dianthus distributed from Maine to Florida can cope with considerable temperature ranges, unlike most Hydroides species. It has been reported as introduced to Europe and Japan, but includes two genetically distinct groups within its native range. Although known as "Australian tubeworm", Ficopomatus enigmaticus is a cryptogenic reef-forming estuarine species. Our test for genetic patterns suggested the presence of three groups with overlapping ranges across their range in Australia. The examples indicate that integrative molecular and morphological taxonomic studies are needed before the origin and invasion pathways of polychaetes can be resolved, and expensive eradication programs are implemented.

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Marine Biosecurity in the Bay of Plenty, New Zealand

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The marine environment in the Bay of Plenty is highly valued for numerous reasons including economic values, cultural values, biodiversity, tourism, recreation, harvesting of seafood, aquaculture, natural character and amenity. In 2013, a single Mediterranean fan worm (Sabella spallanzanii) was detected in Tauranga Harbour Following that detection, a systematic surveillance operation was developed in collaboration with key stakeholders. So far 3427 boats, 36 kms of marina walkway pontoons , 246 swing moorings , 381 wharf piles, 4.6 kms of marina rock walls and 2.3 kms of beach have been searched. This has resulted in the discovery of infestations at Bridge marina (17), Sulphur point marina (11) and moored boats (5). Styela clava was also discovered on some vessels This surveillance, and the management of marine pests in the region, has been based on a collaborative and strategic approach and the development of the Marine Biosecurity Management Plan for the Bay of Plenty. BOPRC, iwi, industry, MPI and other stakeholders work together towards common environmental, cultural, social and economic goals. To support the management plan, BOPRC has developed a Small Scale Management Plan (SSMP) under section 100v of the Biosecurity Act. This was required to give BOPRC powers to manage any new incursions as no marine pests are listed in the current Regional Pest Management Plan. This is the first time a SSMP has been developed in New Zealand.

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Strategic plasticity: Reproductive periodicity and gamete development of an invasive fanworm, Sabella spallanzanii

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The dispersal and establishment of invasive species in new environments can be facilitated by reproductive strategies that give species a competitive edge. Favourable strategies include early maturity, high reproductive capacity and flexibility in reproductive schedules. Understanding the capacity for these reproductive strategies to facilitate successful invasion could therefore provide crucial insight for managers seeking to design eradication programs. The European fanworm, Sabella spallanzanii, has established invasive populations along the southern coast of Australia. Gamete development and reproductive periodicity of this worm were investigated in two locations in Gulf St Vincent, South Australia over a 1 year period. Individuals were sampled monthly and dissected for histological analysis. Worms appeared to be reproductively mature after reaching 60 - 90mm body length (thorax and abdomen). Early results suggest that males and females spawned synchronously between December and March. S. spallanzanii body length and egg size from this population appear to be smaller than conspecifics in its native range and other invasive locations. Differences in the reproductive strategies of invasive species between native and invasive locations have previously been documented. This study suggests the potential for local reproductive plasticity in S. spallanzanii between different invasive locations. Information about the local spawning periodicity and size at reproductive maturity will be crucial for determining the optimum timing of control efforts for S. spallanzanii in South Australia.

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Understanding biofouling assemblages using next generation sequencing

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Marine invasive species (MIS) can be harmful to endemic biodiversity and habitats which may lead to economic and environmental impacts as a consequence. One of the main vectors of MIS is by biofouling on commercial shipping. Globalisation has increased the rate of shipping thus leading to higher spread of MIS, including biofouling species. Early detection allows proper management to implement suitable mitigation measures while can potentially result in eradication. The advent of DNA-based techniques has facilitated improved on-going surveillance of MIS, but

approaches for the analysis of biofouling and their MIS are lacking. DNA metabarcoding is a novel, effective approach that allows better assessment of the biodiversity. We will discuss field trials of larval settlement plates in both Gippsland Lakes, Victoria and South Australia where we will utilise Illumina Miseq to metabarcode biofouling communities. The development of these approaches will ultimately lead to a better understanding of the biofouling ecology by providing detailed analysis of the interactions between endemic and native species, and the environmental factors that contribute to invasion.

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Does epibiosis facilitate the invasion success of marine benthic invertebrates?

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Within the marine environment, any bare solid substrate is quickly colonised making free space for settlement a limited resource. Consequently, the living surfaces of many species are subjected to the constant threat from overgrowth and/or epibiosis. Epibiosis can be deemed to be a form of direct competition for many benthic encrusting organisms. Theoretically, a reduction in a regulating factor such as epibiosis would infer an advantage to a species. Conversely epibiosis presents a mechanism that eliminates the need to find bare space while increasing overgrowth success by settling on competitors. The pattern of epibiosis was examined within naturally assembled communities to understand native:NIS epibiotic interactions. Recruitment phenology was contrasted with settlement preferences and epibiotic pressures of both native and NIS in communities of varying ages in northern Tasmania. Native species were found to have more interactions than expected with natives than with NIS. In contrast, NIS demonstrated no significant preferences between NIS, native and bare substrates: Thus, they see all space as available, compared to native species that show a preference for type of space to settle upon. Building on this, ex situ manipulative experiments examined pairwise interactions controlling for propagule pressure, propagule arrival time and environmental factors. Experimental outcomes demonstrate that native species experience greater epibiotic settlement by both native and NIS, whereas NIS were relatively free of epibiotic load. Since marine assemblages are generally space limited and subjected to intense competition, colonisation of other organisms may be the only successful strategy for survival. Yet, this comes at a cost to the basibiont.

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Alien caridean shrimps along the Mediterranean coast of Israel- introduction through the Suez Canal or aquarium release?

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The infraorder Caridea, is the second most species-rich group within the Decapoda. It comprises 35 families and at least 3,400 known species. To date, 40 caridean species have been listed from the Mediterranean coast of Israel. In order to investigate the diversity and spatial distribution of the caridean species of Israel, field surveys were conducted, in addition to observation of bottom trawls catches, incorporation of diver's involvement and a meticulous literature search. In addition, the entire Caridea collection at The Steinhardt Museum of Natural History and National Research Center, Tel Aviv University was investigated and identified. The current inventory list reveals that there are 11 alien caridean species along the Mediterranean coast of Israel. Two most recent introductions are that of Nikoides sibogae and the marble shrimp, Saron marmoratus. N. sibogae had been collected during scientific survey that was conducted in 2012 along the Mediterranean coast of Israel, and is the first Indo-Pacific representative of the family Processidae. A single male of S. marmoratus was reported for the first time in the northern Mediterranean coast of Israel in July 2013.This species is widely distributed in the Indo-Pacific Ocean and is one of the most common shrimp in the Red-Sea, particularly in the Gulf of Aqaba. Due to its body colors it is also a very popular shrimp among aquarists. After only 24 months since its first report, field observations revealed that the marble shrimp can be found in large numbers along the Mediterranean coast of Israel. Its potential influence on the local fauna is currently investigated experimentally, in addition to the incorporation of molecular tools which will assist in ascertaining its potential source of introduction. Such knowledge is key to our understanding of marine bioinvasion in general, and of caridean shrimp in the Mediterranean Sea in particular.

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Monitoring programmes using larval recruitment plates can be tailored for even earlier detection of aquatic invasive species

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In Canada, managers use larval recruitment plates to detect and monitor fouling aquatic invasive species (AIS). As part of the current surveillance programme in eastern Canada, plates are typically submerged in the water for periods between two and six months between June and October. However, this sampling strategy may not be the most efficient one. Although used for early detection of AIS, several

months may have elapsed since the introduction of new AIS before plate deployment, plate retrieval and species identification. We aim to determine the minimal duration of sampling with plates to detect the presence of targeted marine fouling species (e.g., ascidians, bryozoans). Six deployment periods (duration: 1, 2, 4, 8, 16, and 32 days) were compared in a marina in Nova Scotia, Canada. For 32 consecutive days in July and August (seasonal onset of ascidian recruitment), a new set of plates (n=6 replicates per treatment) was deployed every day. We found that the recruitment patterns on plates were taxon-specific (e.g., bryozoans exhibited pulsed recruitment), which may be attributed to pre-settlement processes (i.e., larval behaviour) and post-settlement processes (i.e., juvenile mortality). Yet, 1- and 2-day sampling durations were not able to uniformly detect targeted fouling ascidian and bryozoan species. These findings suggest that the optimal minimum duration for these fouling species is between 4 and 8 days. This information will help meet the challenges of early detection of AIS by developing efficient sampling programmes to reduce the lag time from AIS introduction to detection.

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Controlling Carcinus maenas in South Africa, is eradication feasible or desirable?

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The European shore crab, Carcinus maenas, is a global invader with ecological impacts across most of its invasive range. It was first detected in South Africa in 1983 and is currently confined to two large sub-tidal harbour populations, approximately 30 km apart. In 2014, a control programme was initiated in the smaller harbour (Hout Bay), to see if extirpation was possible. Based on a mark-recapture study, the population was initially estimated to support 6,700 mature individuals. Several capture methods (baited and non-baited trapping as well as diver collection) were trialled, with traps baited with sardines and soaked for 2 hours each, found to be the most appropriate and cost-effective method. The South African government provided funding for 12 months of intensive control (219 trapping days), during which over 36,200 crabs were captured. The maximum catch rate was achieved in the first few weeks of the programme with 1,079 crabs per day. Catches declined over the remainder of the programme with the minimum catch recorded in the final week (13 crabs per day). The sex ratio of the trapped population was skewed with significantly more females than males captured over the programme duration. The control programme was terminated after 12 months. The population was then monitored for a further six months at a reduced intensity. We suspect eradication would require concerted efforts in both harbours, but without strong evidence that the crabs pose a risk to the South African environment, it is hard to justify a large-scale costly exercise that (without knowledge of why control failed in Hout Bay) has a

high chance of failure. This study was the first attempt at controlling a marine invasive species on the African continent and provides important insight for the control of other marine species.

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Determinants of rapid response success for alien invasive species in aquatic ecosystems

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Alien invasive species (AIS) have received much attention for their harmful effects on health, ecology and the global economy. In response to this threat, many countries have adopted the Convention on Biological Diversity, which requires prevention or eradication of AIS. The best management approach is prevention, however when this fails and AIS establish, it is imperative that cost-efficient, rapid-response (RR) countermeasures be available. We performed a meta-analysis of case studies involving successful and failed RR to AIS in temperate aquatic ecosystems. We examined eight variables including ecosystem type (freshwater vs. marine), method type (chemical vs. mechanical), number of methods (multiple vs. single), taxonomy (animal vs. plant), population abundance (number of organisms), infestation extent (surface area of infestation), habitat size (surface area of management site), and project duration (length of project in number of months). Eradication success was significantly greater for plant (89%) versus animal AIS (64%) while suppression of AIS was most successful for projects using chemical versus mechanical methods and when conducted in small habitats. Managers should expect that taxonomy will be highly influential to the success of eradication-based RR, while both method type and management surface area influence suppression outcomes.

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Trial of an early warning system for marine pests in the Banda Islands, Moluccas, Indonesia

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The transport and establishment of non-indigenous species (NIS) is regarded as one of the greatest threats to the world's biodiversity, with significant environmental, economic, social and health impacts worldwide. Within the marine environment, shipping is recognized as the most important and prevalent transport vector of NIS, across international and domestic borders at ever increasing rates. By surveying fouling communities on hard substrates in Banda Naira, we will develop a baseline dataset essential to identify any NIS in subsequent surveys/analysis using the

Western Australia early-warning system model. The fieldwork will be divided into 4 surveys within 12 months and settlement arrays will be deployed and every 3 months (January, May and August 2016). Species identification will be conducted morphologically and molecularly. Data on commercial and recreational ship traffic will be collected. to determine high-risk vessel types and routes. The recreational vessel questionnaire will be provided to all sailing boats coming to Banda Naira (July/August 2016), which is the main sailing season from Australia. This model biosecurity project and information is expected to later be applied for establishing similar biosecurity approaches in other ports of the Indonesian archipelago. We believe the monitoring of NIS in the Banda Islands to represent an important step to protect marine biodiversity, secure local communities livelihoods and prevent the transport and establishment of potential pest species to other Indonesian regions and to Australia.

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First Record of an Invasive Encrusting Bryozoan: Watersipora subtorquata (d'Orbigny, 1852) in Colombo Port, Sri Lanka.

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Investigations on marine biological invasions have become an important field of study due to its enormous effect on ecology, economy and human health. Fouling on ship hulls considered to be one of the most common pathways of introducing non indigenous species (NIS) across the oceans.The present study was conducted in eight sampling locations within Colombo Port. Biofouling aggregates were collected using artificial settlement plates (10cm x 10cm) submerged in four depths. The first set was 1m below the water surface and others settled in 1m increments. Monthly samples were collected from October 2014 to July 2015 from both replacing and permanently settled collectors. Species were identified microscopically, observing their fine morphological features using stereomicroscopes. Eight morphologically dissimilar encrusting bryozoans were recorded. The most promising finding is the first record of highly invasive encrusting bryozoan, Watersipora subtorquata. They were recorded in two of the sampling locations. In New Pilot Station (NPS), they were recorded at 2m depth covering 12.5% of the panel area and Bandaranayake Quay (BQ) at 1m depth covering 2.19% of the panel area. W. Subtorquata is an encrusting foliaceous colonial bryozoans affiliated to the family Watersiporidae belong to the suborder Ascophora. The colony is dark or black with bright orange outer growing edge. The colony consists with comparatively large and distinct zooecia with numerous pores and distinct mushroom shaped operculum. This species is well recognized as highly invasive in many parts of the world and they facilitate the dispersion of other invasive organisms via providing non toxic substrates to settle in, compete with native bryozoans and other fouling organisms subsequently altering

native fouling community structure.

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Different types of uncertainty affect the non-indigenous status of marine amphipods

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Global inventories of marine alien species focussing on single taxa are relevant to science and management since they facilitate horizon scanning initiatives and monitoring programmes. With the aim of developing a global inventory of marine amphipods introduced by human activities, we cross-checked regional inventories of marine alien species and faunistic accounts on amphipods from the different oceanic regions of the world. This work allowed us to identify species whose disjunct distributions have originated from human-mediated introductions from cases of discontinuous distribution resulting from taxonomic intricacies (complex distributions of several different species belonging to a group of cryptic species), and cases of insufficient knowledge regarding their native origin. The majority of the cases examined revealed sources of uncertainty due to species identity, native origin and other problems related to the alien status of the species. We identified four main types of uncertain records: (1) species indicated as alien in the literature but with uncertain identity, e.g. Stenothoe gallensis Walker, 1904; (2) species indicated as alien in the literature but with uncertain alien status, e.g. Ampelisca cavicoxa Reid, 1951; (3) possible pseudo-indigenous species (species perceived as native in a region where they are non-indigenous), whose identity status requires confirmation, e.g. Ampithoe ramondi Audouin, 1826; (4) possible pseudo-indigenous species, whose alien status requires confirmation, e.g. Caprella danilevskii Czerniavskii, 1868. The high number of problematic records impairs an accurate assessment of the global invasion status of amphipods. Therefore, we acknowledge the usefulness of listing such uncertain records in order to rapidly highlight species or introduction events that require further investigation (at taxonomic, molecular, biogeographic level) and revise the status of alien species in regional accounts.

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Development of Management Strategies for the Invasive Seaweed Sargassum horneri

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Sargassum horneri is a large brown alga native to shallow reefs of eastern Asia. It was first discovered in the eastern Pacific in Long Beach Harbor, California in 2003, and has since spread aggressively throughout southern California, USA, and Baja California, Mexico. Because S. horneri can be locally very abundant (>100 adults per meter squared) and highly persistent, its continued expansion in the eastern Pacific poses a major threat to the sustainability of marine ecosystems in this region. Determining the efficacy and feasibility of removal of S. horneri is critical to developing a strategy to manage its spread and impact. To inform removal efforts, we investigated the phenology of this annual seaweed and the effect of removal of adults from 60 square meter areas on subsequent recruitment. The vast majority of reproduction occurred in the spring, and the removal of adults in late winter reduced recruitment in the next generation by 30%. Based on the significant reduction in recruitment we observed, removing S. horneri for several consecutive years could substantially reduce populations. Such efforts should be targeted in places such as the leading edge of the invasion or areas of special biological or cultural significance.

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Examination of the perceived versus likely establishment risk of Perna viridis in Australia

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The Asian green mussel Perna viridis is a high-risk listed pest species in Australia and in many other parts of the world. This listing is partly based on statements in the literature of the species wide temperature and salinity tolerances. Because of these wide tolerances this species is perceived as capable of establishing anywhere around Australia. Yet, despite these tolerances and the fact that this species is regularly detected as fouling on international vessels, to date there has only been one establishment event in Australia. This talk explores the perceived versus likely risk of establishment posed by this species. Further it seeks to challenge the precautionary perceptions associated with high-risk species.

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The Role of Marine Science in Supporting the New Canadian Aquatic Invasive Species Regulations

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Aquatic Invasive Species Regulations under the Canadian Fisheries Act came into effect 17 June 2015 with the following objectives: 1) to prevent the introduction and spread of aquatic invasive species (AIS) in Canadian waters; 2) to avoid costs associated with the establishment of AIS; 3) to support management activities to control the spread of AIS once introduced into Canada; and 4) to fill regulatory gaps, and ensure a consistent national strategy for the management of AIS. The Science branch of Fisheries and Oceans Canada (DFO) provided advice during the development of these regulations and will provide ongoing scientific support during their implementation. Monitoring and research programs provide information on distribution, abundance, ecology and impacts of marine AIS and generate science advice used in early detection, rapid response, risk assessments, and management decisions. A Canadian Marine Invasive Screening Tool (CMIST) has been developed to screen and set priorities for higher risk species and is being adapted for web access. A national marine recreational boating vector risk assessment is being conducted to determine the role of this vector in AIS introduction and spread. This talk will briefly discuss the new regulations and focus on the role of science in supporting implementation of this regulation in the marine environment.

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Management actions for non-indigenous Bryozoa

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In marine environment, prevention of introductions is considered the most effective management strategy for potential invasions from non-indigenous species. Nevertheless, with the continued movement of craft, people, and goods, even with regulation of vectors, some incursions are inevitable. Eradication, the empirical following option, is technically and financially difficult. Control of population levels, that is, keeping the species at an abundance level which is below a density-dependent adverse effect, may be a more attainable goal for the management of marine invasive bryozoan species. For such, the knowledge of life history traits is determinant for the success of control actions. Therefore, the reproductive cycle of three fouling bryozoan at the Azores Archipelago (islands in the middle of the North Atlantic Ocean) was

accessed. The study revealed that although the release of larvae can occur throughout the entire year, its intensity and the success of local attachment/development of ancestrula, are not even throughout the year. In the light of these findings, it is possible to determine the best time of the year to apply field actions aimed to control invasive population's density levels, optimizing the always scarce financial resources for marine management.

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New Zealand local government prevention and response strategies in the battle against Mediterranean fanworm (Sabella spallanzanii)

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The marine pest Mediterranean Fanworm (Sabella spallanzanii) in was discovered in Whangarei Harbour, Northland, New Zealand in 2012. As the Regional authority Northland Regional Council (NRC) has been initiating innovative tools and approaches to slow the spread of this pest into and around our region. Of the 16 regional authorities in New Zealand only three have rules in their Regional Pest Management Strategies in regards to invasive marine organisms. Therefore most Regional councils don't have legal powers and staff or monetary resources to deal with marine pest incursions. Recently NRC has contracted the development of a set of Interim measures to deal with marine invasive organisms to be made available to Regional Councils. These outline easy, sustainable and effective tools for Regional Authorities to implement immediately. I will discuss a number of the interim measures available and how NRC has implemented these. I will also cover the results and relative costs of the interim measures we have used and the results of this work.

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The mussel Mytilus galloprovincialis on Japanese Tsunami Marine Debris: a potential model species to characterize a novel transport vector

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An unexpected outcome of the tragic 2011 T?hoku Earthquake and Tsunami was that >300 Japanese coastal species (JCS) were transported >5000 km on debris items that made landfall in the central and northwest Pacific Ocean. The invasive mussel Mytilus galloprovincialis was remarkably common, arriving on >60% of the items classified as Japanese Tsunami Marine Debris (JTMD). We used this coastal

filter-feeding species as a model to explore size, reproduction, growth, and dispersal patterns of JTMD biota. Based on 20 JTMD items (2 docks, 1 pallet, 1 tote, and 16 skiffs) collected from 2012 to 2014, the mean length of Mytilus increased by 10 to 19 mm/year on items arriving in the northwest Pacific but not in Hawaii. The occurrence of reproductive Mytilus also varied geographically; <27% of individuals that arrived in Hawai'i had mature or maturing gametes whereas >60% of the individuals collected in the northwest Pacific were reproductive. Based on shell structure and chemistry, Mytilus grew an average of 0.06 mm/day during transit and displayed variable shell edge growth (1 to 23 mm) during coastal residency, identified by elevated shell barium:calcium. When comparing across similar items (skiffs), there was a weak negative relationship between JCS richness and date of arrival (r = -0.31) and a positive relationship between JCS richness and total mussel growth (r = 0.63), with the latter largely driven by low growth and species richness in Hawaii. Interestingly, for JTMD skiffs that landed in the northwest Pacific, JCS richness displayed a stronger relationship with date of arrival (r = -0.55), and there was a significant, negative relationship between JCS richness and mussel growth in coastal waters (r = -0.82), possibly due to competition. Overall, detailed examination of Mytilus can provide novel insights on JTMD as a transport vector.

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Biosecurity planning for the marine renewable energy industry

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Wave and tidal stream energy is a rapidly developing industry with the first commercial arrays set to be operational in the UK by 2020. In the early stages of this industry it is prudent to assess the biosecurity implications and suggest management solutions that can be incorporated into device design and operation procedures. The existence of national and international regulations in place to minimise the impact of non-native species (NNS) also means that the implementation of biosecurity measures is likely to be a governmental requirement. In this project, we identified and prioritised NNS pathways in the industry, assessed the capabilities for NNS to establish on renewable energy devices, and tested possible mitigation measures for preventing NNS transfer and establishment. Pathways and planned biofouling management were evaluated through questionnaire surveys of device developers, and risk categories were assigned to the identified activities. High risk activities included: the use of international vessels (including slow-moving barges) for installation purposes, and the wet-towing of devices and device components across regional or national boundaries e.g. from fabrication location to energy extraction site. Wet-storage and maintenance of devices in harbours was also highlighted as the most likely point in which NNS will colonise devices. Experiments investigating the

effect of paint types on biofouling assemblages indicated that biocidal antifouling and fouling-release paint had significantly less NNS settlement, and the non-native bryozoan Schizoporella japonica was found at a lower density on lighter coloured anti-corrosive paints. Seasonal studies also revealed no settlement of NNS in winter, indicating a possible risk-free window for device maintenance and storage. Based on the findings of this project and literature review, we outline reasonable biosecurity measures that will minimise the risk of NNS transfer and establishment in the marine renewable industry.

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Management of the alien invasive algae, Kappaphycus/Euchema spp in Kaneohe Bay, Oahu through the use of mechanical removal and bio-control efforts

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Kaneohe Bay, Oahu is the largest sheltered body of water in the Main Hawaiian Islands consisting of fringing, patch and barrier reefs. Currently Kaneohe Bay is struggling with multiple anthropogenic stressors including land based pollution, fishing pressure and the introduction of alien species. One group of alien algae in particular, the Kappaphycus/Eucheuma spp. complex (K/E), poses a serious threat to coral reefs. This species complex can invade coral habitat and form large mats that overgrow, smother and kill reef-building corals. The negative impacts of invasive algae on coral reefs in Hawaii have been well documented, however relatively few management techniques have been developed to protect and restore impacted coral reefs. The State of Hawaii's, Division of Aquatic Resources (DAR) and partners have developed a novel approaches to manage invasive algae. The partnership developed an underwater vacuum system nicknamed the "The Supersucker", that is capable of removing large quantities of alien invasive algae. Following mechanical removal, a biocontrol agent, the collector sea urchin (Tripnuestes gratilla) was outplanted to the reef. Collector sea urchins were spawned and reared in an off-site hatchery and released at 3-5 months to graze any remaining algae fragments and controls re-growth. Three large patch reefs (5.2 hectares in area) in Kaneohe Bay received hatchery raised sea urchins at a density of 1-4/m2 following mechanical removal. These reefs were monitored to follow regrowth of invasive algae, settlement of coral recruits, fish diversity/abundance, and population dynamics of added sea urchins. Mechanical removal in combination with out-planting of the native sea urchin, Tripneustes gratilla, is a viable solution until longer-term solutions can be implemented.

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Round goby (Neogobius melanostomus) in the brackish Baltic Sea feeding ecology and impacts on benthic communities.

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In recent decades the round goby (Neogobius melanostomus) is rapidly expanding its distribution area in Europe. The species has successfully colonized the whole Baltic Sea basin, mostly due to anthropogenic drivers. In the Northern Baltic Sea abundant benthic predators have been previously missing from benthic communities. Previously bottom-up regulated benthic communities‘ response to the strong top-down control posed by the invasive predators is largely unknown. Experimental research shows significant impacts in local communities. In the Northeastern area the round goby is larger in size with higher food consumption rates than in other invaded areas or in native areas. Moreover, experiments indicate the round goby to be a generalist feeder, with the ability to consume a diverse diet and no preference towards local prey species. In benthic communities bivalves dominate and the round goby removes a significant amount. Bivalves are important in nutrient depositing and buffering effect of eutrophication through bivalve removal might be compromised. In addition the round goby consumes mobile amphipods, which increases competition with native fish. Thus, impacts on all trophic levels and for the whole ecosystem functioning are likely. So far native predators have failed to control the species abundance. Further investigations of their densities and establishment of a monitoring program are necessary.

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The Sun-Coral Project: the first social-environmental initiative to manage the biological invasion of Tubastraea spp. in Brazil

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In the 1980s two invasive azooxanthellate corals, Tubastraea coccinea Lesson, 1829 and Tubastraea tagusensis Wells, 1982 (Dendrophyllidae) invaded the Southwest Atlantic. They are dispersed by fouling on oil platforms and have expanded their range along 1800km of rocky and coral reefs of the Brazilian coastline. Research carried out since 2000 has clearly demonstrated negative ecological and economic impacts of these invasive corals. The Sun-Coral Project was launched in 2006 as an outreach program aimed at the restoring marine ecosystems, mitigating the environmental

damage and redressing the social and economic impacts caused to coastal communities by the invasion of the sun-coral. The Project is organized to address five distinct activities: research, monitoring, control and eradication, environmental education and extra income. We train collectors to manually remove the corals from the seabed and earn extra income by selling the skeletons, which are used in craftwork sold to tourists. This contributes to sustainable development by engaging human coastal communities in the management of the sun-corals. Between 2010 and 2014, more than 140,000 people have been indirectly and 5,000 directly involved; 1123 people became "multiplying agents" of information through 250 lectures and workshops; 78 publications were generated. Up to now more than 230,000 sun-coral colonies (8,4 T) have been removed, thirteen populations eradicated and 326 sites included in monitoring. The Project has encouraged three other independent management initiatives by the National Biodiversity Conservation Institute. An interdisciplinary 30 member Research, Development and Innovation Network has also been established to provide further information and solutions. This is the first initiative to manage a marine biological invasion in Brazil and has been helping decision makers create suitable science based policies and new regulations.

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Dynamics of biological invasions and pathways over time: the Baltic Sea case study

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Coastal and regional seas ecosystems suffer under several human-induced stressors, incl. bioinvasions. The current paper utilises the most up-to-date information on non-indigenous species (NIS) available in AQUANIS, the new-generation information system designed to assemble, store and disseminate comprehensive data on NIS, and assist the evaluation of the progress made towards achieving management goals. The paper will i) summarise information on NIS invaded the Baltic Sea by major groups pelagic invertebrates, benthic invertebrates, fish; ii) provide country-specific decadalscale invasion dynamics since 1900 and iii) identify the most invasive and/or unique to-location species based on spread. The paper will also analyse temporal dynamics in the country-level distinctiveness of NIS. Most essentially, the paper will link both NIS as well as their taxonomic distinctness to invasion pathways/vectors. As the invasion vectors should be in focus in NIS management, results of the current paper form the basis for designing further management strategies and identifying priority actions to reduce the risk of new NIS invasions to the Baltic Sea.

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Larval development of invasive and non-invasive gammarid species under extreme salinities

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Species environmental tolerance is assumed to be one of the key traits for invasive species success in spreading to new areas. In addition, numerous invasions of freshwater habitats by marine or brackish species have been recently reported. As an extension to another study that explored salinity tolerance of several gammarid species using adult individuals, we have collected larvae produced by those individuals in 0 and 40 ppt and explore larval growth and survival under these extreme conditions. We have examined larval development of three marine gammarid species: Gammarus locusta, G. salinus (both native to the North and Baltic Seas) and G. tigrinus (native to the Gulf of St. Lawrence). The parental populations of larvae were collected at different salinities in the North and Baltic Seas. Larvae were kept at the same salinity encountered at collection sites (control), and in 0 or 40 ppt (depending on the salinity the larvae were produced in). Every two weeks larvae were counted and their growth determined by measuring head length of 30 randomly pooled individuals per treatment. The individuals were examined until all larvae in treatment died or F1 couples appeared and started to reproduce. Preliminary results demonstrate that although parental populations collected in 9 and 16 ppt produced larvae in 0 ppt, those larvae survived only one week. In contrast, larvae of G. salinus and G. tigrinus produced in 40 ppt survived several weeks, however their growth was slower when compared to control groups.

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Risk-based detection/ delimitation survey for Sabella spallanzanii

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The Mediterranean fanworm (Sabella spallanzanii), an unwanted and notifiable organism under the New Zealand Biosecurity Act 1993, was first detected in the Auckland region in 2008. This fouling species is now well established in this region of New Zealand where commercial and recreational vessels are likely to act as vectors spreading this species to other regions across New Zealand. In 2013, Sabella was first reported in the Coromandel region, on two infested vessels. This instigated a response with an initial delimitation survey, an in-water hull cleaning process and a 6-month follow up detection/ delimitation survey in case of accidental propagule

release during vessel cleaning. The design of the detection/ delimitation surveys used predefined zones of highest potential larval propagule density, and an arbitrary survey boundary was delineated, based on modelling the hydrodynamics of the Coromandel harbour. These zones were identified by overlaying suitable habitat for Sabella and the hydrodynamic dispersal pattern from the cleaning location in ARC GIS. The dispersal pattern was based on the results of a validated lagrangian model run for the two weeks following the cleaning operation. Habitat suitability was defined based on expert opinion elicited using the Analytical Hierarchy Process (AHP) technique and a self-administrated questionnaire. The zones were then assigned arisk ranking. Sampling sites were proportionately allocated to the different zones taking into account the estimated search efficiency of the field team and the assumed density of Sabella. This method of incorporating habitat type, hydrodynamics and characteristics such as search efficiency and assumed density specific to a given situation, is a methodology that could be employed in many different situations to develop delimitation or detection surveys for marine pests.

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Predation on the exotic starfish Asterias amurensis by the native seastar Coscinasterias muricata.

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Asterias amurensis is a seastar native to the northern Pacific that was introduced into Port Phillip Bay, Victoria, in 1995. While it is widely viewed as one of the most serious invasive marine pests in Australia, there are few methods available to control new or established populations. This study was undertaken to determine if predation by the native seastar Coscinasterias muricata could be used to augment diver collections to eliminate any new Asterias infestations such as the recent infestation at Tidal River in Wilsons Promontory National Park. Laboratory-based feeding trials showed that small Asterias were usually pinned and eaten quickly by Coscinasterias, but larger Asterias wrestled with Coscinasterias for up to six hours before they were eaten or escaped. A few were partially eaten after they autolysed one or more arms. Field studies indicated that in Port Phillip Bay that Coscinasterias is mostly found in water shallower than 15 m, while Asterias is mostly found in water deeper than 15 m, with the relative density of Asterias to Coscinasterias increasing with depth. In the laboratory trials Coscinasterias consumed Asterias in the presence of alternative mussel prey at the rate of 50/year. Consequently, if they fed at a similar rate in the field, they would be expected to exert significant control over Asterias populations at all depths where the ratio of Asterias/Coscinasterias was less than 50, i.e. at all depths less than 15 m. While further field research is required, this study suggests that Coscinasterias may be very helpful in eliminating newly established populations of Asterias.

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Northward Ho! The Spread of Migrants and Invaders

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Among many climate-related changes, the U.S. Northeast coast is experiencing faster changes in temperature, precipitation, and sea level than many other regions. These rapidly changing environmental conditions are accelerating range expansions of native and non-native species and supporting an influx of new introductions. Using data from six rapid assessment surveys that monitor presence/absence of non-native and native species, short-term changes in selected taxonomic groups illustrate the increased presence of "summer transients" and rate at which some species spread through the region. The short-term changes are reviewed in the context of larger issues of regime shifts and climate-related impacts. The outcome of the surveys has prompted action by some states to address non-native introductions in marine systems, stimulated development of a coordinated volunteer effort to monitor local areas and supported other management efforts.

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Raising the flag on marine alien fouling species

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Harbours are known as introduction foci of marine alien species. They act as recipients of new introductions and as sources for regional spread. We report on subtidal surveys of fouling communities from 14 harbours along the coastline of South Africa. The harbours spanned three ecoregions and varied in nature from large, international shipping hubs to small, regional fishing harbours. Fouling assemblages were assessed using visual and scrape sampling to ensure large mobile and small inconspicuous species were detected. In total, 29 alien species were recorded while the number of species recorded per harbour varied from five to 15. Regression trees were produced to identify factors that best predict alien species numbers in harbours, so as to support prioritisation of monitoring efforts. The number of visually dominant alien species was primarily affected by harbour size, ecoregion and the number of yachts present, with highest numbers of species occurring in large harbours within the Benguela and Agulhas ecoregions that had more than 10 yachts. In contrast, scrape samples identified large numbers of yachts (>118) as the primary driver of high alien species numbers while the presence of ship repair and hull cleaning facilities was also important. These findings suggest that large harbours with many yachts and vessel maintenance facilities are most at risk of invasion by fouling species and in the face of limited resources monitoring programmes should focus on such harbours.

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Investigating the viability of marine organisms in bilge water discharges using DNA and RNA metabarcoding

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Bilge water contained in vessels and towed infrastructure is thought to pose biosecurity risks. The implications for the spread of marine organisms through bilge water transfers, particularly for domestic pathways, are largely unknown. High-throughput sequencing (HTS) technologies provide promising tools for the rapid detection and identification of all marine organisms present in environmental samples. Recent amplicon-metabarcoding studies in marine biosecurity have largely focused on targeting environmental DNA to make inferences on the diversity and distribution of marine organisms. However, DNA may persist extracellularly in the environment for extended periods of time after cell death, making discrimination between functionally active and dormant organisms difficult. This creates challenges when using HTS metabarcoding data for biosecurity monitoring, where determining the viability of organisms is paramount. In this study, bilge water samples were collected from 23 recreational and commercial vessels transiting through the port of Nelson, New Zealand. DNA and RNA molecules were co-extracted from 88 samples, and the V4 region of the nuclear Small Sub-Unit ribosomal (rRNA) gene targeted for metabarcoding. These data highlight the need for careful interpretation of HTS amplicon-metabarcoding data with respect to assessing viable organsims and suggest that bilge water may be an important vector that needs to be considered in biosecurity pathway management. Complete results from this experiment will be presented and future plans outlined.

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Feeding rates, behaviours and their implications for future spread: a comparison of an invasive and native barnacle in South Africa

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Balanus glandula is an invasive intertidal barnacle along the South African coast. This species is the dominant barnacle on the cool and productive West Coast and has recently spread east past the biogeographic break of Cape Point. To understand if this invader is likely to maintain its dominance in these warmer, less productive waters, we investigated the effect of water temperature and food availability on the relative food resource use and feeding behavior of B. glandula in comparison to the native barnacle, Notomegabalanus algicola. Barnacles were fed either a high (32 x 106 algal cells.ml-1) or low (1 x 106 algal cells.ml-1) algal concentration, representing the high and low primary productivity of the coasts respectively, at 13 and 20C. After an hour, the remaining algae cells were quantified using flow cytometry. To further resolve differences in feeding among species, video footage was used to quantify feeding behavior. Notably, both water temperature and food concentration influenced barnacle filtration. However, regardless of thermal and productivity profiles, B. glandula demonstrated higher resource use than the native. Unexpectedly, B. glandula exhibited lowest filtration rates under cooler conditions that are typical of its native range and its initial invaded range along South African West Coast. Under warmer less productive conditions, B. glandula showed faster cirral beat rates than N. algicola, although no differences in the number of feeding barnacles or the time spent feeding were recorded. Results suggest that (1) B. glandula displays heightened food resource use when compared to N. algicola regardless of water temperature or food concentration, (2) this likely reflects different feeding behaviors of the two species, and (3) B. glandulas feeding is enhanced under warmer water conditions. This work suggests that this invader may hold an advantage under South Coast conditions that could facilitate its spread in this newly invaded region.

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New regulations for marine pest management in Queensland

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Queensland faces unique challenges related to the introduction of marine pests and their management - a large coast and extensive network of ports, ranging from small community ports to world-class coal export terminals and a capital city multi-cargo port, and Queensland ports are generally first port of call for international shipping vessels on the east coast of Australia making the risk of marine pest introduction significant. To date, managing the risks associated with marine pest introduction via international shipping has been largely left to the Australian Government, who

monitor ships arriving in Australian ports including verification of ballast water management documentation. The major issues constraining marine pest management in Queensland include: lack of sufficient resources; lack of a single, cohesive legislative framework to manage marine pests; ability to adequately monitor the marine environment and domestic vessel movement; capacity to mount a response; lack of awareness of marine pests and their potential impact; and, differing views on the roles and responsibilities of government and industry. When a new marine pest is detected, a response often relies on participation of Biosecurity Queensland and other organisations. It has historically been a case-by-case negotiation to determine who will undertake and pay for inspections, delimitation, treatment and ongoing surveillance and monitoring. New biosecurity legislation will commence in Queensland in 2016 and provide stronger legislative support for dealing with marine pests in Queensland waters and facilitate more risk-based management responses. This new Biosecurity Act introduces the "General Biosecurity Obligation" which places more onus on risk creators to manage risks associated with marine pests. This poster provides scenarios that help clarify how the new legislation will improve protection of Queensland's economy, environment and way of life from the threats posed by marine pests.

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Changing with the tides - Caulerpa taxifolia management in New South Wales, Australia

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The marine alga Caulerpa taxifolia has been considered one of the worlds most invasive species. Endemic to tropical regions throughout the world, including tropical and sub-tropical areas of northern Australia, C. taxifolia generated significant concern when first detected in April 2000 in the state of New South Wales (NSW), Australia. C. taxifolia has now been discovered in 14 estuaries or coastal lakes of NSW and one small oceanic population near Sydney. To manage the potential impacts of this invasive species the NSW government listed C. taxifolia as noxious marine vegetation in State legislation after its initial discovery. Fishing Closures were applied to some higher risk areas in the early 2000s with restrictions on fishing (netting) activities in these areas in attempt to manage translocation to unaffected areas on recreational and commercial equipment. Through research and management activities over a period of 15 years, much has been learned about C. taxifolia in NSW, including that the impacts of C. taxifolia are not as severe as first feared. In 2014-15 the NSW Department of Primary Industries undertook a review of the management approach to C. taxifolia. The recent knowledge and new approach to managing C. taxifolia in NSW will be discussed.

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New Zealand's marine biosecurity surveillance: reflecting on 15 years of discovery and learnings and looking to the future.

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New Zealands marine high risk site surveillance, or port surveillance programme facilitates the early detection of non-indigenous marine organisms, and consequently increases the success rate of subsequent intervention measures. In combination with the Marine Invasives Taxonomic Service, the port surveillance programme creates a solid foundation with which New Zealands marine biosecurity systems are based on. Much has been learnt since the port surveillance programme was initiated in 2002, and the programme has grown from initially monitoring 8 of New Zealands busiest ports and marinas, to 11 currently. During this time >100,000 sites have been surveyed. Principally the biannual port surveillance targets a number of identified, significant threat species that have not yet been recorded in NZ. It also tracks established marine NIS that are not yet widespread. Additionally, any new or emerging species can be detected and identified. Since inception, there have been a number of detections of species that are new to New Zealand, as well as new to the hemisphere, and some new to science. Looking forward, the programme intends to utilise data generated to date to further refine the surveillance approach, and incorporate advances in science and new technologies to increase efficacy and value for money, to continue to protect New Zealands unique marine values, environments and the reliant economies.

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Applications of next-generation sequencing to the study of biological invasions

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Through the widespread implementation of next-generation sequencing (NGS), analyses of the whole genome (the entire DNA content) and the whole transcriptome (the genes being expressed) are becoming commonplace. Consequently, NGS enables the analysis of vast amounts of previously unattainable genetic information. Genomic and transcriptomic data can be key for understanding ecological and evolutionary mechanisms, especially those relevant to biological invasions such as local adaptation and hybridisation. Despite all this potential, NGS has yet to be widely implemented in genetic studies of biological invasions. In this presentation, I will present a brief introduction to NGS followed by a synthesis of current research in the

genomics and transcriptomics of adaptation and colonisation. I will then highlight research opportunities including: (1) analysing genomes and transcriptomes of non-model organisms, (2) identifying candidate genes and genomic regions underlying adaptive evolution, and (3) studying the adaptive role of gene expression variation. In particular, because non-indigenous species face a broad range of physiological and biotic challenges when colonising novel and variable environments, transcriptomics enables the study of gene regulatory pathways that may be responsible for acclimation or adaptation. To conclude, I will identify a number of research approaches that will aid our future understanding of biological invasions.

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Lost in translation? Standardising the terminology used in marine invasion biology.

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Confusion between terms and ambiguities among definitions has long plagued the field of invasion biology. One result is disruption in flow of information from researchers to policy makers and managers who rely on the scientific literature to inform regulatory frameworks and management actions. Using South Africa as a case study we reviewed the marine biology literature to quantify the current usage of terminology describing marine invasions and found a variety of terms in use, few of which are defined when used. In response we proposed standard terminology that aligns with international practice in non-marine systems. We then interpreted the Blackburn unified framework for biological invasions within the marine context using this as a transparent way to apply the standardised terms to an updated list of marine alien species for South Africa. This resulted in the recognition of 36 alien and 53 invasive species. Most notably this identified gaps in knowledge for at least 11 listed species, paving the way for directed research to support future revisions of the list. It is hoped that by standardising terminology, researchers will better support authorities charged with managing the threat posed by marine alien species.

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Japanese Tsunami Marine Debris: Potential Transoceanic Rafting of Bivalve Parasites and Pathogens

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One of the most common species surviving transoceanic rafting from Japan to North America and the Hawaiian Islands on Japanese Tsunami Marine Debris (JTMD) is the Mediterranean mussel Mytilus galloprovincialis, itself introduced to Japan in the early 20th century. We examined over 1,200 JTMD mussels for endoparasites and pathogens. All mussels were screened for the parasitic hydroid Eutima japonica (known to cause bivalve mortalities) and other macroparasites that can occur on gills or within the mantle cavity. A subset of mussels was further screened (using molecular genetic analyses) for protistan parasites in the genera Perkinsus, Bonamia, and Haplosporidium, which are known to cause diseases in bivalve mollusks. Detected to date have been Eutima (unknown from the Eastern Pacific and thus unambiguously sourced from Japan), and previously unknown lineages of the potentially pathogenic protist Haplosporidium (whose biogeographic origins remains to be determined relative to point-of-acquisition along the JTMD journey). Highly infected with Eutima were mussels on a large dock originating from the Port of Misawa (Honshu) in March 2011 and landing on the Washington coast in December 2012. Eutima were further detected in mussels arriving between 2012 and 2014 in Oregon and Washington on landings of another Misawa-sourced dock, on a buoy, and on a vessel. As our JTMD samples represent only a small fraction of the actual debris landings, we have initiated surveys to determine if Eutima and the novel strains of Haplosporidium are present in mussels and other bivalves in the Pacific Northwest.

Presenting author is Gregory Ruiz ruizg@si.edu

Barcoding non-indigenous macroalgae in the Azores

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Algae invasions in marine habitats represent a recognized worldwide threat to the integrity of native communities, to economy and even to human health. The emphasis of the present work is on non-indigenous marine macroalgae species in the Azores. This archipelago is situated in the North Atlantic Ocean (37-40N, 25-31W), astride the Mid-Atlantic Ridge and is strongly influenced by the sea-surface pathway from the Gulf Stream; nevertheless the affinities of its native marine algal flora are to the continental coasts of Europe and Africa, the Mediterranean Sea and the other Macaronesian islands. Azorean marine ecosystems are relevant by their uniqueness, geographic position, biogeographic mixed algal flora and insularity, highlighting its

susceptibility for alien species introduction. In fact, over 6% of its macroalgae are considered non-indigenous species in contrast to the 3% introduced macroalgae at a global scale (following Williams and Smith 2007 and Guiry 2012). Of the 26 species of non-indigenous species 7 are in the invasive category for their potential impact: Asparagopsis armata, Asparagopsis taxiformis, Bonnemaisonia hamifera, Caulerpa webbiana, Codium fragile subsp. fragile, Grateloupia turuturu and Symphyocladia marchantioides. The aim of this study is to contribute to improve the knowledge of the non-indigenous species and potential invasive macroalgae in the Azorean archipelago by genetic characterization using the mitochondrial CO1-5P barcode region (cytochrome oxidase 1).

Presenting author is Manuela Parente nelaparente@hotmail.com

Forecasting changes in the global shipping network

Sardain, Anthony[1]; Leung, Brian[1];
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The global shipping network (GSN) is the most significant vector of spread for non-native aquatic species. Over the past five years, it has been analyzed in considerable detail such that the connections and dynamics within the GSN are now relatively well understood. This has led to a number of studies venturing to forecast the spread of invasive species through the GSN. Many of these studies focus on climate change as an important driver to consider when forecasting spread. However, overlaying climate change scenarios for the coming decades onto today's GSN assumes the global shipping network will remain unchanged, despite evidence showing global maritime trade has increased over 50% since 2000. Focusing on economic drivers of change, we create a 30-year forecast of the GSN by combining data on 10 years of global shipping movements, 40 years of ship-building trends, and 15 years of monthly bilateral international trade. We analyze and create development curves for groups of economically-similar countries, consider changes in technology (e.g., ship sizes and types), and shipping routes, and also use scenario analysis to explore different possible futures of global economic development. These forecasted trade patterns and resulting changes in shipping traffic will have consequence for the patterns of invasive species transport.

Presenting author is Anthony Sardain anthony.sardain@mail.mcgill.ca

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Quantifying native and invasive oyster distribution in an urbanised estuary

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Urbanisation of the world's estuaries has resulted in changed foreshore habitats, increased marine traffic and increased pollutants. Such alterations create opportunities for the introduction and establishment of invasive species. In south east Australia, the endemic Sydney rock oyster Saccostrea glomerata is under threat from disease and competition from the non-indigenous oyster Crassostrea gigas. This study assessed the size, distribution, and species composition of both invasive and endemic oyster species in Port Jackson (Sydney Harbour, Australia), a heavily urbanised estuary. We tested the hypothesis that the size, abundance and relative proportion of the oysters Crassostrea gigas and Saccostrea glomerata would differ throughout the estuary. To test this, 16 locations and 32 sites were sampled throughout the estuary encompassing all hard surfaces (natural and artificial). Abundance, size and species composition were measured for each site. Lysosomal destabilisation assay was also conducted to determine the presence of bio-available contaminants in oysters from six locations (3 impacted, 3 control). It was found that the abundance and size of oysters was significantly different among locations. Oysters were more abundant, but smaller in the eastern reaches of the estuary, while in the west, oysters were less abundant and larger. The invasive C. gigas was found to comprise 16% of the population, and up to 85% at some upstream sites. C. gigas was found to be more abundant in sites of high contamination (as determined by lysosomal destabilisation), larger in size than the native S. glomerata and more prevalent than previously recorded in other NSW estuaries. Retaining biogenic habitat forming organisms is essential to retaining biodiversity in urban estuaries. This is the first to quantify the presence of C. gigas in Port Jackson, and provides a solid base for gauging any changes in oyster populations in Port Jackson as a result of further urbanisation.

Presenting author is Victoria Cole e.scanes@uws.edu.au

Reproductive life history of roi, the introduced peacock grouper (Cephalopholis argus, Bloch and Schneider, 1801), in Hawaii.

Schemmel, Eva[1]; Donovan, Mary[1]; Grant, Reagan[1]; Friedlander, Alan[1];
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The peacock grouper, Cephalopholis argus, was intentionally introduced from French Polynesia into Hawaii in the late 1950s yet little is known about its life history. This research focused on the reproductive biology of C. argus, locally known by its Tahitian name roi, and investigated the sex ratio, hermaphroditic pattern, and size/age distribution of the Hawaii Island population of this species. The results suggest that C. argus exhibits monandric protogyny (female gonad differentiation with female to male sex change) with females reaching sexual maturity at 1.0 years [CI: 0.7, 1.6] and 19.6 cm [CI: 19.1, 20.8]. The sex ratio of female to male was 3.9:1. The average age and size at sex change was 11.5 years [CI: 11.1, 12.9] and 39.9 cm [CI: 39.5, 41.2]. Current information on spawning seasonality of this species is incomplete, however based on the occurrence of spawning capable and/or activity spawning females, spawning is likely taking place May through October. Evidence of lunar spawning periodicity was found, with increased proportion of spawning capable and actively spawning females and increased female GSI during first quarter and full moon phases. This is the first reproductive life history information for this species, filling a valuable information gap in Hawaii and across its native range.

Presenting author is Eva Schemmel eschemmel@gmail.com

Cryptic invader: green alga Codium fragile ssp. fragile in NSW, Australia

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Codium fragile ssp.fragile is one of the most invasive algae, and its introduction to NSW can have serious environmental implications. Due to its similarity to the native subspecies (tasmanicum and novae-zelandiae), the introduction is likely go undetected until the alga is well established. This study undertook the first quantitative assessment of the invasion by non-native C. fragile in NSW and documented its distribution and abundance along rocky shores and estuaries of the state. This will help to identify the degree of infestation and to assess potential damage to the environment. The results are discussed in the light of potential sources of introduction and management options.

Presenting author is Maria Schreider maria.schreider@newcastle.edu.au

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Diets of the introduced snapper Lutjanus kasmira and native fishes in Hawaii

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It has frequently been suggested that the introduced snapper Lutjanus kasmira has reduced populations of native shallow-water fishery species in Hawaii through competition for food and/or predation. However, to date scientific studies have not effectively addressed these hypotheses. The present study focused on diets of L. kasmira and three native species of goatfish (Mulloidichthys flavolineatus, M. vanicolensis and Parupeneus multifasciatus) to assess ecological relationships between them. Other goatfishes and a native snapper were incorporated into analyses according to the availability of adequate numbers of specimens. Specimens were collected off the south shore and Kaneohe Bay of Oahu, and off the west shore of the Island of Hawaii. Unpublished diet data from separate studies in the Northwestern Hawaiian Islands and Puako Bay on the Island of Hawaii were also incorporated into comprehensive analyses. Analyses compared size, trophic level and taxonomic similarity of prey. The diet of L. kasmira was most similar to P. multifasciatus. However, there was no evidence that abundance of L. kasmira affected the diet or biological condition of P. multifasciatus or any other species in the study. Also, no fish (e.g. P. porphyreus, Zebrasoma flavescens (Acanthuridae)) or invertebrate (e.g. Ranina ranina, Octopus spp.) species that were important to local fisheries were identified as prey of L. kasmira. Ultimately, this detailed analysis of a temporally and geographically diverse data set found no evidence to support hypotheses that implicated L. kasmira in either predation on, or competition with, any native fishery species. Given the lack of evidence of ecological interactions between L. kasmira and other fishery resource species, fears that this introduced snapper has had a measureable detrimental impact on commercially important native species in Hawaii through trophic interactions appear to be unfounded.

Presenting author is Brett Schumacher schumach@hawaii.edu

Geographic and environmental correlates of non-indigenous species composition in New Zealand ports and harbours.

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The national port surveys completed in 2007 established a standardised baseline of information on the distribution of non-indigenous (NIS) marine species within New Zealand's major shipping ports and harbours. The surveys revealed many new records of NIS and potentially new native species within New Zealand at the time.

As such, they are a valuable national asset that can provide information on species density and diversity across a wide range of habitats and ecological niches. Contemporary patterns in the relative abundance and distribution of NIS within New Zealand are complex, as they integrate recent and historical introductions into each location, domestic spread from initial incursions elsewhere in New Zealand and local environmental (including ecological) determinants of survival and abundance. Clear geographic trends were present for native species but although these trends were present, they were less distinct for the NIS and cryptogenic species found at each location. The distribution of individual NIS likely reflects not only local environmental determinants of survival that influence distribution of native species (e.g. temperature, salinity, resource availability, disturbance, etc), but also realised dispersal from the point of initial introduction into the country. Through re-examining this dataset nine years since the completion of the last survey we hope to assess NIS species density across the country at the time and analyse different potential ecological and human mediated transport vectors as prediction metrics and how they may influence species composition in port and harbour assemblages across New Zealand.

Presenting author is Kimberley Seaward kimberley.seaward@niwa.co.nz

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The structure of sessile invertebrate assemblages in artificial habitats along a large-scale latitudinal gradient in Western Australia

Simpson, Tiffany[1]; Smale, Dan[2]; McDonald, Justin[1]; Wernberg, Thomas[1];
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Artificial habitats such as breakwaters, jetties, ports and marinas may represent the most common intertidal and shallow subtidal habitats in urban coastal areas. While they serve a variety of purposes for human activities, this infrastructure introduces novel habitats along the coast that can be colonised by a variety of marine flora and fauna. As these structures continue to replace natural habitats, understanding their ecology is increasingly important for managing the impacts of human activities on marine biodiversity. The artificial hardening of coastlines modifies hydrodynamics and transport processes, which has consequences for the structure and functioning of ecosystems at local and regional scales. Assemblages of benthic organisms associated with artificial structures can be very different to those associated with natural reefs and are often linked with the transfer and establishment of non-indigenous species. The complexity of interacting factors from the physical design of artificial habitats, natural variability of recruitment processes and propagule pressure from various vectors make the ecology of coastal infrastructure very difficult to understand and predict. In this study, we present the first assessment of sessile invertebrate assemblages associated with coastal infrastructure along a large-scale latitudinal gradient in Western Australia. Using settlement panel arrays, we generated assemblage-level metrics including biomass, abundance, taxonomic richness and structure. Along this coastline, temperature has been described as a major driver

of ecological patterns. But although previous studies in WA have demonstrated systematic changes in the structure of assemblages in natural habitats which correspond with the observed gradient in latitude and temperature, sessile invertebrate assemblages in artificial habitats did not show the same clear patterns. The assemblage structure documented some predictability at the regional scale but local-scale variability (and presumably processes acting at this scale) was more pronounced. This is an important consideration for coastal engineers and managers.

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Local temperature tolerance in the native range of an invasive species suggests pre-adaptation to New Zealand conditions

Smith, Kirsty[1]; Agostini, Sylvain[2]; Saito, Yasunori[2]; Fidler, Andrew[1];
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Biological invasions provide an opportunity to observe rapid real-world evolution as introduced taxa adjust to novel biogeographic contexts or habitats. Mitochondrial genome evolution has been assumed to be selectively neutral even though mitochondria are the main producers of cellular energy. However, recent studies indicate that metabolic requirements can exert selective pressures on the mitochondrial genome, leading to mitochondrial genotypes adapted to different environments. Phylogenetic analyses of the globally invasive marine tunicate Didemnum vexillum, using partial COI sequences, revealed two distinct clades: one (clade B) apparently restricted to its native region (NW Pacific) and the other (clade A) now found in temperate coastal areas around the world. We hypothesized that clade Bs restricted distribution may reflect it being inherently less thermotolerant than clade A or its adaptation to warmer waters. Multiple mitochondrial genomes from both clades were sequenced, revealing significant intra- and inter-clade differences in the predicted sequences of enzyme sub-units involved in oxidative phosphorylation. Laboratory experiments, carried out in Japan, examined thermal stress tolerance and mitochondrial enzyme function of colonies from both clades A and B. D. vexillum clade A appears to be better adapted to lower water temperatures than B, consistent with clade As abundance in temperate waters. Nonetheless, recent D. vexillum clade A introductions (e.g., the Mediterranean Sea, southern India) suggest D. vexillum clade A has a remarkable ability to adapt to warm sub-tropical waters. Environmentally induced epigenetic modifications (e.g., DNA methylation) have been proposed as one mechanism underlying rapid adaptive evolution of invasive species. Our future research will seek to elucidate molecular epigenetic changes in D. vexillum genomes associated with both individual and population level adaptation to environmental change.

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Prioritizing biosecurity investments in New Zealand: A discrete choice experiment

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The significant gap between the costs of invasive species management and the limited public funding available to undertake it means that there is a need for robust mechanisms to prioritize expenditure on biosecurity interventions. Decision-makers must evaluate the benefits of intervention against the costs of inaction for a broad range of invasive species. These may include impacts on primary industries, human health, natural environments and social amenity. However, the criteria used to guide prioritization and their relative importance are not often transparent. In this study, we use a discrete choice experiment to understand the implicit judgements that experts make when they consider the merits of intervention against invasive species that have different potential risks. Three groups of criteria were considered in the analysis that represent: (1) the management action, including its cost and likely effectiveness, (2) the potential benefits of intervention, including losses to biodiversity and primary production that will be avoided, and (3) the level of certainty surrounding each of these outcomes. The aim of our study is to examine how intervention decisions against economic and environmental pests are weighted in the context of uncertainty over their long-term benefits. We will use the identified criteria and their relative weightings to develop a multi-criteria decision-making framework for invasive species management.

Presenting author is Tarek Soliman Tarek.Soliman@niwa.co.nz

Exotics and the exodus: the effects of invasive biofouling species on the retention of post-larval mussels

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Aquaculture operations throughout the world are negatively impacted by biofouling organisms. Many of these are invasive species that can achieve enormous abundance on and among cultured shellfish, and the associated farm infrastructure. Because invasive species such as Didemnum vexillum, Styela clava and Undaria pinnatifida have become common, persistent members of biofouling communities, it is likely that they differentially affect all stages of the mussel production cycle. However, studies of the effects of biofouling organisms have almost exclusively focused on impacts on adult shellfish in the latter stages of the production cycle, documenting negative effects on survival and biomass. An emerging concern in shellfish aquaculture is the retention of out-planted post-larvae and juveniles. These early life stages often suffer catastrophic losses following deployment, but the reasons for this are

poorly understood. One source of crop losses early in the production cycle might be fast-growing invaders that smother or displace post-larvae. Alternatively, rates of post-settlement migration of cultured mussels might increase with rates of fouling. Here we examine interactions between a range of invasive biofouling organisms and hatchery reared post-larvae of the cultured green-lipped mussel, Perna canaliculus, in New Zealand.

Presenting author is Paul South paul.south@cawthron.org.nz

Comparison of traditional and novel techniques for identifying rare zooplankton species

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Aquatic invasive species (AIS), including zebra mussel, European shore crab, and golden mussel, among others, have changed the dynamics of many ecosystems since their introduction. Many of these AIS were introduced and moved via ballast water discharged from commercial vessels. When a species is first introduced, its population size will generally be very small. This is the best time to eradicate AIS; however, it is also when detection of the species is most difficult. We hypothesize that rare species will be more easily found as they become more abundant, or when sampling effort devoted to detection is increased. Likewise, more conspicuous species - or those morphologically different than the native fauna - are more likely to be detected. We spiked different densities of Cladocera species never before reported in Lake Ontario into zooplankton samples collected from Hamilton Harbour, western Lake Ontario, to simulate rarity and assess detection rate when using traditional taxonomy versus automated imaging flow cytometry (FlowCAM) technologies. Additionally, water samples from Hamilton Harbour will be analyzed using these techniques to discover rarity in situ. We postulate that the FlowCAM will be able to process a larger amount of data, but that morphologically similar taxa will be distinguished more readily with traditional taxonomy. This study will provide tools to monitor rare aquatic species as well as a means to combat AIS at the frontiers of invasion and provides a way to further test hypotheses of establishment and invasion.

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Metabarcoding environmental DNA: prospects and challenges in biosecurity applications

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DNA isolated and characterised from a variety of substrates including sediments and water is collectively referred to as environmental DNA (eDNA). DNA is shed from a variety of biological secretory processes and provides a means to audit species composition. When combined with next generation sequencing (NGS) and metabarcoding, eDNA can provide a wealth of information for studies of biodiversity, food web dynamics, diet analysis and invasive species monitoring. Metabarcoding eDNA has become feasible only because it is now possible to simultaneously sequence millions of copies of DNA from complex multi-species environmental samples. Our research into marine biosecurity focuses on developing eDNA metabarcoding for detecting invasive marine species (IMS) in Western Australia. This presentation will showcase a variety of experiments that seek to develop an eDNA toolkit. Our work has involved: (1) shotgun sequencing mitochondrial genomes of invasive species of concern to Western Australia; (2) in silico analysis of PCR primers for metabarcoding assays; (3) eDNA metabarcoding from settlement plates; and (4) eDNA metabarcoding from filtered seawater samples. Collectively, this work shows great promise in that it yields information on IMS, but also a wealth of information on baseline biodiversity. Despite the promise of eDNA, questions remain with regards to sensitivity, detection limits, quantitativeness, DNA movement and longevity of eDNA in water. Lastly this presentation also highlights that the sensitivity of eDNA metabarcoding comes with risks - false positive/negatives and contamination. A number of recommendations will be discussed from sample collection to data analysis that will maximise the potential of eDNA metabarcoding to detect IMS. With careful implementation, eDNA methods are set to become a valuable addition to detecting IMS and managing their biological, social and economic impacts.

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Can enhancing habitat and seeding limit the colonisation and establishment of non-indigenous species on seawalls in harbours and ports

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Oysters and mussels are habitat-forming species that enhance ecosystems biodiversity and functioning. Artificial structures typically support impoverished bivalve communities because their flat, vertical surfaces compress the intertidal zone and limit the available 3 dimensional space (e.g. crevices, ledges, pits and pools) for colonisation and growth of native fauna and flora (Moreira et al., 2007; Chapman and Blockley, 2009; Bulleri and Chapman, 2010; Chapman and Underwood, 2011). They are often colonised by invasive species that can alter the biodiversity and ecosystems function (Airoldi et al., 2005; Chapman and Underwood, 2011; Dafforn et al., 2012a; Dafforn et al., 2015). Adding bivalves to these structures via seeding or transplants could enhance their biodiversity and functioning, and minimize the colonization of unwanted species, such as non-indigenous species (Airoldi, 2005; Dafforn, 2012; Perkol?Finkel, 2012). Here we report on a fully orthogonal pilot study using a habitat enhancement unit designed to test the effects of adding habitat complexity and bivalves to seawalls on the native and non-indigenous biodiversity. The results will be used to design a global experiment to incorporate the principles of eco-engineering artificial structures in ports and harbours (sheltered bays and estuaries).

Presenting author is Elisabeth Strain strain.beth@gmail.com

A global invader or a complex of regionally distributed species? Clarifying the status of an invasive calcareous tubeworm Hydroides dianthus (Verill, 1873) using barcoding

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Clarifying taxonomic status is essential to understanding population connectivity and the spread of potentially invasive species. Here we used barcoding to explore the issue in a common fouling invasive species Hydroides dianthus (Verill, 1873). The species was originally described from off Massachusetts, USA, reported along the East coast of North America down to Florida and Grand Caribbean, as well as Brazil, China, Europe, Japan, and West Africa. Unlike most congeners, Hydroides dianthus has tolerance for a wide temperature range, being distributed from temperate to subtropical waters. We barcoded H. dianthus collected from eight locations worldwide and reconstructed phylogenies using cytochrome c oxidase subunit I (COI) gene. Our results support two main clades of all H. dianthus specimens. Clade

1 has a wide distribution from Massachusetts to west coast of Florida, and is also known from Brazil and China. Clade 2 occurs off Galveston, Texas and the Black Sea. Haplotype network analyses revealed low genetic divergence in each clade. Our results indicate that H. dianthus is a complex of two cryptic invasive species. We suggest a greater emphasis on identification of invasive Hydriodes species and managing pathways responsible for Hydroides introductions.

Presenting author is Yanan Sun yanan.sun@austmus.gov.au

Ship hull transport of marine diatoms through freshwater and their link to invasive biofouling

Sweat, L. Holly[1]; Swain, Geoffrey W.[1]; Johnson, Kevin B.[1];

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Diatoms are a dominant component of marine biofilms that form on nearly all submerged surfaces. Diatoms adhering to ship hulls may be carried thousands of miles to become invasive themselves, or to facilitate invasions of larger macrofouling species by encouraging larval settlement. Freshwater shipping routes are less effective than previously thought at killing macrofoulers traveling between oceans. However, no studies to date have examined how freshwater transport affects the mortality of biofilm organisms such as diatoms. Survivorship and transport of marine diatoms were investigated as biofilms traveled through Floridas Okeechobee Waterway on three modern ship hull coatings: a copper antifouling paint, a silicone fouling-release coating, and an inert epoxy basecoat. Marine biofilms cultivated on both the Gulf of Mexico and Atlantic coasts of Florida were relocated through >165 km of freshwater to the opposite coast on the hull of a specially designed test vessel. On-hull transport removed diatoms from all coatings. However, all surfaces contained diatoms that survived the journey. Transport also modified community composition to create more unique assemblages on the coatings, resulting in new biofilms that may alter subsequent macrofouling settlement and growth. These results provide further evidence for global biofilm transport and marine bioinvasions through shipping. Macrofouling community development and succession on these transplanted biofilms will be discussed.

Presenting author is Kevin B. Johnson johnson@fit.edu

Passive sampling for biosecurity surveillance: How effective are settlement plates for identifying invasive species?

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Settlement plates have been used for many aspects of biosecurity research, including detection of new invasions, but the efficacy for detecting such invasions has seldom been investigated. Settlement plates provide habitat for the recruitment of biofouling species and have been used in marine ecological research under many guises, including for sampling non-indigenous species (NIS). Here we examine the efficacy of settlement arrays for detecting invasive species within Waitemata Harbour (Auckland, New Zealand). We used plates attached to PVC frames at two orientations and included surface treatments using small amounts of antifouling paints. NIS tolerant of copper based antifouling have the potential to outcompete native, less tolerant biofouling organisms and enhance the relative capture and detection rate of NIS on biocide treated plates. Our results show that settlement arrays may be useful for careful examination of biofouling communities, with the first array deployment responsible for the first detection of the bryozoan (Celleporaria umbonatoidea) in Waitemata Harbour, previously only recorded in Northern New Zealand ports (Whangarei 2010, Opua 2013). We will discuss the utility of settlement arrays for marine NIS research based on two deployments of settlement arrays during summer 2014-15 and winter 2015, and the potential for antifouling coatings to target NIS tolerant to the common biocides associated with the major vectors of introduction.

Presenting author is Leigh Tait leigh.tait@niwa.co.nz

Invasion of the body-snatchers: Adaptation to parasitism across a co-evolutionary mosaic

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Parasitism represents a potent selective force and evolutionary driver of physiological, morphological, and behavioral change. As such, invasive parasites may have profound impacts on their hosts. We are investigating how the estuarine white-fingered mud crab (Rhithropanopeus harrisii) adapts to parasitism by an invasive castrating, body-snatching Rhizocephalan parasite (Loxothylacus panopaei). The host crab is native across a wide swath of the East and Gulf Coasts, while the parasite is native only to part of this range along the Gulf Coast and southeastern Florida. Fifty years ago, the parasite invaded the Chesapeake Bay, gradually

expanding its range down the coast. As such, the host represents a mosaic of co-evolutionary histories with the parasite. Using nine sites across this mosaic of native and non-native parasite populations, we examined if and how the host's response differs between populations where the parasite is native, invasive, or absent. We present data on host population structure and infection prevalence from field surveys, which demonstrate much higher prevalence of the parasite in its invasive range relative to its native range (>30% versus <5%). This suggests that host populations where the parasite is native may have adapted to resist parasitism, while host populations in the parasite's invasive range lack such defenses. We also present data from laboratory experiments testing susceptibility to infection in different host populations under controlled laboratory conditions. Together, these data are an attempt to understand the impact invasive parasites can have in host populations, and to elucidate the nature and time scale of the host's potential evolutionary defenses.

Presenting author is Carolyn Tepolt carolyn.tepolt@gmail.com

Invasive marine macrophytes: drivers, passengers or backseat driver of ecological change?

Thomsen, Mads[1]; South, Paul[1]; Schiel, David[1];

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More than 300 marine macrophytes have invaded native communities around the world. It is a major scientific challenge to evaluate how these macrophytes impact recipient communities. In this talk we will (i) outline methods for detecting the impacts of non-native species, (ii) provide a brief overview of published field experiments that have quantified impacts from invasive marine macrophytes, and (iii) describe a new impact study with the highly invasive seaweed Undaria pinnatifida. In the case study, we demonstrate some of the methods whereby invasion effects can be quantified and how Undaria itself can be considered a driver, passenger and backseat driver of ecological change, depending on methodology and measured responses. This case study also showed that invasion impact sometimes can be decoupled from invasion success, a finding that may be relevant for other 'weedy-invaders characterized by conspicuous biomass in limited temporal windows. In short, Undaria is clearly a successful cosmopolitan invader, but its impacts on local intertidal communities appear to be specific to a few native species with similar weedy traits.

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Maritime traffic in the Galapagos Marine Reserve as potential vectors of marine alien species

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Although the Galapagos Islands are geographically isolated - located at 1,000 km west of mainland Ecuador - over 700 Ecuadorian flagged vessels travel to and within the Galapagos Marine Reserve (GMR) each year. Boats are known vectors for invasive alien species so this traffic represents a significant risk to the ecological integrity of the GMR. Until recently only seven invasive species were known to occur within the GMR (Acanthaster planci, Asparagopsis taxiformis, Bugula neritina, Cardisoma crassum Caulerpa racemosa, Pennaria disticha, Zoobotryon verticillatum). Some of these pose a serious threat if they spread beyond their point of detection, the probability of which is increased if there is boat traffic. For example the spaghetti bryozoan (Zoobotryon verticillatum) was recently discovered in Tortuga Bay and is known to use maritime traffic to spread and disperse. Other potentially invasive species such as the snow-flake coral (Carijoa riisei) have been detected on the Ecuadorian coast. There is potential for this species to reach the GMR via vessels departing Esmeraldas and Manta to fish illegally within the Marine Reserve. Also many international non-commercial vessels travelling between the Caribbean and the Pacific Islands also stopover in the Galapagos for days or weeks. Both Ecuadorian and international flagged vessels pose direct threats to the marine environment of the GMR by serving as vectors for highly invasive and damaging alien marine species. This paper starts to quantify that risk by describing the maritime routes to and within the GMR that are followed by tourist, cargo, transport and recreational vessels, highlighting particularly the use of sites from which marine invasive species have been recorded.

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Recreational boating as a high-risk vector of spread for alien species around Mediterranean marinas

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The objective of this study is to understand how the connectivity of marinas is correlated with the level of biopollution (abundance x distribution) of marine sessile non-indigenous species (NIS) both regionally and on recreational vessels and across the Mediterranean. The first targets of this work have been the identification of highly connected marinas in the Mediterranean Sea. Over 2015 and 2016, 30 marinas, i.e., 10 marinas from each of the western, central and eastern sub-basins

of the Mediterranean Sea will be sampled for NIS richness on hard bottoms such as pontoons or docks. Additionally, boat owners from each marina will be fed a questionnaire on their hull cleaning practices and travel history. Samples collected from the hulls, will provide data data on NIS richness and abundance describing biopollution regional trends. Finally, a spatial connectivity model to evaluate the level of risk of each marina will be provided. Furthermore some abiotic factors that contribute to higher levels of fouling in marinas will be indicated. The selection of the marinas will encompass the busiest marinas visited by non-resident recreational vessels provided that permission to sample is obtained. In order to ascertain the stage of the invasion process underway, i.e. to find if colonies represent an initial or secondary source of invasion, samples of a chosen model species such as Amathia verticillata will be collected from each region and genetically tested for genetic parameters. Some preliminary results are that the most fouled marinas are either at very close proximity to freshwater sources, or are very old in age.

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Climate-mediated shifts in species distributions, altered species interactions and the tropicalisation of temperate reefs in Japan and Australia

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One of the bestdocumented impacts of ocean warming is a shift in the distribution of marine species, a phenomenon that is particularly noticeable in regions where warming is exacerbated by strong poleward-flowing boundary currents. This is leading to a 'tropicalization' of temperate marine systems around the world and to profound alterations in ecological communities as species interactions shift with the arrival of novel species. Focusing on emerging patterns quantified along the eastern coast of Australia and southern Japan, I will show how ocean warming has been linked to the increased importance of fish grazing in temperate latitudes and to the loss of kelp forests near the warm edge of their distribution. Projections from climate models indicate that ocean isotherms will continue to shift polewards at a rate seven times faster in the 21st century than the 20th century, facilitating further range shifts and intrusions of tropical species into temperate systems. Gaining an understanding of the mechanisms that mediate community-level changes in a warmer ocean as a consequence of these range shifts is therefore becoming essential to manage and conserve marine ecosystems.

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Determining Australia's priority marine pests

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The Marine Pests Sectoral Committee (MPSC), an Australian intergovernmental marine biosecurity policy forum, has agreed to develop the Australian Priority Marine Pests List (APMPL). In effect, MPSC is seeking two lists; (i) a list of priority exotic marine pests not known to be established in Australia, and (ii) a list of established marine pests of national significance. The listing of priority species would foster nationally consistent reporting of new detections and facilitate nationally coordinated actions to prevent, eradicate, contain and/or manage the impacts of such pests. An MPSC task group of technical and policy experts from across Australasia has been convened to populate the APMPL. The policy context for populating and implementation of the APMPL includes the National Environmental Biosecurity Response Agreement (NEBRA), Consultative Committee on Introduced Marine Pest Emergencies, potential national system changes arising from the Australian Government Review of National Marine Pest Biosecurity, the draft National Framework for Management of Established Pests and Diseases of National Significance, and a range of existing marine pest lists at national and state/territory levels. To inform the development of a formal assessment process for listing particular species, the task group has proposed a number of management actions that could be common to species on both lists: national preparedness (exotic species) or management (established species) plans; noxious declaration in jurisdictions; passive and active surveillance; and incursion responses. For a marine pest species to be on the APMPL it needs to rank highly in terms of nationally agreed criteria for national significance and technical feasibility. A semi-quantitative, relative risk assessment approach is being progressed, adapting published methodologies and assessments for marine pest impacts and likelihood of introduction and spread.

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Habitat-associations of a spreading native macrophyte

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The success of invasive species has been linked to having broad environmental tolerances including the ability to colonise multiple habitats. However, once established the impacts on native communities can depend on the recipient habitat colonised. Interestingly, the rapid spread of native species can have impacts that rival those of non-native species. For native species that are undergoing range expansions or becoming locally more abundant we may predict that they also have broad environmental tolerances, and their impacts depend on the habitat they colonise. Using large scale surveys, we tested these two predictions on the native marine alga Caulerpa filiformis (Suhr) Hering. C. filiformis is native to south eastern Australia and is spreading within and outside its known distribution. We found that C. filiformis indeed colonised multiple habitats on subtidal rocky reefs but was most abundant on habitats that had a sediment veneer present and at sites that had narrow reefs. The recipient community did change in the presence of Caulerpa, however only at sites with narrow reefs. Against our predictions associations did not depend on the recipient habitat.

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Next-generation detection of non-indigenous biofouling pests: optimizing sampling strategies for marine surveillance

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As a small island nation, New Zealand is heavily dependent on maritime trade and is particularly vulnerable to harmful organisms and pathogens that are introduced by shipping via biofouling. Passive recruitment surfaces have been proposed as a sampling tool to enhance surveillance for non-indigenous biofouling organisms, but their fitness for this purpose is constrained by the rate at which larval stages encounter these surfaces and the potentially high costs involved in identification of organisms from the plates using conventional morphological taxonomy. Recent advances in metabarcoding hold considerable promise for monitoring and surveillance in marine environments. Metabarcoding can be highly-sensitive to the presence of an organism in a sample and allows hundreds of samples to be processed simultaneously and rapidly. However, a number of research gaps remain, several of which are the focus of this PhD project. 1) Assess the efficacy of metabarcoding for detecting NIS relative to conventional taxonomic methods including the establishment of a

centralised DNA library for NZ marine pests by using the same sampling array for both surveillance strategies and comparing the qualitative results. 2) Examine the association of NIS with common antifouling coatings and examine the biofouling micro-communities which are often unable to be identified using traditional visual taxonomy and correlate this marine primary succession with the biocide effect and the settlement of macroorganisms. 3) Elaborate standardized protocols for international application of metabarcoding in marine bio-surveillance to compare the spread of NIS worldwide to follow their means of distribution and protect unaffected biosystems before they settle and reproduce. This project represents a unique opportunity for optimising marine biosecurity programs and for providing marine management stakeholders with improved biosecurity surveillance tools in NZ and internationally.

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Project "GEBIO": The first step towards control and management of biofouling and bioinvasion in Brazilian coast

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Marine bioinvasions caused by biofouling transportation in ship hulls and other vessels were reported worldwide and together with other vectors represent a risk to environmental biosecurity. Brazil is not an exception to this scenario. In 2011, the IMO addressed guidelines for the control and management of ships' biofouling but until the moment no Brazilian governmental initiative was put into practice. The project GEBIO is a three year cooperation (2013-2016) between IEAPM (Brazilian Navy) and PETROBRAS (CENPES/PDEDS/AMA) implemented to create a basis for control and management of vessels biofouling and the introduction of non indigenous species (NIS) in Brazilian coast. The aims of the project were defined to help to fill in important gaps and to support decision makers. One of the goals of the project was to compile information on the occurrence of fouling species on natural and artificial substrata in coastal waters of Brazil. The Database "Fouling Species from the Brazilian Coast" is an open access site which actually counts with information about 497 fouling species distributed over more than 287 localities along the coast. Complementarily, a scientific collection was organized to catalogue exclusively fouling species (indigenous and non indigenous) from Brazil and has 246 specimens deposited until now. Furthermore, the Forno harbor area at Arraial do Cabo (Rio de Janeiro, Brazil) has been surveyed to study non indigenous species establishment (e.g. Tubastraea spp.) and also has been used as a model area to a risk assessment analysis considering the NIS and the biological provinces of Brazil. We believe that our results will contribute to a better understanding of introduction and expansion of fouling NIS. Moreover, the results should support initiatives to reduce the risks, to develop control and prevention technologies and improve solutions for NIS control in coastal areas.

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Exploration of national state of preparedness through exercising

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Management and eradication of marine pests once they are established in an aquatic environment is very difficult, and often impossible, even with todays modern technologies. The clear priority is for governments and authorities to look to prevention where possible. However, even with the prevention mechanisms and tools in action, we also need to ensure a constant state of preparedness to respond to suspected marine pest incursions. In NSW, Australia, a Simulation Exercise was recently undertaken to test both the State of NSW, as well as national preparedness to a marine pest incursion. The outcome of the Simulation Exercise and lessons learnt will be discussed, and future challenges will be presented.

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How useful is encapsulation as an incursion response tool for managing heavily fouled vessels?

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In September 2014, New Zealand's Ministry for Primary Industries was notified of a heavily fouled commercial fishing vessel berthed in Port Nelson. The vessel had previously berthed at a number of ports in Australia, several of which were known to contain marine species of high risk to New Zealand's natural marine resources. The considerable amount of fouling on the hull presented potential risks to the region. As the vessel was not scheduled to be slipped and defouled for another 28 days, it was decided to encapsulate the vessel's hull to mitigate the risk of spread of marine pests. Encapsulation has been used as an in-water treatment tool for hull biofouling previously in New Zealand, and the fishing vessel presented an opportunity to study the efficacy of encapsulating a heavily fouled hull. Once the vessel was encapsulated with an impermeable plastic wrapping, the dissolved oxygen (DO) of the seawater within was measured periodically and samples taken of the biofouling on the hull. DO levels dropped rapidly to around 50% of ambient levels after 17 hours encapsulation, and were less than 6% by Day 8. Samples of the blue mussel Mytilus galloprovinicialis taken from the hull on Day 8 were dead; however, some species of algae and a new to New Zealand species of barnacle were alive. When the vessel was slipped (Day 28), significant amounts of biofouling had sloughed off the hull and most species still attached were dead, with the exception of some algae

and colonies of the arborescent bryozoan Bugula neritina. The results suggest that encapsulation can mitigate the risks posed by heavily fouled vessels while awaiting haul out. However, efficacy is likely to increase when used in combination with a chemical treatment.

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An initial investigation and dispersal assessment of invasive barnacle in Zhejiang coast of East China sea

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The change of marine environment has aided the establishment and spread of invasive species by providing suitable conditions. The characteristic barnacle Chthamalus challengeri (Hoek, 1883?is adaptable cold water fouling organisms which mainly distributed in Bohai sea and Yellow sea. The geological region mainly in north of Changjiang estuary and never found in the coast of East China sea before 2009. We recorded the distribution and abundance of Chthamalus challenger in Zhoushan archipelago since 2010 and southward to Wenzhou coast in 2014, which was dominant species in some areas. The habitat requirements of the invasive barnacle Chthamalus challengeri were assessed at Zhejiang coast. The invasion of this barnacle species may correlate with the change of the runoff of the Changjiang river. Chthamalus challenger has spread rapidly around Zhejiang coast .Understanding the habitat requirements of invasive species is important if we are to make predictions about their spread and the likelihood of invasion success. Since its initial introduction, becoming locally dominant in many coast areas including the Zhoushan archipelago and Wenzhou coast, with projections of favourable conditions, the continued spread of this species can be expected.

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Improving the performance of predictive niche models for invaders selection of pseudo-absences

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Correlative ecological niche models (CENMs) calibrated using only occurrence data from within the native range of an invasive species (Native Range Models, NRMs) have the advantage that predictions made to the invaded range are less likely to be inflated by spatial dependence between the calibration and test data. However, the predictive capability of NRMs is impaired when there exists considerable niche shift by the species, particularly niche expansion (E), in the invaded range. Pseudo-absences (PAs) are commonly used to calibrate CENMs when valid absence data are lacking. The classical strategy is to select PAs as random points from the entire study area used to calibrate the NRM (PAs-Random). We tested a new strategy for PA selection (PAs-MESS) and compared its performance with two established methods - PAs-Random and a Bioclimatic envelope strategy (PAs-BioClim) - across a range of marine species that exhibit various degrees of E. Considering species native occurrence as reference data, PAs-MESS uses a multivariate environmental similarity surface (MESS) to identify nonanalog environments (i.e., environmental space found in species invaded range which has no overlap with the native range) within the study area from which PAs were randomly selected. Similarly, PAs-Bioclim delineates nonanalog environments by constructing an environmental envelope using species native occurrence data and randomly selects PAs from outside that envelope. We quantified E for each species between its native and invaded range and examined how NRMs calibrated using the different PA strategies performed across a range of E values. Our results show that, for invaders with limited E, selecting PAs from the nonanalog environment (PAs-MESS and PAs-BioClim) significantly improved the predictive accuracy of the NRMs relative to the classical strategy. However, the improvement diminished quickly as E increased, highlighting the difficulty of accurately predicting the invaded range when there is considerable niche change.

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Protecting the Australian marine environment against invasive marine species but what species?

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Invasive marine species (IMS) are one of the greatest anthropogenic threats to the worlds oceans. IMS can substantially alter the structure of local ecosystems, threaten commercial fisheries, introduce diseases into other marine species and even humans and foul industrial structures and piping. The invasion of the mussel Mytilopsis sallei into Darwin Harbour in 1999 served as an important wake-up

call for Australia. A national IMS list of 55 species of concern to Australia has been developed for IMS monitoring. WA has a watch list with an additional 25 species. However, the effectiveness of monitoring programs has been reduced by severe taxonomic problems which create uncertainty about which species are actually of potential concern. The taxonomic issues surrounding three molluscan species (Mytilopsis sallei, Crassostrea gigas and Brachidontes ustulatus) are used as examples. The IMS lists have been developed based on literature analyses of what has been invasive elsewhere, but the same effects may not occur in Australia. The mussel Perna viridis is listed as the species of primary concern, but it has been detected on vessels in Australian waters on numerous occasions and has not become a problem. Better taxonomic information and understanding of biological features of the species involved are urgently needed if we are to protect the Australian marine environment from IMS.

Presenting author is Fred Wells

MITS: The NIWA MPI Marine Invasives Taxonomic Service

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Increasing awareness of the potential impacts of invasive marine species and the need for the accurate identification of specimens collected through biosecurity projects led to the creation of the Marine Invasives Taxonomic Service (MITS) in late 2005. The MITS service is provided by the National Institute of Water and Atmospheric Research Ltd (NIWA) and funded by the New Zealand Ministry for Primary Industries (MPI formally Biosecurity New Zealand). MITS provides a centralised service responsible for the taxonomic identification, curation and storage of marine specimens collected under biosecurity contracts (such as the NIWA/MPI Marine High Risk Site surveillance Contract) as well as incidental collections made by the public and external clients. Since its establishment, MITS has received identified over 70,500 specimens. Over 600 families, 1400 genera and 2600 species are currently held in the MITS specimen collection.

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Bane versus Benefit: Ornamental Species Trade as Invasion Vector or Sustainable Development

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Some of the world's most invasive marine species are aquarium escapees, yet the aquarium trade is a highly lucrative hobby industry and touted as a means for sustainable development in poor nations. On the one hand, nations are attempting to stem new invasions by ornamental species, particularly as the ocean warms and marine species exceed their 'tropical' climate envelopes. On the other hand, the demand for ornamentals provides strong economic incentive for people in developing nations to shift away from wholesale bomb fishing of coral reefs, which supply the majority of the trade. I will present studies from California, the major marine ornamental importer state in the US, and Indonesia, the main exporter, to explore the conundrum of preventing new introductions of ornamental species while fostering economic livelihoods for people without alternatives. Given economic vagaries and regulatory challenges, education campaigns provide a reliable solution to the thorny issue.

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Art following nature: The prevention and control of invasion ecology

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The invasion literature has behaved not unlike an invasive species, so we can ask similar questions. Where did it come from? How did it get here? How has it spread? Has it established? Has it had an impact? Has it encountered biotic resistance? Have there been biocontrol efforts? Early sightings of invasion biology can be found in Darwins On The Origin of Species, but there was a considerable time lag before the wider recognition that followed Eltons Ecology of Invasions. Since then, the populations of case studies, concepts, and vocabulary have proliferated dramatically. These pioneer papers facilitated a second wave of publications proposing unifying frameworks and lexicons, and a third wave calling for prevention and eradication of the whole business. One of the main avenues of criticism, articulated by a number of authors over the last two decades, is that the invasion biology literature has remained unjustifiably distinct from that of mainstream ecology. Here, I pose three questions: Is invasion ecology separate? Does it matter? How can useful connections be made? To answer these questions, I focus on four concepts in invasion biology (biotic resistance, enemy release, invasional meltdown, propagule pressure), quantitatively examine trends in the literature, consider the implications of temporal and spatial patterns, and propose ways to link cutting edges to foundational concepts.

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Modelling the potential effects of two non-indigenous biofouling species (Sabella spallanzanii and Styela clava) on Greenshell mussel farms

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Suspended mussel farms accumulate temporally and spatially variable biofouling communities during cropping. These biofouling communities are typically characterised by opportunistic and invasive biofoulers, including non-indigenous species. Understanding whether, and how, accumulated biofouling influences the mussel crop, and ecotrophic effects of mussel farms, is critical to ensuring productive and sustainable mussel farming practices. Understanding the actual/potential effects of non-indigenous organisms is also crucial for pre- and post-border biosecurity management. Here, we model the potential suspension-feeding effects of two non-indigenous biofouling species, the sabellid tubeworm Sabella spallanzanii and the solitary ascidian Styela clava, on Greenshell mussel (Perna canaliculus) culture lines alongside that of the target crop via a Dynamic Energy Budget (DEB) model. DEB theory is a well-established formal theory utilised in modelling the processes of uptake and use of substrates throughout an organisms life cycle in relation to environmental conditions. Using representative environmental and mussel growth data from two Pelorus Sound Greenshell mussel farming bays, we will provide examples of how the presence of S. spallanzanii and S. clava on infected mussel farms at varying densities could affect mussel crop production, as well as biodeposition accumulation underneath farms.

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Turning the tide: Native species restoration in highly invaded estuaries

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Restoration frequently occurs in habitats that have been dramatically changed by human activities, including the introduction of non-indigenous species (NIS). NIS can pose threats to native species as competitors, predators, or ecosystem engineers. When eradication of NIS is not tractable, one potential tool for restoration practitioners is to take advantage of environmental conditions that alter the impacts of

NIS on species targeted for restoration. We are investigating this option for native oyster (Ostrea lurida) restoration in three California bays. At Elkhorn Slough (Central California), we placed restoration substrates to test the effects of tidal height, shore type, and distance from adult populations on native oysters and sessile NIS that are potential space competitors. We found strong effects of tidal elevation and weaker effects of distance from source population: oysters fared better than NIS at higher tidal elevations (+30 cm vs. -30 cm MLLW) and at greater distances from source populations. In San Francisco Bay, we tested the effects of tidal elevation on predation by the Atlantic oyster drill Urosalpinx cinerea, placing oysters at two tidal elevations (+37 cm and +7 cm). We found a strong effect of tidal elevation, with >50% mortality of oysters due to drill predation at the low elevation in 30 days and no predation at the high elevation even 6 months later. Higher elevations dont give native oysters an advantage everywhere, however. In San Diego Bay, where the non-native oyster Crassostrea gigas is abundant, native oysters settle and survive in greatest abundance at +0.2 m, while C. gigas is most abundant at +0.8 m. To promote native oyster dominance, restoration substrates will be placed at lower tidal elevations. These studies suggest outcomes for native oysters can shift along environmental stress gradients, but details will be dictated by the specifics of site and species present.

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Assessing early shifts in biofouling community composition using a metabarcoding approach

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Timely detection and accurate identification of marine species is a prerequisite for preventing or mitigating the spread of invasive or pest species. This task requires considerable taxonomic expertise, is laborious, and particularly challenging when identifying cryptic species or those at larval stage. Metabarcoding in combination with high-throughput sequencing allows effective species detection and identification from environmental samples, providing presence/absence or semi-quantitative data. Biofouling communities form in marine environments on submerged natural or artificial substrates and are of particular scientific and managerial interests due to their ecological and socio-economical implications. In this experimental study a metabarcoding approach was used to determine the shifts in taxonomical composition of early biofouling communities on over 100 settlement plates in a busy coastal marina over 15 days. Within this period, more than 400 taxa belonging to 7 supergroups, 33 phyla, 73 classes, 132 orders, 195 families and 240 genera were identified from the experimental plates with metabarcoding approach. A few putative non-indigenous organisms were detected in the biofouling community starting from the first day of exposure. The results of the experiment and their implications for non-indigenous species monitoring and pathway management will be presented.

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Detection of invasive species in marine ecosystems using high-throughput sequencing: Research progress and future perspectives

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Introduction and spread of invasive non-indigenous species (NIS) has been clearly recognized as a growing global problem in the marine realm. The detection of an array of invasive species based on traditional morphological methods represents enormous technical challenges in marine ecosystems, as numerous poorly studied organisms may be small and/or have insufficient morphological distinctive features. The use of DNA-based approaches has largely increased the detection accuracy and efficiency. Owing the obvious advantages such as the high power to detect extremely low abundance species and low cost per sequence, high-throughput sequencing (HTS)-based methods have been popularly used or proposed for early detection of NIS in marine ecosystems. Although HTS-based approaches have been approved robust for the census of NIS in aquatic ecosystems, especially for those present at extremely low abundance, many factors in experimental design and data collection can cause errors including both false negatives and false positives. Here we provide an overview to identify these factors responsible for errors, discuss causes and consequences, propose possible solutions, and finally provide take-home massages for experimental design and data processing when utilizing high-throughput sequencing for NIS detection.

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