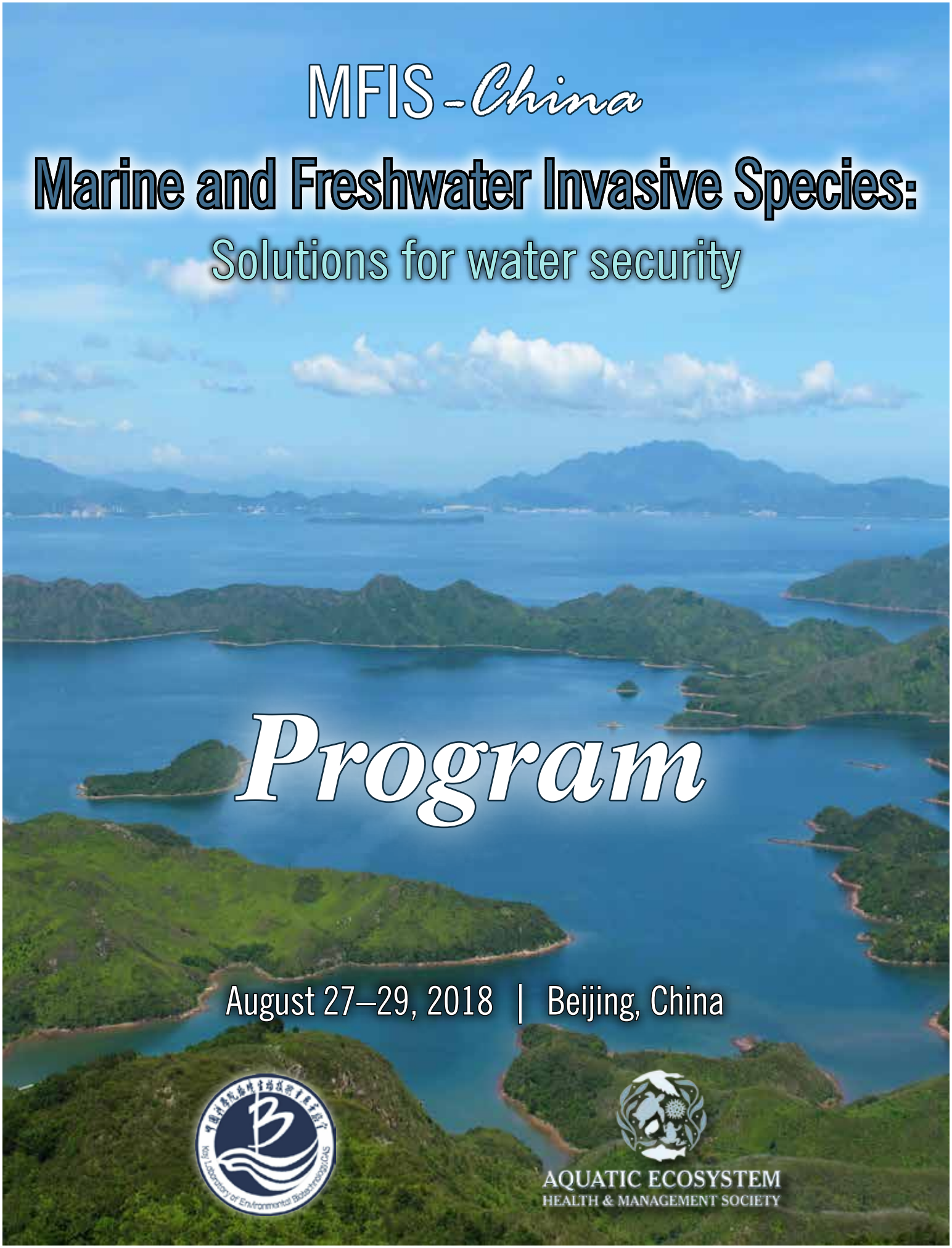

MFIS-China

Marine and Freshwater Invasive Species:

Solutions for water security

Program

August 27–29, 2018 | Beijing, China

AQUATIC ECOSYSTEM
HEALTH & MANAGEMENT SOCIETY

Contents

Welcome to historic and beautiful Beijing!

Aquatic invasive species (AIS) are a serious emerging problem in both marine and freshwater ecosystems, responsible for impacting ecology, habitats, and economies across the world. A wide range of aquatic organisms are being transported routinely through human activities such as international shipping, aquaculture and stocking programs, as well as live trade. The high volume of international marine traffic operating in the Asia Pacific region presents an obvious risk for the transfer of AIS, yet invasion biology in the Asia Pacific region is understudied. As elsewhere in the world, it is hypothesized that introductions to this highly populated region have resulted in ecological impacts including competition with and predation on native species, changes to nutrient cycling, and food-web alterations. Other impacts include biofouling of man-made structures, depletion of economically valuable populations and deterioration of coastal habitats. There is an urgent need to understand the risks posed and to implement preventive actions; to exchange information with experts around the world managing similar species and vectors through a state-of-the-art international conference.

This is the third in a series of international conferences on AIS organized by the Aquatic Ecosystem Health & Management Society (AEHMS). It follows the meetings in Oman (Feb, 2014) and Argentina (May, 2016). Like the previous conferences, it aims to bring together leading researchers and managers from the region and across the world, to share the current state of knowledge on the biology, ecology, impacts, risks, and management of both marine and freshwater AIS and their vectors. The Key Laboratory of Environmental Biotechnology, Chinese Academy of Sciences, Beijing, China and the AEHMS, Canada are jointly organizing the event, and we cordially invite all researchers, managers, students to take advantage of this unique opportunity.

Themes

1. Risk assessment, management and mechanism of fish invasions
2. Invasion risks and management
3. The biology, ecology, and control of the freshwater golden mussel *Limnoperna fortunei*
4. Nucleic acids-based tools for non-native species surveillance

The conference is being hosted in historic Beijing (北京) the capital of the People's Republic of China located in the northeastern part of the country. It is one of the Four Great Ancient Capitals of China. Due to its rich history, the city is full of famous sights, including seven UNESCO World Heritage Sites, such as the Forbidden City, parts of the Great Wall, and temples like the Temple of Heaven. An optional post-conference excursion to the Forbidden City, Tian'anmen Square, and Mutianyu Great Wall has been arranged to ensure participants have a chance to explore this historic place.

As announced, the AEHMS plans to publish papers based on the presentations at this conference in a special issue of its journal: Aquatic Ecosystem Health & Management (AEHM, published by Taylor and Francis, Philadelphia). Presenters interested in joining the publication are asked to submit their papers to the AEHMS for consideration and peer-review by November 30th, 2018. Special issue encourages shorter articles (up to 10 printed pages). Instructions for preparation of articles for AEHM are available at www.aehms.org.

The conference committee is indeed pleased to welcome you to Beijing, China. We hope that this conference will be productive and benefit from the knowledge of the experts and keynotes. Hopefully the meeting will be useful in highlighting the research in China and the Asia Pacific region in developing ecosystem-based management approaches and policies for overcoming the expansion and threat of alien species.

We extend a very warm welcome to all participants for an exciting, fruitful and interesting experience.

All the best,
The Organizing and Scientific Committees

Introducing AEHMS's mission and global reach

The Aquatic Ecosystem Health & Management Society (AEHMS) is a not-for-profit scientific society established in 1989. Our mission and objectives are as follows:

- Promote the ecosystem health approach and ecosystem science-based concepts for the conservation and management of global aquatic resources.
- Encourage integrated, multidisciplinary, multi-trophic and sustainable practices for the remediation and restoration of marine and freshwater ecosystems.
- Enhance understanding of ecological health and integrity by applying holistic initiatives, novel methods, models and technologies.

ACTIVITIES

The Society has four broad objectives centering on health, management, the convening/sponsoring of conferences/symposia, and publications via its international primary journal, monograph series and its website (www.aehms.org).

1. Convening of timely national and international conferences, symposia and workshops for promoting multi-disciplinary communication between scientists, managers, students, institutes, government, industry and the public sector.
2. Establishing Working Groups to coordinate and focus collaboratively on research themes and management approaches. Working Groups have been established by the AEHMS on the Great Lakes of the World (GLOW), Marine & Freshwater Invasive Species (MFIS), Health of the Gulf Ecosystem (GULF), and Remedial Action Plans (RAPs).
3. Publication of the AEHMS's peer-reviewed international primary journal: **Aquatic Ecosystem Health & Management** (AEHM) quarterly with *Taylor & Francis, Philadelphia, U.S.A,* (www.taylorandfrancis.com). It is an ISI-rated journal which often publishes special issues on selected themes and topics. So far over 50 special issues have been published by the journal (see http://aehms.org/publications/journal/).
4. The **Ecovision World Monograph Series** (EWMS) focuses on the paradigm of life on our ever-changing planet and its sustainability under the impact of physical, chemical, biological, and human influences. It covers detailed and comprehensive treatments of various topics, subjects, issues and ecosystems. It focuses on the interactions of multiple stressors originating from air, water, and land. The Ecovision book series is a peer-reviewed publication which is dedicated to integrated and ecosystem science-based approaches, merging the high quality of a journal with the comprehensive approach of a book. Currently more than 20 peer-reviewed books have been published on diverse topics (http://aehms.org/publications/ecovision/) which are distributed *by Michigan State University Press, East Lansing, Michigan* (www.msupress.org).

UPCOMING CONFERENCES

The AEHMS is active organizing conferences worldwide. Upcoming Society events include the following conferences and symposia:

- *Managing the health of the Gulf ecosystem: Dealing with climate change, invasive species, and coastal alterations (GULF 3)*, November 2018, Al-Ain, UAE
- *Emerging frontiers for African Great Lakes: Promoting blue economy, food security, and conservation (GLOW 9), April 2019, Kisumu, Kenya*

MEMBERSHIP

The Society welcomes researchers, managers, students and senior scientists from a variety of disciplines who are interested in global topics dealing with ecosystem health and ecosystem science- based management. The AEHMS cordially invites you to join the Society to support global conservation and education. Membership includes 4 quarterly issues of the journal with on-line access, as well as discounts on conference registration fees, purchases of Ecovision books and back issues of our journal. A discounted membership is available for the participants of this conference, students and retired colleagues. Please see our website for more info (www.aehms.org).

M. Munawar

President: Aquatic Ecosystem Health & Management Society

Chief Editor: Aquatic Ecosystem Health & Management

AQUATIC ECOSYSTEM HEALTH & MANAGEMENT SOCIETY

ECOVISION World Monograph Series

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We request participants to switch off mobile phones in the conference hall.

You should consider your personal name badge as your entry ticket. Please wear your badge at all times during the conference.

Liability: Neither the organizers, the AEHMS, nor any of the conference sponsors can be held responsible for damage, loss or theft during the conference. Please take precautions to ensure the safety of yourself and your valuables.

Program

Monday, August 27th			
9:00		**Registration**	
9:30-10:00		**Conference opening** • Greeting by Aibin ZHAN, Conference Co-chair • Welcome by Mohiuddin MUNAWAR, Conference Co-chair	
10:00-10:40	Plen.1	Gordon COPP	Risk analysis of non-native aquatic species – identification and assessment of high-risk species to inform policy, legislation and management
10:40-11:10		**Break**	
Session 1.	**Risk assessment, management and mechanism of fish invasions**		
	Session Chairs: Hui WEI & Shan LI		
11:10-11:50	S1. Key1	Lorenzo VILIZZI	A global trial of a new risk screening tool (AS-ISK) across a broad range of aquatic non-native species and risk assessment areas
11:50-12:10	S1.01	Ratcha CHAICHANA	Pre-import screening for non-native fish in Thailand using laboratory experiments and fish invasiveness screening kit
12:10-12:30	S1.02	Fujiang TANG	Piscivory cannibalism increased fitness of an alien species, Clearhead Icefish (*Protosalanx hyalocranius*)
12:30-12:50	S1.03	Ruibin YANG	Comparative transcriptome analysis provides insights into the response to the extreme environment of the Tibetan Plateau in invasive species, *Misgurnus anguillicaudatus*
12:50-2:40		**Lunch**	
2:40-3:20	S1. Key2	Darren YEO	Risky business: Assessing potential invasions from the ornamental fish industry in Singapore
3:20-3:40	S1.04	Wen XIONG	Invasive aquatic plant (*Alternanthera philoxeroides*) facilitates the invasion of Western Mosquitofish (*Gambusia affinis* Baird & Girard, 1853) in Yangtze River catchment, China
3:40-4:00	S1.05	Yiwen ZENG	Stemming the spread: Trophic complexity regulates fish invasion into Singapore's forest streams
4:00-4:20	S1.06	Liqing FAN	Non-native fish species in Tibet
4:20-4:50		**Break**	

Monday, August 27th			
4:50-5:10	S1.07	Jiao QIN	Invasions of two estuarine Gobiid species interactively induced from water diversion and saltwater intrusion
5:10-5:30	S1.08	Jie GUO	Status and progress of invading alien fish in the Yangtze River Basin
5:30-5:50	S1.09	Bjorn Schmidt	Inter-basin water transfer facilitates movement and invasion for the Yangtze grenadier anchovy in Eastern China
6:30		**Dinner**	

Tuesday, August 28th			
9:30-10:10	Plen.2	John DARLING	Genetic methods for monitoring aquatic invasive species: A case study in rapid evolution
Session 2.	**Invasion risks and management**		
	Session Chair: Mohiuddin Munawar		
10:10-10:30	S2.01	Farrah CHAN	Biological invasion risk in the marine Arctic: Current status and patterns of nonindigenous species
10:30-10:50	S2.02	Arturo ACERO	Lionfish invasion: A real threat to Caribbean coral reef biodiversity
10:50-11:20		**Break**	
11:20-11:40	S2.03	Claudia TAN	Can alien *Macrobrachium nipponense* (Decapoda, Palaemonidae) become a threat in a native stronghold habitat?
11:40-12:00	S2.04	Yiwen ZENG	Drivers of spread and impacts of freshwater non-indigenous species in a tropical city
12:00-12:20	S2.05	Thomas THERRIAULT	The invasion risk of species associated with Japanese tsunami marine debris in Pacific North America and Hawaii
12:20-12:40	S2.06	Haroon KHAN	Effect of herbicides on the management of Duckweed growth and production
12:40-2:40		**Lunch**	

Tuesday, August 28th			
Session 3.	**The biology, ecology, and control of the freshwater golden mussel *Limnoperna fortunei***		
	Session Chair: Mengzhen XU		
2:40-3:00	S3.01	Mengzhen XU	Effects and prevention measures of the Golden Mussel biofouling in water transfer projects
3:00-3:20	S3.02	Na ZHAO	Preliminary study on Golden Mussel invasion caused by a large inter-basin water diversion project in northern China
3:20-3:40	S3.03	Wei LIU	Implication of ecological amplitudes of the invasive freshwater Mussel (*Limnoperna fortunei*)
3:40-4:00	S3.04	Wenxin LIU	Monitoring of Golden Mussel invasion through water diversion projects
4:00-4:30		**Break**	
4:30-5:10		**Poster Session**	
6:30		**Dinner**	

Posters	
Listed alphabetically by presenting author	
Zhijun DONG	Occurrence of *Phyllorhiza* sp. (Cnidaria: Scyphozoa) in a Chinese coastal aquaculture pond: potential threat to the shrimp aquaculture
Du LUO	List of the alien fish species colonizing in natural waters and the progress of their ecological risk assessment based on niche, in China
Kit MAGELLAN	INVASIVESNET: International Association for Open Knowledge on Invasive Alien Species
Fanglei SHI	Biological characteristics and population genetics of a widely introduced Salangid, *Neosalanx tangkahkeii* in China
Liping YANG	Genetic structure analysis of *Pseudorasbora parva* in the four major water systems in Yunnan based on mitochondrial Cytb

Wednesday, August 29th			
9:30-10:10	Plen.3	Darren YEO	Singapore as a Southeast Asian case study for aquatic invasive species research
Session 4.	**Nucleic acids-based tools for non-native species surveillance**		
	Session Chair: John DARLING		
10:10-10:30	S4.01	Zhiqiang XIA	Early detection of a highly invasive bivalve based on environmental DNA (eDNA): Method development and optimizations
10:30-10:50	S4.02	Erin GREY	A global eDNA metabarcoding survey of ports allows testing of ship-borne species spread models
10:50-11:20		**Break**	
11:20-11:40	S4.03	Gordon COPP	Is it present or not: A highly-sensitive eDNA protocol for detecting alien fishes and forming management decisions on eradication
11:40-12:00	S4.04	John DARLING	Using DNA metabarcoding for ballast water monitoring: An assessment for three major United States ports
12:00-12:40		**Panel Discussion**	
12:40-1:00		**Conference Overview and Summary**	
1:00		**Lunch**	

Thursday, August 30th
Optional Post-Conference Excursion
Forbidden City, Tian'anmen Square, and Mutianyu Great Wall

Abstracts

Given in order of presentation.

Plenary 1

COPP, G.

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Risk analysis of non-native aquatic species – identification and assessment of high-risk species to inform policy, legislation and management

An essential process for the implementation of legislation and regulatory controls to manage non-native species, and thus avoid or mitigate the adverse impacts of invasive species, is risk-based identification and assessment of non-native species for their potential invasiveness. Derived from the hazard assessment protocols developed for the nuclear industry, the various non-native species (NNS) risk analysis schemes take many forms, both qualitative and quantitative. Some NNS risk schemes are specific to a taxonomic group (e.g. plants, fish, mammals) and some are generic (all species) or specific to the environment, e.g. aquatic. But virtually all aim to identify, assess and manage the risks of NNS entry, establishment, dispersal and impacts. This presentation will focus on the aquatic environment, discussing the general principles of risk assessment (RA) and examples of how decision-support (DS) tools, both generic and aquatic-environment specific, can be applied to aquatic species (with examples for fishes and invertebrates) to determine: (i) Which NNS are likely to be invasive in a given RA area; (ii) How these NNS may be assessed in greater detail; (iii) How the RA outcomes should be interpreted (with respect to assess confidence in the available information on the NNS); (iv) How the risk level of a NNS can increase or decrease as a result of new information; and (v) How NNS legislation, management and policy decisions can be informed by a species' risk and confidence rankings.

S1.Keynote 1

VILIZZI, L.[1]*, COPP, G.[2]

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A global trial of a new risk screening tool (AS-ISK) across a broad range of aquatic non-native species and risk assessment areas

An essential process for implementation of non-native species legislation, regulatory controls and management to avoid or mitigate adverse impacts, is risk-based identification and assessment. To facilitate this process for aquatic species, an electronic decision-support tool was developed: the Aquatic Species Invasiveness Screening Kit (AS-ISK), which is available for free download at: www.cefas.co.uk/nns/tools/.

The talk will summarise the outcome of initial trials of AS-ISK to a broad range of species and risk assessment (RA) areas. Compliant with the 'minimum requirements' for use with the new EU Regulation on invasive alien species of EU concern, AS-ISK includes question to assess the potential risks and impacts under both current and predicted future climate conditions to rank species by their likelihood of being invasive in the RA area concerned. To assess

AS-ISK's applicability across broad taxonomic, geographic and climatic ranges, our trials consisted of two groups of assessment, with delegates of the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) undertaking a notable proportion of the assessments: (i) single or duplicate assessments of a wide range of marine, fresh, brackish water species that are not native to the risk assessment (RA) areas selected by the assessors, including species and RA areas in Europe, North America and Asia; and (ii) multiple assessments of the Manila Clam *Ruditapes philippinarum* for RA areas across the globe. The results will inform decision makers and environmental managers on whether an RA area specific threshold score (distinguishing high risk and lower risk species) is needed, or if a generic threshold score may be used. Establishment of a threshold score is crucial to the allocation of increasingly scarce resources to combat invasive species by identifying which species require a full RA, to determine more precisely the potential risks, and which do not.

S1.01

DANGCHANA, P.[1], SENANAN, W.[2], POUNGCHAREAN, S.[1], KANJANABURANGKURA, M.[3], CHAICHANA, R.[1]*

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Pre-import screening for non-native fish in Thailand using laboratory experiments and fish invasiveness screening kit

Pre-import screening of exotic animals is a crucial tool to prevent introduction of non-native invasive species. The objectives of this study were to evaluate the potential invasiveness of alien fish Barcoo Grunter (*Scortum barcoo*), an Australian freshwater fish, by using laboratory and field experiments. Studies included fish morphology, feeding habits, ability of native predators to control Barcoo Grunter and tolerance of Barcoo Grunter to different oxygen concentrations. Furthermore, a Fish Invasiveness Screening Kit (FISK) was used to predict its invasiveness. The results showed that stomach fullness index was highest in the morning (7.00 am) and five major food items were found (fish, shrimp, aquatic insects, plants and algae). When comparing the amount of food in fish stomachs in the laboratory, Barcoo Grunter consumed aquatic fauna up to 80%, whereas Striped Tiger Nandid and Red Tinfoil Barb consumed less aquatic fauna by about 50% and 30%, respectively. The results of a semi-natural experiment in net cages (mesh size of 3.5 cm) revealed that Striped Tiger Nandid had a higher ratio of food weight per body weight than Barcoo Grunter and Red Tinfoil Barb, respectively ($p < 0.05$). However, food found in the stomach of Barcoo Grunter was more diverse (8 items). It was also found that four native predatory species could prey upon Barcoo Grunters up to a length of 6 cm. In particular, Giant Snakehead preferred *S. barcoo* over other prey and the ratio of consumption accounted for 96.70%; 33.30% for Silver Barb. Barcoo Grunter survived at low oxygen supply for 30 days, but with reduced food intake and slower growth rates. Evaluation of this invasive alien species with FISK V2 program scored six points, indicating moderate invasiveness.

S1.02

TANG, F.*, LIU, W., WANG, J.

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Piscivory cannibalism increased fitness of an alien species, Clearhead Icefish (*Protosalanx hyalocranius*)

Piscivory/cannibalism is considered the cause of intra-cohort size divergence in fish, and is usually believed to increase fitness in survival and reproduction. However, direct evidence of piscivory/cannibalism as the cause of increased reproductive fitness has not been demonstrated until now. Clearhead Icefish (*Protosalanx hyalocranius*) is a small fish with a life span of about 1 year, which makes it a good candidate for study of this topic. The life cycle of alien P. hyalocranius was investigated in Lake Xingkai (Khanka) from March 2010 through March 2011. Size-frequency exhibited a bimodal distribution from July through January; i.e. the population diverged into an upper modal group and a lower modal group. Stomach content analysis revealed that the lower modal group and other fish juveniles served as prey and the upper modal group were predators. Adults became mature in October and spawned mainly in January, while upper modal group females matured a little earlier than the lower modal group and reproductive investment was much larger in the upper modal group than in the lower modal group. Lower modal group males accounted for the majority of the population after the main reproduction period in January, which meant they may have had few opportunities to participate in reproduction. Therefore, piscivory/cannibalism increased fitness of the upper modal group of *P. hyalocranius.*

S1.03

MA, Z., YANG, X., YANG, R.*

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Comparative transcriptome analysis provides insights into the response to the extreme environment of the Tibetan Plateau in invasive species, *Misgurnus anguillicaudatus*

Misgurnus anguillicaudatus is widely distributed in the middle and lower reaches of the Yangtze River basin; however, it has now successfully invaded to the Tibetan Plateau and established natural populations. How they adapt to high-altitude aquatic environments with higher ultraviolet radiation (UVR) at the molecular level remains unknown. In this study, we performed comparative transcriptome analyses of dorsal skin and visceral peritoneum of wild *M. anguillicaudatus* between Chabalang Wetland in Tibet (3592.3 m a.s.l) and Beisha Lake in Hubei (18.3 m a.s.l), respectively. We identified 1,710 differentially expressed genes (DEGs) in dorsal skin of *M. anguillicaudatus* from Chabalang Wetland, including 660 up-regulated genes and 1,050 down-regulated genes. And in visceral peritoneum, we found 9,598 DEGs, 5,098 of which were increasing and the others were decreasing. Functional categorization of the DEGs in dorsal skin and visceral peritoneum both revealed the differential regulation of cellular process, binding, metabolic process, catalytic activity, cell part, and response to stimulus. Intriguingly, KEGG analyses showed that several DEGs in visceral peritoneum involved in DNA replication and repair, p53 signaling pathway and melanogenesis were significantly enriched ($P < 0.05$), indicating the visceral peritoneum may act as an important defense against UVR through regulating the expression of genes associated with DNA damage response and repair and pigmentation.

S1.Keynote 2

ZENG, Y.[1], CHAN, J.[1], YEO, S.[1], CHUA, K.[1], TAN, H.[2], YEO, D.[1]*

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Risky business: Assessing potential invasions from the ornamental fish industry in Singapore

As one of the world's largest importers and exporters of freshwater ornamental fishes, Singapore is particularly susceptible to invasion by non-native fishes. Many species introduced into the country's freshwater habitats originate from this pathway and have the potential to impact not only the environment (e.g. native fishes, freshwater habitats), but also economy and human health. In light of that, this talk covers several efforts to quantify the risk these fish species could pose in Singapore. Specifically, these studies utilize quantitative trait-based risk assessments, as well as semi-quantitative methods such as Fish Invasiveness Screening Kit (FISK) v2, to determine establishment and invasive risk, respectively. Through these techniques, we identified several traits, such as climate match and phylogeny, as important predictors of freshwater fish establishment in Singapore fresh waters, with Cichlids being a particularly high-risk group of fishes. We discuss the implications of our findings on the local ornamental trade, and draw comparisons to the updated semi-quantitative technique i.e. Aquatic Species Invasiveness Screening Kit (AS-ISK).

S1.04

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Invasive aquatic plant (*Alternanthera philoxeroides*) facilitates the invasion of Western Mosquitofish (*Gambusia affinis* Baird & Girard, 1853) in Yangtze River catchment, China

Habitats selections are essential for invasion of non-native species. However, few studies have investigated habitat selection by Western Mosquitofish in invaded ecosystems. We investigated seasonal habitat selection of Western Mosquitofish to increase understanding of the ecology of this species. Sampling was conducted during both its reproductive and non-reproductive seasons in four habitat types: *Alternanthera philoxeroides* habitat, *Typha angustifolia* habitat, *Paspalum distichum* habitat, and no vegetation habitat. Western Mosquitofish catch per unit effort (CPUE) was significantly lower in Typha habitat than in the other three habitats in reproductive seasons. *T. angustifolia* can exude allelopathic chemicals which have the potential to negatively influence Western Mosquitofish. In the non-reproductive season, CPUE and water temperature were significantly higher in Alternanthera habitat than in the other three habitats. The results suggest that mats of *A. philoxeroides* provided an insulating layer for Western Mosquitofish overwintering. Therefore, Western Mosquitofish could expand its range further north in China as *A. philoxeroides* spreads northward with climate change. We suggest that an effective way for controlling this invasion is through eradicating invasive macrophyte (*A. philoxeroides*) stands while retaining and restoring more native emergent macrophyte (*T. angustifolia*) stands; this strategy could limit overwintering habitat for Western Mosquitofish and may draw them into open water habitats where they could easily be removed.

S1.05

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Stemming the spread: Trophic complexity regulates fish invasion into Singapore's forest streams

Disentangling factors that drive various stages of the invasion process is important for understanding, predicting, and controlling species invasion. In Singapore, high numbers of non-native fishes are found in artificial or disturbed habitats such as reservoirs (impounded rivers). These non-native species can spread into directly connected natural forest streams—which are the last strongholds for most of the nation's native freshwater fishes—and potentially cause ecological impacts. This talk discusses a study of this key stage of the invasion process, which identifies abiotic conditions and trophic complexity as important factors in regulating the spread of non-native reservoir fishes into native forest stream fish communities. These findings further our understanding of species invasions, and can also promote conservation and management options.

S1.06

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Non-native fish species in Tibet

We found 15 species of non-native fishes in Tibet, most of which were distributed in the midstream of the Yarlung Zangbo River and ranged from 2660 to 4485 m above sea level. The most widely distributed and abundant non-native fishes were the Loach *Misgurnus anguillicaudatus*, Goldfish *Carassius auratus* and Topmouth Gudgeon *Pseudorasbora parva*. Ten fishes were introduced for sale and aquaculture to provide new food resources and 5 were introduced unintentionally. They were released for religious devotion all over the province and escaped from farms around Lhasa City and Nyingchi City.
In the Lhasa River, the biggest tributary of the Yarlung Zangbo River, nearly half of the fish species were non-native. Non-native fishes mainly occurred in the downstream of the Lhasa River basin, preferring mud substrate, warm and shallow water with slow flow. The percentage of these fishes in the assemblage was correlated with the distance to fish farms and religious release, and unrelated to human population density and the rural residents' per capita net income of the town. Fish assemblage of the basin can be distinguished as 3 clusters by Cluster and Multidimensional Scaling analysis, with cluster 1 containing a large number of non-native fishes in release sites and sites near fish farms in the downstream of the basin; cluster 2 composed of a number of non-native fishes in release sites in the midstream of the basin and cluster 3 including native fish assemblage in other sites of the basin.

S1.07

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Invasions of two estuarine Gobiid species interactively induced from water diversion and saltwater intrusion

The East Route of South-to-North Water Transfer Project of China (ESNT) uses the Grand Canal as the main pathway for water conveyance from the Yangtze River to northern China and also links five major lakes that serve as water storage along the route. ESNT was completed in 2013 and was expanded from the older Northern Jiangsu Water Transfer Project (NJWT), which had been in place since the 1960s. We observed invasions of two estuarine Gobies, *Taenioides cirratus* (Blyth, 1860) and *Tridentiger bifasciatus* (Steindachner, 1881), into the linked lakes. *T. cirratus* was first reported in Luoma Lake in 2005 and Nansi Lake in 2011. *T. bifasciatus* was first observed in Luoma Lake and Nansi Lake in 2015 and in Dongping Lake in 2016. The invasion of *T. cirratus* was probably associated with the operation of the NJWT, and enhanced by the operation of ESNT; while the invasion of *T. bifasciatus* was associated with the operation of the ESNT. ESNT/ NJWT mainly operates during winter and spring, when the Yangtze River is at its annual minimum discharge. Impoundment of the reservoirs upstream of the Yangtze River and its tributaries, has dramatically declined river discharge during this season, inducing saltwater intrusion upstream to the donor area of the ESNT. Thus, estuarine Gobies, such as *T. cirratus* and *T. bifasciatus,* can reach the donor region, and be dispersed through water diversion.

S1.08

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Status and progress of invading alien fish in the Yangtze River Basin

Invasive non-native species are a classic environmental issue, which pose a widespread threat to the biodiversity of freshwater ecosystems. The high heterogeneity of the river habitat in the Yangtze River basin provides a good basis for invasion of alien fish and this has provoked widespread concern. This paper reviews a published survey of the invasion alien fish in the Yangtze River Basin, including their species, geographic distribution and ecological impact. We summarize current knowledge about invasive freshwater species, including studies on processes, mechanisms, research methods and risk assessments for fish invasion. Finally, this paper provides some measures for the prevention and control of invading alien fish and the sustainable development of the fishery in the Yangtze River Basin.

S1.09

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Inter-basin water transfer facilitates movement and invasion for the Yangtze grenadier anchovy in Eastern China

China's South-to-North Water Diversion Project is the world's largest inter-basin water transfer project, diverting water from the Yangtze River to northern regions of China. The east route of this project (ESN, 2013) intersects five large freshwater lakes in Jiangsu and Shandong Provinces: Gaoyou Lake, Hongze Lake, Luoma Lake, Nansi Lake, and Dongping Lake. Artificial connections across drainage divides provide new pathways for dispersal between communities that can often lead to species invasions and range expansions. The freshwater Yangtze grenadier anchovy, *Coilia nasus* (formerly *brachynathus*) has had a range expansion into Dongping Lake in 2013 following operation of the ESN. This species has become one of the dominant species in the lake with multiple size classes observed in 2016, likely indicating local reproduction and recruitment. A study was done to determine the genetic signature and diversity of this invasive population of *C. nasus* and determine whether the newly established population derived from the most likely proximate source in the water transfer system. Additionally, individuals from the other four lakes were examined to detect other patterns of recent movement along the route. Fifty to one hundred individuals were sampled from each lake and genotyped at 8 microsatellite loci. Approximate Bayesian Computation was used to compare probabilities of invasion models into Dongping Lake from different source lakes along the route. Genetic diversity indices were compared among the invasive population and the populations in the other four lakes. Genetic assignment tests (Geneclass2 and BayesAss) were used to detect individuals in lakes that were likely migrants or offspring of migrants from other lakes to determine general patterns of movement facilitated by water transfer along the ESN. Preliminary results are discussed which provide insight into ongoing community and metapopulation changes following artificially enhanced structural connectivity in this system.

Plenary 2

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Genetic methods for monitoring aquatic invasive species: A case study in rapid evolution

All management actions aimed at mitigating the ecological and economic harms done by aquatic invasive species are predicated on detection. General risk management, prevention of new incursions, control and eradication of established invasive species, all depend on the ability to detect individual organisms, often when populations are at extremely low densities. The associated need for improved monitoring tools—those that are more accurate, more sensitive, more easily deployable, and less expensive—is increasingly driving the development of methods based on the capture and analysis of nucleic acids in the environment. This talk is about the trajectory of this rapidly growing field. I will discuss the past, present and future of these potentially game-changing methodologies, with an eye toward both the extraordinary gains already made and the hurdles—technological, logistical, and even political—that remain. I will focus the talk primarily on two advances made in the past decade, one conceptual (the notion that organisms might be detected "sight unseen" by the presence of their shed environmental DNA) and one technological (the emergence and growing accessibility of high throughput sequencing), and will examine how researchers and managers alike are addressing challenges such as the interpretation of genetic detections, the need for quantification of target populations, and the importance of assessing viability in certain monitoring

contexts. I will present a case for the promise of these methods, which have the potential to vastly improve our capacity to manage aquatic invasions over the coming decade. In doing so, I hope also to encourage cross-disciplinary engagement in the development of genetic monitoring tools, to ensure that future tools are responsive to management needs.

S2.01

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Biological invasion risk in the marine Arctic: Current status and patterns of nonindigenous species

Nonindigenous species (NIS) are increasingly threatening the Arctic environment partly due to the effects of climate change. Warming climate is promoting human-mediated introductions and natural spread of NIS into the Arctic. The Arctic environment is becoming more suitable for temperate species, allowing for successful establishment once introduced. In this study, we examined information on 48 introduction events of 31 NIS in the marine Arctic to better understand temporal and spatial patterns and to identify important source and introduced regions. We studied single- and multi-pathway NIS. The rate of NIS introduction ranged from 0-3 new NIS per year during the studied period. The Norwegian Sea, Barents Sea, and Iceland Shelf had the greatest numbers of introductions, and many NIS came from the Northwest Pacific, Northeast Atlantic, and unknown sources. Shipping was the pathway that introduced the greatest number of NIS to the Arctic, including phyla Ochrophyta and Arthropoda, which had the highest numbers of introduction events. We found that a lack of baseline taxonomic data compromised the identification of new NIS, as in most cases it is unknown whether the species has historically occurred within the Arctic. Further inventory of Arctic biodiversity is needed, particularly as climate change creates a more hospitable environment for new species. Finally, we reviewed management techniques that may be effective in mitigating NIS in the marine Arctic when implemented promptly. The Arctic ecosystem is expected to undergo rapid changes which may facilitate the establishment of invasive NIS; therefore further study and management of the area is crucial.

S2.02

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Lionfish invasion: A real threat to Caribbean coral reef biodiversity

Lionfish consumes at least 250 fish and crustacean prey species in the Western Atlantic. Main taxa eaten include: Grunts (*Haemulon aurolineatum*), Wrasses (*Thalassoma bifasciatum* and *Halichoeres* spp.), Damselfishes (*Stegastes partitus* and *Chromis cyanea*) Gobies (*Coryphopterus personatus*), Labrisomids (*Malacoctenus triangulatus*) and *P. volitans*. Because Lionfish prey on such a long list of Caribbean reef fauna, it should be considered a generalist invasive species that even threatens commercially and ecologically important species such as Grunts, Groupers, Snappers, Triggerfishes, Parrotfishes, Surgeonfishes, Gobies, Lobsters and Cleaner Shrimps. Four richness estimators indicate that Lionfish may consume around 300 species. Lionfish diets from the Colombian Caribbean appear distant from the Bahamas and Cayman Island diets in a cluster analysis. Research and monitoring of this dangerous invading species should be maintained.

S2.03

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Can alien *Macrobrachium nipponense* (Decapoda, Palaemonidae) become a threat in a native stronghold habitat?

Determining the potential invasive risk of non-native species, specifically the likelihood of inflicting negative impacts on recipient ecosystems, is vital in invasive species management. This is especially so in areas where the non-native species may co-occur with native congeners. One of the species of concern is *Macrobrachium nipponense*, a non-native freshwater Shrimp established in disturbed, open, rural streams in Singapore. To this end, studies were conducted to understand its potential impacts on *Macrobrachium malayanum,* an abundant native congener that co-occurs with *M. nipponense* in rural streams, but mainly inhabits the connecting natural, tree-dominated native strongholds within forest streams. The survivorship of *M. nipponense*, and its potential impacts on *M. malayanum* was thus investigated in both rural and forest stream habitats through a 14-day in-situ survivorship experiment under different species combination-interaction scenarios. Additionally, the differences in exploitation rates on a common food resource were investigated by comparing both species' functional responses under open and forest stream conditions. The non-native Shrimp in isolation was found to tolerate mild forest stream conditions as well as rural stream conditions, indicating a wider range of physiological tolerance of *M. nipponense* could allow it to potentially spread into the forest stream strongholds of the native Shrimp. However, when placed together with native *M. malayanum*, the survivorship of *M. nipponense* in forest stream conditions significantly decreased, indicating the native species' competitive superiority within its forest stream strongholds. Functional response experiments also suggested potential invasive impacts, although further investigation is required. This combination of studies provides insight into the invasive threat posed by a non-native species with wide environmental range, highlighting the need to preserve the ecosystem integrity of native species strongholds.

S2.04

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Drivers of spread and impacts of freshwater non-indigenous species in a tropical city

Singapore, a highly urbanized city within tropical Southeast Asia, is the largest contributor (via import and export) to the global ornamental fish/aquarium trade. Through this pathway, many non-indigenous species (NIS) have been introduced into Singapore's fresh waters, especially within novel habitats such as canals and reservoirs. Ecological impacts of NIS have generally been limited, as these artificial, urban waterbodies contain few native species. However, in recent years, a subset of these NIS has been observed within natural forest streams connected to reservoirs/canals. This spread of NIS represents an emerging ecological threat, as these streams are among the last refuges for many of Singapore's native freshwater species. This talk highlights studies conducted to determine the drivers (e.g. abiotic and biotic conditions) of spread of NIS (particularly fishes and decapod crustaceans) into forest streams in Singapore. Efforts to quantify impacts associated with this species spread will also be discussed, with species such as the Redclaw Crayfish (*Cherax quadricarinatus*) identified as notable threats to native fauna. The identification of these drivers and impacts represents an important step in the development of relevant management and conservation strategies.

S2.05

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The invasion risk of species associated with Japanese tsunami marine debris in Pacific North America and Hawaii

Marine debris from the Great Tsunami of 2011 represents a unique transport vector for Japanese species to reach Pacific North America and Hawaii. Over 600 debris items attributed to the tsunami have been intercepted thus far and over 380 species of algae, invertebrates and fish have been identified and associated with Japanese Tsunami Marine Debris (JTMD). Most of the species encountered are native to Japan, not currently present in Pacific North America or Hawaii, and their invasion risk is unknown. Thus, it is important to characterize the risk their introduction may pose to Pacific North American and Hawaiian ecosystems, as risk assessments can inform policy and management decisions about potential invasive species, including informing monitoring programs. Here we characterize the risk of individual invertebrate species associated with JTMD using a screening-level risk assessment tool – the Canadian Marine Invasive Screening Tool (CMIST). This tool scores both the probability and consequences (impacts) of an invasion for receiving ecosystems, to generate an overall risk score that encompasses assessor uncertainty, thereby identifying relatively higher risk species associated with JTMD. Higher-risk invertebrate invaders were identified for each of five different ecoregions on the Pacific coast of North American and Hawaii. Some of these species are well-known global invaders, such as the Mussel *Mytilus galloprovincialis* and the Ascidian *Didemnum vexillum*, which already have invasion histories in some of the assessed ecoregions. Others, like the Sea Star *Asterias amurensis* and the Shore Crab H*emigrapsus sanguineus,*

have yet to invade large portions of the assessed ecoregions, but are also recognized global invaders. Although most of the species assessed were considered relatively low to moderate risk, in part due to a lack of reported invasion history and impacts elsewhere, it remains possible that any JTMD species could become invasive in Pacific North America or Hawaii.

S2.06

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Effect of herbicides on the management of Duckweed growth and production

In the Department of Weed Science, University of Agriculture, Peshawar, an experiment was conducted in the summer of 2016. The study aim was to investigate the effect of herbicides on the management of Duckweed (*Lemna* spp.). The experiment was arranged in completely random design with 3 repeats. Duckweed was grown in pots having a diameter of 5˝. Maximum fresh biomass (4.45 g pot^{-1}) was recorded for weedy check, while least fresh biomass (2.98 g pot^{-1}) was noted for glyphosate. Similarly, maximum budding (58.7%) was found for control, while the minimum (24%) was observed for glyphosate. Moreover, lowest plant mortality was noted for weedy check, while highest (24.33%) was recorded for glyphosate. Furthermore, maximum water surface coverage (%) after 4 weeks (20.3%) was noted in isoproturon, while the minimum was observed in glyphosate. It is concluded that glyphosate effectively controlled the Duckweed, followed by MCPA (a powerful, selective, widely used phenoxy herbicide).

S3.01

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Effects and prevention measures of the Golden Mussel biofouling in water transfer projects

Golden Mussels (*Limnoperna fortunei*) are filter-collectors of Zoobenthos in natural rivers. They easily invade water transfer tunnels and attach on their walls and structures at extremely high densities, resulting in serious biofouling, decreasing water transfer efficiency and threatening the engineering operation. In this study, we reviewed the biological characteristics of Golden Mussel, analyzed the negative effects of biofouling on water transfer projects and summarized the prevention and control measures applied in practice. Risk assessment and systematic quantitative monitoring of biofouling were carried out in typical water transfer projects in China and corresponding management strategies were suggested, which provide technical support for the management of grand water transfer projects South-to-North for preventing biofouling related to the Golden Mussel.

S3.02

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Preliminary study on Golden Mussel invasion caused by a large inter-basin water diversion project in northern China

Due to the uneven distribution of water resources, the number of inter-basin water diversion projects in China is increasing, which may cause ecological problems such as biological invasion. Golden Mussel (*Limnoperna fortunei*) is a typical invasive species that originated in the waters of southern China and is now invading northward through various means. In this study, a large-scale inter-basin water diversion project in northern China (from Danjiangkou Reservoir to Beijing and Tianjin) and the major reservoirs along this project were selected as research sites. Field sampling, laboratory identification and statistics were used to study the distribution of Golden Mussel larvae along the project, and to reveal their status of attachment in the main buildings of this project. Results indicated that Golden Mussel larvae were found in the water along the whole project and density increased due to the water source. There were Golden Mussels living in some reservoirs along the project, which may have been caused by the injection of water. The highest attachment density of Golden Mussel in the aqueduct was 10190 individuals m^{-2}, which was related to factors such as aqueduct shape, water conditions in the aqueduct, and internal structure of the aqueduct. This water diversion project not only exacerbated the invasive process of Golden Mussel to the new catchment, but also caused biofouling. Therefore, certain measures should be taken to prevent and control Golden Mussel invasion in the project.

S3.03

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Implication of ecological amplitudes of the invasive freshwater Mussel (*Limnoperna fortunei*)

The Golden Mussel (*Limnoperna fortunei*) is an invasive species originating from China which has caused worldwide problems for local ecology and human facilities due its high abilities for reproduction, vitality and attachment. There is dubious information about its tolerance to environmental stress. To determine the ecological amplitude and to explore the Mussels' physiological metabolism reaction under environmental stress, a set of laboratory tests were conducted. Their endurance to environmental parameters, including water temperature, pH, dissolved oxygen, illumination, concentration of ammonium, and food supply, were determined. Effects of different environmental stresses on survival rate, adhesive rate, and metabolic rate of the species were analyzed. The preliminary results indicated that a) in contrast to what was commonly believed, *Limnoperna fortunei* was not sensitive to water temperature, pH or illumination; b) the adhesive behavior was significantly affected and even lost before the death; c) findings of the ecological amplitudes and life cycle traits are critical for developing strategies to control Mussel invasion.

S3.04

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Monitoring of Golden Mussel invasion through water diversion projects

The Golden Mussel (*Limnopema fortunei*) is an invasive species of macroinvertebrates. This species is native in rivers of south China. Golden Mussels can live well in waters of high velocity and low dissolved oxygen; in addition they have a high reproduction rate and easily attach themselves to walls of pipelines. Consequently, they become a nuisance in Chinese grand water transfer systems, especially those in North China which were not naturally inhabited by Golden Mussel. Early monitoring and warning has been regarded as among the most important strategies for controlling this invasion.

In colonized water transfer systems, Golden Mussels were found attached on almost all types of facilities, including open channels, aqueducts, tunnels, etc. To monitor this invasion in North China, through water diversion activities, in-situ water sampling was conducted from the water intake to the outlet of a grand water transfer channel. Density variations of Golden Mussel larvae and adults were detected, and the environmental parameters affecting the densities were investigated. Sixteen monitoring sections were set along the 1400 km long channel. Plankton larvae and attached Mussel densities were determined by taking water samples from the transported waterbody and measuring Mussels attached on the channel walls at each section, from March to November of 2017.

Monitoring results showed that the larval density increased irregularly, while the adult density decreased irregularly from the intake section to the outlet section of the channel. Moreover, the ratio of different larval stages varied along the channel monthly. Our preliminary analysis indicated that dissolved oxygen played a positive role on larval density, while total nitrogen restrained the increase of larval density. Experimental studies were carried out to reveal the influences of different environmental parameters on the density variations.

Poster 1

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Occurrence of *Phyllorhiza* sp. (Cnidaria: Scyphozoa) in a Chinese coastal aquaculture pond: potential threat to the shrimp aquaculture

We report the first record of the scyphomedusa *Phyllorhiza* sp. in China. These specimens have been identified based on a combination of morphological characteristics and mitochondrial 16S DNA sequences data. Adult, juvenile and an ephyra have been observed in an aquaculture pond located in the Jiangsu Province coast. Although no scyphistomae have been found so far, the presence of all pelagic stages (adults, juveniles and ephyrae) suggests that this species completes its whole metagenetic life cycle within the pond. We observed through laboratory observations that these medusae were capable of killing shrimp using the nematocysts on its oral arms but they were unable of eating them, probably because of their large size in relation to the micromouths.

Poster 2

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List of the alien fish species colonizing in natural waters and the progress of their ecological risk assessment based on niche, in China

China is the quantitatively leading country both in aquaculture and aquariums in the past few decades. Up to now, 567 species of aquatic animals have been, legally or illegally, introduced into China according to an incomplete statistics. Most of the introduced non-native organisms are fish species, which are serious threats to biodiversity, fish fauna and human health. Colonization is a key step in the process of changing from alien species to invasive species. Therefore, we listed the introduced fish species colonizing natural waters in China, and reviewed the progress of their ecological risk assessment based on niche. The results showed that about 60 fish species, 11.9% of the introduced fish species, have successfully colonized natural waters. 49.5% of the introduced fish species for aquaculture have been recorded in fish resources investigations. Reports showed that the researchers paid attention to the management strategies and legal countermeasures to control the alien fish species. Although there is some work on the risk assessment system and method of invasion for alien fishes, the risk assessment of specific fish species is seriously insufficient. *Pseudorasbora parva*, *Carassius auratus* and three transgenic fish are a few species that have been risk assessed based on niche or niche models. The current risk assessment measures are neither detailed enough nor strict enough for the introduction and promotion of a new fish species. An all-round ecological risk assessment for the colonized species is an extremely urgent need. Furthermore, a comprehensive ecological risk assessment following operational management measures will greatly contribute to the sustainable development of aquaculture and society.

Poster 3

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INVASIVESNET: International Association for Open Knowledge on Invasive Alien Species

In a world where invasive alien species (IAS) are recognised as one of the major threats to biodiversity, leading invasion biology scientists from five continents have created INVASIVESNET: an international association for open knowledge and open data on invasive species (https://www.invasivesnet.org). This new association will develop a sustainable network on IAS.

In addition to their inclusion in the CBD Strategic Plan for Biodiversity, the increasing ecological, social and economic impacts associated with IAS have driven the development of legal instruments globally. This increases the need for greater co-operation and information flow among scientists, management and the community of practice. INVASIVESNET links networks of all interested stakeholders including scientists, citizens, international and national expert working groups and initiatives, database managers, thematic open access journals, environmental agencies, practitioners, managers, industry, non-government organisations and educational bodies. The association will promote networking opportunities, knowledge sharing and learning and provide resources via high quality communication, information, publication and education services.

To date, sustainability of many strategic national and international initiatives on invasive species has unfortunately been hampered by time-limited grants or funding cycles. Recognising that IAS initiatives need to be on-going, we will develop a sustainable knowledge sharing association to network the outputs of developing invasion biology and inform the consequential management and societal challenges arising from introductions of invasive alien species.

Poster 4

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Biological characteristics and population genetics of a widely introduced Salangid, *Neosalanx tangkahkeii* in China

Family Salangidae is endemic to East Asia, with the greatest species concentration in China. All species in the family have innate biological characteristics referred to as extreme R-selected strategy, which is beneficial to their recruitment and in strengthening their tolerance to overexploitation. Unfortunately, the nationwide introduction of *Neosalanx tangkahkeii* was initiated in 1979 in China. This species further invaded all provinces in mainland China by the end of 2000, with the exception of Tibet. To clarify the invasion mechanism in *Neosalanx tangkahkeii,* based on an expanding data set in terms of life-history strategy and population genetics within/between introduced stock or between introduced and natural populations, we summarized the variations on life-history strategies in 4 natural and 7 introduced populations, and studied genetic diversity in natural and introduced populations based on enough sample, using molecular makers, mtDNA cyt b sequence and mircosatellite. By biological and ecological investigations, we found that *Neosalanx tangkahkeii* is not only a typical R-strategist similar to other Salangids, but it is also well adapted to the changes in temperature, salinity as well as the period after introduction, having the highest ecologic plasticity within its congeners. Almost all natural and introduced populations still keep a comparatively high genetic diversity level; the marine populations have the lowest genetic diversity and the highest genetic differentiation from other populations. Bayesian clustering analysis suggests a three-cluster model (K=3) as the most parsimonious possibility. However, individuals from several populations do not appear to assign consistently to a single cluster, possibly showing a high level of admixture and mixture of individuals from different geographical origins. We also hope to boost regional research capacity and international cooperation on fish biodiversity conservation through this study.

Poster 5

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Genetic structure analysis of *Pseudorasbora parva* in the four major water systems in Yunnan based on mitochondrial Cytb

Pseudorasbora parva was originally found in Jinshajiang and Nanpanjiang in Yunnan. However, it has now been widely distributed in all major water systems and become an invasive fish in the other four water systems in Yunnan. In order to reveal the differences of genetic diversity and genetic differentiation of *Pseudorasbora parva* within Yunnan after the invasion, and the native region, we collected 215 samples distributed in 13 different sites

of Lancang River, Nujiang, Honghe and Irrawaddy River in Yunnan, and 5 native places in Huang He, Yangtze, and Pearl River. Here we analysed a 1072 base pair fragment of the mitochondrial cytochrome b gene to examine the genetic diversity and genetic structure. Haplotype diversity of the introduced populations from the four river systems in Yunnan was higher than that of the native populations. There were special haplotypes (9 and 18) in Huang He population, while those in the invasive populations in Yunnan were mixed with that in Yangtze, and Pearl River. Analysis of molecular variance (AMOVA) revealed significant genetic subdivision among individuals within populations and among populations within rivers, but not among rivers, indicating distribution of genetic diversity was inconsistent with contemporary hydrological structure. That may be the human effect, as they introduced them from many native regions. It is proposed that it would be better to avoid the introduction of *Pseudorasbora parva* from Huang He, to reduce its diversity and reduce its harmful effects on indigenous species and the fishery culture in Yunnan.

Plenary 3

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Singapore as a Southeast Asian case study for aquatic invasive species research

Aquatic invasive species are a looming, but still largely overlooked, issue in tropical Southeast Asia. As an international trade and travel hub located in the heart of the region, Singapore is a major centre for key invasion pathways, such as the ornamental pet trade and live food trade. These pathways, coupled with a variety of introduction modes (e.g. intentional release for aesthetical, ethical reasons, or as unwanted pets or live bait), are the likely sources of novel (alien-dominated) communities in the island's mostly artificial to highly modified fresh waters. With a recent surge in invasion biology work in Singapore, this highly urbanized island city-state can serve as a microcosm that provides much needed insights into tropical aquatic invasive research, which could be applied/adapted for other rapidly developing/urbanising Southeast Asian cities and territories.

This talk will feature prominent examples of aquatic alien species/taxa in Singapore and Southeast Asia, and efforts to investigate their natural history/ecology, distributions, pathways, spread, and possible impacts. These include studies of mechanisms behind various stages in the invasion process. Unlike its freshwater environments, however, Singapore's coastal waters show a scarcity of marine bioinvasions, despite predictions to the contrary. Possible reasons for the apparent low rate of marine invasions relate to key knowledge gaps that need to be addressed, not just in Singapore, but also throughout Southeast Asia. Challenges to studying and managing aquatic invasive alien species in Southeast Asia are briefly discussed.

S4.01

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Early detection of a highly invasive bivalve based on environmental DNA (eDNA): Method development and optimizations

Management of invasive non-indigenous species is challenging owing in part to limitations of early detection and identification. The advent of environmental DNA (eDNA) techniques provides an efficient way to detect non-indigenous species when their abundance is extremely low. However, eDNA-based species detections often use non-optimized primers with respect to achieving low detection threshold and fail to test and report their limit of detection (LoD). This represents a critical gap, given that eDNA is typically used to detect rare species. Here we developed an eDNA-based early detection method using the mitochondrial cytochrome c oxidase subunit I gene (COI) for invasive Golden Mussels, *Limnoperna fortunei.* We optimized the detection by screening highly sensitive primers and PCR methods with two independent experiments, both of which were carried out in laboratory mesocosms and field waterbodies. Also, we discussed technical issues such as sampling methods and replicate numbers which may affect detection probability. We found that a primer pair with lower limit of detection (LoD) can detect target species earlier from mesocosms or with higher detection probability in field waterbodies than that with a higher LoD. Both conventional and quantitative PCR had similar LoD, while the latter had a higher detection probability for both laboratory (100% versus 87.9%) and field (68.6% versus 47.1%) samples. Laboratory detection was affected by availability of eDNA (i.e. both Mussel abundance and incubation time). Sampling water containing re-suspended matter from the bottom layer had a higher capacity for detecting Golden Mussels versus sampling only surface waters. The false negative rate was inversely related to the number of replicates, indicating that replicate sampling can improve eDNA-based detection. We strongly suggest optimizing methods in order to achieve high sensitivity and reporting the LoD to mitigate false negatives in any eDNA-based non-indigenous species surveillance program.

S4.02

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A global eDNA metabarcoding survey of ports allows testing of ship-borne species spread models

The unintentional transport of invasive species through the global shipping network causes substantial losses to social and economic welfare. Addressing this global challenge requires identification of potentially harmful species, and confirmation of their movement along highly frequented shipping routes.
As we have previously shown, properly calibrated network models are able to describe passive movement of nonindigenous species around the world. These models can be substantially improved with suitable in-situ biological data becoming available, now possible by sequencing of environmental DNA (eDNA) from port waters. Here we report a simple and scalable approach to generating metabarcoding data of 18S ribosomal and other eDNA collected from ports of varying sizes, ecosystems, and shipping connectivity. We use this data to test for the

effects of geographic distance, environmental similarity, and shipping connectivity on community similarity metrics, revealing the relative role of shipping in current port biodiversity patterns.
With further port DNA sampling and network model refinements, we will also soon be able to provide global assessments of ship-borne invasive species spread to inform management and policy decision makers.

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Is it present or not: A highly-sensitive eDNA protocol for detecting alien fishes and forming management decisions on eradication

To prove, with the highest level of confidence possible, where a non-native fish species exists and where it does not, environmental managers need a sufficiently sensitive and reliable sampling and analytical approach. To address this need, a nested PCR (nPCR) protocol was developed to detect the environmental DNA (eDNA) of a case-study species: the Topmouth Gudgeon, *Pseudorasbora parva,* (TMG), which is highly invasive in Europe, and in the UK is the subject of a national campaign for its eradication. To test this nPCR protocol in the field following laboratory tests, a series of coordinated field surveys were undertaken that employed eDNA and conventional (minnow trap) sampling at a commercial angling venue in southern England, where an initial eDNA survey, based on conventional PCR (cPCR), found TMG to be present in only one of seven angling ponds at that site. Laboratory trials showed the nPCR protocol to be on average 100× more sensitive than cPCR, yielding a 100% detection rate at DNA concentrations of 1×10^{-8} ng μl^{-1}. The coordinated pond sampling trials of nPCR and conventional approaches both found evidence of TMG in only one of the seven angling ponds, which confirmed the previous cPCR-based study. After the venue owner had undergone eradication operations (i.e. drain down and liming, with rescue and salt-bath treatment of large fishes of commercial angling interest), no eDNA of TMG was detected in either the formerly-infested pond or in the adjacent holding pond. Where the veracity of negative results may be of equal importance as that of confirmation of positive detections, such as in management decisions to make best use of scarce resources, nPCR protocols represent a useful analytical approach with which to inform decision makers responsible for non-native species management.

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Using DNA metabarcoding for ballast water monitoring: An assessment for three major United States ports

Ballast water represents a significant vector of non-native aquatic species introduction, despite increased global efforts to reduce risk of ballast water mediated invasions. Unfortunately, assessment of biodiversity transported in ships' ballast remains challenging and costly, and estimates of the propagule pools entering ports have been limited to a small number of studies. Here we employ metabarcoding based on high-throughput sequencing (HTS) to assess the diversity of propagule pools entering three major US ports over a period of several years. Ballast water samples were collected from over 150 ships entering Chesapeake Bay, Galveston, Texas, and Valdez, Alaska between 2012 and 2014. Representative DNA sequences were obtained from individual samples using the Illumina MiSeq platform. Using standard bioinformatics approaches based on sequence data derived primarily from the nuclear 18S ribosomal RNA locus, we describe delivery of biodiversity into these ports and investigate the degree to which HTS data can be used to draw inferences regarding sources of ballast water-borne diversity or effectiveness of management, specifically mid-ocean ballast exchange. Our results suggest that DNA metabarcodes reflect biodiversity signals enabling identification of ballast water source regions, and that these signals are obscured by mid-ocean exchange. While exchange does not reduce overall diversity carried with vessels, it does result in significant assemblage shifts; a subset of coastal taxa including mollusks, decapods, bryozoans, and cnidarians are strong, significant predictors of unexchanged ballast, whereas exchanged ballast shows significantly higher frequencies of planktonic taxa. Analyses based on assigned identities of operational taxonomic units also suggest the possibility that metabarcoding may provide early indications of potentially novel species introductions, particularly in unmanaged ballast. Our research provides additional evidence that HTS is emerging as an important tool for understanding invasion risks associated with ballast water discharge, and for assessing the effectiveness of management approaches designed to mitigate those risks.

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