3rd GEF-UNDP-IMO GloFouling R&D Forum and Exhibition on Biofouling Prevention and Management for Maritime Industries

4-8 November 2024
Busan, Republic of Korea

PROCEEDINGS

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Cover photo: Emilio Mancuso

ACKNOWLEDGEMENTS

LILIA KHODJET EL KHIL
Project Technical Manager
GEF-UNDP-IMO Glofouling Partnerships

These proceedings compile a wide selection of presentations, posters, and discussions from the *3rd Research and Development Forum and Exhibition on Biofouling Prevention and Management for Maritime Industries*, held from 4 to 8 November 2024 in Busan, Republic of Korea. This Forum was organized by the GEF-UNDP-IMO GloFouling Partnerships project, a global initiative led by the International Maritime Organization (IMO) to support countries in addressing the transfer of invasive aquatic species via ships' biofouling, while also minimizing related greenhouse gas emissions.

This milestone event gathered more than 250 participants from various sectors, including government officials, researchers, scientific experts, technology developers, service providers, industry representatives, NGOs, as well as regional and other organizations. Over five days, the Forum offered a rich and diverse programme of twelve thematic sessions, two parallel tracks, and an extensive poster and exhibition segment, complemented by live demonstrations and a dedicated day of technical site visits.

Our sincere thanks go to the Government of the Republic of Korea for hosting this Forum and for their continued leadership in marine environmental protection. We are especially grateful to the Ministry of Oceans and Fisheries and the Korea Research Institute of Ships and Ocean Engineering (KRISO) for their instrumental role in planning and delivering the event, as well as to the Korea Register (KR) for their strong support.

We extend our appreciation to all speakers, moderators, panellists, poster presenters and exhibitors for their invaluable contributions. Special thanks to Dr. Evangelina Schwindt for her compelling keynote address and to Mr. Jon Stewart, who masterfully moderated the Forum and guided its discussions.

We warmly thank the organizers of the site visits and demonstration activities, including the Korea Institute of Ocean Science and Technology (KIOST), the Korea Marine Equipment Research Institute (KOMERI), Samsung Heavy Industries, and all participating institutions and companies, for opening their doors and sharing their expertise so generously with delegates. Special thanks are extended to TAS Global and SLM Global, two members of the project's Global Industry Alliance for Marine Biosafety, as well as to Orient Shipyard, for organizing dedicated demonstration activities tailored to the beneficiary countries of the GloFouling Partnerships and TEST Biofouling projects, offering participants a first-hand look at practical solutions and technologies in action.

The exhibition greatly enriched the Forum by showcasing state-of-the-art innovations, including underwater cleaning robots, real-time monitoring tools, antifouling coatings, and sensor-based technologies, all contributing to the global effort to tackle marine biofouling sustainably. The exhibition featured over a dozen organizations from both the public and private sectors, including CleanSubSea, Hempel AS, Nippon Paint Marine, KRISO, KIOST, SLM Global, TAS Global, Fleet Robotics, I-Tech AB (developers of Selektope), AkzoNobel, and KCC Marine Coatings, among others. We extend our sincere appreciation to all exhibitors for their active engagement and high-quality contributions.

Finally, we would like to recognize the GloFouling Partnerships and TEST Biofouling project teams, whose tireless efforts and dedication were central to the successful coordination, logistics, and content curation of the Forum. Their behind-the-scenes work ensured a smooth, high-quality experience for all participants.

Finally, special thanks to Tomas Mills, who efficiently supported the team to finalize these proceedings.

LILIA KHODJET EL KHIL

Project Technical Manager
GEF-UNDP-IMO GloFouling Partnerships

GYORGYI GURBAN

Head of Projects

Sub-Division for Maritime Development, Technical Cooperation and Implementation Division, IMO

Biofouling remains one of the most persistent and overlooked vectors for the introduction of invasive aquatic species, posing significant threats to marine biodiversity and coastal livelihoods. At the same time, it directly affects ship fuel efficiency and contributes to greenhouse gas emissions, placing it at the intersection of biodiversity conservation, climate action, and sustainable maritime transport.

The *3rd GEF-UNDP-IMO GloFouling R&D Forum and Exhibition on Biofouling Prevention and Management for Maritime Industries*, held in Busan, Republic of Korea, convened a wide range of stakeholders from across the biofouling community including governments, researchers, industry, regional bodies, and other key stakeholders to examine the environmental, economic, regulatory and technological dimensions of biofouling prevention and management.

The premiere of the short documentary *Silent Invaders*, commissioned by the Global Industry Alliance (GIA) for Marine Biosafety, offered a compelling visual narrative on the impact of invasive aquatic species, available solutions, gaps and the need for urgent action, helping to further engage with the audience. Over five days, participants engaged in thematic sessions, technical discussions, live demonstrations, and site visits that spotlighted both persistent challenges and cutting-edge solutions.

This 3rd R&D Forum was intentionally designed to bridge research and real-world application. It placed a strong focus on showcasing practical technologies, industry-led innovations, and operational solutions to biofouling challenges. From live technology demonstrations to interactive discussions with solution providers, the Forum provided participants not only with knowledge, but with tangible tools, methods and approaches that can be adopted, replicated, adapted, or scaled. This hands-on, problem-solving spirit is at the heart of the GloFouling Partnerships' mission and it will continue to drive progress as the global community advances toward more robust and enforceable frameworks for biofouling management.

This Forum came at a pivotal moment for global marine biosafety governance. With updated IMO Biofouling Guidelines and international guidance on in-water cleaning now in place, the momentum is strong. In April 2025, the Marine Environment Protection Committee (MEPC) of IMO agreed to initiate the development of a new mandatory international instrument on biofouling management. This decision marks a significant shift from voluntary guidelines toward a regulatory regime, with far-reaching implications for Member States, industry, and other stakeholders. In this context, gatherings such as the *GloFouling R&D Forum and Exhibition* are more important than ever. They serve as inclusive, knowledge-driven platforms to align perspectives, identify implementation challenges, and support informed policy development. The work ahead, toward a binding global instrument, requires exactly the kind of dialogue, transparency, and innovation that this Forum fostered.

We hope these proceedings will serve not only as a reference but also as a source of inspiration for the global maritime community. Going forward, the collective work all the stakeholders having an interest in this issue are performing will be instrumental in ensuring that aquatic invasive species introduced via ships' biofouling are minimized and oceans are managed in a sustainable way.

GYORGYI GURBAN

Head of Projects
Sub-Division for Maritime Development,
Technical Cooperation and Implementation Division, IMO

OPENING SPEECHES

HIS EXCELLENCY DR. DO-HYUNG KANG

Minister

Ministry of Oceans and Fisheries (MOF)

Good morning, ladies and gentlemen!

I am Kang Do-Hyung, Minister of Oceans and Fisheries.
The Ministry is pleased to host the 3rd GloFouling R&D Forum and Exhibition on Biofouling Prevention and Management for Maritime Industries in Korea, and I would like to extend my sincerest welcome to all of you.

First and foremost, I would like to thank the International Maritime Organization for hosting this forum in Korea and the KRISO for their efforts in preparing this Forum with the Ministry of Oceans and Fisheries.
I would also like to extend my sincere gratitude to all the officials and experts from 56 countries around the world, including Dr. Evangelina Schwindt, who has traveled all the way from Argentina to deliver the keynote speech.

Honorable distinguished guests,
We know very well about the bountiful nature of the ocean.
We also understand that the oceans stabilize the climate and sustain biodiversity. Today, however, as production and consumption accelerate, international trade volumes and ship movements increase, the marine environment and ecosystems are under growing threat.

According to the United Nations World Ocean Assessment, population growth, economic activity, technological advances, and climate change are all impacting the marine environment, and the report warns that the overall situation shows no signs of improvement.

Globally, human activities have introduced nearly 2,000 non-indigenous marine species into new habitats. These invasive species invade existing ecosystems, reducing biodiversity and disrupting ecological balance.
While ballast water, a major vector of invasion, is managed internationally following the 2017 Ballast Water Management Convention, no international agreement exists to control and manage biofouling.

In addition to damaging the marine environment, biofouling also slows down ships, causing economic loss. They also have a negative impact on global warming by increasing carbon emissions.

Distinguished guests,
These marine environment and global warming issues transcend borders and therefore require international cooperation.
The UN Law of the Sea emphasizes international efforts and regional cooperation to protect the marine environment. The UN Convention on Biological Diversity also calls for the prevention and control of introducing non-native species into marine ecosystems.
International efforts are already underway to reduce the damage caused by biofouling. The GloFouling

Partnerships Project, which organized today's Forum, was formed in collaboration with the Global Environment Facility, the United Nations Development Programme, and IMO, and it is leading international discussion on the subject matter.

Since its inception in 2018, the Project has been working tirelessly to promote policy and institutional arrangements and enhance national capacities on the issue of biofouling. On behalf of the Republic of Korea, I would like to express my deepest gratitude for your efforts. I look forward to this third Forum to reflect on the achievements so far and to continue fruitful discussions and collaboration.

The Republic of Korea is committed to joining international efforts to address the issue of biofouling. Organizing this Forum today is part of such a commitment.
The Korean government is participating in developing the Guidance on matters relating to in-water cleaning with IMO.

We are also investing $21 million in government R&D projects from 2021 to 2025 to develop safe and eco-friendly biofouling treatment technologies and to conduct research to assess risks in the marine environment.
Based on the achievements of this R&D, we are also sharing eco-friendly biofouling treatment technologies to bridge the gap between countries.

Distinguished guests,
Despite the significant risks posed to biodiversity, biofouling matters have not been sufficiently managed and regulated. It is time to recognize the damage they cause and adopt more active management and regulation.

Ultimately, we need an international convention on biofouling, like the Ballast Water Management Convention, to properly deal with the problem. This goal calls for the attention and wisdom of all of us.
I look forward to hearing from the international organizations, policymakers, and experts here today. As the Minister of Oceans and Fisheries of the Republic of Korea and a marine biology researcher, I will make every effort to assist.

Once again, I want to express my deepest gratitude to all the distinguished guests, and I hope that you will have a meaningful and enjoyable time here at the Forum. Please take some time to enjoy the beauty of late fall in Korea as well.

Thank you!

HIS EXCELLENCY DR. DO-HYUNG KANG
Minister
Ministry of Oceans and Fisheries (MOF)

KEYYONG HONG

President

Korea Research Institute of Ships & Ocean Engineering (KRISO)

Distinguished Guests,

Ladies and Gentlemen,

Good morning!

I am Hong Keyyong, President of the Korea Research Institute of Ships & Ocean Engineering (KRISO), one of the co-hosts of this Forum.

I would like to congratulate you on the opening of the "3rd GloFouling R&D International Forum and Exhibition" and warmly welcome everyone in attendance.

First, I would like to express my gratitude to the Director General of Oceans and Fisheries, Dr. Choi Seong-Yong, Chairman of the Korean Register, Mr. Lee Hyung-Cheol, and the Secretary-General of the International Maritime Organization (IMO), Mr. Arsenio Antonio Dominguez Velasco, who will be delivering congratulatory remarks via video.

I also wish to thank Mr. Jon Stewart, who will be moderating this Forum, and Ms. Lilia Khodjet El Khil, Project Technical Manager of the GloFouling Partnerships, along with all the Secretariat staff, GEF, UNDP, and other stakeholders who have worked to make this event possible.

Furthermore, I extend a warm welcome to Dr. Evangelina Schwindt, who will deliver the keynote address, as well as all the session presenters, discussants, and biofouling experts from around the world.

I think this GloFouling R&D Forum, co-hosted by KRISO, the Korean Ministry of Oceans and Fisheries, and the IMO’s GloFouling Partnerships Secretariat, is a highly meaningful occasion.

It serves as a platform for sharing the latest technologies and policy measures for the prevention and management of biofouling, which threatens the sustainability of the marine environment and maritime industry, and for discussing international cooperation on this critical issue.

Distinguished experts,

The ocean is both the present and the future of humanity. Throughout history, humanity has developed rich civilizations and prosperous lives through the ocean. It is the source of life and provides a wide range of ecosystem services.

However, the sustainability of the ocean is being threatened by various human activities. We face numerous challenges such as the marine climate crisis, biodiversity disruption, environmental pollution, and the destruction of coastal habitats.

Therefore, it is imperative that we harness our collective wisdom, knowledge, and cooperation to maintain the health of our oceans and promote the continuous growth of the blue economy.

The issue of biofouling, which we will address at this Forum, is a serious concern.

According to some studies, 69% of marine ecosystems are being disturbed by invasive alien species (IAS). As you are aware, in the marine environment, biofouling, in which organisms attach themselves to the hulls of ships and are transported to new locations, is one of the primary pathways for the introduction of IAS, alongside ballast water.

Over the past 20 years, the international community has made significant efforts, centered around the IMO, to manage invasive alien aquatic species (IAS) transported via ballast water, through extensive collaboration among countries and experts.

In particular, over the past decade, the GEF-UNDP-IMO Global Ballast Water Partnership Project was implemented, and in 2017, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted.

However, despite these new measures for ballast water management, the issue of ecosystem disruption caused by biofouling, which involves organisms attaching to ship hulls and moving to new regions, remains an unresolved challenge.

Biofouling not only disrupts marine ecosystems but also slows down ship operations, leading to increased carbon emissions.

Some statistics indicate that by removing biofouling and smoothing the surface of the hull, fuel consumption can be reduced by 2% to 12%, resulting in significant economic benefits and reduced carbon emissions.

In response, the international community, led by the IMO, is working diligently to strengthen biofouling management.

I am aware that many of the experts here today are actively involved in related activities, and I deeply appreciate your hard work and dedication.

Especially in recent years, as the existing guidelines for biofouling management are being revised, we anticipate that, as planned, by 2025, the development of detailed guidelines for in-water cleaning of biofouling will be completed.

This will strengthen international regulations on biofouling, significantly reducing the threat of invasive species in our oceans.

In preparation for the IMO regulations, many countries and regions are already tightening their regulations on biofouling.

In Korea, we have also established a management system aimed at protecting the ecosystems of our ports from invasive species introduced through biofouling on ships arriving from international ports.

KRISO, as the only government-funded research institute in Korea's ship and ocean engineering sector, is conducting various R&D projects to remove and treat biofouling on ship hulls with the support of the Ministry of Oceans and Fisheries and in collaboration with the industry.

In particular, we are developing underwater cleaning robots to remove marine organisms attached to niche areas of the hull surface, where biofouling cleaning is challenging.

We are also conducting academic research on optimal hull inspection cycles for biofouling management based on field trials.

Distinguished experts,

Through this Forum, we will have the opportunity to discuss the challenges posed by biofouling to the marine environment and explore various policy and technological solutions from a multidisciplinary perspective.

In addition to the traditional presentation sessions, this Forum will also feature open dialogue panel discussions, providing a special opportunity for all participants to learn from each other, engage in meaningful discussions, and build constructive partnerships for future collaboration.

I hope that all of you will gain valuable insights and information from this Forum.

Lastly, I would like to express my sincere gratitude once again to the IMO GloFouling Partnerships, government delegations, and all participants who have contributed to the success of this event.

Thank you!

KEYYONG HONG

President

Korea Research Institute of Ships & Ocean Engineering (KRISO)

HYUNGCHUL LEE

Chairman and CEO
Korea Register (KR)

Distinguished Guests,

Ladies and Gentlemen,

Good morning, and welcome to the opening ceremony of the GloFouling R&D Forum.

I am Hyung Chul LEE, Chairman and CEO of Korean Register (KR) – one and only ship classification society headquartered in Korea.

First of all, I would like to express my heartfelt gratitude to Mr. Arsenio Antonio Dominguez Velasco, Secretary-General of the IMO; Dr. Do-Hyung Kang, the Minister of Oceans and Fisheries; Dr. Keyyong Hong, President of KRISO; and the dedicated teams from the IMO, GEF, and UNDP. Your efforts have been instrumental in organizing this vital forum, and bringing together stakeholders from around the world in pursuit of a shared goal.

Ladies and gentlemen,

It is both an honor and a pleasure to welcome you to Busan, a city renowned for its breathtaking coastline and rich maritime heritage. Hosting this significant gathering here in Busan, the heart of Korea's maritime sector, is particularly fitting as we gather to address a critical issue that impacts us all - marine biofouling.

Today and in the following days, the participants will address the urgent challenges posed by the marine biofouling. As you are well aware, biofouling acts as a transmitter of invasive aquatic species, which poses a threat not only to marine biodiversity and ecosystem, but also has adverse effect on a ship's hydrodynamic performance. Consequently, by addressing biofouling, we can minimize the spread of invasive aquatic species, and simultaneously improve a ship's energy efficiency and reduce emissions which is in line with the 2023 IMO Strategy on the reduction of GHG Emissions from Ships.

From a classification society' perspective, this issue is particularly pressing as we aim to go beyond our remit as class to verify compliance to rules and regulation and promote sustainable practices within the maritime sector. KR for one is committed to developing robust standards, providing technical guidance, and supporting our stakeholders in implementing solutions that mitigate the effects of biofouling on marine ecosystems.

Ladies and gentlemen,

This Forum presents a unique opportunity for us to adopt a comprehensive, united approach by bringing together global experts, regulatory bodies, and diverse industries. Here, we can share the outcome of the latest research, discuss technical advancements, and collaborate on the effective management strategies to collectively address this pressing issue.

Moreover, achieving our goals requires the harmonization of standards and best practices. In this context, the IMO Guidelines on biofouling management provide a valuable framework, but translating these guidelines into effective action necessitate ongoing dialogue and collaboration between the relevant stakeholders.

This involves not only the partnership between the regulators and the industry, but also cooperation among the member states which have unique maritime ecosystems and challenges of their own. In this respect, I am confident that this Forum will serve as a vital platform for fostering such dialogue, allowing us to work toward developing global standards that are technically sound, practical, and economically viable.

For this, I encourage each of you to engage actively in the discussions throughout this Forum to share your insights, raise questions, and explore innovative solutions. Together, we have an opportunity to pave the way for a sustainable maritime future, where environmental stewardship is integrated into every aspect of our business operations. Let us seize this occasion to build a cleaner, safer, and more resilient marine environment for future generations!

In closing, I would like to wish you all very fruitful discussions and hope that you will find time between meetings to enjoy the beautiful scenery and the warm hospitality that the City of Busan has to offer.

Thank you!

HYUNGCHUL LEE
Chairman and CEO
Korea Register (KR)

WELCOME ADDRESS FROM THE INTERNATIONAL MARITIME ORGANIZATION (IMO)

ARSENIO DOMINGUEZ

Secretary General

IMO

Ladies and gentlemen,

It is a great pleasure to welcome you to the 3rd GloFouling Partnerships Project Research and Development Forum. I wish to extend my appreciation to the Government of the Republic of Korea and the Ministry of Oceans and Fisheries for hosting this pivotal event and for their continuous commitment to fostering a sustainable maritime future. In particular, I would like to thank the Korea Research Institute of Ships and Ocean Engineering for their support in the planning and delivery of this event.

This 3rd edition of this Global Forum brings together experts and policymakers to highlight the challenges and solutions to the environmental and economic problems posed by biofouling, namely the potential introduction of invasive aquatic species via biofouling on ships' hull and increase of Greenhouse Gas emissions due to the resulting increased drag. These issues are a concern not only for the maritime industry but for our entire planet.

The GloFouling Partnerships project, led by the IMO, demonstrates our collective efforts to mitigate biofouling's impact while promoting sustainable solutions. With the strong involvement from national governments and the private sector, through the Global Industry Alliance (GIA) , the project has made great strides in raising awareness, building capacity, and sharing best practices. I thank and congratulate all partner countries, the GIA and strategic partners for their continued dedication.

This week offers a valuable platform to assess the progress, explore new opportunities for partnership, and chart the way forward. Through partnership, we can scale up our efforts to implement IMO's Biofouling Guidelines, ensuring a global consistent approach to biofouling management.

And this will also support the Sustainable Development Goals, particularly SDG 14 on the ocean conservation, SDG 13 on climate action and SDG 15 on addressing biodiversity loss.

A key initiative of the GloFouling Partnerships Project supports SDG 5 on gender equality by targeting women working in the biofouling arena, particularly in government. I am pleased to see a panel on gender representation in marine biosafety and diversity throughout this week's sessions showing our commitment to supporting women in maritime.

Over the next days, I invite all of you to engage in open and constructive discussions, share your experiences, and explore new pathways to address the complex challenges of biofouling management. Next year's World Maritime theme is

Our Ocean

Our Obligation

Our Opportunity

making your work this week particularly relevant by ensuring that our ocean remains healthy, productive, and resilient for generations to come.

Thank you, and I wish you a successful and productive Forum.

ARSENIO DOMINGUEZ
Secretary General
International Maritime Organization (IMO)

JON STEWART

Moderator

GloFouling R&D Forum

Mr. Stewart has been involved in the maritime industry for nearly 30 years. He has helped develop and co-founded 2 companies providing services and ship equipment for prevention of oil pollution, wastewater and ballast water. Since founding International Maritime Technology Consultants, Inc. (IMTCI) in 2005, Mr. Stewart, in his consulting role has provided guidance to manufacturers of ship's environmental systems with a focus on systems optimization and type approvals as well as regulatory guidance to shipowners and their associations.

Since 2006, Mr. Stewart has acted as technical advisor to various delegations of IMO sub-committees including MEPC, PPR and III. Mr. Stewart has been in the forefront assisting Administrations with implementation of environmental regulations for biosecurity, ranging from development of pilot programs, analysis of challenges for inspections and proposals for alternative compliance options. He has attended various MOU technical committee meetings making presentations on these subjects.

Mr. Stewart is currently involved in projects ranging from new technology development for biofouling control on ships and offshore installations, system development approvals, emissions monitoring and testing for regulatory compliance to digitalization and programs for long term "beyond compliance" strategies.

In addition, Mr. Stewart has acted as Chairman and/or moderator for approximately 30 international conferences covering the full spectrum of maritime environmental issues for numerous conference organizers.

Good morning to all and welcome to the 3rd GloFouling Partnerships R&D Forum and Exhibition on Biofouling Prevention and Management for Maritime Industries!

My name is Jon Stewart and it will be my pleasure to act as the moderator for this event on behalf of the GloFouling Partnerships. My consultancy has been engaged in maritime environmental work since 2005 with a strong focus on the Invasive Aquatic Species area.

But this topic goes well beyond that, all the way back to the Convention on Biological Diversity of 1992. The specific issue of biofouling of ships was first addressed with the 2011 Guidelines to minimize further transfer of Invasive Aquatic Species adopted at the 62nd Session of the IMO Marine Environment Protection Committee and subsequently revised in 2023 at the 80th session.

All of these efforts with 1 primary goal….to minimize the transfer of IAS, which is widely acknowledged as one of the greatest threats to the global marine environment.

So here we are to spend 5 days together. I want to thank our hosts from Korea, The Ministry of Oceans and Fisheries, Korea Research Institute of Ships and Ocean Engineering (KRISO), Korea Register (KR) and of course the team from the GloFouling Partnerships for bringing us all together here in Busan.

We have 5 days of education and information on the latest work in the areas of science, technology, and regulation, as well as on site experiences planned. The best and brightest in their respective fields have been assembled to inform us.

But beyond that, this Forum is an opportunity for you all, delegates, presenters and organizers to break boundaries and develop new relationships and collaborations.

The IAS issue is a complex one and requires many stakeholders working in unison with creativity, innovation, clear and transparent communications and collaboration across sectors.

Please use these 5 days to break your own boundaries. This Forum is yours. Use it to the greatest advantage. Ask questions, express your ideas, challenge each other…participate. From there, it will be my goal to foster that spirit of collaboration during these 5 days so that we may all contribute to achieving this crucial environmental goal of minimizing the introduction and spread of IAS.

Before I open the Forum and introduce our initial session, please indulge me while I tend to some housekeeping issues and announcements…

I would now like to officially open our proceedings by thanking the Republic of Korea for their warm welcome and congratulatory remarks and of course Arsenio Dominguez Secretary General of IMO for his welcome address.

I now have the pleasure of introducing our keynote speaker for the Forum,

Dr. Evangelina Schwindt, Research Director, Institute of Marine Biology (IBIOMAR-CONICET), Argentina; and Coordinating Lead Author, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Invasive Alien Species Assessment Report.

Thank you so much to all of our distinguished opening speakers who have really set the tone for our event in the most elegant manner.

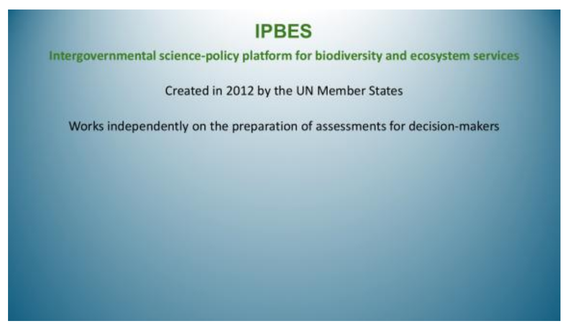
Prior to commencing our first session, I would like to turn the floor over to Lilia Khodjet El Khil who will introduce one of the highlights of the Forum, the film premiere of “Silent Invaders: The Unseen Impact of Invasive Aquatic Species”.

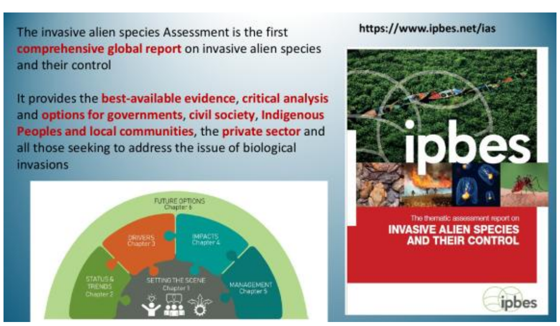
JON STEWART
GloFouling R&D Forum Moderator

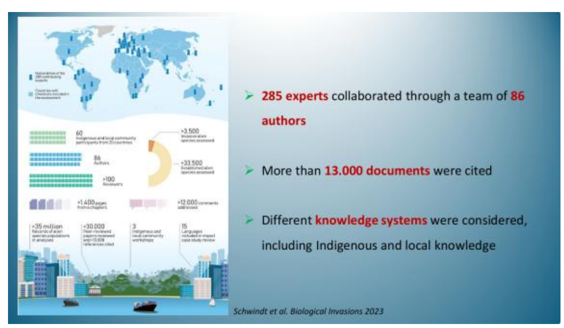
DR. EVANGELINA SCHWINDT

Research Director | Coordinating Lead Author
Institute of Marine Biology (IBIOMAR – CONICET), Argentina | Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Invasive Alien Species Assessment Report, Argentina

Dr. Evangelina Schwindt is the Director of the Coastal Environments Ecology Group (GEAC) and a Principal Investigator at IBIOMAR-CONICET, Argentina, based in Patagonia. With over 30 years of experience studying marine invasions, she has published more than 120 articles, book chapters, and reports. Her research focuses on the patterns, processes, and consequences of marine invasions in natural coastal areas, ports and marine protected areas. Given the importance of managing biological invasions, she also studies various prevention and monitoring methods. Dr. Schwindt collaborates with national and international governments to support decision-making processes.








Key main findings


People and nature are threatened by invasive alien species in all regions of Earth
ipbes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ipbes
Current policies have been insufficient in managing biological invasions and preventing and controlling invasive alien species


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People are the heart of the problem, as many human activities facilitate the transport, introduction, establishment and spread of invasive alien species


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Biological invasions and their adverse impacts can be prevented and mitigated through effective management


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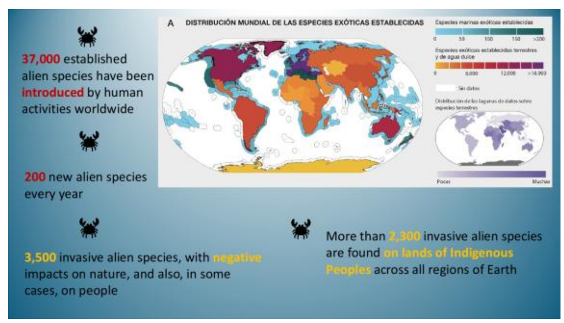
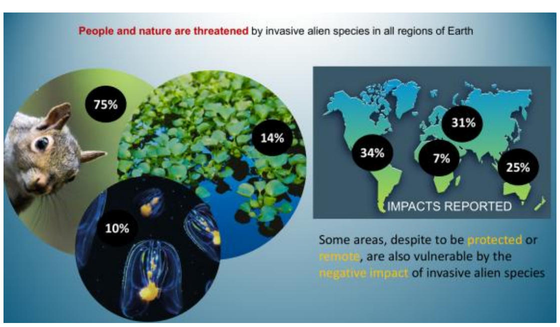
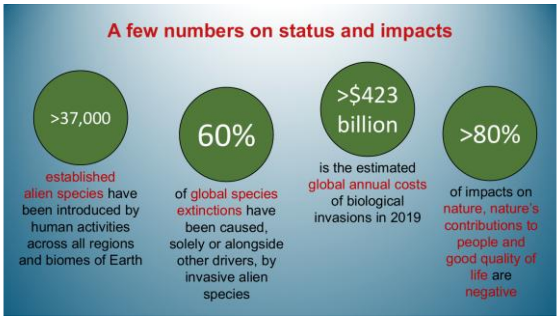
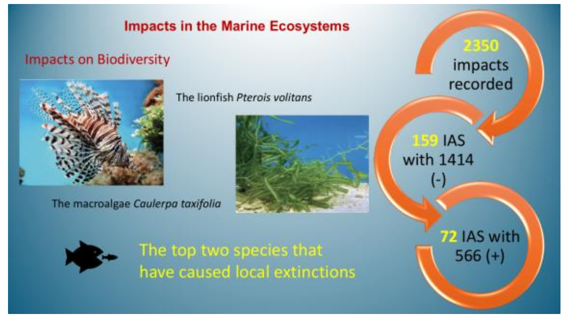
Biological invasions and their adverse impacts can be prevented and mitigated through effective management
Ambitious progress in biological invasion management can be achieved with integrated governance

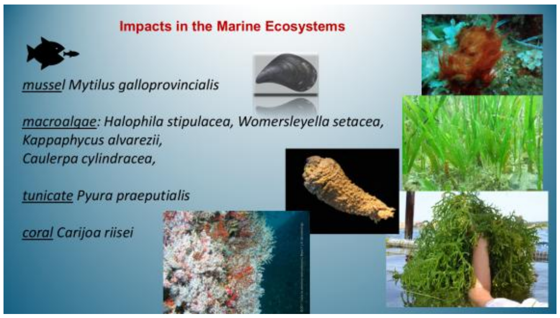

37,000 established alien species have been introduced by human activities worldwide
A DISTRIBUCIÓN MUNDIAL DE LAS ESPECIES EXÓTICAS ESTABLECIDAS
200 new alien species every year
3,500 invasive alien species, with negative impacts on nature, and also, in some cases, on people
More than 2,300 invasive alien species are found on lands of Indigenous Peoples across all regions of Earth

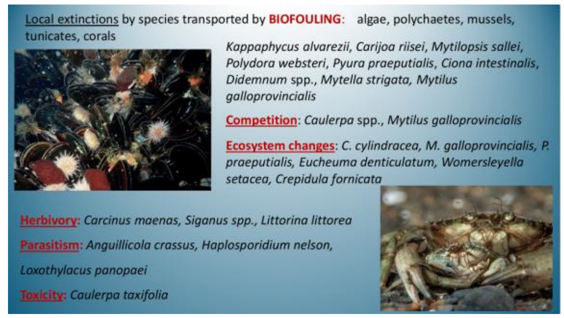

People and nature are threatened by invasive alien species in all regions of Earth
75%
14%
10%
34%
31%
7%
25%
IMPACTS REPORTED
Some areas, despite to be protected or remote, are also vulnerable by the negative impact of invasive alien species


Invasive alien species are a major driver of species extinctions, impose an economic burden and overwhelmingly undermine good quality of life


A few numbers on status and impacts
>37,000
established alien species have been introduced by human activities across all regions and biomes of Earth
60%
of global species extinctions have been caused, solely or alongside other drivers, by invasive alien species
>$423 billion
is the estimated global annual costs of biological invasions in 2019
>80%
of impacts on nature, nature's contributions to people and good quality of life are negative

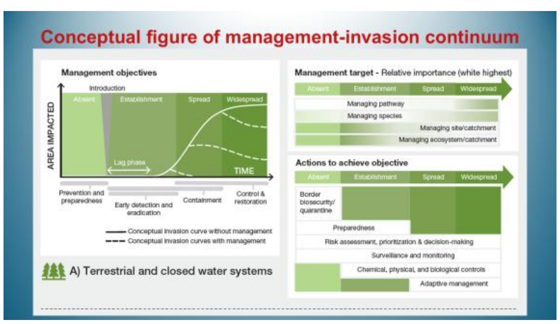

Impacts in the Marine Ecosystems
Impacts on Biodiversity
The lionfish Pterois volitans
The macroalgae Caulerpa taxifolia
The top two species that have caused local extinctions
2350 impacts recorded
159 IAS with 1414 (-)
72 IAS with 566 (+)

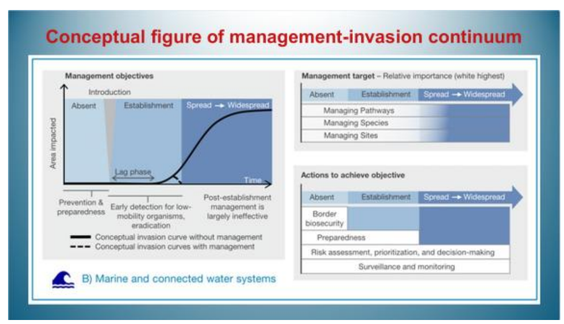

Impacts in the Marine Ecosystems
mussel Mytilus galloprovincialis
macroalgae: Halophila stipulacea, Womersleyella setacea, Kappaphycus alvarezii, Caulerpa cylindracea,
tunicate Pyura praeputialis
coral Carijoa riisei


Local extinctions by species transported by BIOFOULING: algae, polychaetes, mussels, tunicates, corals
Kappaphycus alvarezii, Carijoa riisei, Mytilopsis sallei, Polydora websteri, Pyura praeputialis, Ciona intestinalis, Didemnum spp., Mytella strigata, Mytilus galloprovincialis
Competition: Caulerpa spp., Mytilus galloprovincialis
Ecosystem changes: C. cylindracea, M. galloprovincialis, P. praeputialis, Eucheuma denticulatum, Womersleyella setacea, Crepidula fornicata
Herbivory: Carcinus maenas, Siganus spp., Littorina littorea
Parasitism: Anguillicola crassus, Haplosporidium nelson, Loxothylacus panopaei
Toxicity: Caulerpa taxifolia

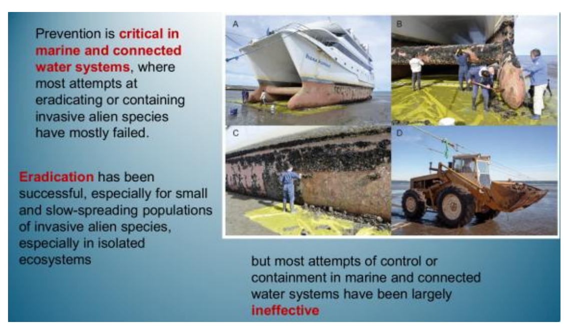

Impacts on socio-economical activities
Tunicates as Ciona intestinalis or Styela spp. affect aquaculture


Sea-use change and climate change increasingly facilitate the establishment and spread of IAS
Sea-use changes may increase the vulnerability of natural ecosystems and alter processes that cause natural disturbance of seascapes
Transportation and utility infrastructures can create corridors that facilitate the spread of IAS
Marine and aquatic infrastructure may alter seascapes and the functioning of marine ecosystems, facilitating the spread of IAS


Conceptual figure of management-invasion continuum
Management objectives
Introduction
Absent
Establishment
Spread
Widespread
AREA IMPACTED
Lag phase
TIME
Prevention and preparedness
Early detection and eradication
Containment
Control & restoration
Conceptual invasion curve without management
Conceptual invasion curves with management
A) Terrestrial and closed water systems
Management target - Relative importance (white highest)
Managing pathway
Managing species
Managing site/catchment
Managing ecosystem/catchment
Actions to achieve objective
Border biosecurity/ quarantine
Preparedness
Risk assessment, prioritization & decision-making
Surveillance and monitoring
Chemical, physical, and biological controls
Adaptive management

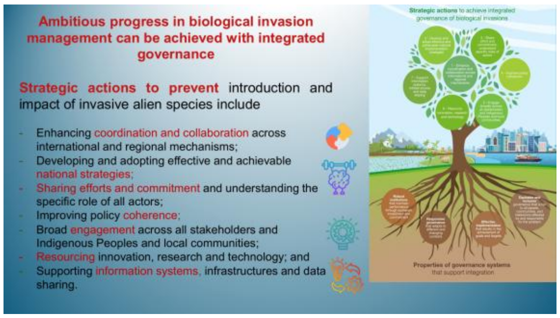

Conceptual figure of management-invasion continuum
Management objectives
Introduction
Absent
Establishment
Spread → Widespread
Area impacted
Lag phase
Time
Prevention & preparedness
Early detection for low-mobility organisms, eradication
Post-establishment management is largely ineffective
Conceptual invasion curve without management
Conceptual invasion curves with management
B) Marine and connected water systems
Management target – Relative importance (white highest)
Managing Pathways
Managing Species
Managing Sites
Actions to achieve objective
Border biosecurity
Preparedness
Risk assessment, prioritization, and decision-making
Surveillance and monitoring


Prevention and preparedness are the most cost-effective options
pathway management:
- import controls,
- pre-border, border and post-border biosecurity,
- rapid response protocols & agreements.


Prevention is critical in marine and connected water systems, where most attempts at eradicating or containing invasive alien species have mostly failed.
Eradication has been successful, especially for small and slow-spreading populations of invasive alien species, especially in isolated ecosystems
but most attempts of control or containment in marine and connected water systems have been largely ineffective
A
B
C
D


Prevention & Preparedness requires:
biosecurity legislation, regulations & policy –appropriate & enforceable
biosecurity border inspection facilities, quarantine,& diagnostic services
offshore intelligence gathering & pest risk analysis
surveillance, detection & diagnostics
rapid response approaches, plans & agreements
scientific & technical cooperation
technology, genomic & digital tools
adequate & sustained resources
capacity building


Current policies have been insufficient
to manage biological invasions and to
prevent and control IAS
Although most countries (80%) have targets for the management of biological invasions within their national biodiversity strategies and action plans
83% of countries have no national legislation or regulations specifically aimed at the prevention and control of IAS
Almost half of the countries (45%) do not invest in IAS management


Ambitious progress in biological invasion management can be achieved with integrated governance
Strategic actions to prevent introduction and impact of invasive alien species include
- Enhancing coordination and collaboration across international and regional mechanisms;
- Developing and adopting effective and achievable national strategies;
- Sharing efforts and commitment and understanding the specific role of all actors;
- Improving policy coherence;
- Broad engagement across all stakeholders and Indigenous Peoples and local communities;
- Resourcing innovation, research and technology; and
- Supporting information systems, infrastructures and data sharing.
Strategic actions to achieve integrated governance of biological invasions
Properties of governance systems that support integration


Thank you
schwindtcnp@gmail.com

PROGRAMME


3rd GloFouling
R&D Forum and Exhibition
on Biofouling Prevention and Management for Maritime Industries
SHAPING THE FUTURE OF BIOFOULING MANAGEMENT
4 - 8 November 2024 | The Westin Josun, Busan, Republic of Korea

Monday 04 November 2024

08:00 – 09:00 REGISTRATION – Grand Ballroom lobby

09:00 – 10:00 OPENING SESSION

Welcome address from the Republic of Korea, His Excellency Dr. Do-Hyung Kang, Minister of

Ministry of Oceans and Fisheries (MOF)
Welcome Remarks: Keyyong Hong, President, Korea Research Institute of Ships and Ocean Engineering(KRISO)
Congratulatory Remarks: Hyungchul Lee, Chairman and CEO, Korea Register (KR)

Welcome address from the International Maritime Organization (IMO)Arsenio Dominguez, Secretary General, IMO (recording)

Welcome remarks from Jon Stewart, GloFouling R&D Forum Moderator

Keynote Speaker:
Dr. Evangelina Schwindt, Research Director, Institute of Marine Biology (IBIOMAR-CONICET), Argentina; andCoordinating Lead Author, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services(IPBES) Invasive Alien Species Assessment Report, Argentina

10:00 – 10:30 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*

10:30 – 12:00 SESSION 1 - Invasive Aquatic Species and their Impacts

Chair of the session: Dr. Mario Tamburri, Professor, University of Maryland Center for Environmental Science, the United States of America

Film Premiere - "Silent Invaders: The Unseen Impact of Invasive Aquatic Species"

A short documentary commissioned by the Global Industry Alliance for Marine Biosafety

Presentations

Update on the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) Working Group 44 (WG 44): Biofouling Management

Dr. Mario Tamburri, Chair of GESAMP WG44

Biofouling and Offshore Renewable Energy: Industrial and Environmental Impacts

Dr. Andrew Want, Lecturer, Energy and Environment Institute, University of Hull, the United Kingdom

Informed means Armed: The Role of Information Systems on Non-*Indigenous* Species in Biofouling Managementand Research

Dr. Greta Srėbalienė, Researcher, Marine Research Institute, Klaipeda University, Lithuania

Questions and answers with all presenters and the keynote speaker

12:00 - 13:00 LUNCH (PDR Room, second floor)

13:00 – 14:30 **SESSION 2 - Innovative Solutions for Biofouling Management – Coatings**

Chair of the session: Jon Stewart, GloFouling R&D Forum Moderator

Presentations

Always clean hulls - Revolutionizing vessel efficiency by combining low-friction hard coatings with grooming robots

Dr. Marciel Gaier, CTO and Director, GIT Coatings, Canada
Balancing Energy Efficiency and Marine Biodiversity: A Holistic Framework for Biofouling Management in theMaritime Industry

Dr. Viktor Avlonitis, Hull Performance Solution Manager, Hempel A/S, Denmark

Effective Biofouling Management Strategies: The Challenges with Ship-Specific Functional Specifications andCoating Selection

Dr. Ralitsa Mihaylova, Head of Special Projects, Safinah Group, the United Kingdom

Enhancing Biofouling Resistance in Organo Silane-Coated Polyethylene Aquaculture Cage Nets with Nano CarbonDot: (CuO:TiO2) Composite Materials

Dr. Muhamed Ashraf Pachareentavita, Principal Scientist, Central Institute of Fisheries Technology (ICAR),India

Questions and answers with all presenters

14:30 – 15:00 **COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)***

15:00 - 17:00 **SESSION 3: Panel discussion on Gender Diversity**

Chair of the session: Dr. Bev Mackenzie, Head of Intergovernmental Organization (IGO) Engagement, The Balticand International Maritime Council (BIMCO), the United Kingdom

Presentations

Gender Diversity in the biofouling-related industries

Jurga Šaule, Senior Project Assistant, GloFouling Partnerships project, IMO

Marija Vranic, Project Assistant, TEST Biofouling project, IMO

Questions and answers with all presenters

The interactive survey, followed by a panel discussion:

Ervin Vargas Wilson, Director, Maritime Technology Cooperation Centre (MTCC) Latin America, Panama

Maya Guellner, Intern, Marine Environment, Technical Directorate, Lloyd's Register, the United Kingdom

Ralitsa Mihaylova, Head of Special Projects, Safinah Group, the United Kingdom

Suha Nedhal Khalil Abu Zeid, Chartering & Logistics officer, Jordan National Chapter, Arab Women in Maritime Association (AWIMA), Jordan

18:00 – 20:00 **WELCOME DINNER SPONSORED BY THE REPUBLIC OF KOREA *(PDR Room, second floor)***

Tuesday 05 November 2024

08:30 – 09:50 **SESSION 4 - Current status and Prospects in the Republic of Korea for In-Water Cleaning Technology**

Chair of the session: Dr. Seong-Gil Kang, Korea Research Institute of Ships & Ocean Engineering (KRISO), theRepublic of Korea

Presentations

Biofouling management in South Korea and legislative & policy improvement measures
Dr. Su Jin Park, Korea Maritime Institute (KMI), the Republic of Korea

Characterization and risk assessment of attached bacteria in major ports in Korea
Dr. Sae-Hee Kim, Institute of Bioscience & Biotechnology, Hanyang University, the Republic of KoreaFlux of the Wetted Surface Area on Ships' Hulls in Major Ports of Korea
Dr. Rahman Sourav, Chung-Nam National University, Bangladesh

Risk assessment of materials released during in-water cleaning of hull-fouling organisms
Dr. Kyoungsoon Shin, Korea Institute of Ocean Science and Technology (KIOST), the Republic of Korea

Questions and answers with all presenters

09:50 - 10:10 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*

10:10 – 12:00 **SESSION 4 (continued) - Current status and Prospects in the Republic of Korea for In-Water CleaningTechnology**

Development of technology for treatment (removal, collection, treatment) of biofouling in Korea: Innovativesolutions for biofouling management
Yusik Kim, CEO, TAS Global, the Republic of Korea Overview of KRISO's R&D on biofouling management technology
Dr. Pan-Mook Lee, Korea Research Institute of Ships & Ocean Engineering (KRISO), the Republic of KoreaHull Cleaning Robot and Filter System for Marine Environmental Protection
Dr. Man Soo Choi, SLM Global, the Republic of Korea.

International Guidance on In-Water Cleaning
Colin Henein, Director, Marine Protection Environment Policy, Transport Canada, Canada

Questions and answers with all presenters

12:00 - 12:50 LUNCH *(Grand Ballroom)*

12:50 END OF THE DAY

Tuesday 5 November 2024 - AFTERNOON

Site visits and technology demonstrations (closed event)

For GloFouling Partnerships and TEST Biofouling beneficiary countries and regional organizations participating in projects.

08:30 – 10:00 **SESSION 5 - Innovative Solutions for Biofouling Management – In-Water Cleaning**

Chair of the session: Jon Stewart, GloFouling R&D Forum Moderator

Presentations

In-Water Cleaning – Implications for Environmental Stewardship

Chris Scianni, Environmental Program Manager, Marine Invasive Species Program, California State LandsCommission, the United States of America

Development of an autonomous cleaning methods based on a manipulator for the cleaning of niche areas of aship hull

Dr. Daegil Park, Senior Researcher, Korea Research Institute of Ships & Ocean Engineering (KRISO), theRepublic of Korea

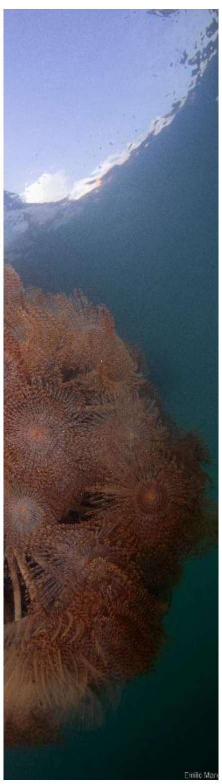
Hull performance, going from extrapolation and
interpretation to big data

Åge Højmark, CEO, Shipshave, Norway
Assessment of Operational Performance to Onshore Treatment Facilities for Ship Biofouling WashingWastewater

Dr. Sang-Ho Park, Team Leader and General Manager, Machinery system team, S & SYS, the Republic ofKorea

Questions and answers with all presenters

10:00 - 10:30 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*



10:30 – 12:00 **SESSION 6 - Monitoring, Testing, Early Detection and Rapid Response**

Chair of the session: Dr. Guillaume Drillet, SGS Marine Services, Asia-Pacific and Chair of Global TestNet,Singapore

Presentations

Predicting environmental concentration of metals released by in-water hull cleanings in an international harbor –considering the contribution from paint particles
Moonkoo Kim, Principal Research Scientist, Korea Institute of Ocean Science and Technology (KIOST), theRepublic of Korea

Ocean Science, Early Warning Systems and Hazards

Joape Ginigini, Senior Scientific Officer, Pacific Islands Marine Bioinvasions Alert Network (PacMAN) ProjectManager, Institute of Applied Sciences, University of the South Pacific, Fiji

A Real-Time Impedimetric Sensor for Early Detection of Biofouling

Dr. Young Wook Kim, CEO, ProxiHealthcare, the Republic of Korea

Proposed Guidelines for the Evaluation of Efficacy of Marine Growth Prevention Systems (MGPS)

Dr. Thomas Vance, Chief Operating Officer, PML Applications / Paper Lead Author, Global TestNet, theUnited Kingdom

Questions and answers with all presenters

12:00 – 13:00 LUNCH *(PDR Room, second floor)*

13:00 – 15:00 **SESSION 7 – Innovative Solutions for Biofouling Management – Emerging Technology**

Chair of the session: Sarita Krissy Emmanuel, Project Officer, Maritime Technology Cooperation Centre (MTCC)Caribbean, Trinidad and Tobago

Presentations

Biofouling Management through Digital Solutions

Petter Korslund, Regulatory Affairs Manager, Performance Coatings, Jotun, Norway

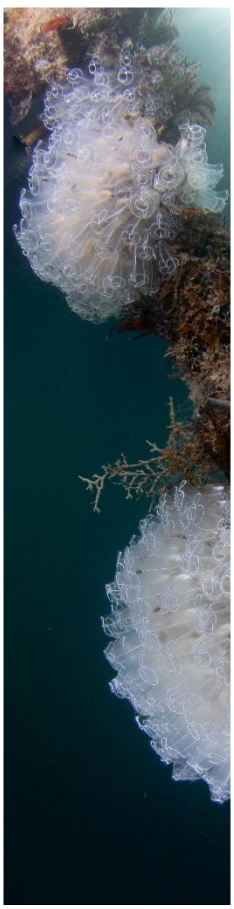
Next steps in the development of UV-C as the ultimate fouling prevention technology
Dr. Neil Oxtoby, Worldwide Marine Laboratory, AkzoNobel, the United KingdomEfficacy and Biological Impact of Ultrasonic Transducers
Pernille Bohn, Business Area Manager, DHI, Denmark

Advanced Hull Cleaning Technology Transport Canada Performance Verification Study

Karl Lander, Environmental Services Director, Subsea Global Solutions, the United States

Questions and answers with all presenters

15:00 – 15:30 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*



15:30 - 17:00 **SESSION 8 – Biofouling Management in Marine Protected Areas (MPAs) and Particularly Sensitive SeaAreas (PSSAs)**

Chair of the session: Dr. Inti Keith, Principal Investigator, Marine Biodiversity Research, Charles DarwinFoundation, Galapagos Islands, Ecuador

Presentations

Biofouling Management in Marine Protected Areas and Particularly Sensitive Sea Areas: State of Play

Will Griffiths, Technical Project Analyst, GloFouling Partnerships project, IMO
The journey towards declaring the Thermal Dome as a Particularly Sensitive Sea Area (PSSA)

Sonia Angélica Jurado Caicedo, Sargadom Thermal Dome Project coordinator, MarViva, Colombia

Assessing the Risk of Non-Indigenous Species in Marine Protected Areas: A Framework for the Eastern TropicalPacific

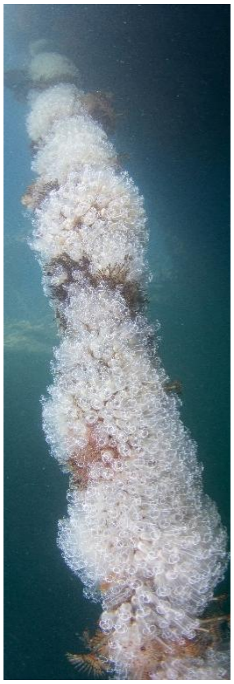
Dr. Inti Keith, Principal Investigator, Marine Biodiversity Research, Charles Darwin Foundation, GalapagosIslands, Ecuador

Questions and answers with all presenters

Followed by a panel discussion

Dr. Evangelina Schwindt, Research Director, Instituto de Biologia de Organismos Marinos (IBIOMAR-CONICET), Argentina
Joape Ginigini, Senior Scientific Officer, Pacific Islands Marine Bioinvasions Alert Network (PacMAN) ProjectManager, Institute of Applied Sciences, University of the South Pacific, Fiji
Sharloth Fernandez, Head of the Environmental Management Department, National Directorate of AquaticSpaces (DIRNEA), Ecuador
Sonia Angélica Jurado Caicedo, Sargadom Thermal Dome Project coordinator, MarViva, Colombia

17:00 END OF THE DAY



08:30 – 10:00 **SESSION 9 – Policy Developments and Standards**

Chair of the session: Colin Henein, Director, Protection Environment Policy, Transport Canada, Canada

Presentations

Lessons learned from 6+ years of enforcing biofouling management regulations in California
Chris Scianni, Environmental Program Manager, Marine Invasive Species Program, California State LandsCommission, the United States of America

Driving Change on A Global Scale: New Zealand's Vessel Biofouling Requirements

Yasmin Gabay, Ministry for Primary Industries, New Zealand
Biofouling actions in Norway and the need for a mandatory global regime

Sveinung Oftedal, Director, Ministry of Climate and Environment, NorwayApplication of the 2023 Biofouling Guidelines- Industry Insights
Dr. Bev MacKenzie, Head of IGO Engagement, BIMCO, the United Kingdom

Questions and answers with all presenters

10:00 - 10:30 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*

10:30 – 12:00 **SESSION 9 (continued) - Policy Developments and Standards**

Updates on the development of ISO Standards related to In-Water Cleaning

Dr. Irene Øvstebø Tvedten, Senior Advisor Maritime, The Bellona Foundation, Norway

Dr. Mario Tamburri, Professor, University of Maryland, the United States of America

Clean Hull Notation - Achieving Best of Both Worlds

Sahan Abeysekara, Lloyds Register, the United Kingdom

Questions and answers with all presenters

Followed by a panel discussion

Dr. Bev Mackenzie, Head of IGO Engagement, BIMCO, the United Kingdom
Chris Scianni, Environmental Program Manager, Marine Invasive Species Program, California State LandsCommission, the United States of America
Yasmin Gabay, Ministry for Primary Industries, New Zealand
Sveinung Oftedal, Director, Ministry of Climate and Environment, Norway
Teo Karayannis, Head, Marine Biosafety, Sub-Division for Protective Measures, Marine EnvironmentDivision, IMO

12:00 – 13:00 LUNCH *(PDR Room, second floor)*

13:00 – 15:00 **SESSION 10 – Fuel Efficiency and GHG Emissions**

Chair of the session: Amelia Bola, Maritime GHG Officer, Maritime Technology Cooperation Centre (MTCC)Pacific, Fiji

Presentations

Effects of Hull Cleaning on the Ship Performance

Beom Jin Park, Principal Research Engineer, Advanced Ship Research Division, Korea Research Institute ofShips & Ocean Engineering (KRISO), the Republic of Korea
International Collaborative Research in Ship Drag Penalty Due to Hull Roughness: From Laboratory to FieldExperiment

Prof. I Ketut Aria Pria Utama, Professor of Ship Hydrodynamics, Department of Naval Architecture, InstitutTeknologi Sepuluh Nopember (ITS), Indonesia
An Assessment of Skin-Friction Drag Over a Recently Cleaned Ship Under Steady Cruising Via a Combination ofIn-Situ Laser Based Measurement, Laboratory Experiment, Computational Fluid Dynamics (Cfd), and Empirical Estimation

Dr. Bagus Nugroho, Lecturer, the University of Melbourne, Australia
Quantifying the hull performance impact of biofouling and stopping unnecessary fuel and emissions "leakage"Abigail Robinson, Vice President of Sustainability, ECOsubsea, Norway

Questions and answers with all presenters

13:00 – 15:00 COFFEE-BREAK AND EXHIBITION VISIT (*Grand Ballroom lobby)*

15:30 - 17:00 **SESSION 11 *(Grand Ballroom)* – RiskManagement in ports**

Chair of the session: Chris Scianni, EnvironmentalProgram Manager, Marine Invasive Species
Program, California State Lands Commission, theUnited States of America

Presentations

Biofouling Ecology of Tropical Anthropized CoastalEnvironments in Manila Bay, Philippines

Dr. Benjamin M Vallejo Jr, Professor of Environmental Science, University of the Philippines Diliman, the Philippines
Enhancing the Biodiversity in Ports to Limit theIntroduction of Non-Native Species

Dr. Jasmine Ferrario, Researcher, Universityof Pavia, Italy
Biofouling in the English Channel: a two-yearmonitoring on two coatings in the port of Cherbourg (France)

Marion Vial, PhD Student, Corrosion andBiocorrosion Center, Corrodys and the University of Caen Normandie, France

Questions and answers with all presenters

17:00 – 17:30 Closure of the Forum *(Grand Ballroom)*

Friday 08 November 2024

09:00 DEPARTURE FROM THE WESTIN JOSUN BUSAN HOTEL

Visits and tours in:

KIOST South Sea Research Institute (https://www.kiost.ac.kr/eng.do)
KOMERI Korea Marine Equipment Research Institute (http://eng.komeri.re.kr/main/) Samsung Heavy Industries (https://www.shi-mci.com/facilities/shi.html)

Lunch will be provided at the Geoje Restaurant

17:10 RETURN TO THE WESTIN JOSUN BUSAN HOTEL

Photo credits: Emilio Mancuso; Shutterstock; Ashley Coutts; WikiCommons; piqsels; Creative Commons; Hans Hillewaert; Paolo Varrella; Subsea Industries; Mariano Rodríguez - @argentinasubmarina; piqsels; Flickr; Wikimedia Commons; Jean-Pierre Bazard; Eric Gao; piqsels; Flickr; pexels; Emilio Mancuso

CONFERENCE PROCEEDINGS

MODERATOR

JON STEWART

Moderator

GloFouling R&D Forum

Mr. Stewart has been involved in the maritime industry for nearly 30 years. He has helped develop and co-founded 2 companies providing services and ship's equipment for prevention of oil pollution, as well as wastewater and ballast water. Since founding International Maritime Technology Consultants, Inc. (IMTCI) in 2005, Mr. Stewart, in his consulting role has provided guidance to manufacturers of ship's environmental systems with a focus on systems optimization and type approvals as well as regulatory guidance to shipowners and their associations.

Since 2006, Mr. Stewart has acted as technical advisor to various delegations of IMO sub-committees including MEPC and PPR. Mr. Stewart has been in the forefront assisting Administrations with implementation of environmental regulations for biosecurity, ranging from development of pilot programs, analysis of challenges for inspections and proposals for alternative compliance options. He has attended various MOU technical committee meetings making presentations on these subjects.

Mr. Stewart is currently involved in projects ranging from new technology development for biofouling control on ships and offshore installations, system development approvals, emissions monitoring and testing for regulatory compliance to digitalization and programs for long term "beyond compliance" strategies.

In addition, Mr. Stewart has acted as Chairman and/or moderator for approximately 30 international conferences covering the full spectrum of maritime environmental issues for numerous conference organizers.

FILM PREMIERE – "SILENT INVADERS: THE UNSEEN IMPACT OF INVASIVE AQUATIC SPECIES"

LILIA KHODJET EL KHIL
Project Technical Manager
GEF-UNDP-IMO Glofouling Partnerships

After obtaining with honors her PhD in Maritime Law in France, Dr Lilia Khodjet El Khil joined the IMO's Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) where she spent nine years supporting Mediterranean coastal States to strengthen their capacity and implement regulations and best practices for marine environmental protection. Lilia was awarded the "Mérite Maritime" from the French government in recognition of her work at REMPEC.

In 2010, Lilia relocated to Montreal, Canada, where she joined the Shipping Federation of Canada, a trade association representing international shipping in Canada, to lead on environment files. During her time with the Shipping Federation of Canada, she engaged with Governments on policy developments, advocated for shipping and guided members through complex regulatory and compliance issues. She later joined the CSL Group Inc., a major Canadian shipping company operating domestically and worldwide, where she held the position of Manager, Sustainability and Government Relations, to implement a sustainable development strategy across the company and also advocate for domestic shipping's interests.

In 2016 Lilia launched her own consultancy business, Maritimis Consulting to provide services to the industry, governments and non-for-profit organizations on environmental issues related to shipping. In June 2019, she joined the International maritime Organisation to lead the execution of a multiyear flagship IMO project dealing with marine biosafety, namely the GloFouling Partnerships project.

Ladies and Gentlemen,

It is my pleasure to introduce the premiere of Silent Invaders: The Unseen Impact of Invasive Aquatic Species, a film commissioned by the Global Industry Alliance for Marine Biosafety, or GIA for short. The GIA a unique group of industry leaders established under GloFouling Partnerships to help global efforts toward the uptake of best management practices to address biofouling and invasive species.

This film sheds light on a critical yet often overlooked issue: the impact of invasive species carried by ships' biofouling on our oceans and coasts. Through powerful storytelling, Silent Invaders reveals the challenges that these species impose on fisheries, coastal livelihoods, and entire communities—affecting marine biodiversity and ecosystems, food security, and economies around the world.

But this is not just a film about challenges. Silent Invaders also highlights the innovative solutions emerging in biofouling management, showcasing research and collaborative efforts among scientists, industry leaders, and policymakers. The message is clear: if we work together, we can protect marine life, safeguard communities, and sustain the oceans that connect us all.

We hope this film inspires you to think about one of the key drivers for biodiversity loss globally and the urgent need for cooperation in addressing these crucial issues.
Thank you for your attention and enjoy the movie!

CHAIR OF THE SESSION

JON STEWART

Moderator

GloFouling R&D Forum

DR. MARIO TAMBURRI

Director

Alliance for Coastal Technologies and Marine Environmental Resource Center

Director of the Alliance for Coastal Technologies

Director of the Marine Environmental Resource Center

Recent Awards:

2015 University of Maryland Center for Environmental Science President's Award for Science Application

2017 University System of Maryland Regents Faculty Award for Excellence in Public Service

Areas of Expertise

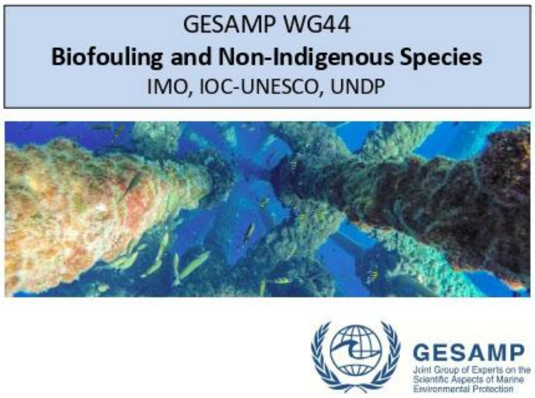
- *Sustainable urban waterfronts*
- *Environmental technologies and observing*
- *Chemical ecology of aquatic organisms*
- *Invasive species ecology, prevention and management*

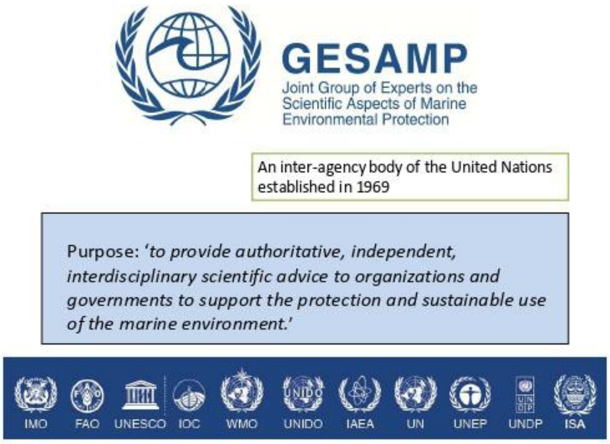
Education

- *B.A. Marine Sciences, University of California, Santa Barbara*
- *M.S. Biology, University of Alabama*
- *Ph.D. Biology and Marine Sciences, University of South Carolina*

GESAMP WG44
Biofouling and Non-Indigenous Species

Presentation slides





GESAMP Working Groups

WG 1 – evaluation of the hazards from harmful substances carried by ships – IMO (self-funded)

WG 34 – review of applications for 'active substances' in ballast water management systems – IMO (self-funded)

WG 38 – atmospheric inputs of chemicals to the ocean – WMO

WG 40 – sources, fate & effects of plastics and microplastics – IOC-UNESCO, UNEP

WG 41 –Ocean interventions for climate change mitigation- WMO, IOC-UNESCO, UNEP

WG 42 – impacts of wastes and other matter in the marine environment from mining operations including marine mineral mining – IMO, UNEP, ISA

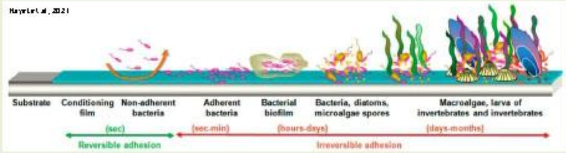
WG 43 – Sea-based sources of marine litter including fishing gear and other shipping-related litter – FAO, IMO, UNEP

WG 44 – Biofouling and Non-Indigenous Species – IMO, IOC-UNESCO, UNDP

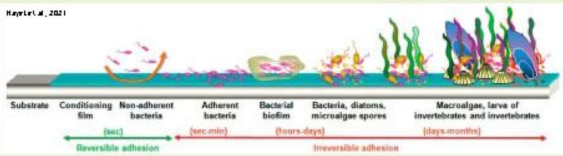
WG45 – Climate change and greenhouse gas related impacts on contaminants in the ocean – IAEA, IOC-UNESCO, WMO, IMO

WG 46 – Life Cycle GHG Intensity of Marine Fuels – IMO

Biofouling



Biofouling



- Interferes directly with operations
- Facilitates the transfer of non-indigenous species (NIS) as either a direct vector or as a 'stepping stone'

GESAMP WG44

- The objective was to build a broader understanding on introduction and spread of NIS via biofouling across all maritime industries. Started work in 2020 and final report by December 2023.
- Terms of Reference:
  1. Identification and description of both primary and secondary pathways for the transfer of NIS, including:
     a. fishing (e.g. ships, gear, lines);
     b. aquaculture (e.g. structures, cages, buoys, netting);
     c. shipping (e.g. hulls, niche areas, propellers, ropes, anchors);
     d. other shipping (e.g. recreational boating, recreational fishing, Aids to Navigation);
     e. marine offshore operations (e.g. offshore platforms and structures);
     f. ocean renewable energy generation (e.g. underwater turbines, shafts);
     g. ocean monitoring (e.g. measuring instruments); and
     h. coastal industry infrastructure (e.g. ports, marinas, cooling towers, water purifying units)
  2. Description and assessment of impacts on biodiversity of the introduction and/or spread of NIS via the pathways.
  3. Description and assessment of impact of and costs resulting from the introduction and/or spread of NIS via the pathways (human health, social activities, fisheries, aquaculture, tourism, etc).
  4. An analysis of best management approaches within impacted industries, including the use of emerging technologies, techniques and methods and their efficacy and safety.
  5. Recommendations to reduce or prevent the introduction or spread of NIS.
  6. Identification of data gaps and prioritization for further work.

GESAMP WG44

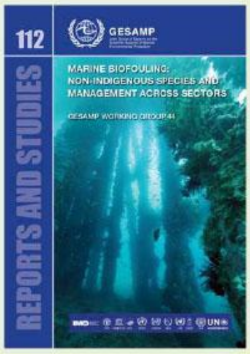
Current Members

Name	Surname	Institution	Country	Subject
Joao	Coolen	Wageningen University	The Netherlands	Oil and Gas
Andrew	Want	Heriot Watt University	United Kingdom	Renewables
Pedro	Almeida Vinagre	WavEC Offshore Renewables	Portugal	Constructions
Serena	Teo	National University of Singapore (NUS)	Singapore	Aquaculture
Youna	Lyons	Centre for International Law (NUS)	Singapore	Environmental Governance
Nina	Bloecher	SINTEF	Norway	Aquaculture
Kamal	Ranatunga	University of Sri Jayewardenepura	Sri Lanka	Ports
Agnese	Marchini	Università di Pavia	Italy	Marinas
Koebraa	Peters	Stellenbosch University	South Africa	Boating
Mario	Tamburri	University of Maryland Center for Environmental Science	United States	Shipping
David	Smith	Plymouth Marine Laboratory	United Kingdom	Shipping
Marnie	Campbell	Murdoch University	Australia	Biosecurity socioeconomy
Evangelina	Schwindt	Centro Nacional Patagonico	Argentina	Marinas
Hiroshi	Kawai	Kobe University Research Center for Inland Seas	Japan	Bioinvasions
Jung-Hoon	Kang	Korea Institute of Ocean Science and Technology (KIOST)	Republic of Korea	Risk assessments

Jake Rice (Canada) consultant and former members include Katja Broeg (Germany), Pei-Yuan Qian (China), and Anna Yunnie (UK).

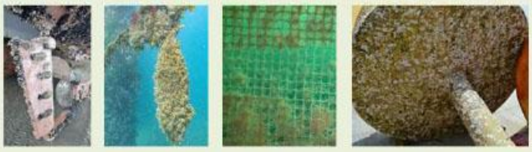
Marine Biofouling: Non-Indigenous Species and Management Across Sectors

- 10 peer-reviewers
- ~ 150 pages
- Released 30 August 2024
- Download available at:
  - www.gesamp.org/publications
  - www.glofouling.imo.org/publications-menu
  - unesdoc.unesco.org/home



Marine Biofouling: Non-Indigenous Species and Management Across Sectors

- All marine sectors deal with biofouling (and its impacts) and most marine resource managers are concerned with the threat of biofouling NIS.
- Several strategies/tools to prevent, minimize, or manage biofouling have been developed and adopted to address operational impacts but biofouling as an NIS vector is usually a secondary consideration.
- Currently, all strategies, tools, and regulatory measures have both strengths and limitations, which vary depending on application.
- Strengths and weaknesses of each measure can affect suitability, performance, and risks differently in the various sectors.



Marine Biofouling: Non-Indigenous Species and Management Across Sectors

- Examines policies and regulatory actions commonly used and how they affect the potential for the sector-specific management of biofouling NIS risks.
- Highlights opportunities to increase efficacy in minimizing the movement of biofouling NIS across the marine sectors.
- Concludes that, for each sector, there is no single 'best solution' and various combinations of strategies, tools, and regulatory measures are necessary for effective prevention or control of biofouling NIS.
- Concludes that regulatory frameworks, with clear standards, are needed to minimize the risk of biofouling NIS but they must be:
  - appropriate for the sector,
  - supported by adequate monitoring,
  - ensure capacity for compliance,
  - updated with new knowledge/innovations,
  - not cause other unintended consequences.

IMO and GESAMP

IMO provides the formal Secretariat for GESAMP within its offices in London, since it's inception in 1969. The office provides support to GESAMP and its Members, as well as coordination between the 10 UN Sponsoring Organizations.

For IMO, GESAMP provides:

- Independent, transparent, and authoritative advice to its committees (e.g. Marine Environment Protection Committee - MEPC, the London Convention/Protocol governing bodies and Scientific Groups) upon request, through dedicated Working Groups or ad hoc Task Teams; and
- Direct advice to its regulatory processes through long-standing Working Groups (e.g. WG 1, WG 34), such as evaluation of chemicals or Ballast Water Management Systems.

GESAMP Working Groups

- Working Groups are set up by GESAMP to carry out individual studies and assessments requested by one or more of its Sponsoring Organizations.
- WGs are proposed, established, and supported by a UN Sponsoring Organisation to address an issue of concern identified by the Organisation, by the Members, or by a Member State and to carry out individual studies and assessments
- These groups are chaired by a GESAMP Member and are made up of leading global experts who are not necessarily members of GESAMP itself. This broadens the GESAMP network activities and allows Working Group expertise to be tailored to specific projects.
- WGs have formal Terms of Reference and Membership as agreed with the Sponsoring Organisation
- Reports of the Working Groups are normally considered for publication in the GESAMP Reports and Studies series after peer review and approval by GESAMP

GESAMP WG44
Biofouling and Non-Indigenous Species

- GESAMP has agreed to continue to provide independent advice on biofouling through WG44 for one more year and to work with Sponsoring Organizations on drafting possible revised ToRs.
- www.gesamp.org

GESAMP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

- Mario Tamburri
  Chair of WG44
  tamburri@umces.edu
  +1-410-326-7440

DR. ANDREW WANT

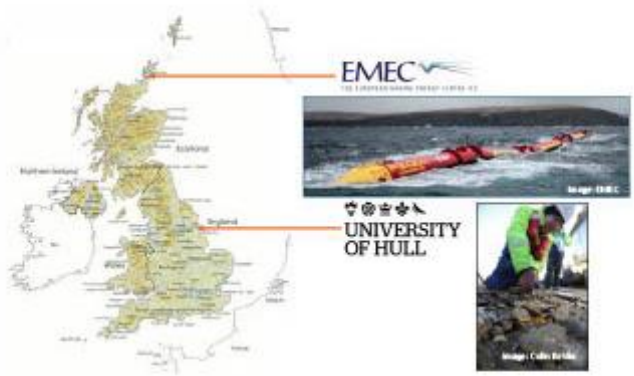
Lecturer in Renewable Energy

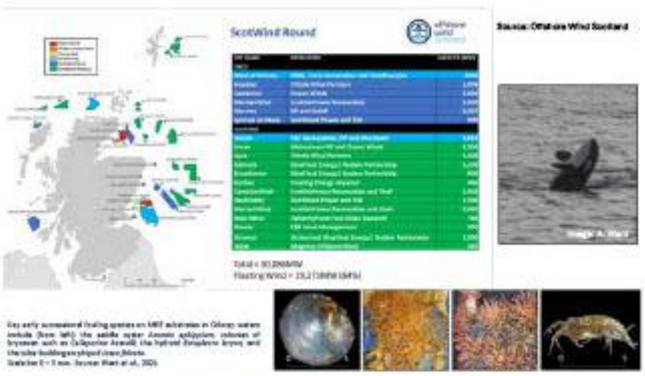
University of Hull's Energy and Environment Institute

Andrew Want is a Lecturer in Renewable Energy at the University of Hull's Energy and Environment Institute. Andrew's research explores the interactions between the offshore renewable energy (ORE) industry and the marine environment. This includes examining the role that ORE devices and infrastructure play on biofouling communities through enhanced provision of hard artificial substrates. Subtopics of interest include the management of invasive species, the impacts of marine growth on ORE technologies, and population connectivity. Andrew provides expertise to the GloFouling programme, the GESAMP 44 Working Group on Biofouling Management, and the ICES Working Group on Marine Benthal and Renewable Energy Developments.

Biofouling and Offshore Renewable Energy: Industrial and Environmental Impacts

Presentation slides





Biofouling Impacts on ORE

- Increased roughness: ↑drag ↓energy capture (Orme et al., 2001; Walker et al., 2014)
- Increased weight on mooring systems/cables: ↓performance/survivability
- Accelerating corrosion of components: ↓survivability ↑costs (Yerba et al., 2004)
- Removal of fouling/antifouling strategies are expensive and require additional operational 'down-time': ↑costs (Yerba et al., 2008; Shultz et al, 2011)
- Fouling of access areas: ↓safety
- Fouling of anodes and coatings: ↓cathodic protection ↑corrosion (Kiljinstra et al., 2017)

New Industry – New Issues

- Novel components/materials used in the sector (Tiron et al., 2015)
- Use of dynamic subsea power cables with floating technologies (Thies et al., 2019)
- Devices are being placed in poorly understood habitats (Want et al., 2023) where coatings and other antifouling solutions are untested (Kiil et al., 2002; Walker et al., 2014)
- Hydrodynamic and mechanical consequences of biofouling on moving structures, e.g. static rotating turbines (Stringer and Polagye, 2020)
- Sensor accuracy may be compromised leading to inaccurate determination of device performance and resource assessment (Want et al., 2017)

All images: A. Want

Ecological Impacts of Biofouling in ORE

Artificial substrates provide additional and varied habitat resource for epibenthic/fouling communities.

'Positive' Ecological Impacts:

- Enhanced biodiversity, including 'priority' or protected species
- 'Blue carbon' sequestration
- Nutrient cycling, water filtration
- 'Spill-over' benefits to higher trophic levels

'Negative' Ecological Impacts:

- Changes in hydrodynamics forces, i.e. movement of larvae, nutrients, scour
- Creation of 'stepping-stones' that facilitate the connectivity of IAS

Desmophyllum (Lophelia) pertusa

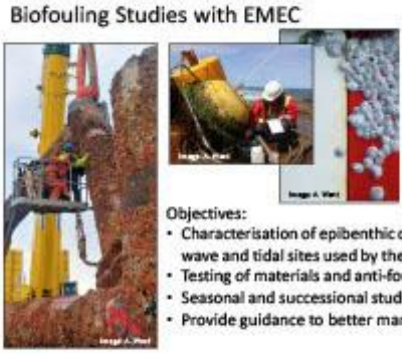
Corella eumyota

Biofouling and ORE:

- Limited studies in biofouling of ORE (Copping and Hemery, 2020)
- Most published research is representative of NW Europe (Vinagre et al., 2020)
- Biofouling will occur throughout the water column (Degraer et al., 2020)

Degraer et al., 2020

Biofouling Studies with EMEC



Objectives:

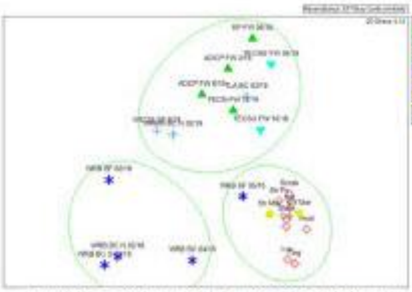
- Characterisation of epibenthic communities at extreme-energy wave and tidal sites used by the ORE sector
- Testing of materials and anti-fouling strategies used by the sector
- Seasonal and successional studies of epibenthic community
- Provide guidance to better manage fouling...

BioFREE

NERC
SCIENCE OF THE ENVIRONMENT

Site	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fall of Warness	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Billia Croo	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Shapinsay Sound	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scapa Flow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Deployment water depth (depth) and maximum height of the frame above the seabed (height) of BioFREE frames deployed at EMEC test sites in July 2019



- 200+ species recorded
- 7 IAS (in harbours/marinas)

Want *et al.*, 2023

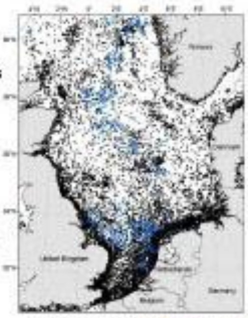
Biofouling - key findings:

BioFREE

- Proven success of BioFREE monitoring and testing system which can be used to provide detailed characterisation anywhere and at any chosen placement within the water column **(Want et al., 2021)**
- Knowledge of epibenthic species and settlement timing may inform biofouling management **(Loxton et al., 2017)**
- ORE fouling varies locally depending on:
  - Hydrodynamic conditions
  - Orientation (relative to flow)
  - Other factors include depth in water column, substrate type, distance from shore/ports
- Anti-fouling coatings performance has had preliminary studies in high-flow and extreme wave exposed conditions (e.g. scour; dissolution; biofouling) **(Vance [PML] et al., 2017)**

Connectivity:

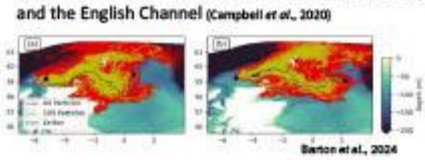
- Only ~ 15% of natural hard substrate in the North Sea supplemented by ~27,000 shipwrecks and offshore structures (oil and gas, wind ...) **(Coolen et al., 2019)**
- Devices may create 'stepping stones', facilitating population connectivity; 'good' vs 'bad'?
- Little evidence of discrimination between natural and artificial substrate **(Boutin et al., 2023)**
- Dispersion and settling of epibenthic organisms occurs in the larval stage and underpins connectivity **(Barton et al., 2024)**
- Existing studies are primarily based on unvalidated models of larval dispersal **(Dannheim et al., 2020)**



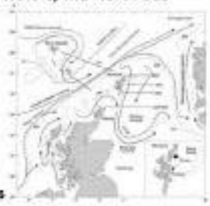
North Sea wrecks and O&G installations
From: Coolen et al. 2019

Connectivity – studies:

- Ocean currents mean that a passive and neutrally buoyant contaminant, particle or organism (planktonic) can change location – this is the basis for many connectivity models **(Hyder et al., 2017)**
- The Scottish Shelf Model is a hindcast model, run from 1993 to 2019, covering Scottish continental shelf waters as well as most of UK waters, the North Sea and the English Channel **(Campbell et al., 2020)**



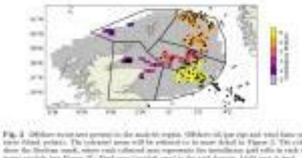
Barton et al., 2024



Turrell et al., 1996

Connectivity - key findings:

- Limited validation of models using molecular techniques or enhanced monitoring **(Dannheim et al., 2020)**
- Resilience and recovery of connectivity can depend on strength of the hard substrate network **(Barton et al., 2024)**. This can be engineered
- Concerns exist over the role of ORE 'networks' in facilitating IAS movement



Barton et al., 2024

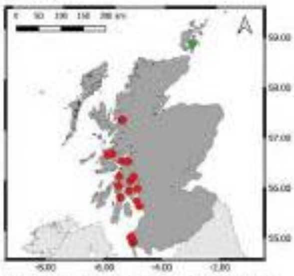
Invasive aquatic species - studies:

- 193 identified artificial hard-substrate species in the North Sea (Coolen et al., 2020); some of these are IAS
- ORE devices may function as 'stepping stone' pathways to connectivity of IAS (Knights et al., 2024)

Austrominius modestus | *Corella eumyota* | *Schizoporella japonica* | *Caprella mutica*

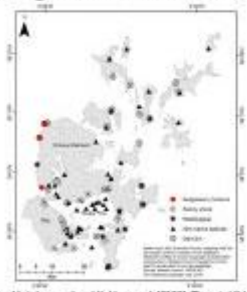
Note: no IAS have been recorded at full-scale ORE sites in Orkney

Styela clava



Want, A. and Kakkonen, J. (2021). A new range-extending record of the invasive sea squirt *Styela clava* in the north of Scotland. *Marine Biodiversity Records.*

Sargassum muticum



Want, A., Matejusova, I and Kakkonen, J. (2023). The establishment of the invasive non-native macroalga *Sargassum muticum* in the north of Scotland. *Journal of the Marine Biological Association of the United Kingdom*

Invasive aquatic species - key findings:

- Limited opportunities exist to study IAS *in situ* on ORE
- Service vessels may also increase the risk of transfer of IAS (Nall et al., 2015)
- Hydrodynamic conditions may create hydrographic barriers to IAS
- IAS appear to be absent from ORE test sites (Want et al., 2021; 2023), but:
  - ORE have not been studied at the same detail
  - ORE locations are much more challenging to study
  - Common survey methods, such as ROV, may lack resolution necessary to identify IAS (Gormley et al., 2018)

Next steps...

Waldman et al., 2024 DOI 10.5281/zenodo.7109882.

Key gaps in ORE biofouling and connectivity:

- In the ORE industry, biofouling is a lower priority than other technical issues
- Published studies of ORE and biofouling are limited and largely absent from much of the Globe's oceans
- Greater data sharing is necessary, especially at the Global scale
- Antifouling strategies are less well understood in high energy ORE habitats including performance of antifouling coatings

Want et al., 2023


Key gaps in ORE and IAS:
• Biosecurity is not generally recognised as a high priority to the ORE industry
• Siting of installations may minimise connectivity between harbours and ORE
• Regulations regarding IAS in consenting process
• Regulations regarding movement of ORE infrastructure from place of manufacture to deployment, etc
• Floating ORE technologies may create new challenges with IAS...
• How do decommissioning options affect IAS? (Knights et al., 2024)
US Dept. of Energy


GloFouling
PARTNERSHIPS
GESAMP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
ICES Working Group on Marine Benthal and Renewable
CIEM Energy Developments
IEC
International Electrotechnical Commission
TC 114
Marine energy - Wave, tidal and other water current converters


Many thanks!
a.want@hull.ac.uk
KRISO
Ministry of Oceans and Fisheries
GloFouling
PARTNERSHIPS

DR. GRETA SRĖBALIENĖ

Researcher

Marine Research Institute, Klaipeda University, Lithuania

Dr. Greta Srėbalienė is a distinguished researcher at the Marine Research Institute of Klaipėda University, Lithuania. Her PhD research focused on the quantitative evaluation of the effects of bioinvasion on marine ecosystems, providing valuable insights into the ecological impact of invasive species.
Dr. Srėbalienė is currently developing innovative methods to identify and assess the risks posed by harmful organisms and diseases transported through ballast water and biofouling. Her work also includes contributing to the development and regional standardization of early warning systems for marine ecosystems. By incorporating cutting-edge techniques such as environmental DNA (eDNA), she is enhancing the accuracy and efficiency of these systems to safeguard marine biodiversity.

Informed Means Armed: The Role of Information Systems On Non-Indigenous Species In Biofouling Management And Research

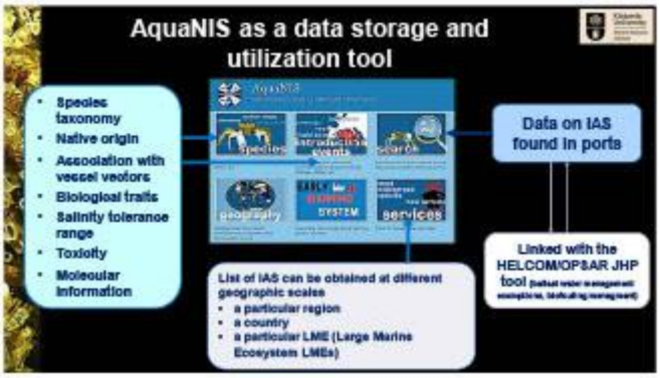
Sergej Olenin, Greta Srėbalienė, Aleksas Narščius

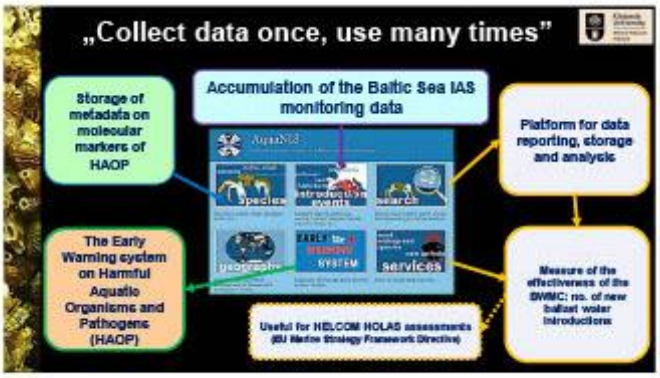
Effective biofouling management policies require access to up-to-date, precise, and readily accessible data that can be easily comprehended and utilized for informed decision-making.

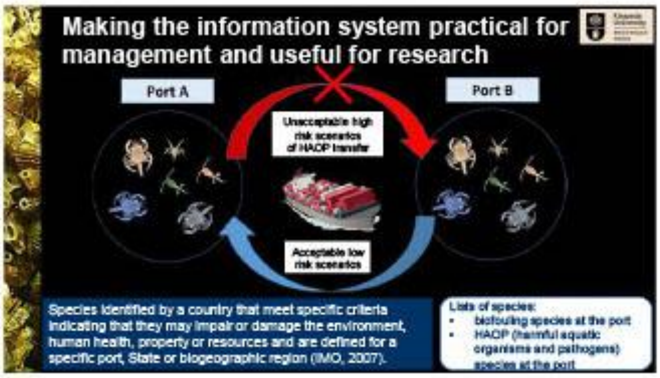
The effectiveness of the IMO 2023 IMO Biofouling Guidelines, the IMO Ballast Water Management Convention (2007), or other international or national instruments that aim to reduce the spread of invasive alien species (IAS) can be assessed by estimating the decrease in the number of new arrivals through different means of introduction, such as biofouling. This data is derived from monitoring and focused scientific research. However, efforts expended research, monitoring, and assessment of IAS will only be effective for biofouling management if they are presented in a clear and easily understandable manner. The data should be collected, quality checked, harmonized, and presented through user-friendly and reliable information systems, such as AquaNIS, a global information system on aquatic non-indigenous (NIS) and cryptogenic species < www.corpi.ku.lt/databases/aquanis >. This system has played a central role in gathering data on national and regional NIS inventories, determining the most harmful IAS, measuring and summarizing the ecological effects of specific taxa, identifying key pathways and vectors of NIS introductions, and studying species traits and ecological preferences. Utilizing AquaNIS improves the analytical and predictive aspects of biofouling research, transitioning from a mere scientific curiosity to a more practical approach driven by management needs.

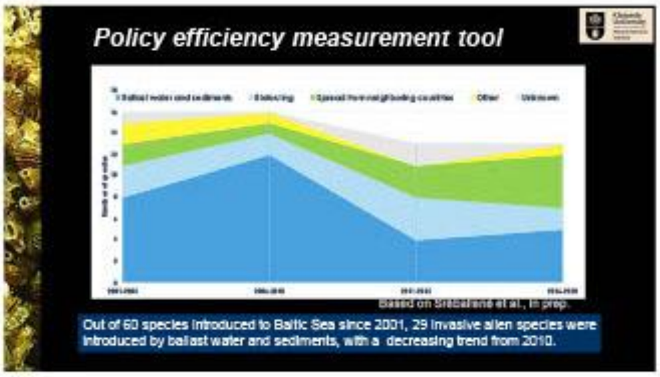
The paper discusses the valuable insights gained from over 25 years of experience in NIS databasing and how these insights can be effectively utilized in biofouling management and research. This highlights the flexibility of a NIS information system, which operates on the principle of "collect data once, use it many times". The system enables the utilization of the collected data for operational purposes, as well as the ability to analyze and predict outcomes based on NIS registration in different geographical areas. It also provides relevant search functions for biological traits, environmental tolerance limits, and the impacts on native biodiversity, ecosystem functioning, economy, and public health. Ultimately, the paper highlights the importance of maintaining a dynamic and resilient database, emphasizing the need for support from regional and/or global organizations and conventions to ensure the longevity and sustainability of the information system.

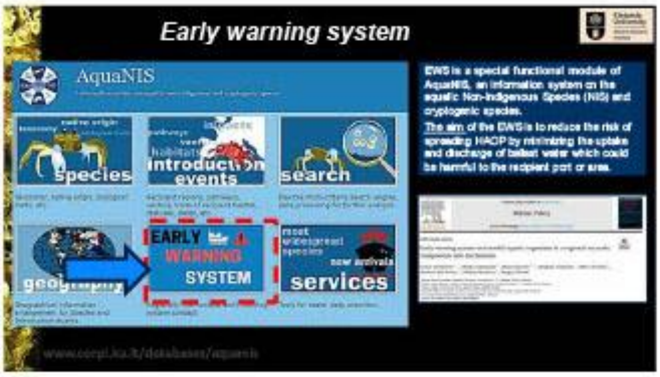
Presentation slides

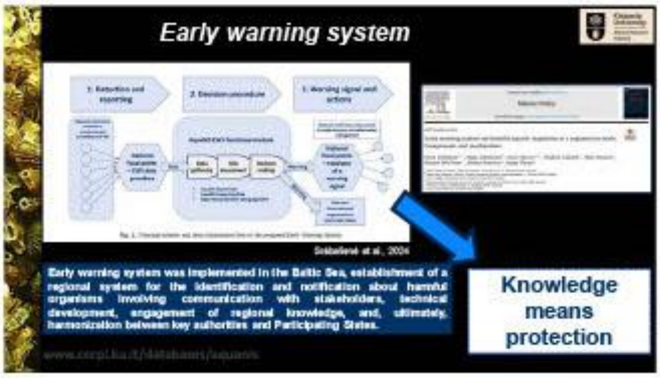







Policy efficiency measurement tool
Based on Srėbalienė et al., in prep.
Out of 60 species introduced to Baltic Sea since 2001, 29 invasive alien species were introduced by ballast water and sediments, with a decreasing trend from 2010.


Early warning system
AquaNIS
species
introduction events
search
EARLY WARNING SYSTEM
services
new arrivals
EWS is a special functional module of AquaNIS, an information system on the aquatic Non-indigenous Species (NIS) and cryptogenic species.
The aim of the EWS is to reduce the risk of spreading HAOP by minimizing the uptake and discharge of ballast water which could be harmful to the recipient port or area.


Early warning system
2. Decision procedure
Srėbalienė et al., 2024
Early warning system was implemented in the Baltic Sea, establishment of a regional system for the identification and notification about harmful organisms involving communication with stakeholders, technical development, engagement of regional knowledge, and, ultimately, harmonization between key authorities and Participating States.
Knowledge means protection


Conclusions
It is necessary to determine for what purposes (e.g. research, management, environmental assessment, early warning, etc.) and how the system will be used.
Effective biofouling management policies require access to up-to-date, precise and readily accessible data that can be easily comprehended and utilized for informed decision-making.
Utilizing AquaNIS improves the analytical and predictive aspects of biofouling research, transitioning from a mere scientific curiosity to a more practical approach driven by management needs.
Acknowledgement:
COMPLETE
Interreg
South Baltic
SEQUENCH

Innovative Solutions for Biofouling Management - Coatings

CHAIR OF THE SESSION

JON STEWART

Moderator

GloFouling R&D Forum

DR. MARCIEL GAIER

CTO and Director

GIT Coatings, Canada

With a steadfast 7-year tenure as Founder and CTO of Graphite Innovation and Technologies Inc., I have led the charge in advancing sustainable marine coatings within the shipping sector. As both Founder and Board Member, my role has been instrumental in defining the company's strategic course with a strong emphasis on sustainability and innovation, aiming to drive positive transformation in the marine coatings industry. This journey involved setting overarching goals, shaping the company's mission, vision, and core values, and curating a diverse, skilled team with complementary expertise

My academic foundation includes a PhD in Materials Science from Dalhousie University, where I cultivated a deep understanding of advanced materials and their applications. This expertise has been pivotal in my success in research and development, culminating in the creation of three patent families that highlight the innovative technologies at the core of our product offerings

As Co-founder and Chief Technology Officer, I have honed my leadership prowess, navigating complex technical landscapes, shaping strategic roadmaps, and fostering high-performance teams. I have championed financial sustainability, aligning with the company's oversight needs, while my venture capital engagement and ability to evaluate investment opportunities position me to contribute substantively to company investment decisions. My adeptness in government relations, extensive experience in commercializing intellectual property, and dedication to diversity and inclusion further underline my potential as a valuable addition to the Clean & Ocean Tech industry.

Always clean hulls: Revolutionizing vessel efficiency by combining low-friction hard coatings with grooming robots

Dr. Marciel Gaier and Philippos Sfiris

The maritime industry is on a pivotal journey towards sustainability, driven by the dual challenges of improving operational efficiency and meeting stringent environmental targets. The adoption of the International Maritime Organization's (IMO) new biofouling guidelines underscores the sector's commitment to minimizing the environmental impact of ship operations. This paper presents an innovative solution to achieve these goals: the combination of advanced low-friction marine coatings and grooming technologies designed to keep ship hulls perpetually clean, thereby preventing biofouling and avoiding extra power penalty associated with hull fouling. Light slime coverage can trigger a 20-25% increase in GHG emissions, highlighting the urgent need for effective biofouling management strategies. Currently, fouling is cleaned from vessels in a reactive way, releasing high concentrations of biocides and damaging the coatings that are not engineered to be cleaned.

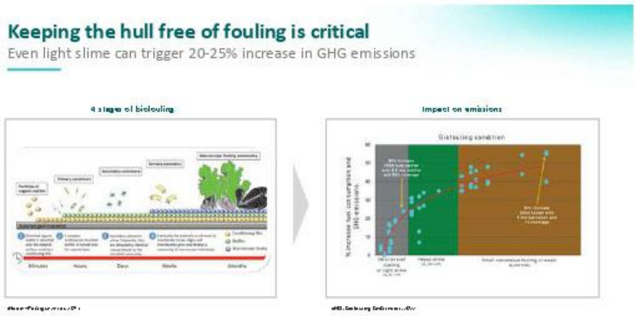
The core of our solution lies in its proactive approach to biofouling management, aligning with the IMO's emphasis on prevention. By integrating advanced low-friction marine coatings with enhanced foul release performance, and mechanical performance with state-of-the-art grooming technologies, our approach not only adheres to the new biofouling guidelines but sets a new standard in sustainable maritime operations.

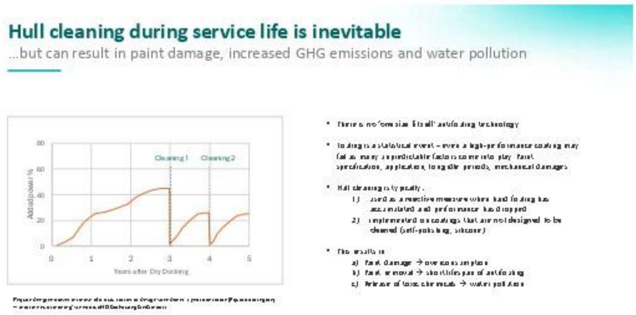
Keywords: Biofouling management, grooming, slime free, hull coatings, hard foul release

Presentation slides

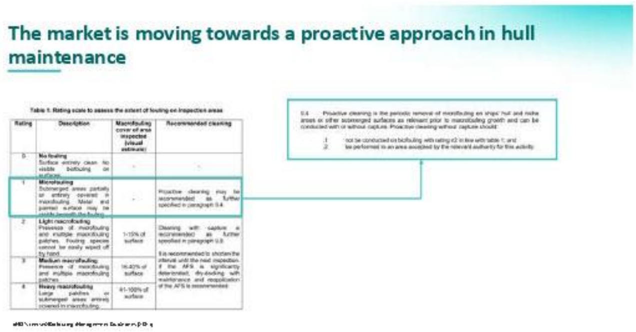

GIT COATINGS
Always clean hulls
Revolutionizing vessel efficiency by combining low-friction hard coatings with grooming robots
Marciel Gaier, PhD – CTO
E: Marciel.gaier@gitcoatings.com
SCAN ME


GIT Coatings – Who we are
New player on the market – Founded in 2017.
Focused on high-performance coatings for the hull and propeller
HQ and manufacturing facilities in Canada – stock points in Turkey and China
Presence in Greece, Germany, Denmark, Estonia, USA, Singapore
+50 employees globally
Patented graphene-based hard foul release technology
~400 vessel applications since 2022
Financially backed by a global syndicate of climate action, ocean health funds, private investors, shipowners and green financing banks
GIT COATINGS


Keeping the hull free of fouling is critical
Even light slime can trigger 20-25% increase in GHG emissions
4 stages of biofouling
Impact on emissions
Biofouling condition
Minutes
Hours
Days
Weeks
Months


Hull cleaning during service life is inevitable
...but can result in paint damage, increased GHG emissions and water pollution
Cleaning 1
Cleaning 2
Added power %
Years after Dry Docking

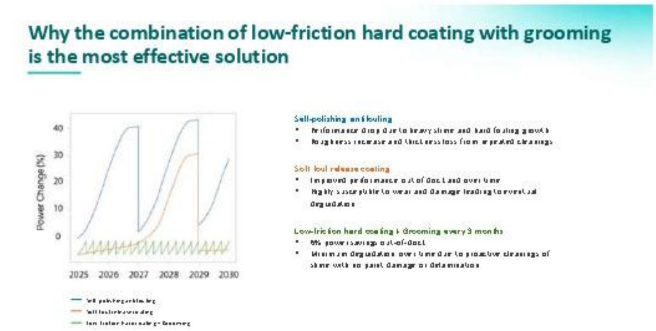

Increasing regulatory pressure to minimize the use of biocides
Moving towards restrictions or ban of existing antifouling active substances
Korea
Europe
Biocidal Products Regulation
Current trends:

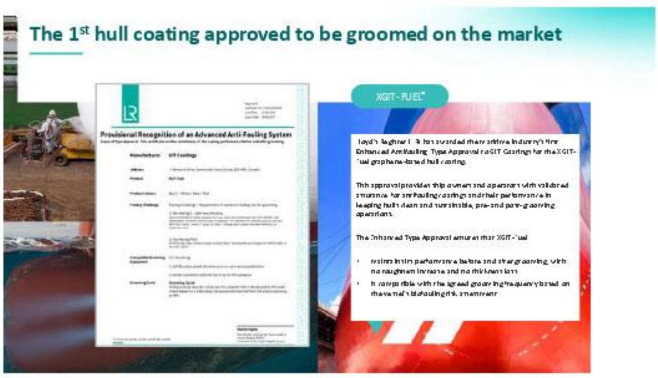

The market is moving towards a proactive approach in hull maintenance
Table 1. Rating scale to assess the extent of fouling on inspection areas
Rating
Description
Recommended cleaning
No fouling
Microfouling
Light macrofouling
Medium macrofouling
Heavy macrofouling

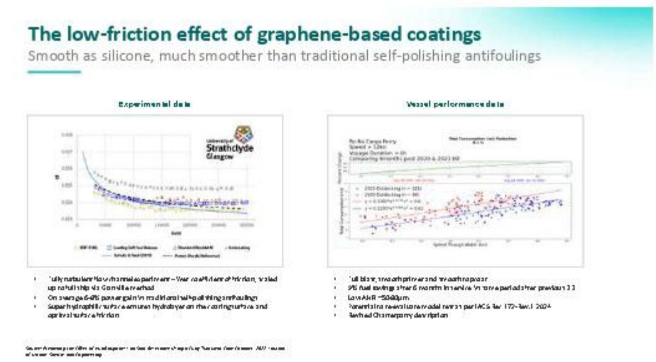

How grooming is different from cleaning
Graphene-based coatings are best suited for grooming


Engineered Coating to be groomed
Graphene-based coatings are best suited for grooming
• Durability and wear resistance for grooming. Resistance of brushes and cavitation.
• Out of dock and overtime AHR.
• Continuous antifouling performance over consecutive grooming cycles.
Fouling + Grooming
Visual assessment
Hull roughness
Micro-roughness
Paint thickness
Gloss
Grooming test results with GIT's graphene-based coating


Always clean hulls: A vision for the future
What
How
Who
Graphene-based coating
Hull grooming
GIT
CLIIN
Shipshave


Why the combination of low-friction hard coating with grooming is the most effective solution
Power Change (%)
40
30
20
10
0
2025
2026
2027
2028
2029
2030
Self-polishing antifouling
Foul release coating
Low-friction hard coating + Grooming every 3 months


The 1st hull coating approved to be groomed on the market
Provisional Recognition of an Advanced Anti-Fouling System
XGIT-FUEL


The low-friction effect of graphene-based coatings
Smooth as silicone, much smoother than traditional self-polishing antifoulings
Experimental data
Vessel performance data
University of Strathclyde Glasgow


We support our customers in planning and implementing hull grooming programs
Biofouling risk assessment
Grooming program
Grooming feasibility assessment
Selection of grooming tech
TCO & payback
Robot deployment & crew training
Fouling warnings
Inspections & cleanings
Reporting & recommendations
Real-time advisory

VIKTOR AVLONITIS

Team Leader Non-Mettalics & Coatings

Hempel A/S, Denmark

Viktor Avlonitis works in the Marine division of Hempel A/S, where he has held roles across technical advisory services, aftersales strategy, and regulatory affairs. With over 10 years in the maritime industry, Viktor has overseen numerous in-water hull inspections and cleanings, advising shipping companies on biofouling protection through the installation of antifouling coatings, monitoring plans, and maintenance practices. As Hempel's representative in the IMO GloFouling Project's Global Industry Alliance and a SEA Europe delegate to the IMO's PPR and MEPC sessions, he contributes to shaping international biofouling standards and advancing sustainable practices. Viktor also supports ISO standards for in-water hull cleaning and AMPP standards for inspections. He holds an MSc and PhD from Copenhagen Business School.

Balancing Energy Efficiency and Marine Biodiversity: A Holistic Framework for Biofouling Management in the Maritime Industry

Viktor Avlonitis, Yigit Demirel, Francisco Aprile

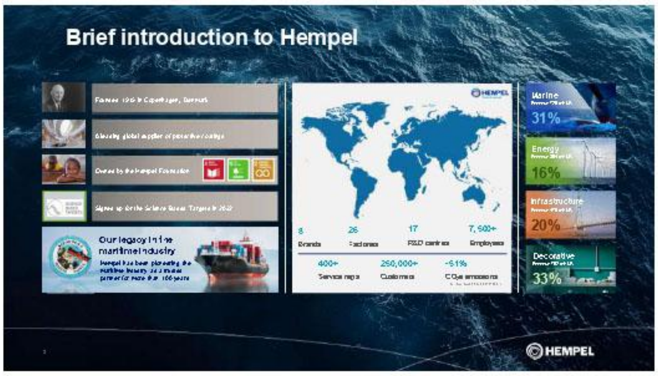
Retaining a clean and smooth hull, free of biofouling growth, ensures optimal hydrodynamics which in turn can significantly reduce the energy demand of the global fleet. Additionally, keeping ship hulls clean and appropriately managing biofouling growth is critical to the preservation of marine biodiversity.

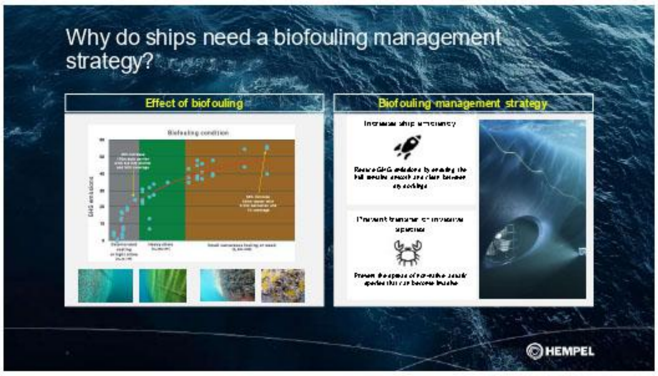
A primary consideration when choosing a biofouling management strategy is the choice of the antifouling coating system and corresponding maintenance requirements during its lifetime in the form of in-water cleaning. With this paper we argue that the choices entailed in biofouling management activities will need to balance the trade-offs between emissions to air (i.e. energy reduction from clean hulls) and emissions to water (passive or accelerated release of waste substances to ensure a clean hull).

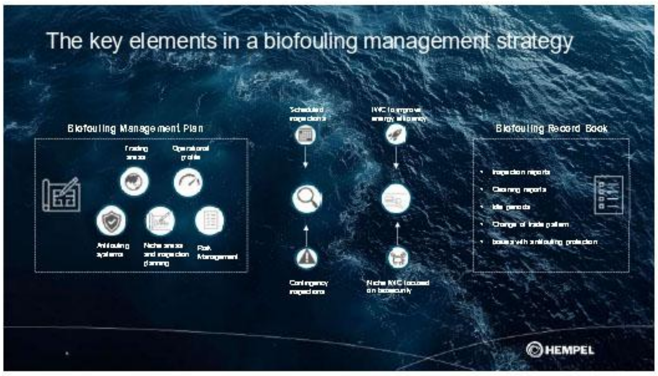
We develop a framework to evaluate biofouling management strategies and simulate alternative scenarios for a bulk carrier exemplary case. We model the impact of alternative biofouling management strategies on energy efficiency (fuel consumption and carbon intensity rating) and on the water column (emissions from antifouling coatings and in-water cleaning). This allows to provide a holistic perspective of alternative biofouling management strategies that consider both emissions to air and emissions to water. Our analysis considers insights from extant academic literature on antifouling coatings and in-water cleaning, internal data from Hempel A/S, and recently issued results from in-water cleaning simulations by independent organizations. Our results guide market and policy actors towards more sustainable practices, contributing to the broader goal of reducing energy demand without compromising the marine environment.

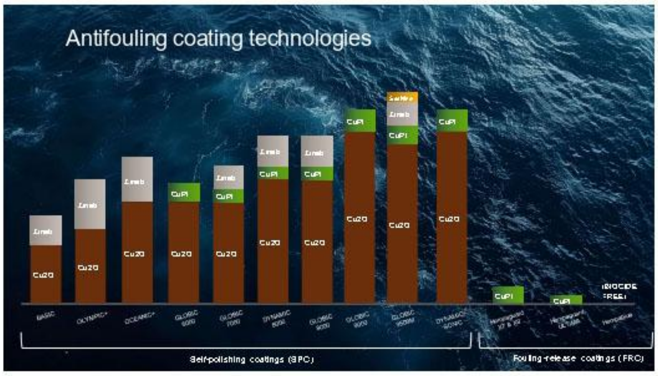
Keywords: biofouling management, antifouling systems, in-water hull cleaning, emissions to air, emissions to water, fuel efficiency

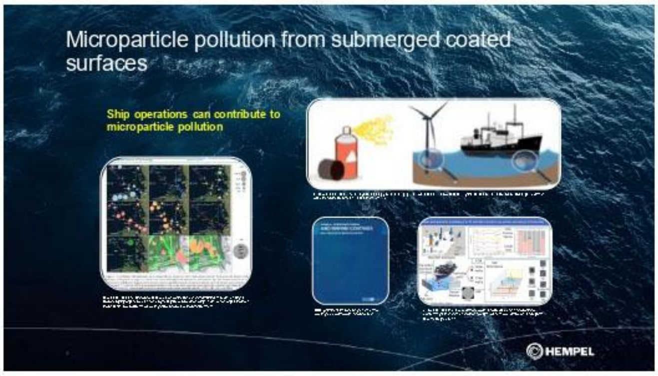
Presentation slides





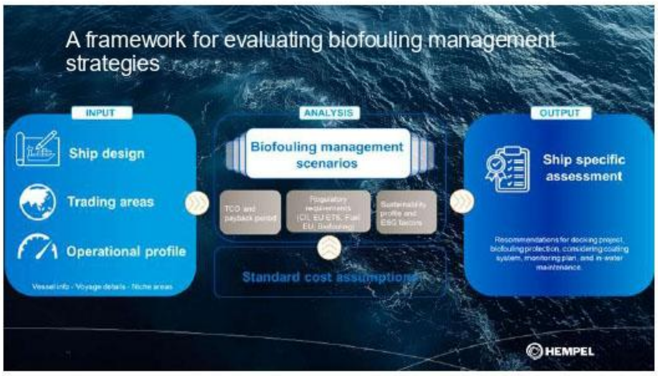


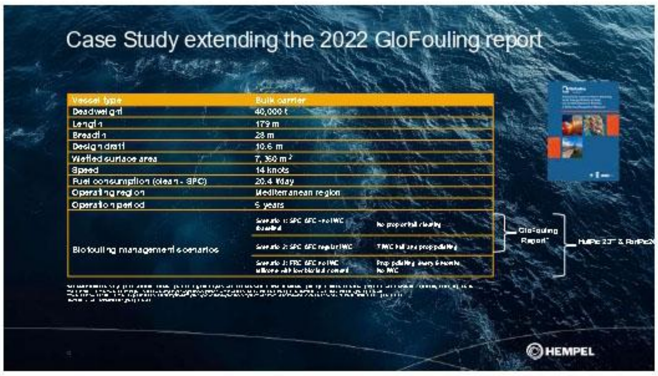

Antifouling coating technologies
Cu2O
Zineb
CuPI
Self-polishing coatings (SPC)
Fouling-release coatings (FRC)
(BIOCIDE FREE)

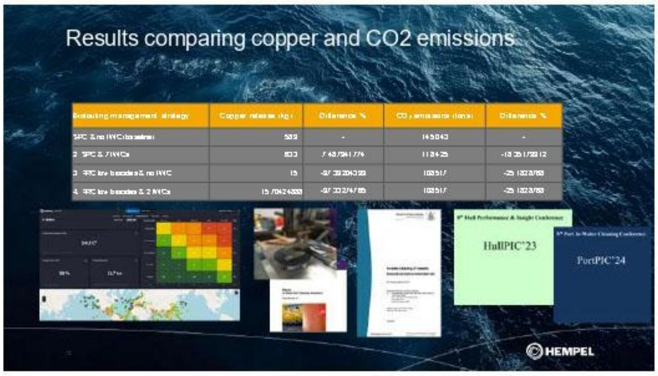

Microparticle pollution from submerged coated surfaces
Ship operations can contribute to microparticle pollution
HEMPEL

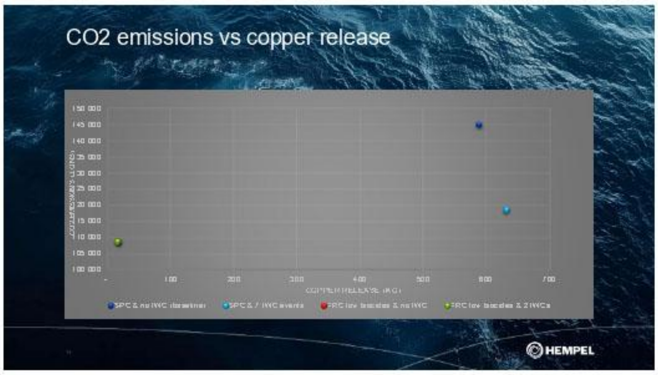

Pollution resulting from in-water hull cleaning
Increased focus on the risk of seawater contamination from in-water cleaning operations
HEMPEL


How to balance the benefits and risks entailed in biofouling management strategies?
Environmental benefits
Improve ship hydrodynamics and reduced fuel consumption
Minimize the transfer of invasive aquatic species
Environmental risks
Passive release of paint particles (biocides, polymeric particulates)
In-water hull cleaning waste material
HEMPEL


A framework for evaluating biofouling management strategies
INPUT
Ship design
Trading areas
Operational profile
Vessel info - Voyage details - Niche areas
ANALYSIS
Biofouling management scenarios
TCO and payback period
Regulatory requirements (CII, EU ETS, Fuel EU, Biofouling)
Sustainability profile and ESG factors
Standard cost assumptions
OUTPUT
Ship specific assessment
Recommendations for docking project, biofouling protection, considering coating system, monitoring plan, and in-water maintenance.
HEMPEL


Case Study extending the 2022 GloFouling report
Vessel type | Bulk carrier
Deadweight | 40,000 t
Length | 179 m
Breadth | 28 m
Design draft | 10.6 m
Wetted surface area | 7,350 m²
Speed | 14 knots
Fuel consumption (clean - SPC) | 20.4 t/day
Operating region | Mediterranean region
Operation period | 5 years
Biofouling management scenarios
GloFouling Report
HEMPEL


Results comparing copper and CO2 emissions
HullPIC'23
PortPIC'24
HEMPEL


CO2 emissions vs copper release
HEMPEL


Implications and directions for future work
Trade-offs between emissions to air and water: Biofouling management strategies need to consider efficiency savings from coatings, and impact to the water column. Monitoring and maintenance requirements are key, and so is the availability and quality of cleaning services.
FRC coatings with low biocidal content are the most promising biofouling control technology to maximize environmental benefits and minimize the risks (for most ship profiles). Such coatings require less in-water maintenance and contain fewer active substances.
Future research directions:
HEMPEL


Three main points today
Navigating biosecurity and fuel efficiency
A holistic approach is needed when choosing a biofouling management strategy
Multiple technologies are needed to protect the whole ship
(in-water inspections, cleanings, niche areas)
HEMPEL


HEMPEL
Trust is earned
Thank you!

DR RALITSA MIHAYLOVA AMRINA

Head of Special Projects

Safinah Group

Dr Ralitsa Mihaylova is the Head of Special Projects for Safinah Group, a leading independent coating consultancy based in the United Kingdom. Her background is in shipping business and operations with experience in data analysis and machine learning techniques. Ralitsa has a keen interest in sustainable solutions and the regulatory framework governing international shipping. She is actively participating in industry-led initiatives and working groups related to biofouling. At Safinah Group, Ralitsa is responsible for coordinating the company's research and development activities and delivering data-driven solutions and insights to inform strategic decisions.

Effective Biofouling Management Strategies: The Challenges with Ship-specific Functional Specifications and Coating Selection

Developing effective biofouling management strategies for different vessels is challenging due to the variability in operating parameters, activity profiles, and trade-specific requirements. Selecting the optimal system, or a combination of systems, for a specific ship is a complex task as there are multiple options to choose from.

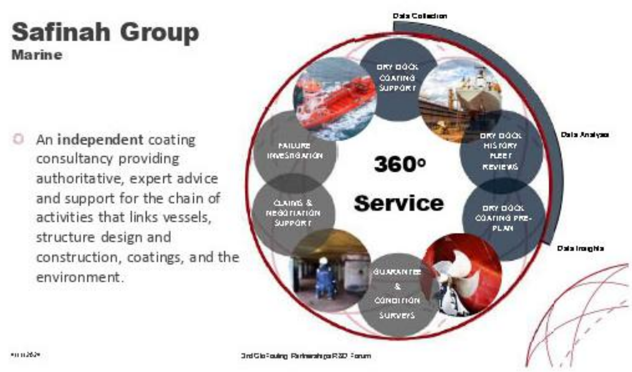
Data on the in-service performance of biofouling control products independently collected through dry dock project supervision can be used to enhance the coating selection and specification process.

The presentation aims to introduce a data-driven approach to coating selection and specification that allows for continuous learning and serves as the basis for an evidence-based biofouling management strategy.

The findings include insights on product and scheme performance based on more than 800 dry dock projects and over 600 specification reviews, as well as challenges with implementing a ship-specific approach to biofouling management and common misconceptions regarding product selection and expected performance.

Keywords: biofouling management, coating selection, coating specification

Presentation slides

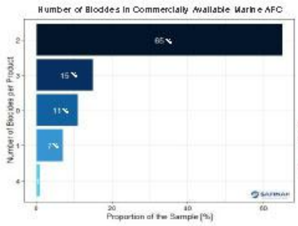


Hull Coatings

- **Anti-fouling coating (AFC)**
  - means a surface coating or paint designed to prevent, repel or facilitate the detachment of biofouling from hull and niche areas that are typically or occasionally submerged [MEPC.378(80)].

Commercially available AFCs

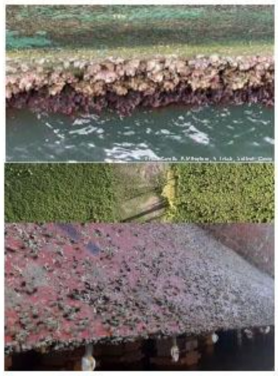
Segment	Products	Total Products
Marine	378	917
Yacht	539	



AFC

Performance and Impacts

- **Coating Performance:** biofouling control under different conditions
  - AFC Type
  - Environmental conditions
  - Operational conditions
  - Age effect on properties
  - Maintenance interventions (in-water cleaning / treatment)
- **In-service [maintenance]:** potential effects on the environment
  - Biofouling removed (biosecurity risks)
  - Biocide release
  - Microplastics
  - Other



Performance Data

- **Sample Definition:**
  - Data from coating supervision projects at drydock
  - 800+ projects
  - 200+ projects annually

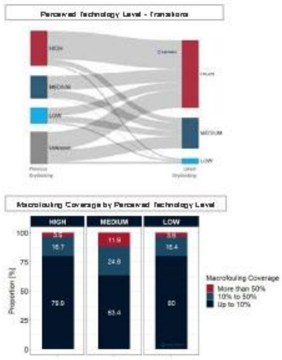
AFC

Selection and Performance

- **Coating Selection Trends:**
  - Increase in perceived 'high technology level' products?
  - Variability by segment of the fleet / ship particulars / area?
  - Better performance?
- **Coating Performance Trends**
  - High technology products offer more reliable performance?
  - Product positioning accurate?
  - Contributing factors?

> High / Low - No difference in terms of in-service performance?

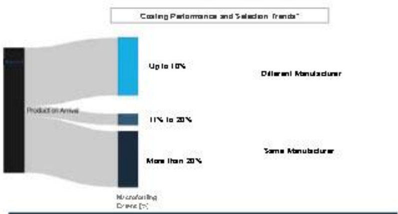
> Ship-specific approach to selection and specification required.



AFC

Selection and Performance

- **Highlights**
  - Across the sample*, on average >1,300 m² per vessel covered in hard macrofouling
  - 20% of vessels have less than 1% of hard macrofouling on arrival in drydock (total area)**
  - Inconsistent performance across coating technology levels

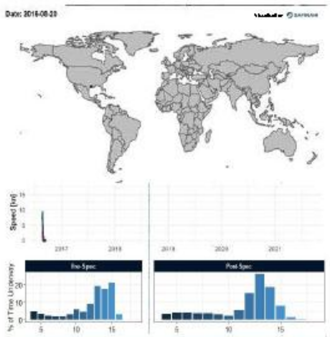


More than half of the ships with >20% macrofouling on arrival in drydock opted for the same manufacturer and often the same product.

>> Lack of systematic review of fleet coating performance and effective pre-planning.

Case Study 1

- **Highlights**
  - Coating manufacturers consulted during planning stage
  - Premium AFC applied
- **Outcome**
  - Poor in-service performance
  - Severe polish through (to tie coat)
- **Potential reasons/contributing factors**
  - Inappropriate specification – environmental / operational parameters not ship-specific
  - In-water cleaning events (timing / equipment) – at least one known IWC
- **Prevention**
  - Methodical planning prior to dry-docking



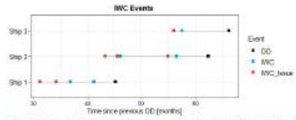
Historical or current specification did not match the operational profile of the ship.

Case Study 2

- **Highlights**
  - Extensive screening programme for innovative solutions
  - Trial of a novel coating (biocide-free)
- **Outcome**
  - Poor in-service performance – extremely high biofouling accumulation rates
  - Early dry-docking required
- **Potential reasons/contributing factors**
  - Inappropriate product selection
- **Prevention**
  - Consider evidence of (in-service) performance / track record
  - Develop systematic testing programmes of novel solutions (in service)

Case Study 3

- **Highlights**
  - Extensive AFC selection and specification planning
  - Biofouling management and contingency actions considered
  - Strategic partnerships with IWC providers in key locations
  - Crew training on biofouling management and onboard equipment
- **Outcome**
  - Proactive IWC not possible in practice
  - AFC damages due to biofouling condition / delays
  - Poor in-service performance (post-IWC)
- **Potential reasons/contributing factors**
  - IWC equipment reliability
  - IWC provider lack of contingency measures / poor logistics
- **Prevention**
  - Consider contingency measures in case of equipment failures
  - Develop networks for proactive/reactive IWC

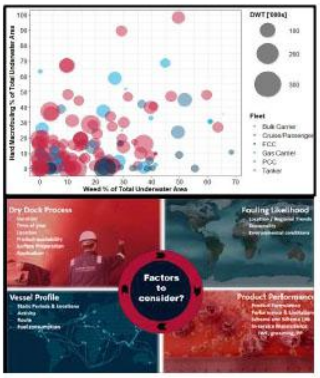


Biofouling Management
Emerging Issues

- **AFC specification**
  - Predictability of operations / environmental conditions
  - Quality / completeness of data
  - Flexibility to accommodate unforeseen circumstances
- **AFC selection**
  - Fragmented market with many options – evidence of in-service performance under different conditions?
  - Combination of technologies for different areas
- **In-water cleaning strategy**
  - Coating type and scheme suitability
  - IWC equipment capability (capture / no capture)
  - IWC equipment / biofouling condition
  - Frequency
  - Extent / niche areas
  - Availability in key locations
  - Reliability (equipment / operation)

Summary

- **Tools:**
  - **Data** on coating performance across ship types, operational profiles, coating technologies, and specific products is critical for optimal product selection
  - **A systematic approach to coating specification and selection** (functional specifications) and periodic reviews are key to robust evidence-based biofouling management strategies



Safinah Group
360° Coating & Engineering Experts

Dr Rai Mihaylova
Head of Special Projects

MUHAMED ASHRAF P

Principal Scientist

ICAR Central Institute of Fisheries Technology, Cochin, India

Muhamed Ashraf P, Ph D, working as Principal Scientist in ICAR Central Institute of Fisheries Technology, Cochin, India and his area of research is the nanotechnological application for the development of antifouling strategies in aquaculture cage nets, corrosion and deterioration of marine materials, sensors for aquatic systems and synthesis of nano materials from fish wastes. He is working in the area last 28 years. He received his PhD degree from University of Kerala and published more than 80 research papers in peer reviewed journals.

Enhancing Biofouling Resistance of Organo Silane-Coated Polyethylene Aquaculture Cage Nets with (CuO:TiO2): Nano Carbon Dots

Muhamed Ashraf P., Sahla VA, Gopika R and Manjulekshmi N

Biofouling is a major issue among aquaculture farmers and its management costs 25% of the total project cost. Traditional technologies involve coating aquaculture cage nets with biocides using binders or polymeric substances. However, these methods have disadvantages, including the use of higher amounts of biocide, its leaching into the environment, and challenges associated with managing the increased weight of the net. Nano technology offers efficient solutions to mitigate the biofouling issue in aquaculture cage nets. Aquaculture cage nets mainly fabricated polyethylene, which is a non-polar polymer. The surface of the polyethylene is modified using nano polyaniline through an in situ method and treated with 0.02% nano copper oxide, resulting in excellent biofouling resistance [1]. Surface modification of polyethylene with polyaniline is tedious and generates more waste, thus leading to less adoption by farmers. Organosilane molecules extensively employed to modify the surface of cotton; however, their application has not been attempted in polyalkene polymers. The present study aimed to modify the surface of polyethylene aquaculture cage nets using (3-glycidyloxypropyl) trimethoxysilane molecules, followed by treatment with the biocide nano carbon dot: (CuO-TiO2), and evaluate its effectiveness in resisting biofouling in a marine environment. The characterisation of the silane – biocide treatments were evaluated using FTIR, SEM and UV –Visible spectroscopy revealed that the silane were attached over the net and the biocide interacted through C-O-C of silane and conjugated double bonds of carbon dots. The hydrophobic polyethylene cage net become partially hydrophobic - hydrophilic nature enhanced biofouling resistance. 8 months exposure of the treated aquaculture cage net in the estuarine environment revealed that the treatment 0.05% each of carbon dot: (CuO:TiO2) exhibited excellent biofouling resistance. Introduction of nano copper oxide and carbon dot along with titanium oxide reduced the band gap, which enhanced the photocatalytic activity and hence increased reactive oxygen species, free radicals and higher electronic movement in the vicinity of the cage net inhibited the approach of microorganism.

Key words: Biofouling, aquaculture cage net, titanium oxide, reactive oxygen species.

References:

[1] P. Muhamed Ashraf, K.G. Sasikala, Saly N. Thomas, Leela Edwin (20)Biofouling resistant polyethylene cage aquaculture nettings: A new approach using polyaniline and nano copper oxide. Arabian Journal of Chemistry. Volume 13, Issue 1, January 2020, Pages 875-882

Presentation slides

Enhancing Biofouling Resistance of Organo Silane-Coated Polyethylene Aquaculture Cage Nets with ($CuO:TiO_2$) :Nano Carbon Dots

P Muhamed Ashraf,* Sahla VA, Gopika R and Manjulekshmi N

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GloFouling Nov 04, 2024

ICAR Central Institute of Fisheries Technology, Kochi, India

- Fishing Technology
- Fish Processing
- Biochemistry and Nutrition
- Microbiology, and Biotechnology
- Quality Assurance and Management
- Engineering
- Extension, Economics and Statistics
- ABI Business Incubation Centre

- Marine material degradation
- Anti fouling – aquaculture nets – nano materials
- Nano sensors
- Nano materials from fish wastes
  - ISO 17025 (NABL) accredited lab chemical and microbial (>400 parameters)
  - FSSAI National Reference Laboratory and National Referral Laboratory for Food and seafood products quality

Introduction

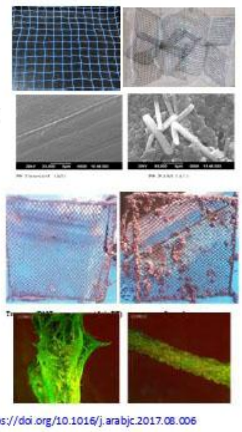
- India ranked second largest producer of fish through aquaculture and 70% of total fish production is from aquaculture (12.2 MT). Total 16.2 MT
- Recent years cage aquaculture getting popular and major crops includes pangasius, tilapia, carps (like rohu and catla), and high-value species like seabass (*Lates calcarifer*) and groupers in coastal cages.
- In 2023, inland cage aquaculture fish production around 25,000 metric tons showing a steady increase from previous years. (www.pib.gov.in)
- Cage aquaculture production China 10 MMT, Norway 1.5 MMT, Chile 1.2 MMT, Vietnam 0.5 MMT, Indonesia 0.8 MMT (FAO 2024)

FAO. 2024. *The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action*. Rome

- Major issues: disease outbreaks, water pollution, high operational cost, biofouling and lack of technical knowledge,
- Biofouling in aquaculture cages, management costs 10-25% (Braithwaite et al 2007).
- Antifouling strategies – CuO coatings,
  - High-pressure water or air jets
  - Silicone elastomers or hydrophobic coatings,
  - Copper pyrithione, zinc pyrithione,
  - Fluoropolymers or hydrogels,
  - Chitosan, alginate, or other natural biopolymers.
  - Electrochemical devices integrated into the net structure
  - *Nano materials are promising biocides*

R.A. Braithwaite, et al,(2007) Aquaculture. 262 (2) 219-226. http://dx.doi.org/10.1016/j.aquaculture.2006.11.027

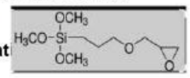
- PE is mainly used for fabrication of Aquaculture cages – non polar nature – difficult to incorporate biocides.
- non polar surface of PE to polar by in situ synthesizing of polyaniline (PANI), a conducting polymer, over the PE (Ashraf et al 2021)
- Loaded with nano CuO over PE-PANI net
- Field evaluation exhibited excellent biofouling resistance.
- Nano CuO acted as tiny island and inhibited / delayed the microorganism attachment and macro foulers (Ashraf et al 2023)
- Low adoption, multiple process for coating PANI, unused waste



P.M. Ashraf, et al (2020) Arabian Journal of Chemistry. 13(1) 875-882. https://doi.org/10.1016/j.arabjc.2017.08.006
P.M. Ashraf, et al (2023) Aquaculture and Fisheries 8 : 538-543. https://doi.org/10.1016/j.aaf.2022.01.002

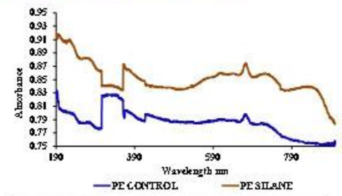
Organo silane surface modification

- Functionalized textile fibres are fabricated using organo silane based sol gel materials to improve chemical and physical properties of fabrics [Sfameni et al 2022 a].
- Organo silane used to load enzymes, hydrophobic coating,
- Low cost, non toxic, [Sfameni et al 2022 b],
- Cotton fibres are non-polar, and silanes coat adhesion.
- Not much study to modify polymeric alkenes using silanes
- Optimised 0.02 M (3-glycidyloxypropyl)trimethoxysilane (Silane), immersed 3h and dried at 60 °C for 2h

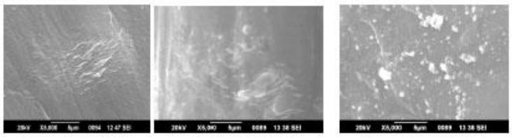


S. Sfameni, et al (2022 b) Gels. 8, 528. https://doi.org/10.3390/gels8090528
S. Sfameni, et al (2022a) Nanomaterials (Basel). 12(19): 3404. doi: 10.3390/nano12193404

Characterisation of PE-Silane net



- The PE exhibited absorption at 740, 676, 400, 350, 275 and 197 nm.
- The PE-silane absorptions at 608, 573, 536 and 340 nm with slight shifts in the absorptions compared to PE absorption indicated that silane was attached successfully over the net.



PE | PE silane | PE-silane-CuO: TiO2 -CD

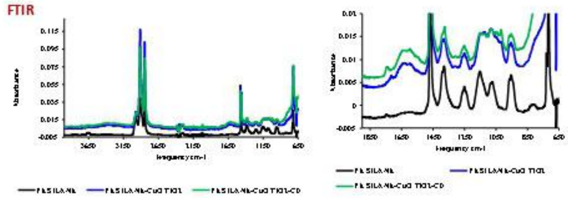
- The CD, nano CuO:TiO_2 were distributed uniformly in the silane treated matrix

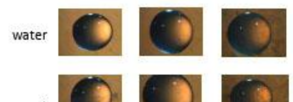
Biocide nano CuO:TiO2-CD

- Nano TiO_2 promising photocatalyst in presence of UV and wide band gap (3.2 eV) [Liu et al 2019]
- To improve photocatalytic activity in visible light, doping of metal oxide like CuO preferred (2.1 eV) [Rekeb et al 2019]
- The optimum nano CuO: TiO_2 mixture ratio was 1:2.
- Shawky et al. (2024) introduced Ag with CuO-TiO2 to improve charge separation and transfer through p-n junction of CuO-TiO_2.
- MWCNT, graphene oxide, carbon dots also improved the photocatalytic effect through e/h+ recombination [Wang et al 2017, Yedeta et al , 2023), Fahri et al 2022]

A.M. Shawky, et al(2024) Sci. Rep. 14 (2024) 2456. https://doi.org/10.1038/s41598-024-52454-0
Y. Wang, et al (2017). Ceram. Int. 43(2017) 4866–4872. https://doi.org/10.1016/j.ceramint.2016.12.130
T.F. Yadeta, et al (2023), Applied Surface Science, 637 : 157880, https://doi.org/10.1016/j.apsusc.2023.157880.
A.N. Fahri, et al (2022) Materialia, 26 (2022) 101588, https://doi.org/10.1016/j.mtla.2022.101588.
L. Rekeb, et al (2019) J. Hydrog. Energy 44 10541–10553. https://doi.org/10.1016/j.ijhydene.2019.02.188
G. Liu, et al. (2019) Appl. Surf. Sci. 465 : 902–910 https://doi.org/10.1016/j.apsusc.2018.09.216

FTIR



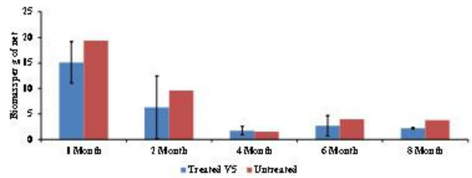


- The FTIR data revealed that Si was interacted with CuO:TiO_2 and CD interaction mainly through conjugated C=C double bond with transition metal electron clouds and silane organics.

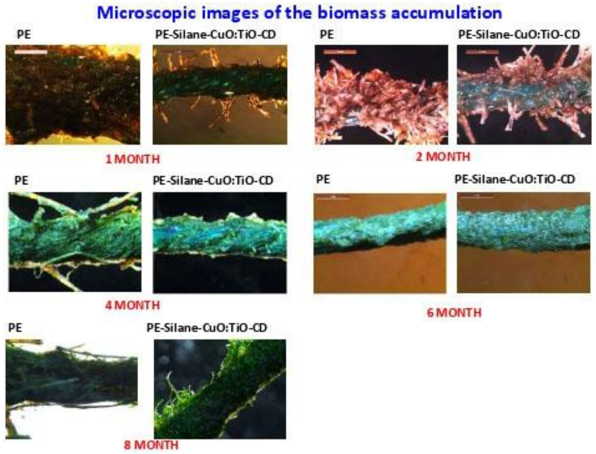
- fabrication of a semi hydrophilic and hydrophobic surface expected to give efficient biofouling inhibition.

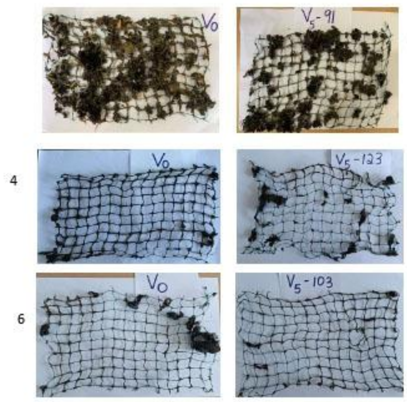
Field Exposure Studies

- Silane coated PE aquaculture cage net treated with nano CuO:TiO_2
- Varied concentrations of carbon dot from fish eye
- The treated net samples were exposed in the test sites of Cochin estuary for 3 months
- The best among the sample was 0.05% each of CuO:TiO_2 and CD exhibited excellent biofouling resistance compared to other treatments.
- The experiment was repeated by exposing the above treatment with untreated PE for 8 months



Microscopic images of the biomass accumulation





- One month samples exhibited severe attack of an exotic bivalve named *Mytiliae strigata*. The treated cage net overcomes the spontaneous attack of mytilidae species with 22% efficiency
- 4 and 6 month samples are retrieved during monsoon season June and August respectively

Conclusion

- *Surface modification of PE with Silane*
- *Biocides CuO:TiO2-CD effective,*
- *Bivalves like Mytillae sp. needs more specific biocides.*
- *More research on nano materials as biocides which resist all types of foulers.*
    - *nano inorganic – organic composites, like nano sized carbon dot/ graphene/ CNTs / Mxenes / varied carbons etc, used individually or their composites*
- *Explore new coating materials*

Acknowledgements

- ICAR CIFT
- IMO GLOFOULING
- Laboratory staffs
- Students

Thank you

CHAIR OF THE SESSION

DR. BEV MACKENZIE

Head of Intergovernmental Organization (IGO) Engagement

The Baltic and International Maritime Council (BIMCO), the United Kingdom

Dr Mackenzie is Head of Intergovernmental Engagement at BIMCO, the world's largest direct-entry membership organisation for the shipping industry. She is the London-based Representative at the International Maritime Organization and also provides the link between BIMCO and IMO and other intergovernmental organisations, particularly those within the UN Ocean family, across the globe to ensure that BIMCO's technical expertise can be best utilised by decisions makers- to support practical and harmonised regulation for the shipping industry.

She has a degree in chemical oceanography and a PhD in physical oceanography from the University of Liverpool, UK and applies that scientific knowledge to help understand the science-engineering-policy interface. She has expertise in operational oceanography and ocean observing and issues relating to maritime industries and the environment including issues such as sea-based sources of marine plastics, biofouling management, climate change and air pollution and marine pollution.

She is on the board for the UK's Net Zero Oceanographic Capability programme and is a Trustee of Plymouth Marine Laboratory. She is a Fellow of the IMarEST and of the Marine Biological Association of the UK and a Chartered Scientist and Chartered Marine Scientist.

JURGA ŠAULE

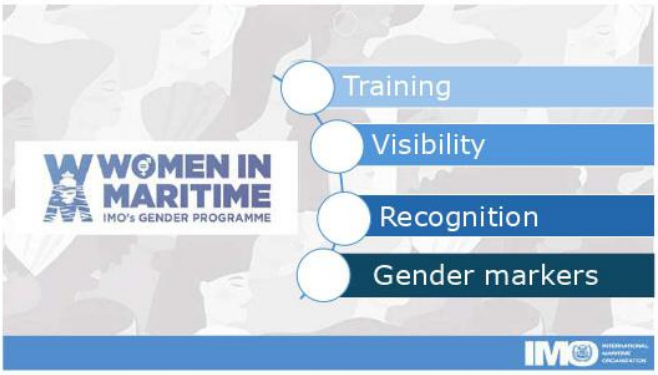
Senior Project Assistant

GloFouling Partnerships project, IMO

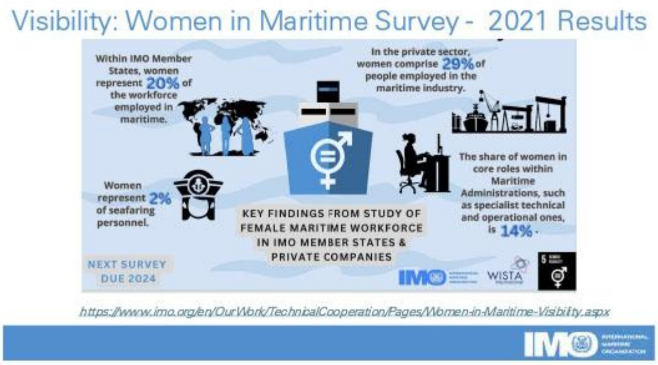
Jurga Šaule holds BSc in Biology and is a Senior Project Assistant, who has been part of the GloFouling Partnerships project coordination unit for five years and has extensive knowledge about the work of the Project and International Maritime Organization (IMO) as a whole. Jurga has worked in international organizations for over seven years assisting in their combined goal of knowledge sharing and activities implementation at international level, including being part of the IMO's Marine Environment Division secretariat supporting the Marine Environment Protection Committee (MEPC) and the Sub-Committee on Pollution Prevention and Response (PPR) meetings.

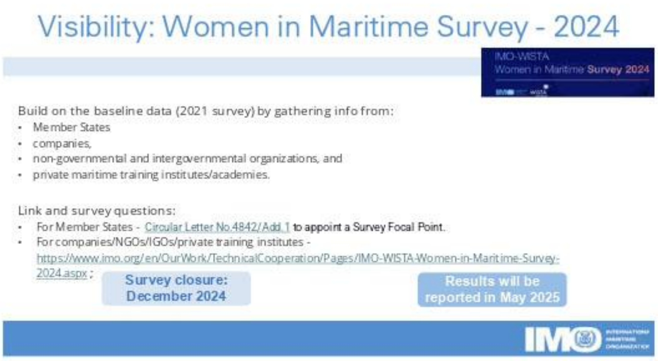
Gender Diversity in the biofouling-related industries: Actions taken by IMO and GloFouling Partnerships project to achieve gender diversity

Presentation slides

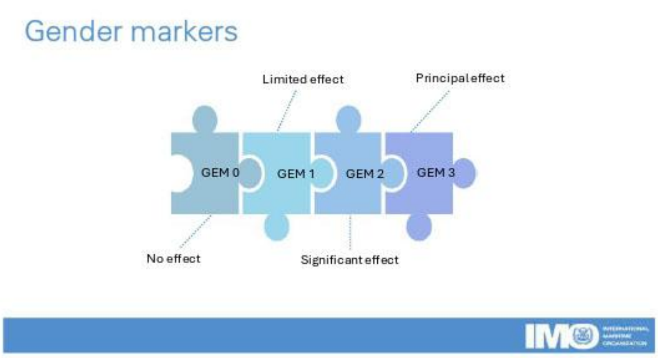



Visibility
International Day for Women in Maritime
18 May (every year)
https://www.imo.org/en/About/Events/Pages/International-Day-for-Women-in-Maritime-2024.aspx
Maritime Speakers Bureau
Global database of female experts in all fields of maritime
Free for speakers and organizers
https://maritimespeakers.com/
Participation in Panels
Secretary-General pledge for minimum representation in panels
Panels where at least one woman is present
Women in Maritime - Survey
Carried out for the first time in 2021
Current Survey is live now, and runs until Dec 2024.
5


Visibility: Women in Maritime Survey - 2021 Results
Within IMO Member States, women represent 20% of the workforce employed in maritime.
In the private sector, women comprise 29% of people employed in the maritime industry.
Women represent 2% of seafaring personnel.
The share of women in core roles within Maritime Administrations, such as specialist technical and operational ones, is 14%.
KEY FINDINGS FROM STUDY OF FEMALE MARITIME WORKFORCE IN IMO MEMBER STATES & PRIVATE COMPANIES
NEXT SURVEY DUE 2024
https://www.imo.org/en/OurWork/TechnicalCooperation/Pages/Women-in-Maritime-Visibility.aspx


Visibility: Women in Maritime Survey - 2024
IMO-WISTA
Women in Maritime Survey 2024
Build on the baseline data (2021 survey) by gathering info from:
Member States
companies,
non-governmental and intergovernmental organizations, and
private maritime training institutes/academies.
Link and survey questions:
For Member States - Circular Letter No.4842/Add.1 to appoint a Survey Focal Point.
For companies/NGOs/IGOs/private training institutes - https://www.imo.org/en/OurWork/TechnicalCooperation/Pages/IMO-WISTA-Women-in-Maritime-Survey-2024.aspx;
Survey closure: December 2024
Results will be reported in May 2025


Recognition
https://www.imo.org/en/OurWork/TechnicalCooperation/Pages/Women-in-Maritime-Recognition.aspx
GENDER EQUALITY AWARD
IMO GENDER EQUALITY AWARD
2025
Call for nominations
DOWNLOAD WORD FORM

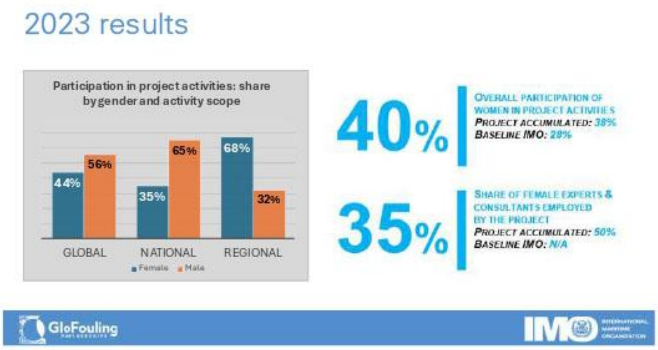

Gender markers
Limited effect
Principal effect
GEM 0
GEM 1
GEM 2
GEM 3
No effect
Significant effect

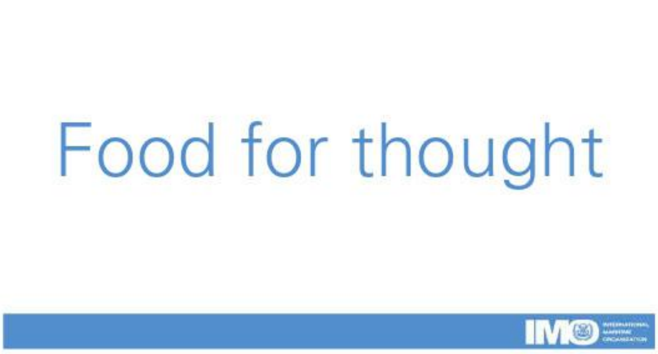

GloFouling Partnerships project
GloFouling

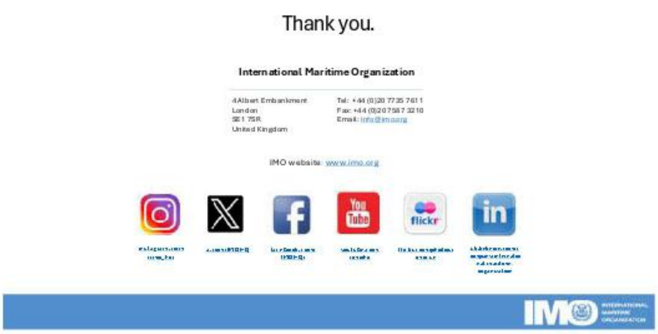

GloFouling Partnerships Project
started in December 2018
will close in May 2025.
https://www.glofouling.imo.org/
Project document 2018
Gender Analysis and Action Plan
Includes Gender Markers
GloFouling


What do we do?
Dedicate
Collaborate
Encourage
Organize
GloFouling


AWIM-BMW
GloFouling


2023 results
Participation in project activities: share by gender and activity scope
44%
56%
35%
65%
68%
32%
GLOBAL
NATIONAL
REGIONAL
Female
Male
40%
OVERALL PARTICIPATION OF WOMEN IN PROJECT ACTIVITIES
PROJECT ACCUMULATED: 38%
BASELINE IMO: 28%
35%
SHARE OF FEMALE EXPERTS & CONSULTANTS EMPLOYED BY THE PROJECT
PROJECT ACCUMULATED: 50%
BASELINE IMO: N/A
GloFouling


Food for thought


Thank you.
International Maritime Organization
4 Albert Embankment
London
SE1 7SR
United Kingdom
Tel: +44 (0)20 7735 7611
Fax: +44 (0)20 7587 3210
Email: info@imo.org
IMO website: www.imo.org

MARIJA VRANIC

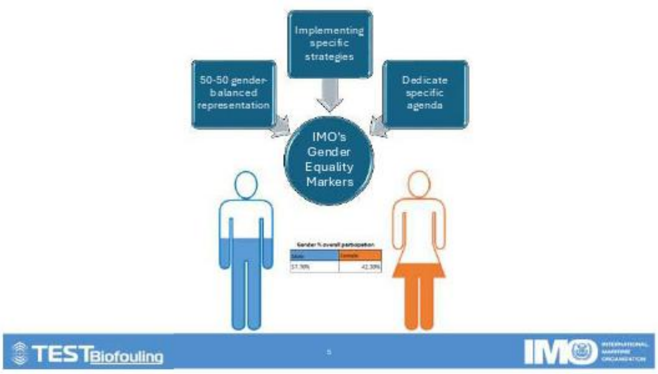
Project Assistant

TEST Biofouling project, IMO

Marija Vranic holds a BSc in Human Resources and Management and has over 13 years of experience working with international organizations across the fields of law, cooperation and security, and maritime affairs. For the past five years, Marija has been with the International Maritime Organization (IMO), a specialized United Nations agency, where she joined the Sub-Division of Partnerships and Projects within the Technical Cooperation and Implementation Division. Marija has provided expertise in various projects focused on marine biodiversity, greenhouse gas (GHG) emissions, and sustainability initiatives. Marija has also contributed to key IMO initiatives, including the Innovation Forum, NextGEN, and FINSMART, supporting global efforts to drive maritime decarbonization and environmental protection.

Gender Diversity in the biofouling-related industries

Presentation slides

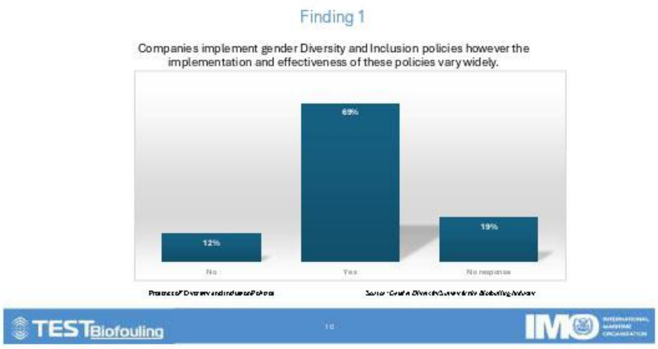


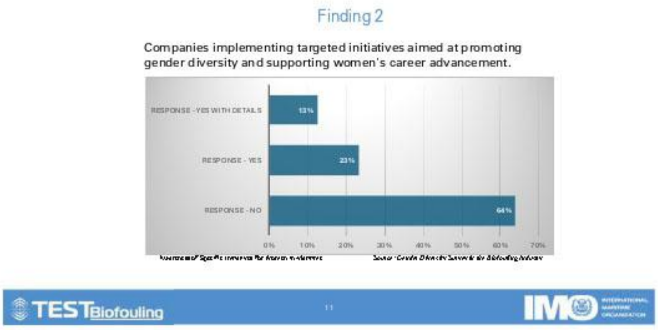

'He for She Champions'
Featured across various sectors who actively promote gender equality in their organizations to inspire and amplify their impacts.
Women's participation in relevant conferences
Support women representatives from beneficiary countries to maritime-related conferences
Elevating Women's Voices in Biofouling Management
Support women from the private sector in sharing their insights on biofouling management through contributions to maritime publications
HE FOR SHE
I'm Featured!
Abigail Robinson
TEST Biofouling
IMO

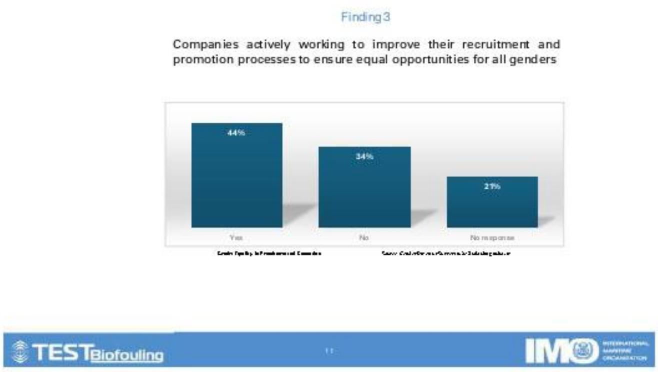

Women in Biofouling network
With 190 members, the network empowers women in maritime through knowledge exchange, mentorship, and leadership opportunities in biofouling industry including private sector.
Women in Biofouling Network
TEST Biofouling
IMO


Arab Women in Maritime-Biofouling Management Workshop
Networking Opportunities
Empowerment and Recognition
Understanding of Gender Challenges
Diverse perspectives
Latin America and the Caribbean Women in Maritime Biofouling Management Workshop
TEST Biofouling
IMO

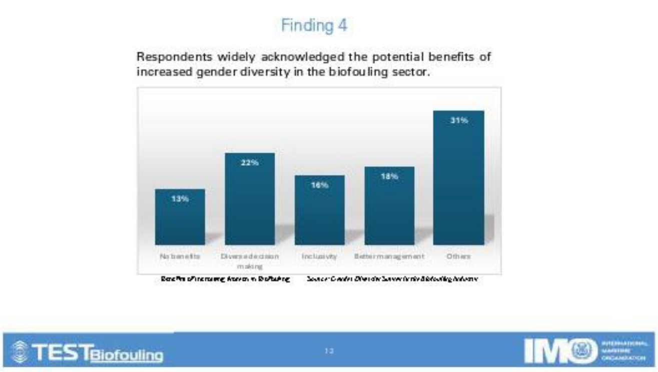

Gender Diversity in Biofouling
Explore the state of gender diversity within the biofouling industry and private sector
Gain insights into the representation of women in various biofouling-related roles
Provide insights into various aspects of gender diversity
Gender Diversity in Biofouling Industry and private sector
TEST Biofouling
IMO


Finding 1
Companies implement gender Diversity and Inclusion policies however the implementation and effectiveness of these policies vary widely.
12%
69%
19%
No
Yes
No response
TEST Biofouling
IMO

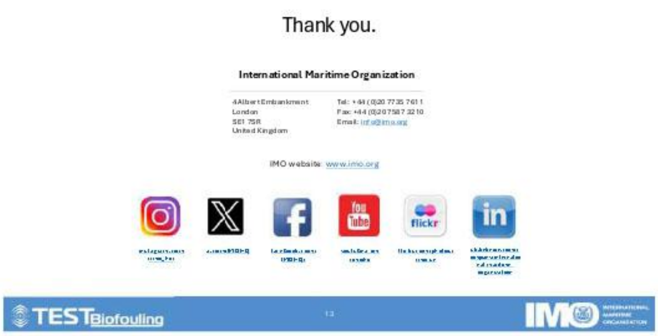

Finding 2
Companies implementing targeted initiatives aimed at promoting gender diversity and supporting women's career advancement.
RESPONSE - YES WITH DETAILS
RESPONSE - YES
RESPONSE - NO
13%
23%
64%
0%
10%
20%
30%
40%
50%
60%
70%
TEST Biofouling
IMO



Finding 3
Companies actively working to improve their recruitment and promotion processes to ensure equal opportunities for all genders
44%
34%
21%
Yes
No
No response
TEST Biofouling
11
IMO



Finding 4
Respondents widely acknowledged the potential benefits of increased gender diversity in the biofouling sector.
13%
22%
16%
18%
31%
No benefits
Diverse decision making
Inclusivity
Better management
Others
TEST Biofouling
12
IMO



Thank you.
International Maritime Organization
4 Albert Embankment
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Fax: +44 (0)20 7587 3210
Email: info@imo.org
IMO website: www.imo.org
TEST Biofouling
13
IMO

Current Status and Prospects in the Republic of Korea for In-Water Cleaning Technology

CHAIR OF THE SESSION

DR. SEONG-GIL KANG

Korea Research Institute of Ships & Ocean Engineering (KRISO)

The Republico f Korea

Dr. Seong-Gil Kang, born in 1968, currently works as Principal Researcher at the International Maritime Research Division of the Korea Research Institute of Ships and Ocean Engineering (KRISO). He also serves as the Director of NOWPAP MERRAC (Marine Environmental Emergency Preparedness and Response Regional Activity Centre of the Northwest Pacific Action Plan), a UNEP Regional Sea Programme hosted and operated by KRISO since 2000.

He earned his bachelor's degree (1986-1991), master's degree (1991-1993) and Ph.D. degree (1993-2000) from the Department of Oceanography at Seoul National University, Republic of Korea, with a specialization in marine benthic ecology.

Having joined KRISO in 2000, he has accumulated over 20 years of professional experience in the field of marine environmental science and engineering. His expertise encompasses marine pollution assessment, oil spill response, carbon storage in offshore sediment, etc. He has authored more than 70 scientific papers and has participated in around 170 projects. Additionally, since 2008, he has been serving as the Director of NOWPAP MERRAC, leading regional collaborative activities in the field of marine pollution response among the governments of China, Japan, South Korea and Russia.

DR. SU JIN PARK

Korea Maritime Institute (KMI)

Republic of Korea

Dr. Su Jin Park has worked as a director of Dokdo and Ocean Legal Regime Division and senior research fellow at Korea Maritime Institute (KMI), which is a government-affiliated research entity under the Prime Minister's Office. She has researched for international maritime legal regime and policy development in the areas of climate change, marine environment, marine bio, global cooperation etc.

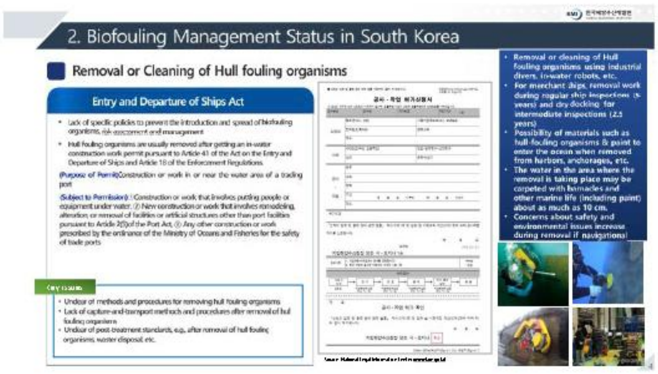
She is a Ph.D. in international law at the Kyung Hee University Graduate School in 2004.

As a legal expert, she has performed various developments of Korean maritime and environment law such as 'the Act on Marine Ecosystem Conservation and Management', 'Marine Environmental Management Act' etc. She has also been working on various researches about the international cooperation and multilateral agreements, including the UN BBNJ Agreement, the CBD, Nagoya Protocol, and the UN Plastics Convention.

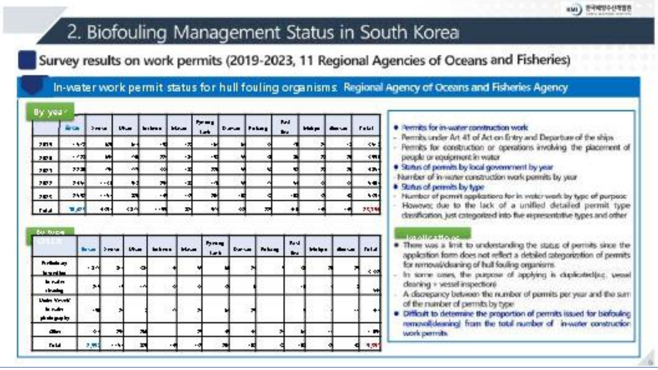
Her recent publications include 'How Will the United Nations (UN) Biological Beyond National Jurisdiction (BBNJ) Agreement Affect the Shipping Industry in the Future?(2023)', 'Climate change response strategy in the marine and fisheries sector to implement the Paris Agreement(2020)', and 'The Legal Frameworks and Relevant Issues on the Marine Protected Areas in the Areas beyond National Jurisdiction(2018)'.

Biofouling Management in South Korea and Legislative & Policy Improvement Measures

Presentation slides

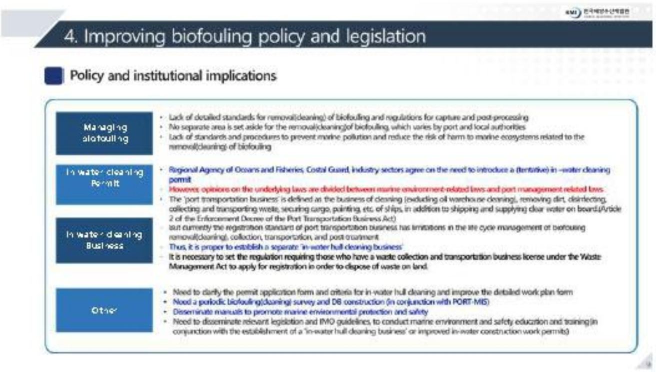



2. Biofouling Management Status in South Korea
Managing Entity of hull fouling organisms & Survey Results (2021-2023)
Regional Agency of Oceans and Fisheries
Coast Guard
Understand the status of enforcement of laws and regulations under current laws
Legislative improvement of Marine Environment Management Act, including the establishment of new industry of removing the hull fouling organisms
Industries
Understand the reality of how the industry is actually removing, treating and disposing the biofouling, and collecting opinions from the industry
Marine recreational facilities
Understand the current situation and collect opinions on how biofouling is removed and disposed of for the marine recreation industry, etc.

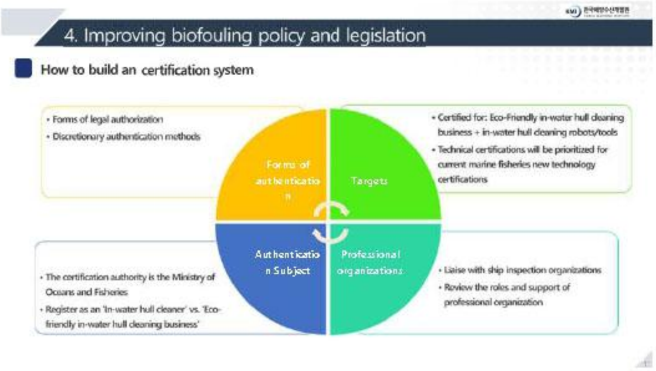

2. Biofouling Management Status in South Korea
Survey results on work permits (2019-2023, 11 Regional Agencies of Oceans and Fisheries)
In-water work permit status for hull fouling organisms: Regional Agency of Oceans and Fisheries Agency
By year
By type
Permits for in-water construction work
Permits under Art. 41 of Act on Entry and Departure of the ships
Permits for construction or operations involving the placement of people or equipment in water
Status of permits by local government by year
Number of in-water construction work permits by year
Status of permits by type
However, due to the lack of a unified detailed permit type classification, just categorized into the representative types and other
There was a limit to understanding the status of permits since the application form does not reflect a detailed categorization of permits for removal/cleaning of hull fouling organisms
In some cases, the purpose of applying is duplicated(e.g. vessel cleaning + vessel inspection)
A discrepancy between the number of permits per year and the sum of the number of permits by type
Difficult to determine the proportion of permits issued for biofouling removal(cleaning) from the total number of in-water construction work permits


3. Key legislation for biofouling in South Korea
Protecting the marine environment and marine ecosystems
Marine Environmental Management Act(MEMA)
(Purpose) Contribute to the protection of public health and property by regulating the management of marine pollutant sources such as ships, marine facilities, and marine space, and the prevention, improvement, response, and restoration of marine pollution
(Feature) Legislation directly related to the treatment of biofouling
(Implication) Lack of standards and procedures for the treatment(removal, collection, and disposal) of biofouling
Review
Until a new international convention is adopted, national legislation for the management of biofouling needs to be reviewed and improved
Ships Pollution Prevention Rules
- Enforcement Decree and Rules of the MEMA -
(Implication) Lack of detailed criteria, methods, and procedures for biofouling
Review
Amendments to the Pollution Prevention Rules for Ships
The 2023 revision of the IMO guidelines for the management of biofouling is advisory, revisions are premature
Amendments to the Enforcement Decree of the Marine Environment Management Act and the implementation Regulations


3. Key legislation for biofouling in South Korea
Protecting the marine environment and marine ecosystems
Marine Waste and
Marine Contaminated Sediment Management Act
(Implications) Organisms, paints, etc. from the removal of hull fouling may constitute marine waste or marine polluted sediments
Review
Identify and choose laws that need to be amended
Conservation and Management of
Marine Ecosystems Act
(Purpose) Conservation and sustainable utilization of marine ecosystems and marine biodiversity
(Implications) marine ecosystem disturbance due to biofouling, marine biodiversity and marine ecosystem risk
Review


4. Improving biofouling policy and legislation
Policy and institutional implications
Managing biofouling
Lack of detailed standards for removal(cleaning) of biofouling and regulations for capture and post-processing
No separate area is set aside for the removal(cleaning)of biofouling, which varies by port and local authorities
In-water cleaning Permit
Regional Agency of Oceans and Fisheries, Costal Guard, industry sectors agree on the need to introduce a (tentative) in-water cleaning permit
However, opinions on the underlying laws are divided between marine environment-related laws and port management related laws
In-water cleaning Business
Thus, it is proper to establish a separate 'in-water hull cleaning business'
It is necessary to set the regulation requiring those who have a waste collection and transportation business license under the Waste Management Act to apply for registration in order to dispose of waste on land.
Other
Need to clarify the permit application form and criteria for in-water hull cleaning and improve the detailed work plan form
Need a periodic biofouling(cleaning) survey and DB construction (in conjunction with PORT-MIS)
Disseminate manuals to promote marine environmental protection and safety


4. Improving biofouling policy and legislation
Legislative direction and priorities
Improving legislation
Eco-Friendly In-water cleaning business
(Option 1) Certify/Authentify Eco-Friendly in-water cleaning business through Interim guidelines
However, it is necessary to establish a minimum standard for in-water hull cleaning business and relevant industry
For legislation Considerations
Full life cycle management system: In-water hull cleaning -> capture and collection -> transporation -> water treatment -> land disposal of residues(in principle, in accordance with the Waste Management Act)
policy goals, ④ Foster sectors and specific tasks, and ⑤ Provide technical and financial support.


4. Improving biofouling policy and legislation
How to build an certification system
• Forms of legal authorization
• Discretionary authentication methods
Forms of authentication
Targets
• Certified for: Eco-Friendly in-water hull cleaning business + in-water hull cleaning robots/tools
• Technical certifications will be prioritized for current marine fisheries new technology certifications
Authentication Subject
Professional organizations
• The certification authority is the Ministry of Oceans and Fisheries
• Register as an 'In-water hull cleaner' vs. 'Eco-friendly in-water hull cleaning business'
• Liaise with ship inspection organizations
• Review the roles and support of professional organization


Thanks for your attention!
Su jin PARK
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DR. SAE-HEE KIM

Institute of Bioscience & Biotechnology
Hanyang University, Republic of Korea

GENERAL INFORMATION

Name | (First Name) Sae-Hee (Family name) Kim
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Position | Post-doctoral researcher

EDUCATION

Degree	*University*	*Department*	*Year*
Ph.D.	*Hanyang University*	*Life Science*	*2024*
B.Sc.	*Hanyang University*	*Life Science*	*2015*

EMPOLYMENT

2024/Sep. to Present: Institute of Bioscience & Biotechnology, Hanyang university, Seoul, Korea
2022/Sep. to 2022/Oct.: Korea Institute of Ocean Science & Technology, Geoje, Korea
2021/Jan. to 2022/Aug: Korea Institute of Ocean Science & Technology, Busan, Korea

RESEARCH KEYWORDS

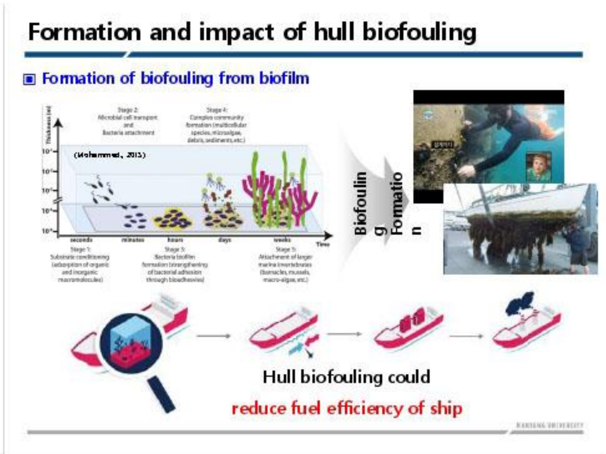
Ocean Microecosystem, Mesocosm, Biofouling, Pathogenic Bacteria, Assessment of ecosystem.

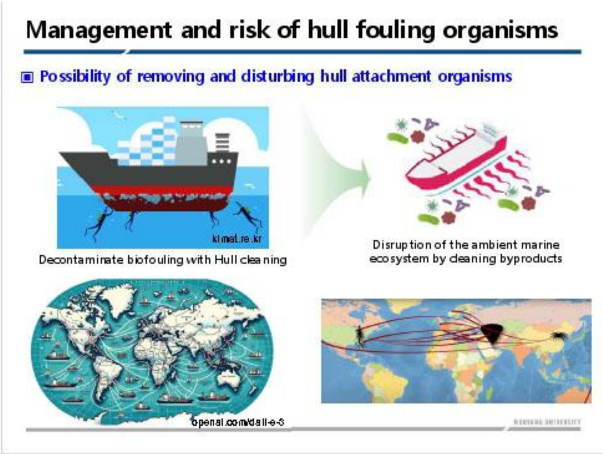
AWARDS

1) *2019, The Prize of Korean Society of Ecology and Infrastructure Engineering*

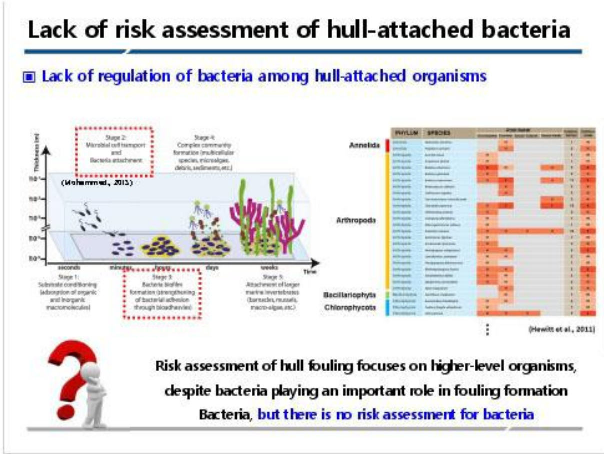
Characterization and risk assessment of attached bacteria in major ports in Korea

Presentation slides

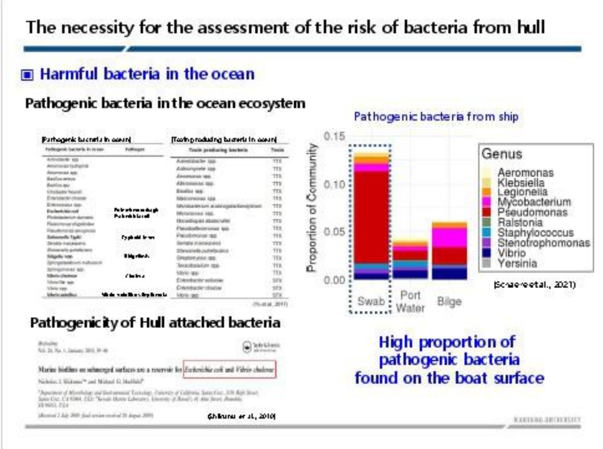




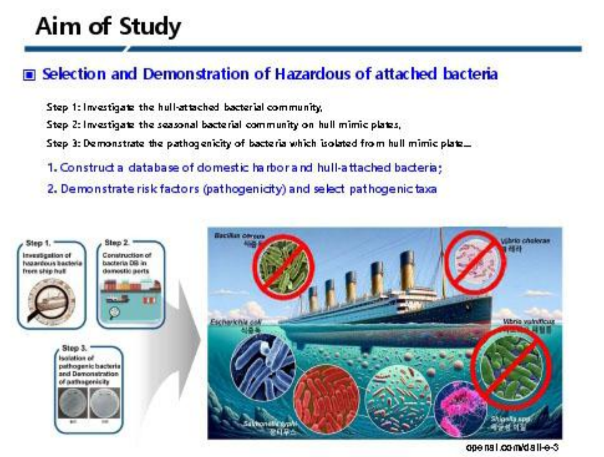
Management and risk of hull fouling organisms
Possibility of removing and disturbing hull attachment organisms
kimst.re.kr
Decontaminate biofouling with Hull cleaning
Disruption of the ambient marine ecosystem by cleaning byproducts
openai.com/dall-e-3



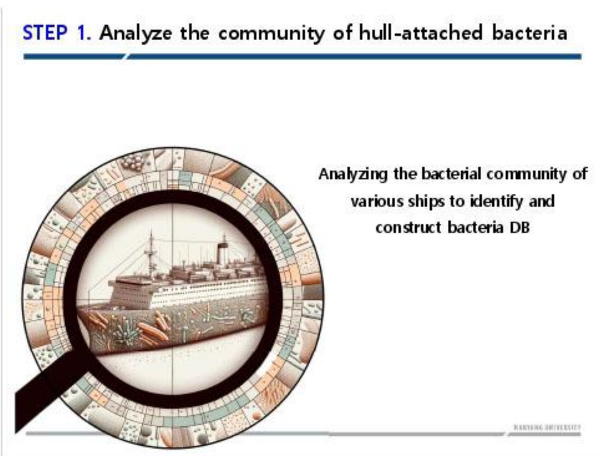
Lack of risk assessment of hull-attached bacteria
Lack of regulation of bacteria among hull-attached organisms
(Mohammed, 2013)
Annelida
Arthropoda
Bacillariophyta
Chlorophycota
(Hewitt et al., 2011)
Risk assessment of hull fouling focuses on higher-level organisms,
despite bacteria playing an important role in fouling formation
Bacteria, but there is no risk assessment for bacteria



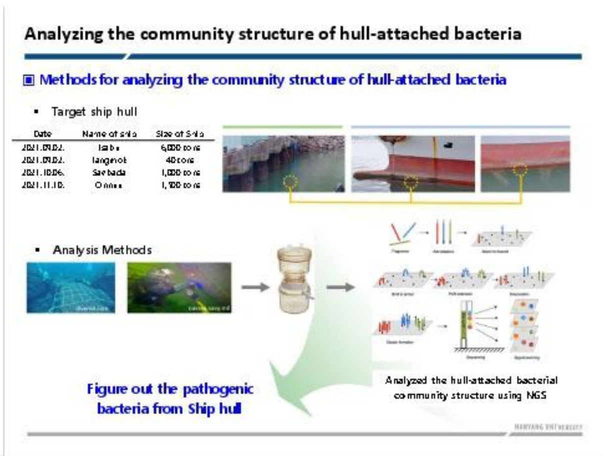
The necessity for the assessment of the risk of bacteria from hull
Harmful bacteria in the ocean
Pathogenic bacteria in the ocean ecosystem
Pathogenic bacteria from ship
Proportion of Community
Genus
Aeromonas
Klebsiella
Legionella
Mycobacterium
Pseudomonas
Ralstonia
Staphylococcus
Stenotrophomonas
Vibrio
Yersinia
Swab
Port Water
Bilge
(Schaerer et al., 2021)
Pathogenicity of Hull attached bacteria
Marine biofilms on submerged surfaces are a reservoir for Escherichia coli and Vibrio cholerae
(Shikuma et al., 2010)
High proportion of pathogenic bacteria found on the boat surface



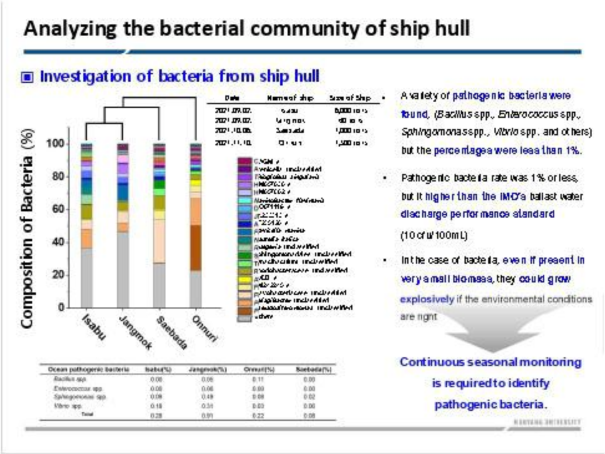
Aim of Study
Selection and Demonstration of Hazardous of attached bacteria
Step 1: Investigate the hull-attached bacterial community,
Step 2: Investigate the seasonal bacterial community on hull mimic plates,
Step 3: Demonstrate the pathogenicity of bacteria which isolated from hull mimic plate...
1. Construct a database of domestic harbor and hull-attached bacteria;
2. Demonstrate risk factors (pathogenicity) and select pathogenic taxa
Step 1. Investigation of hazardous bacteria from ship hull
Step 2. Construction of bacteria DB in domestic ports
Step 3. Isolation of pathogenic bacteria and Demonstration of pathogenicity
Bacillus cereus
Vibrio cholerae
Escherichia coli
Vibrio vulnificus
Salmonella typhi
Shigella spp.
openai.com/dall-e-3

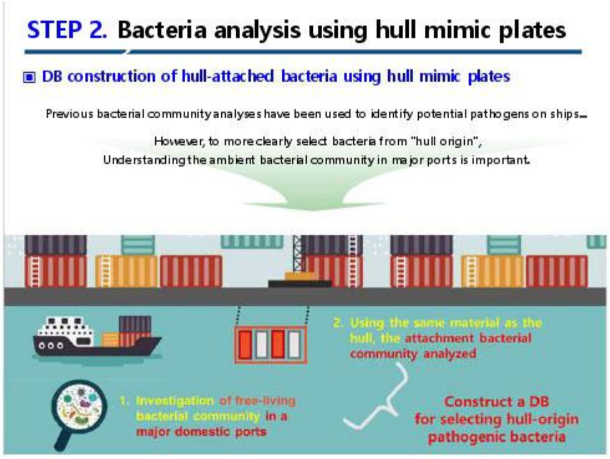


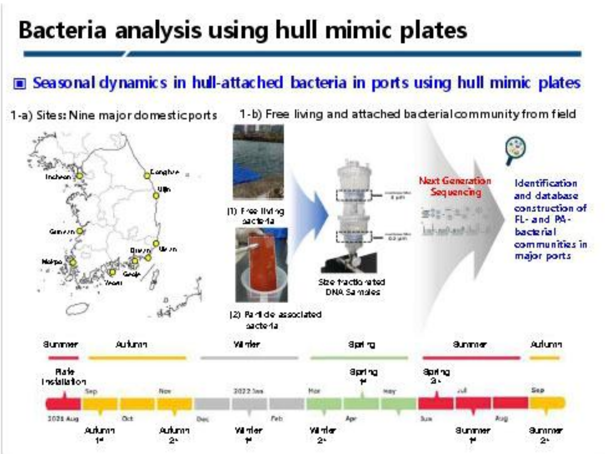
STEP 1. Analyze the community of hull-attached bacteria
Analyzing the bacterial community of various ships to identify and construct bacteria DB

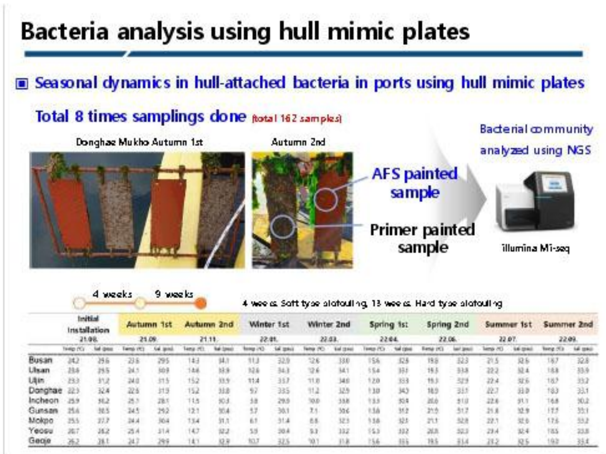


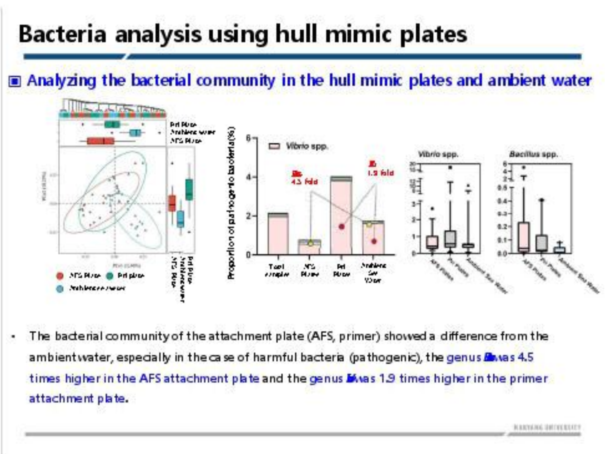
Analyzing the community structure of hull-attached bacteria
Methods for analyzing the community structure of hull-attached bacteria
Target ship hull
Date
Name of ship
Size of ship
Analysis Methods
Analyzed the hull-attached bacterial community structure using NGS
Figure out the pathogenic bacteria from Ship hull

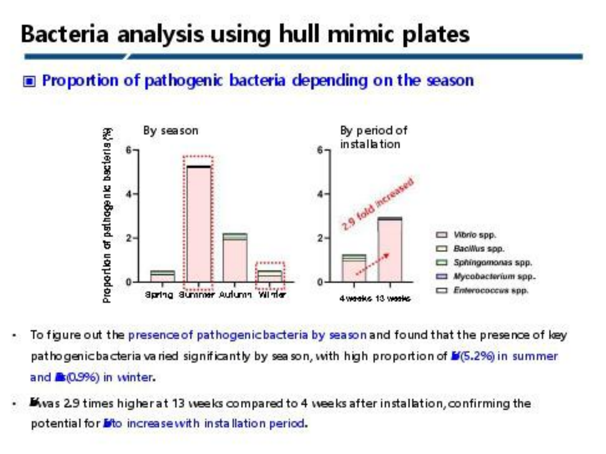

Analyzing the bacterial community of ship hull
Investigation of bacteria from ship hull
Composition of Bacteria (%)
Isabu
Jangmok
Saebada
Onnuri
A variety of pathogenic bacteria were found, (Bacillus spp., Enterococcus spp., Sphingomonas spp., Vibrio spp. and others) but the percentages were less than 1%.
Pathogenic bacteria rate was 1% or less, but it higher than the IMO's ballast water discharge performance standard (10 cfu/100mL)
In the case of bacteria, even if present in very small biomass, they could grow explosively if the environmental conditions are right
Continuous seasonal monitoring is required to identify pathogenic bacteria.


STEP 2. Bacteria analysis using hull mimic plates
DB construction of hull-attached bacteria using hull mimic plates
Previous bacterial community analyses have been used to identify potential pathogens on ships...
However, to more clearly select bacteria from "hull origin",
Understanding the ambient bacterial community in major ports is important.
2. Using the same material as the hull, the attachment bacterial community analyzed
1. Investigation of free-living bacterial community in a major domestic ports
Construct a DB for selecting hull-origin pathogenic bacteria


Bacteria analysis using hull mimic plates
Seasonal dynamics in hull-attached bacteria in ports using hull mimic plates
1-a) Sites: Nine major domestic ports
1-b) Free living and attached bacterial community from field
(1) Free living bacteria
(2) Particle associated bacteria
Size fractionated DNA Samples
Next Generation Sequencing
Identification and database construction of FL- and PA- bacterial communities in major ports
Summer
Autumn
Winter
Spring
Plate Installation

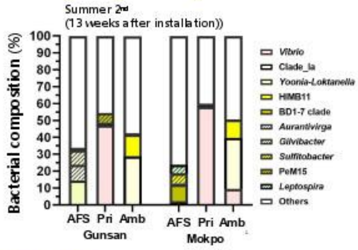

Bacteria analysis using hull mimic plates
Seasonal dynamics in hull-attached bacteria in ports using hull mimic plates
Total 8 times samplings done (total 162 samples)
Donghae Mukho Autumn 1st
Autumn 2nd
AFS painted sample
Primer painted sample
Bacterial community analyzed using NGS
Illumina Mi-seq
4 weeks
9 weeks
4 weeks: Soft type biofouling, 13 weeks: Hard type biofouling
Busan
Ulsan
Uljin
Donghae
Incheon
Gunsan
Mokpo
Yeosu
Geoje


Bacteria analysis using hull mimic plates
Analyzing the bacterial community in the hull mimic plates and ambient water
Proportion of pathogenic bacteria(%)
Vibrio spp.
Bacillus spp.
4.5 fold
1.9 fold
The bacterial community of the attachment plate (AFS, primer) showed a difference from the ambient water, especially in the case of harmful bacteria (pathogenic), the genus was 4.5 times higher in the AFS attachment plate and the genus was 1.9 times higher in the primer attachment plate.


Bacteria analysis using hull mimic plates
Proportion of pathogenic bacteria depending on the season
By season
By period of installation
Proportion of pathogenic bacteria (%)
Spring
Summer
Autumn
Winter
4 weeks
13 weeks
2.9 fold increased
Vibrio spp.
Bacillus spp.
Sphingomonas spp.
Mycobacterium spp.
Enterococcus spp.
To figure out the presence of pathogenic bacteria by season and found that the presence of key pathogenic bacteria varied significantly by season, with high proportion of (5.2%) in summer and (0.9%) in winter.
was 2.9 times higher at 13 weeks compared to 4 weeks after installation, confirming the potential for to increase with installation period.

Bacteria analysis using hull mimic plates

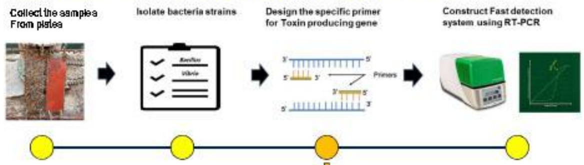
▣ Proportion of pathogenic bacteria depending on the region



- During the summer, [illegible] was found to be more than 40% on primer plate in Gunsan and Mokpo.
- In summary, [illegible] found on ships with primer paint exposed for a long time in summer, and regionally, it could found high ratio in the West Sea.
  In this study, the genus [illegible] was selected as a candidate bacterial taxonomic group for pathogenic effects

STEP 3. Demonstrate the pathogenicity of attached bacteria

▣ Detection of toxin-producing genes in pathogenic bacteria



	Target species (gene)		Primer (5' to 3')	Reference
1. Pathogenic bacteria specific primer	*Vibrio cholerae*	Forward	GCGTTGGGAGTGGCGTAA	Park et al. 2013
		Reverse	GGACTCGCCGCTGTAGACA	Malick et al. 2020
	Vibrio vulnificus	Forward	GATCGTTGTTTGACCGTAAACG	Park et al. 2013
		Reverse	TGCTAAGTTCGCACCACACTGT	Sharma et al. 2017
	E. coli, *Shigella* spp.	Forward	ATGGAATTTCGCCGATTTTGC	Gadamba et al. 2017
		Reverse	ATTGTTTGCCTCCCTGCTGC	Heijnen and Medema 2006
2. Toxin producing gene specific primer	*Vibrio* spp. (ctxA)	Forward	CTCAGACGGGATTTGTTAGGCACG	Kondo et al. 2000
		Reverse	TCTATCTCTGTAGCCCCTATTACG	Gubala et al. 2006

Strain acquisition using hull mimic plates

▣ Isolation and identification of hull-attached bacteria from hull mimic plates

- **Identification of isolated bacterial strains**

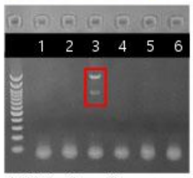
- 33 strains isolated from hull mimic plates
  20 potential pathogenic bacteria acquired

* Red text indicates pathogenic strains

Class	Species	Strain name	Isolation date
Alphaproteobacteria	*Paracoccus huijuniae*	[illegible]	2022. 04.
Bacilli	*Bacillus cereus*	[illegible]	2022. 04.
Flavobacteriia	*Muricauda aquimarina*	[illegible]	2022. 04.
Flavobacteriia	*Winogradskyella* sp.	[illegible]	2022. 04.
Flavobacteriia	*Winogradskyella poriferorum*	[illegible]	2022. 04.
Flavobacteriia	*Muricauda* [illegible]	[illegible]	2022. 04.
Gammaproteobacteria	[illegible]	[illegible]	2022. 04.
Gammaproteobacteria	*Marinobacter adhaerens*	[illegible]	2022. 04.
Gammaproteobacteria	*Marinobacter* [illegible]	[illegible]	2022. 04.
Gammaproteobacteria	*Marinobacter* [illegible]	[illegible]	2022. 04.
Gammaproteobacteria	*Pseudoalteromonas carrageenovora*	[illegible]	2022. 04.
Gammaproteobacteria	*Pseudoalteromonas* [illegible]	[illegible]	2022. 04.
Gammaproteobacteria	*Pseudoalteromonas* [illegible]	[illegible]	2022. 04.
Gammaproteobacteria	*Pseudoalteromonas lipolytica*	[illegible]	2022. 04.
Gammaproteobacteria	*Pseudoalteromonas lipolytica*	[illegible]	2022. 04.
Alphaproteobacteria	*Sulfitobacter dubius*	[illegible]	2023. 05.
Alphaproteobacteria	*Sulfitobacter pontiacus*	[illegible]	2023. 05.
Gammaproteobacteria	*Pseudoalteromonas marina*	[illegible]	2023. 05.
Gammaproteobacteria	*Pseudoalteromonas* [illegible]	[illegible]	2023. 05.
Alphaproteobacteria	*Paracoccus marcusii*	[illegible]	2023. 05.
Alphaproteobacteria	*Paracoccus marcusii*	[illegible]	2023. 05.
Alphaproteobacteria	*Paracoccus* [illegible]	[illegible]	2023. 05.
Betaproteobacteria	[illegible]	[illegible]	2023. 05.
Actinomycetia	*Micrococcus luteus*	[illegible]	2023. 05.
Actinomycetia	[illegible]	[illegible]	2023. 05.
Actinomycetia	[illegible]	[illegible]	2023. 05.
Bacilli	*Bacillus* [illegible]	[illegible]	2023. 05.
Bacilli	*Bacillus infantis*	[illegible]	2023. 05.
Bacilli	*Bacillus infantis*	[illegible]	2023. 05.
Bacilli	*Bacillus infantis*	[illegible]	2023. 05.
Bacilli	*Bacillus infantis*	[illegible]	2023. 05.
Bacilli	*Bacillus* [illegible]	[illegible]	2023. 05.

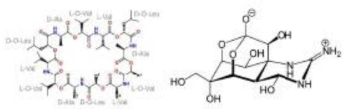
Demonstrate the pathogenicity of attached bacteria

▣ Detection of toxin-producing genes in candidate bacteria



1. *Vibrio chagasii*
2. *Vibrio neonatus*
3. *Vibrio corralliirubri*
4. *Vibrio jasicida*
5. *Vibrio diabolicus*
6. *Vibrio diabolicus*

- Six strains of the genus [illegible] selected as risk assess were examined for the presence of the Cholera toxin producing gene ([illegible]), confirming the presence of the toxin producing gene in [illegible]
- To determine the presence or absence of another toxin-producing genes in other bacteria, cereulide and tetrodotoxin also additionally will test on [illegible] and [illegible]



Cereulide (left), a toxin produced by Bacillus cereus, and Tetrodotoxin (right), a toxin produced by Vibrio alginolyticus.

Summaries and Conclusions

- [illegible] and [illegible], which are major pathogenic bacteria in the ocean, are not found in Hull ship. However, a variety of pathogenic bacteria, including [illegible] spp., were found.
- A total of 160 bacterial communities of the hull mimic plate were analyzed, and [illegible] and [illegible] was found as a high ratio.
- To demonstrate the pathogenicity of the bacteria isolated from the hull mimic plates, the presence of toxin production genes was tested, and the presence of [illegible] genes was confirmed in [illegible] species.
- To manage of pathogenic(hazardous) bacteria in domestic major ports, continuous monitoring should be perfomed.

DR. KEUN-HYUNG CHOI

Chung-Nam National University
Republic of Korea

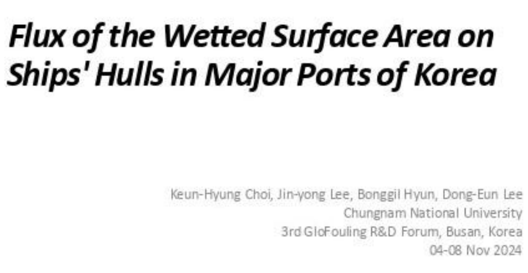
Dr Keun-Hyung is engaged in research of zooplankton ecology around Korean seawaters as well as invasive zooplankton. His recent research includes the effect of hypoxia on zooplankton and the impact of gelatinous zooplankton on plankton ecosystem in Korean waters.

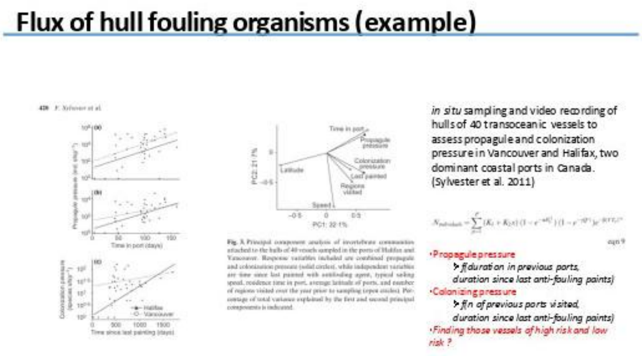
Flux of the Wetted Surace Area on Ships' Hulls in Major ports in Korea

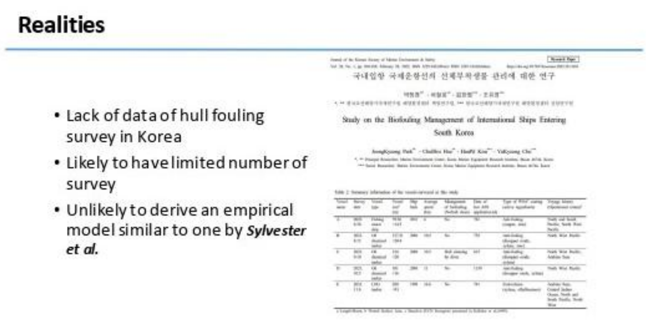
Keun-Hyung Choi

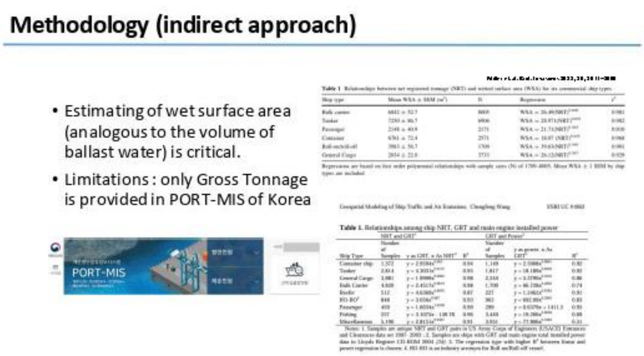
Biofouling is a significant means for introducing non-indigenous marine species internationally, which can alter habitats and disturb marine ecosystems. This study estimated the flux of ships' wetted surface area (WSA) to Korea in 2020 to assess the risks of biological invasion via biofouling on ships' hulls. The annual total WSA flux entering Korea was estimated to be 418.26 km2, with short-stay vessels (< 3 weeks) contributing to 99.7% of the total WSA flux. Busan and Ulsan ports were identified as the main sources of high-risk flux, with container ships being a major vector in Busan and tankers in Ulsan. Gwangyang port had the third-highest total WSA flux, with nearly half of the flux driven from coastwise voyages, making it particularly vulnerable to the spread of hull fouling organisms. These findings could help enhance the management and inspection of hull fouling organisms in Korea.

Presentation slides

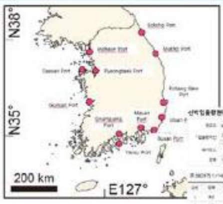








Methods



- 12 major ports of 2020
- 64,629 vessel arrivals, from Korea's PORT-MIS information

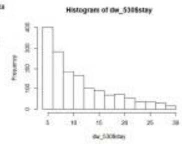
Considerations

Long-stay vessels
For those vessels intending to remain in New Zealand for more than 3 weeks and/or visit areas other those designated under the Act as Places of First Arrival, the threshold for long-stay vessels applies.

Science underpinning the thresholds proposed in the CRMS: Biofouling on vessels arriving to New Zealand

MPI Technical Paper No: 2014/22
by Eugene Georgiades and Daniel Kluza

ISBN No: 978-0-478-43717-1 (online)
ISSN No: 2253-3923 (online)

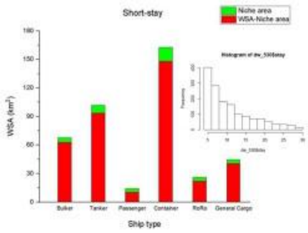


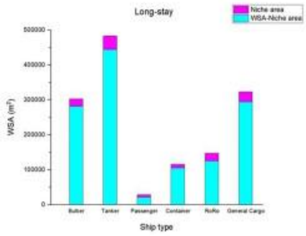
Niche areas where biofouling can accumulate

1

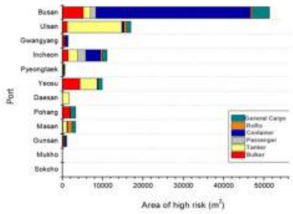
Results : Total Flux

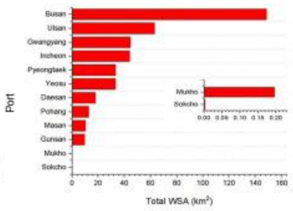
Detailed Analysis by Stay and Ship Type





The picture of high risk and Model

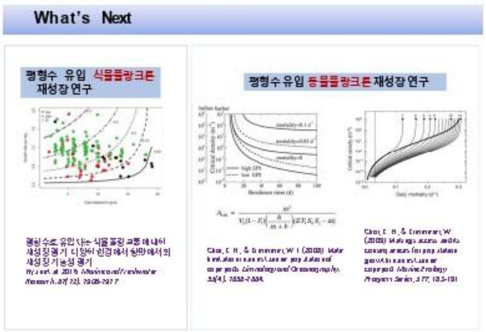


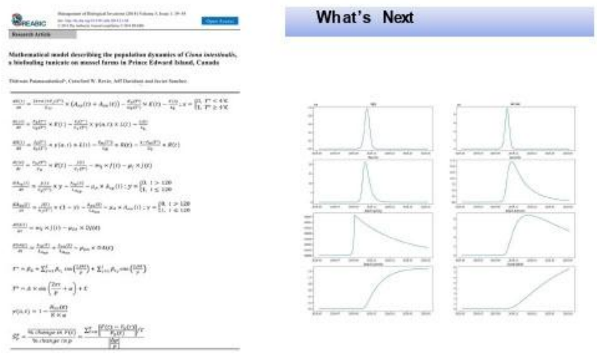


$$Fa * \overline{Sa} * fLs * fNa$$

Conclusions

- Importance of Busan and Ulsan Port
- Importance of tankers and general cargo
- Gwangyang and Pyeongtak Port has a high potential to contribute to the spread of NIS.


What's Next
평형수 유입 식물플랑크톤 재성장 연구
평형수 유입 동물플랑크톤 재성장 연구


Research Article
Mathematical model describing the population dynamics of Ciona intestinalis, a biofouling tunicate on mussel farms in Prince Edward Island, Canada
What's Next

2

DR. KYOUNGSOON SHIN

Korea Institute od Ocean Science and Technology (KIOST)

Republic of Korea

Kyoungsoon Shin has research background in marine plankton physiology and ecology. He has been conducting research on reducing the transportation of aquatic organisms through ships for more than 20 years. Shin is responsible for test facility and testing QA/QC for type approval of Ballast Water Management System (BWMS) on behalf of the government. He serves as a government advisory group to the Marine Environmental Protection Committee (MEPC) and sub-committee on Pollution Prevention and Response (PPR) in International Maritime Organization (IMO). Shin is a committee member of Advisory Panel on Marine Non-indigenous Species (AP-NIS) in North Pacific Marine Science Organization (PICES). Currently, he is the head of the R&D project in the fields of ballast water and ship's biofouling, and is the director of Ballast Water Research Center in the Korea Institute of Ocean Science & Technology (KIOST).

Risk assessment of materials released during in-water cleaning of hull-fouling organisms

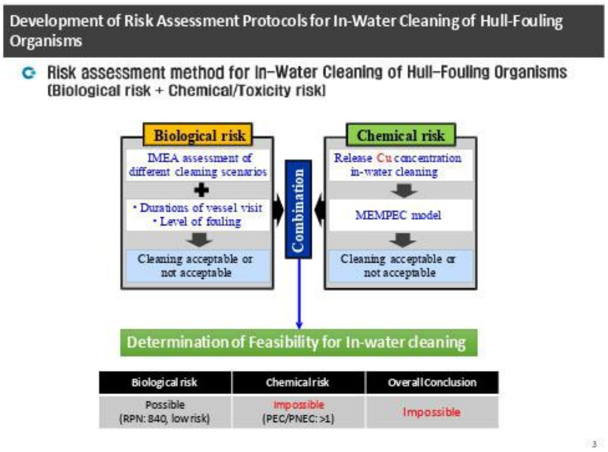
Vessel fouling, a well-known pathway for the introduction and subsequent spread of marine nonindigenous species (NIS), has potential risks of biosecurity and chemical contaminants when vessel in-water cleaning (IWC) is applied to reduce hull fouling and improve vessel operating efficiency. This study aims to provide the scientific foundation for the systematic management and prevention of disturbances to the marine ecosystem caused by IWC of hull-fouling organisms in ports. This is achieved by developing both a biological risk assessment protocol and a chemical risk assessment protocol for in-water cleaning of hull-fouling organisms. A development of protocols for biological risk assessment is primarily divided into three stages: selection of core elements, scenario design for IWC of hull-fouling organisms, and design of biological risk evaluation index. Six core elements (biofouling origin, duration time before cleaning, duration time after cleaning, fouling rating, debris capture efficiency during IWC, and use of post-treatment system) were selected, and 240 IWC scenarios were designed based on the selected core elements.

The environmental hazard of harmful substances can be assessed by calculating the predicted environmental concentration (PEC) using an environmental concentration prediction model and determining the Predicted No-Effect Concentration (PNEC) for aquatic organisms using toxicity data of such harmful substances, when the harmful substance is released to the environment. This study estimated the PEC of active substances within the ports using the MAMPEC (Marine Antifoulant Model to Predict Environmental Concentrations) model, an environmental prediction model for harmful substances. This was achieved by calculating the elution rate through the measurement of the concentrations of active substances, the effluent emission, and the cleaned area during IWC. To drive the MAMPEC model, it is crucial to obtain data on the characteristics and water quality of major ports where IWC is likely to be implemented. This is to derive a PEC that reflects the unique characteristics of each port. This study is systematizing the K-IMEA as a biological risk assessment method to manage the environmental risks of effluents generated during in-water cleaning and is also systematizing methods for calculating PEC and PNEC suitable for domestic ports for chemical risk assessment.

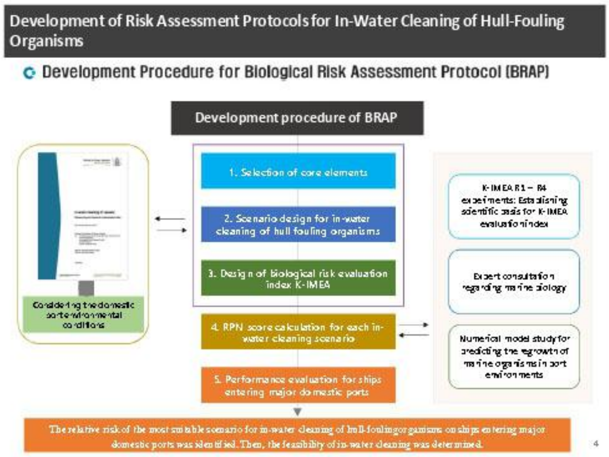
Presentation slides

Nov. 2024
Busan
3rd GloFouling R&D Forum
Risk assessment of materials released during in-water cleaning of hull-fouling organisms
5 Nov. 2024
Kyoungsoon Shin, Bonggil Hyun, Pung-Guk Jang, Jung-Hoon Kang, Moonkoo Kim and Jihuyn Jung
(KIOST, Korea Institute of Ocean Science & Technology)
KIOST

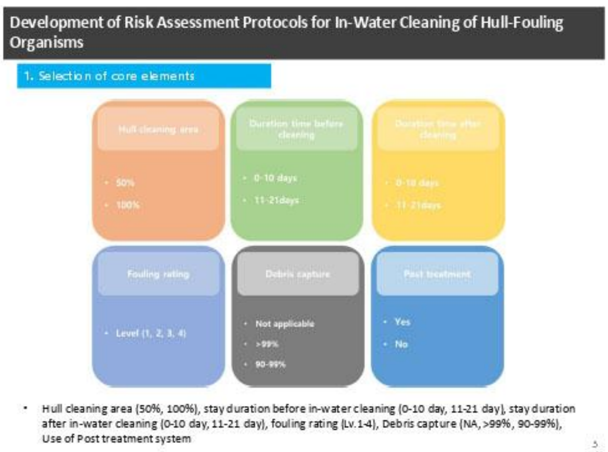
Background of R&D
[Past hull in-water cleaning → Future hull in-water cleaning]
Currently, during the process of in-water divers removing the biofouling, the discharge falls to the bottom of the sea floor, causing serious pollution to the port-specific ecosystem.
In-water cleaning is changing to a method that limits the use of divers and minimizes the generation of pollutants
In the future, in-water cleaning should be able to operate remotely and should be able to suck up cleaning byproducts to minimize the contamination generated during cleaning.
2



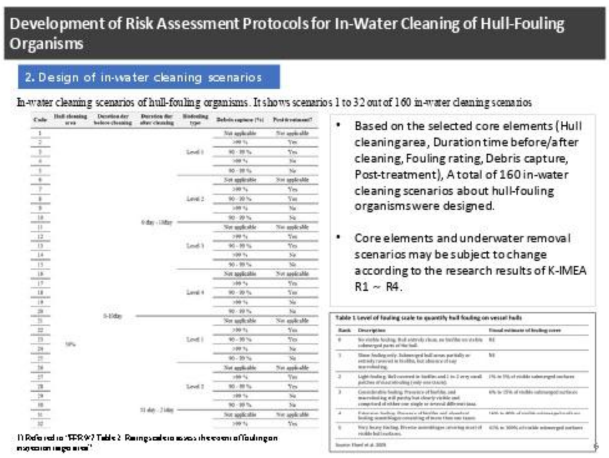
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
Risk assessment method for In-Water Cleaning of Hull-Fouling Organisms (Biological risk + Chemical/Toxicity risk)
Biological risk
IMEA assessment of different cleaning scenarios
• Durations of vessel visit
• Level of fouling
Cleaning acceptable or not acceptable
Combination
Chemical risk
Release Cu concentration in-water cleaning
MEMPEC model
Cleaning acceptable or not acceptable
Determination of Feasibility for In-water cleaning
Biological risk | Chemical risk | Overall Conclusion
Possible (RPN: 840, low risk) | Impossible (PEC/PNEC: >1) | Impossible
3



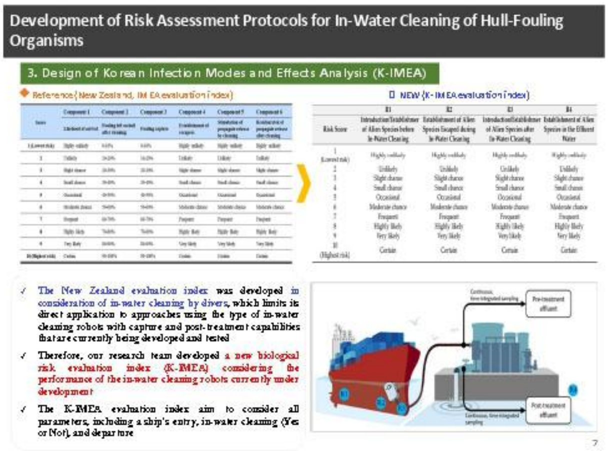
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
Development Procedure for Biological Risk Assessment Protocol (BRAP)
Development procedure of BRAP
1. Selection of core elements
2. Scenario design for in-water cleaning of hull fouling organisms
3. Design of biological risk evaluation index K-IMEA
4. RPN score calculation for each in-water cleaning scenario
5. Performance evaluation for ships entering major domestic ports
Considering the domestic port environmental conditions
K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index
Expert consultation regarding marine biology
Numerical model study for predicting the regrowth of marine organisms in port environments
The relative risk of the most suitable scenario for in-water cleaning of hull-fouling organisms on ships entering major domestic ports was identified. Then, the feasibility of in-water cleaning was determined.
4

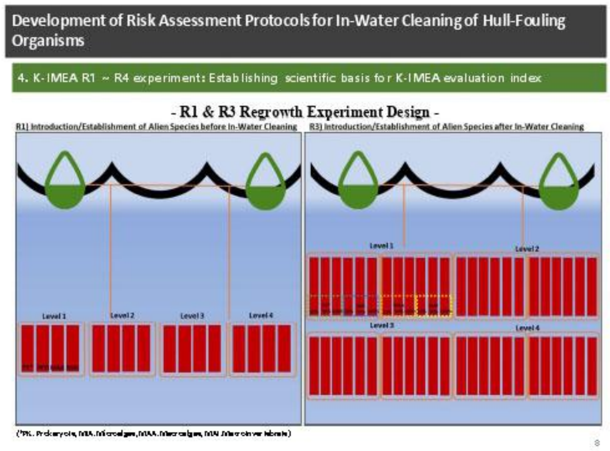


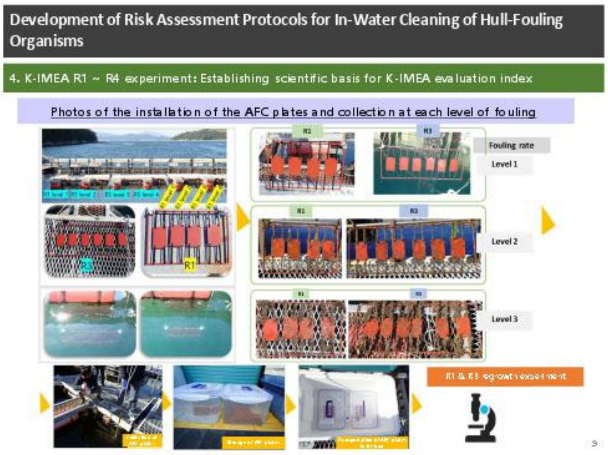
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
1. Selection of core elements
Hull cleaning area
50%
100%
Duration time before cleaning
0-10 days
11-21days
Duration time after cleaning
0-10 days
11-21days
Fouling rating
Level (1, 2, 3, 4)
Debris capture
Not applicable
>99%
90-99%
Post treatment
Yes
No
Hull cleaning area (50%, 100%), stay duration before in-water cleaning (0-10 day, 11-21 day), stay duration after in-water cleaning (0-10 day, 11-21 day), fouling rating (Lv.1-4), Debris capture (NA, >99%, 90-99%), Use of Post treatment system
5

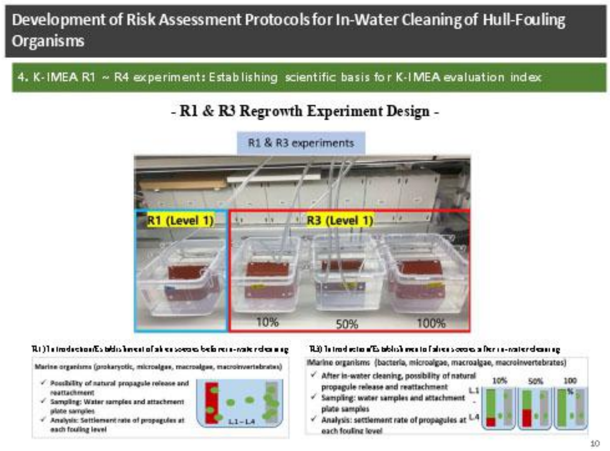


Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
2. Design of in-water cleaning scenarios
In-water cleaning scenarios of hull-fouling organisms. It shows scenarios 1 to 32 out of 160 in-water cleaning scenarios
Based on the selected core elements (Hull cleaning area, Duration time before/after cleaning, Fouling rating, Debris capture, Post-treatment), A total of 160 in-water cleaning scenarios about hull-fouling organisms were designed.
Core elements and underwater removal scenarios may be subject to change according to the research results of K-IMEA R1 ~ R4.
Table 1 Level of fouling scale to quantify hull fouling on vessel hulls
6

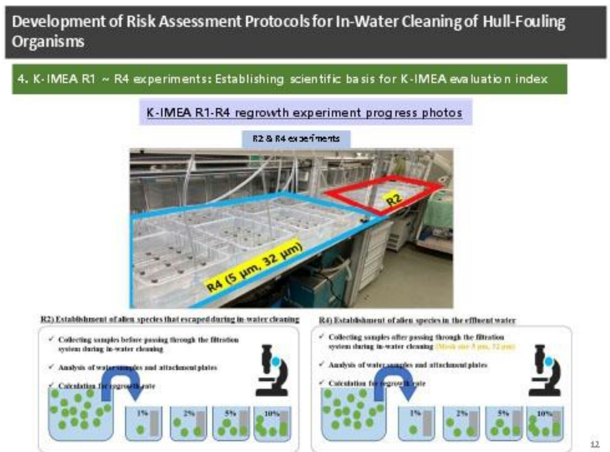

Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
3. Design of Korean Infection Modes and Effects Analysis (K-IMEA)
Reference (New Zealand, IMEA evaluation index)
NEW (K-IMEA evaluation index)
The New Zealand evaluation index was developed in consideration of in-water cleaning by divers, which limits its direct application to approaches using the type of in-water cleaning robots with capture and post-treatment capabilities that are currently being developed and tested
Therefore, our research team developed a new biological risk evaluation index (K-IMEA) considering the performance of the in-water cleaning robots currently under development
The K-IMEA evaluation index aim to consider all parameters, including a ship's entry, in-water cleaning (Yes or Not), and departure
7


Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
4. K-IMEA R1 ~ R4 experiment: Establishing scientific basis for K-IMEA evaluation index
- R1 & R3 Regrowth Experiment Design -
R1) Introduction/Establishment of Alien Species before In-Water Cleaning
R3) Introduction/Establishment of Alien Species after In-Water Cleaning
Level 1
Level 2
Level 3
Level 4
8


Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
4. K-IMEA R1 ~ R4 experiment: Establishing scientific basis for K-IMEA evaluation index
Photos of the installation of the AFC plates and collection at each level of fouling
Fouling rate
Level 1
Level 2
Level 3
R1 & R3 regrowth experiment
9


Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
4. K-IMEA R1 ~ R4 experiment: Establishing scientific basis for K-IMEA evaluation index
- R1 & R3 Regrowth Experiment Design -
R1 & R3 experiments
R1 (Level 1)
R3 (Level 1)
10%
50%
100%
Marine organisms (prokaryotic, microalgae, macroalgae, macroinvertebrates)
Possibility of natural propagule release and reattachment
Sampling: Water samples and attachment plate samples
Analysis: Settlement rate of propagules at each fouling level
L1 – L4
Marine organisms (bacteria, microalgae, macroalgae, macroinvertebrates)
After in-water cleaning, possibility of natural propagule release and reattachment
Sampling: water samples and attachment plate samples
Analysis: settlement rate of propagules at each fouling level
10


Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
4. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index
- Biofouling and Wastewater Sampling (R2 & R4) -
Organism collection
K-IMEA R2&R4 experiments
Measurement of environmental parameters
11

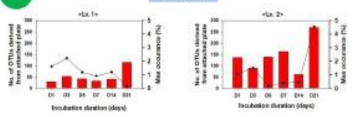

Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms
4. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index
K-IMEA R1-R4 regrowth experiment progress photos
R2 & R4 experiments
R2
R4 (5 μm, 32 μm)
R2) Establishment of alien species that escaped during in-water cleaning
Collecting samples before passing through the filtration system during in-water cleaning
Analysis of water samples and attachment plates
Calculation for regrowth rate
R4) Establishment of alien species in the effluent water
Collecting samples after passing through the filtration system during in-water cleaning
Analysis of water samples and attachment plates
Calculation for regrowth rate
1%
2%
5%
10%
12

Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)

Organisms	**Index: R1** Introduction/Establishment of alien species before in-water cleaning
Prokaryotes	- Prokaryotic regrowth observed even at low biofouling levels 1 and 2
Microalgae	- Microalgae regrowth did not occur at fouling level 1; however, it was observed at fouling level 2
Macroalgae	- **No regrowth was observed**
Macroinvertebrates	- **No regrowth was observed**

* The R1 & R3 experiments have completed sampling up to Lv.4, but the results so far only consider data up to Lv.2



The number of OTUs of reattached prokaryotes originating from the attachment plates (bar graph) and the maximum occupancy of those OTUs (line graph) over the cultivation period

Photograph of diatoms observed to have regrowth in the K-IMEA R1 experiment

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Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)

Organisms	**Index: R2** Establishment of alien species that escaped during in-water cleaning
Prokaryotes	- In all dilution treatments, the number of OTUs and occurrence frequency of ship hull-derived prokaryotes tended to increase as the incubation period increased. - This suggests that the released **prokaryotic community is viable in a port environment even at a debris capture efficiency of 99%** during the in-water cleaning process.
Microalgae	- Microalgae regrowth in the samples of ship 2, 4, and 5 was observed even in the experimental group assuming a capture efficiency of 99%.
Macroalgae	- ***Ulva compressa*** **regrew** in all experimental groups, indicating the possibility of macroalgae regrowth **even under high debris capture efficiency (99%)**.
Macroinvertebrates	- **No regrowth was observed**

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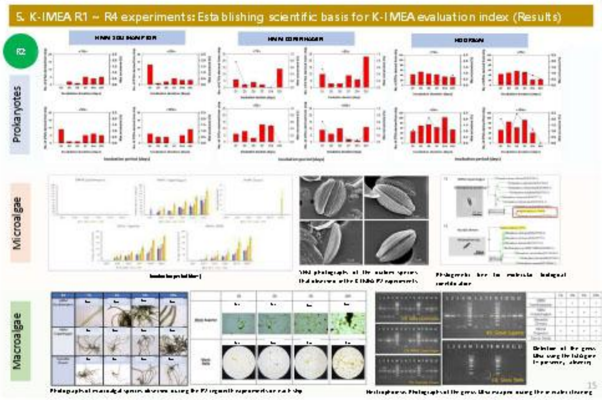
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)



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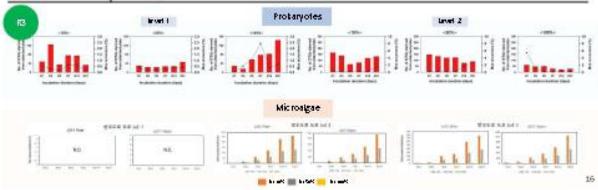
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)

Organisms	**Index: R3** Introduction/Establishment of alien species after in-water cleaning
Prokaryotes	- Prokaryotic regrowth observed even at low biofouling levels 1 and 2
Microalgae	- Microalgae regrowth did not occur at fouling level 1; however, it was observed at fouling level 2 and 3 - Regrowth of microalgae was observed in the experimental groups where 10% and 50% cleaning was considered, whereas **no regrowth was observed in the 100% experimental group where the entire area was cleaned**
Macroalgae	- **No regrowth was observed**
Macroinvertebrates	- **No regrowth was observed**



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Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)

Organisms	**Index: R4** Establishment of alien species in the effluent water
Prokaryotes	- Prokaryotes were observed in all effluent samples after filtration with a 5 μm net
Microalgae	- **No regrowth was observed in the effluent after filtration with a 5 μm or 32 μm nets.** - Microalgae were more efficiently removed using filtration than were prokaryotes.
Macroalgae	- In the sample filtered with a 32 μm filter, no regrowth was observed in the HD Dream and Glovis Stella, but in other ships, some experimental conditions (5-10%) showed growth of *Ulva* species. - In the sample filtered with a 5 μm filter, no regrowth was observed except for Glovis Superior. - **The use of filtration** systems with smaller mesh diameters is expected to be **effective in reducing the introduction of macroalgae from the hull surface during in-water cleaning.**
Macroinvertebrates	- **No regrowth was observed**

✓ The results of the R4 regrowth experiment suggest the need for disinfection processes, such as UV and NaOCl, in addition to simple filtration, for the elimination of biological organisms during post-treatment

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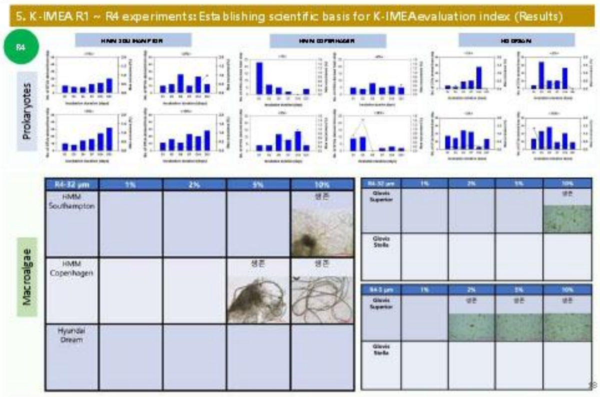
Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

5. K-IMEA R1 ~ R4 experiments: Establishing scientific basis for K-IMEA evaluation index (Results)



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Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

6. Calculation of overall risk ranking for each in-water cleaning scenario
- Method for calculating biological risk for each scenario -

Examples: Calculation of overall risk ranking for each in-water cleaning scenario	
R1 Introduction/Establishment of alien species before in-water cleaning	0-10 days* Lv.1*: 1, +Lv.2: 3, +Lv.3: 4, +Lv.4: 7 11-21 days Lv.1: 3, +Lv.2: 4, +Lv.3: 6, +Lv.4: 8
R2 Establishment of alien species that escaped during in-water cleaning	Lv.1+NA: 4, +>99%: 1, +90-99%: 2 Lv.2+NA: 8, +>99%: 2, +90-99%: 5 Lv.3+NA: 9, +>99%: 4, +90-99%: 6 Lv.4+NA: 10, +>99%: 5, +90-99%: 7
R3 Introduction/Establishment of alien species after in-water cleaning	Hull cleaning area: 50% 0-10 days* Lv.1: 2, +Lv.2: 5, +Lv.3: 6, +Lv.4: 8 11-21 days Lv.1: 4, +Lv.2: 6, +Lv.3: 8, +Lv.4: 10
	Hull cleaning area: 100% 0-10 days* Lv.1: 1, +Lv.2: 1, +Lv.3: 4, +Lv.4: 6 11-21 days Lv.1: 2, +Lv.2: 2, +Lv.3: 6, +Lv.4: 7
R4 Establishment of alien species in the effluent water	Post-treatment: Yes* + Lv.1-3: 1, Lv.4: 2 Post-treatment: No & NA +Lv.1: 3, +Lv.2: 6, +Lv.3: 7, Lv.4: 10

✓ **Calculation of RPN score by multiplying component scores (R1×R2×R3×R4) for each in-water cleaning scenario**

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Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

4. Examples of biological risk priority number (RPN) score

- Distribution of risk priority number (RPN) and overall risk ranking among in-water cleaning scenarios -

- RPN decreased exponentially were identified as "high-risk", those in the section where RPN gradually decreased were identified as "medium-risk", and those in the section where RPN stabilized were identified as "low-risk".
- High-risk scenarios (RPN 8000–1000) include 44 (27.5%) of 160 in-water cleaning scenarios; most feature high fouling levels and the absence of debris capture or post-treatment.
- The medium risk scenarios (RPN 1000–100) include 53 scenarios (33.1%); except for cases where the fouling level is very low (Level 1), most include debris capture, post-treatment processes, or both.
- The low-risk scenarios (RPN ~1–100) include 63 scenarios (39.4%), most of which have a low fouling level (Levels 1–2) and involve debris capture or post-treatment.

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Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

Summary

① After selection of core elements, the draft for in-water cleaning scenarios and the K-IMEA R1-R4 index has been completed.
② Experiments for K-IMEA R1 and R3, is currently ongoing using next-generation sequencing (NGS) and high-magnification microscopy for biological group analysis.
③ Confirmed that prokaryotes, microalgae, macroalgae have the potential to regrow even at a 99% capture efficiency (R2 results).
④ In the post-treatment process using 5 μm mesh filtration, no regrowth was observed in any biological groups except for prokaryotes and the *Ulva* species of macroalgae (R4).
⑤ In cases where the hull-fouling level is 4, even if collection and post-treatment processes are conducted, it is not classified as a low-risk scenario.

✓ Prokaryotes and microalgae can regrow within 3 days after detachment from the hull surface. In particular, prokaryotes and some macroalgae that passed through a 5 μm mesh can regrow. This suggests the importance of capturing and post-processing cleaning by-products in the in-water cleaning system to protect the aquatic ecosystem.

✓ We suggest that the protocol can provide a scientific basis for managing hull fouling of ships entering a port, and can be used to diagnose biological risks that may occur when hull fouling is cleaned using in-water cleaning systems.

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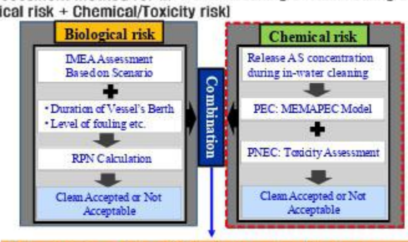
Development of Risk Assessment Methods for Chemical/Toxicological Impact

Risk assessment method for In-Water Cleaning of Hull-Fouling Organisms (Biological risk + Chemical/Toxicity risk)



Determination of Feasibility for In-water cleaning

Biological risk	Chemical risk	Overall Conclusion
Possible (RPN: 840, low risk)	Impossible (PEC/PNEC: >1)	**Impossible**

- Active Substance (AS)
- Predicted Environmental Concentration (PEC)
- Predicted No-Effect concentration (PNEC)
- Marine Antifoulant Model to Predict Environmental Concentrations (MAMPEC)

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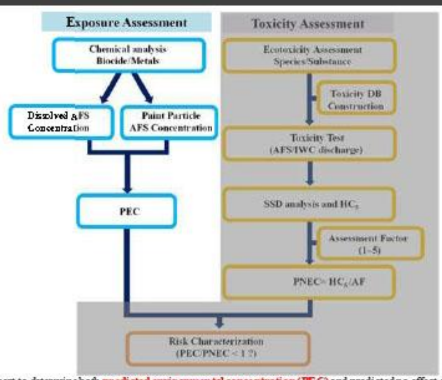
Development of Risk Assessment Methods for Chemical/Toxicological Impact



Flowchart to determine both **predicted environmental concentration (PEC)** and predicted no effect concentration (PNEC) of active substances in effluents of cleaning water from in-water hull cleaning for Risk Assessment

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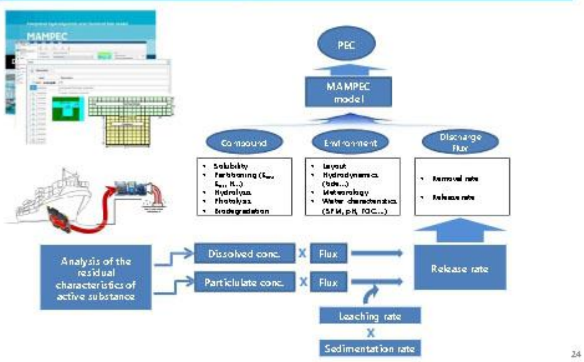
Development of Risk Assessment Methods for Chemical/Toxicological Impact

Utilization of the MAMPEC Model & Analysis of Active Substance for PEC Calculation



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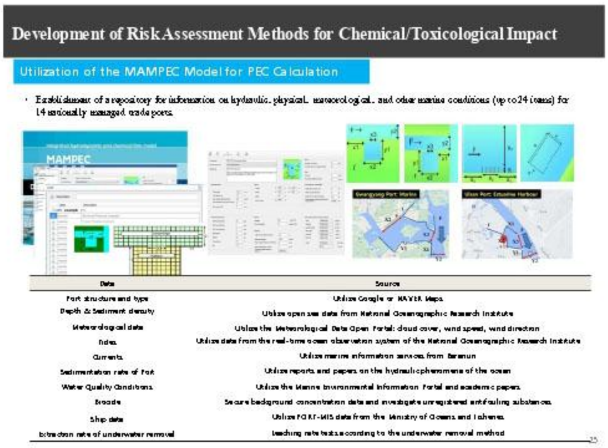
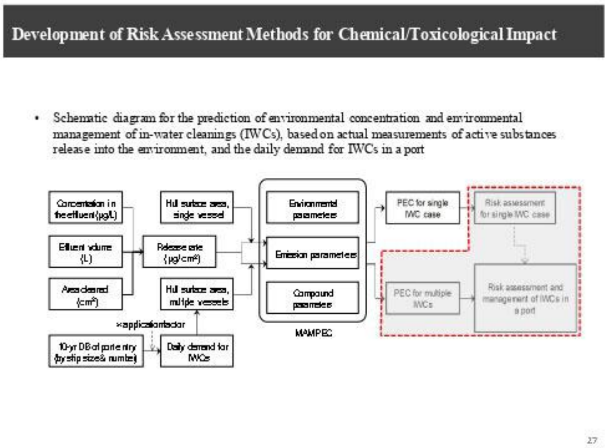
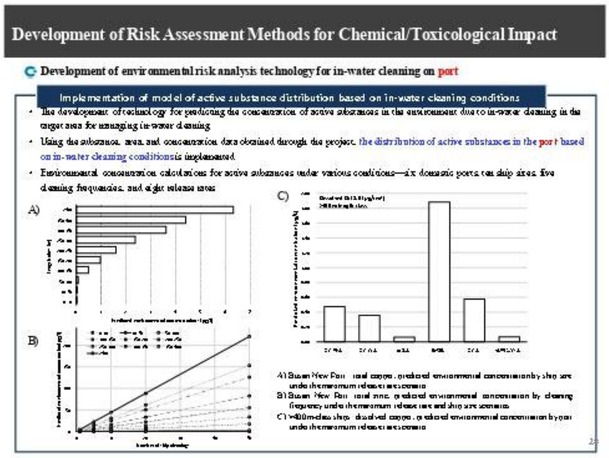
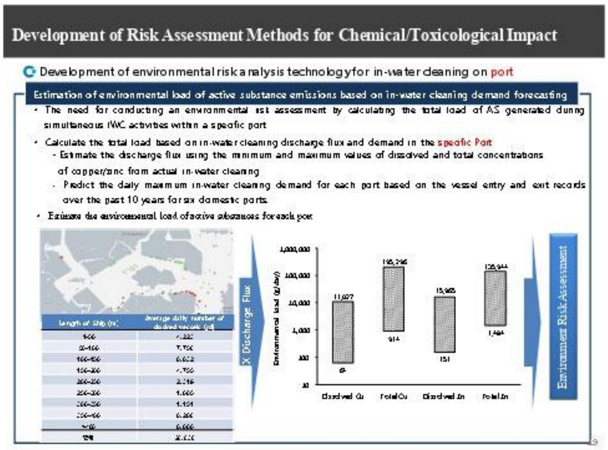
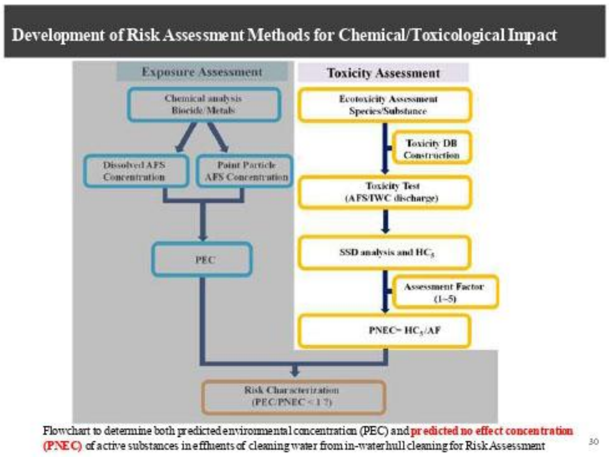

Development of Risk Assessment Methods for Chemical/Toxicological Impact
Utilization of the MAMPEC Model for PEC Calculation
Establishment of a repository for information on hydraulic, physical, meteorological, and other marine conditions (up to 24 items) for 14 nationally managed trade ports.
MAMPEC
Data
Source
Port structure and type
Utilize Google or NAVER Maps
Depth & Sediment density
Utilize open sea data from National Oceanographic Research Institute
Meteorological data
Utilize the Meteorological Data Open Portal: cloud cover, wind speed, wind direction
Tides
Utilize data from the real-time ocean observation system of the National Oceanographic Research Institute
Currents
Utilize marine information services from Baranun
Sedimentation rate of Port
Utilize reports and papers on the hydraulic phenomena of the ocean
Water Quality Conditions
Utilize the Marine Environmental Information Portal and academic papers
Biocide
Secure background concentration data and investigate unregistered antifouling substances
Ship data
Utilize PORT-MIS data from the Ministry of Oceans and Fisheries
Extraction rate of underwater removal
leaching rate tests according to the underwater removal method
25


Development of Risk Assessment Methods for Chemical/Toxicological Impact
Analysis of Active Substances (Behavioral Assessment)
Residual Characteristics of Dissolved and Particulate Active Substances in Discharge Water from In-water Cleaning
Identify the residual characteristics of dissolved and particulate active substances (11 inorganic and 10 organic) in the discharge water from 11 ship hull cleanings.
Key data for calculating discharge flux, environmental concentration, and conducting environmental risk assessments for in-water cleaning.
Accumulation of data on the emission characteristics of active substances under various in-water cleaning conditions.
Utilized for the preliminary prediction of environmental risks associated with in-water cleaning.
Inorganic Active Substance (11)
Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Ba, Pb
Organic Active Substance (10)
Zinc pyrithione, Copper pyrithione, DCMU, Cybutryne, DCOIT, Dichlofluanid
Dissolved Inorganic AS
Particulate Inorganic AS
Dissolved Organic AS
Particle distribution characteristics
AS Analysis
Discharge Flux
26


Development of Risk Assessment Methods for Chemical/Toxicological Impact
Schematic diagram for the prediction of environmental concentration and environmental management of in-water cleanings (IWCs), based on actual measurements of active substances release into the environment, and the daily demand for IWCs in a port
Concentration in the effluent (μg/L)
Effluent volume (L)
Area cleaned (cm²)
Hull surface area, single vessel
Release rate (μg/cm²)
Hull surface area, multiple vessels
× application factor
10-yr DB of port entry (by ship size & number)
Daily demand for IWCs
Environmental parameters
Emission parameters
Compound parameters
MAMPEC
PEC for single IWC case
Risk assessment for single IWC case
PEC for multiple IWCs
Risk assessment and management of IWCs in a port
27

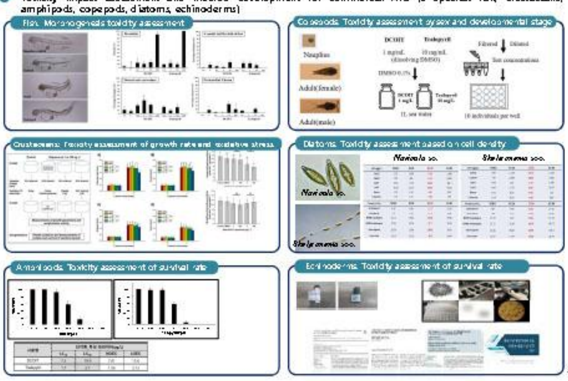

Development of Risk Assessment Methods for Chemical/Toxicological Impact
Development of environmental risk analysis technology for in-water cleaning on port
Implementation of model of active substance distribution based on in-water cleaning conditions
The development of technology for predicting the concentration of active substances in the environment due to in-water cleaning in the target area for managing in-water cleaning
Using the substance, area, and concentration data obtained through the project, the distribution of active substances in the port based on in-water cleaning conditions is implemented.
Environmental concentration calculations for active substances under various conditions—six domestic ports, ten ship sizes, five cleaning frequencies, and eight release rates
A)
B)
C)
A) Busan New Port : total copper, predicted environmental concentration by ship size under the maximum release rate scenario
B) Busan New Port : total zinc, predicted environmental concentration by cleaning frequency under the maximum release rate and ship size scenarios
C) >400m-class ships : dissolved copper, predicted environmental concentration by port under the maximum release rate scenario


Development of Risk Assessment Methods for Chemical/Toxicological Impact
Development of environmental risk analysis technology for in-water cleaning on port
Estimation of environmental load of active substance emissions based on in-water cleaning demand forecasting
The need for conducting an environmental risk assessment by calculating the total load of AS generated during simultaneous IWC activities within a specific port
Calculate the total load based on in-water cleaning discharge flux and demand in the specific Port
- Estimate the discharge flux using the minimum and maximum values of dissolved and total concentrations of copper/zinc from actual in-water cleaning
- Predict the daily maximum in-water cleaning demand for each port based on the vessel entry and exit records over the past 10 years for six domestic ports.
Estimate the environmental load of active substances for each port
Length of Ship (m)
Average daily number of docked vessels (ea)
X Discharge Flux
Environmental load (g/day)
1,000,000
100,000
10,000
1,000
100
10
11,027
195,296
15,965
126,944
914
151
1,494
Dissolved Cu
Total Cu
Dissolved Zn
Total Zn
Environment Risk Assessment


Development of Risk Assessment Methods for Chemical/Toxicological Impact
Exposure Assessment
Toxicity Assessment
Chemical analysis Biocide/Metals
Dissolved AFS Concentration
Paint Particle AFS Concentration
PEC
Ecotoxicity Assessment Species/Substance
Toxicity DB Construction
Toxicity Test (AFS/IWC discharge)
SSD analysis and HC5
Assessment Factor (1~5)
PNEC= HC5/AF
Risk Characterization (PEC/PNEC < 1 ?)
Flowchart to determine both predicted environmental concentration (PEC) and predicted no effect concentration (PNEC) of active substances in effluents of cleaning water from in-water hull cleaning for Risk Assessment
30

Development of Risk Assessment Methods for Chemical/Toxicological Impact

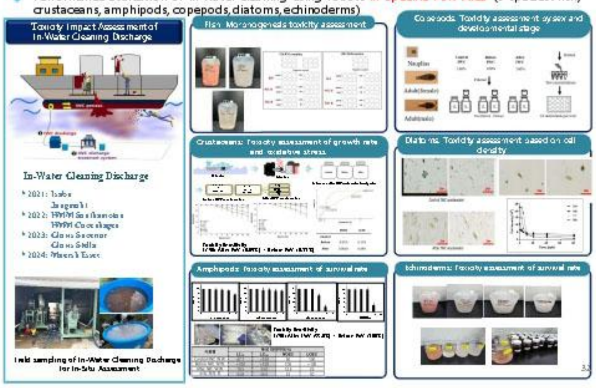
Toxicity impact assessment and method development for commercial AFS (6 species: fish, crustaceans, amphipods, copepods, diatoms, echinoderms)



31

Development of Risk Assessment Methods for Chemical/Toxicological Impact

Performance evaluation of in-water cleaning using robots in Specific Port Area (6 species: fish, crustaceans, amphipods, copepods, diatoms, echinoderms)

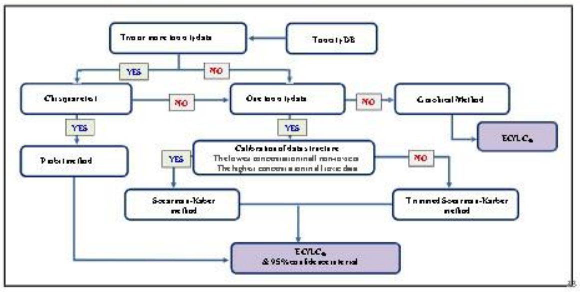


32

Development of Risk Assessment Methods for Chemical/Toxicological Impact

Methodology for Determining Toxicity Parameters in the Ecotoxicological Assessment of Hull In-water Cleaning Discharge

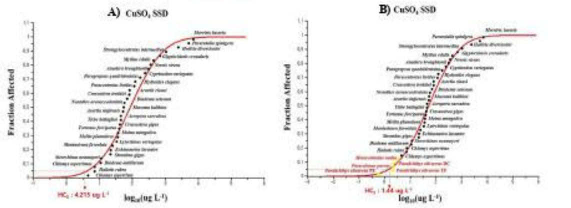
Method for obtaining EC_{50}/LC_{50} values for Constructing the Specie-Sensitivity distribution (SSD) Curve



33

Development of Risk Assessment Methods for Chemical/Toxicological Impact

Species Sensitivity Distribution graph of Copper(II) Sulfate ($CuSO_4$) and an example of HC_5 estimation, (A) using only the toxicity DB (ECOTOX) value, (B) the result of reflecting the toxicity test value of native species together in this study



Although **HC5** provides a solid foundation for determining PNEC, it is not directly used as the final PNEC. To account for uncertainties, an **Assessment Factor (AF)** is applied to HC5. The **AF** adjusts for potential gaps in data, variability among species, and the overall uncertainty in predicting environmental impacts. The size of the AF typically ranges from 1 to 5, depending on the quality and quantity of the toxicity data available, and the diversity of species used in the analysis.

PNEC = HC5/AF

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Development of Risk Assessment Methods for Chemical/Toxicological Impact

Summary

- The chemical risk assessment of ports should shift from individual ship cleaning to a more holistic environmental management approach, given that the PEC is significantly higher when multiple ships undergo simultaneous cleaning within a port.
- Quantitative and qualitative evaluation of toxicity data, including indigenous species, can reduce uncertainty in managing domestic ports and enable the calculation of PNEC for port protection.
- When the discharge water containing by-products from in-water cleaning is treated directly on-site, it is necessary to establish a certification system to evaluate the performance of the post-treatment system for the protection of the marine environment.

35

Development of Risk Assessment Protocols for In-Water Cleaning of Hull-Fouling Organisms

- ✓ Even on ships with minimal fouling levels, in-water cleaning can introduce bacteria and macroalgae into aquatic ecosystems if cleaning by-products are not managed appropriately.
- ✓ As the frequency of in-water cleaning increases, additional heavy metals, biocides, and microplastics are released along with organic matter. Although these substances can be effectively captured, it remains challenging to treat at concentrations that are environmentally benign.
- ✓ It is essential to consider advancements in coatings resistant to in-water cleaning and to explore innovations in anti-fouling paints.

36


KIOST
Acknowledgement
This research was supported by the Korea Institute of Marine Science and Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries, Republic of Korea.
Thanks to Dr. Bonggil Hyun, Pung-Guk Jang, Jung-Hoon Kang, Moonkoo Kim and Jihyun Jung for providing the data and slides.
Ministry of Oceans and Fisheries
해양수산과학기술진흥원
Thank you for your attention
Reduction in transport of aquatic species
Ecosystem protection & management

YUSIK KIM

CEO

TAS Global, Republic of Korea

Kim Yusik is a visionary leader in the field of robotics and marine technology, serving as the CEO of TSS Global, a company he established in August 2014. Under his leadership, TAS Global quickly rose to prominence, securing 31 patents and 4 trademarks across 19 countries, and developing groundbreaking technologies in underwater robotics.

Yusik's innovative approach has been recognized globally, with TAS Global's robotic solutions featured in major publications such as the Herald Economic Daily and Korea Economic Daily. His commitment to advancing marine technology led to significant achievements, including the world’s first commercialization of a ship-mounted underwater cleaning robot in 2019.

Yusik has actively participated in international seminars and conferences, sharing his expertise and insights. Notably, he represented TAS Global at the 1st GEF-UNDP-IMO GloFouling R&D Forum in Australia and the Singapore APM2022 Shipbuilding and Offshore Plant Exhibition. In 2021, his leadership was further acknowledged when he was elected as the chair of the Global Industry Alliance (GIA) for Marine Biosafety of GloFouling Partnerships project executed by the International Maritime Organization (IMO).

In addition to his role at TSS Global, Yusik has been instrumental in advancing sustainable maritime practices as a Technical Advisor for the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA). His dedication to innovation, sustainability, and excellence also led to TAS Global's selection as a preliminary Ocean Star company by the Ministry of Oceans and Fisheries in September 2022. Yusik has been honored with numerous awards, including the Minister of Oceans and Fisheries Award and the Robot Category Grand Prize at the 4th Industrial Revolution Awards, solidifying his reputation as a trailblazer in the industry.

Development of technology for treatment (removal, collection, treatment) of biofouling in Korea: Innovative solutions for biofouling management

TAS Global is at the forefront of underwater robotic technology, driving innovation in maritime maintenance and sustainability. A highlight of our advancements is the magnetic belt ROV (Remotely Operated Vehicle), which uses materials like silicon, MC nylon, and urethane mixed with stainless steel to tackle microfouling to macrofouling up to 10 cm.

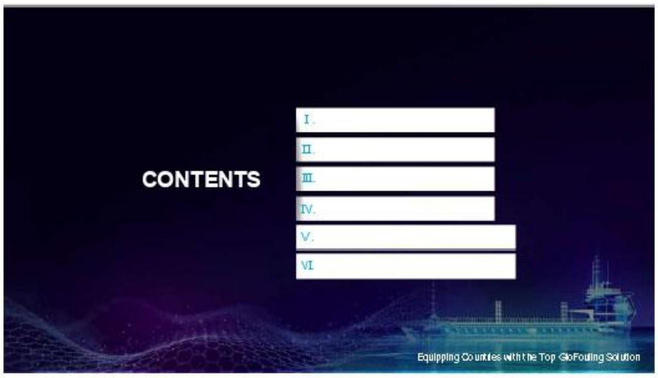
Our ROVs are designed with a unique ability to attach and detach from one another, enabling complex rescue operations and seamless transitions even in restricted seaside environments. As one ROV cleans the ship's bottom, it can transition to the port side, detach, and be replaced by another ROV, ensuring continuous operation.

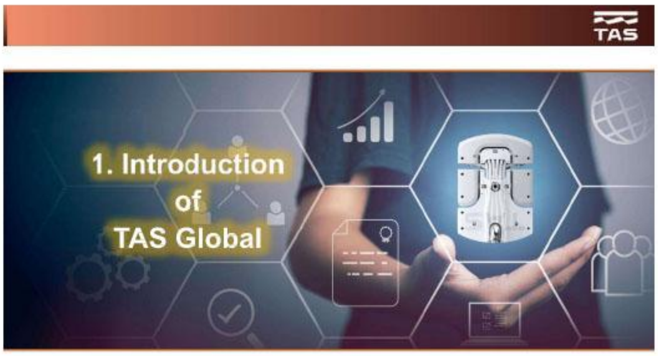
Further innovations include a robotic arm that cleans the bilge keel, demonstrating our commitment to thorough maintenance solutions. The new 3.0 version is faster and more efficient, capable of fully cleaning a 300-meter container ship in under 8 hours. It also features an advanced capture and filtration system, removing debris as small as 10 microns with 99% efficiency.

Through our K-Biofouling initiative, TAS Global is equipping countries and companies with our complete system, including technology and personnel training. This project, set for completion within two years, has already started in developing countries.

Moreover, TAS Global is pioneering efforts by being the first to undertake the BIMCO test with KOMERI. The guidelines established will be a milestone for the maritime industry, advancing sustainability and setting new standards in marine operations.

Presentation slides

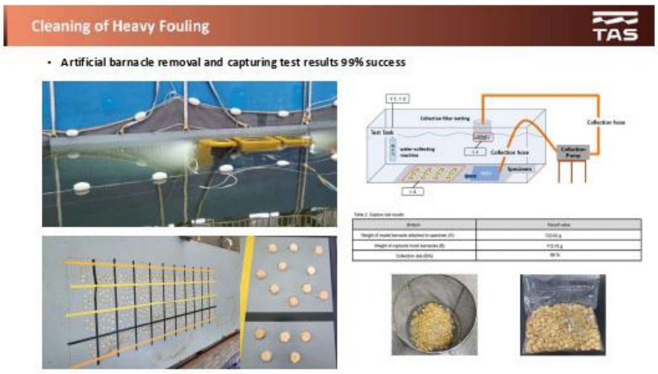





TAS
3. IWC Robots

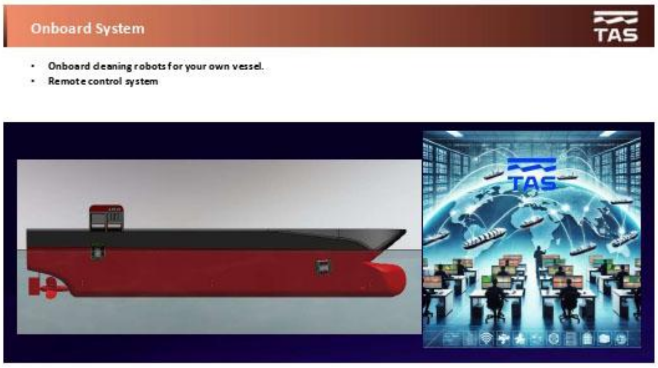

IWC Service Robots
TAS
CAPABLE
Terminals and Anchorage; Cleaning up to 3 Knots possible
300m vertical in 4-6 hours
Treatment System 10um
Semi-autonomous Cleaning
Robot Rescue
Multi-purpose arm for bilge keel
Regimes; Pro-active and Reactive
Switching removers accordingly


Cleaning of Soft Fouling
TAS
13:53:46pm 06-09-2024


Cleaning of Heavy Fouling
TAS
Artificial barnacle removal and capturing test results 99% success


A New Challenge
TAS
Drill ship and FPSO underwater cleaning in Brazil
Size 10cm or more and Mohs hardness 4 (Concrete)

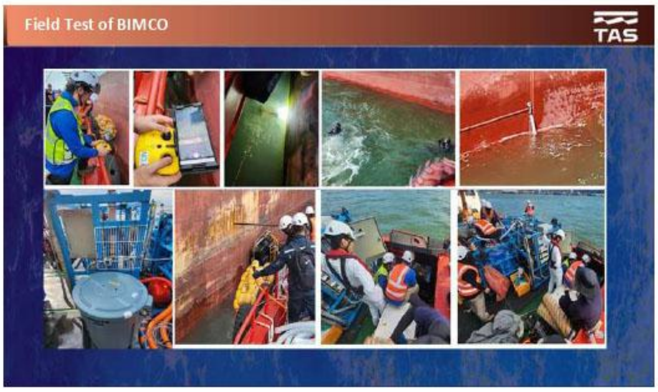

TAS
4. Onboard System


Onboard System
TAS
• Onboard cleaning robots for your own vessel.
• Remote control system
TAS


Expansion of Onboard System
TAS
• Industrial, Inspection, niche area cleaning, military, etc.

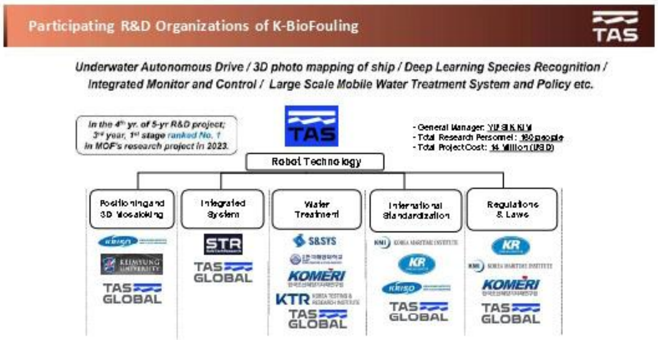

TAS
5. BIMCO Test


Contributing to Global Standardization Efforts in Hull Cleaning
TAS
➢ World's 1st to carry out global IWC standard by Baltic and International Maritime Council
➢ We conducted three field tests and achieved 80% success.
Old
New
7 times better of capture and treatment system
Test Results
✓ Cleaning rate : Satisfaction with cleaning completion rate of over 90%
✓ Filter Performance : TSS passed, PSD 90~93% failed
✓ TAS GLOBAL will conduct ISO or BIMCO Tests with new robots and new filter systems to achieve 100% pass by 2025.


Field Test of BIMCO
TAS


TAS
6. K-BioFouling


K-BioFouling; Equipping Countries with A to Z Biofouling Solutions
TAS
BioFouling
IWC Industry
AI Hull Monitoring
Regulations
Trained Personnel
Official Development Assistance (ODA) or other source of funding


Participating R&D Organizations of K-BioFouling
TAS
Underwater Autonomous Drive / 3D photo mapping of ship / Deep Learning Species Recognition / Integrated Monitor and Control / Large Scale Mobile Water Treatment System and Policy etc.
In the 4th yr. of 5-yr R&D project; 3rd year, 1st stage ranked No. 1 in MOF's research project in 2023.
- General Manager: YU SIK KIM
- Total Research Personnel: 160 people
- Total Project Cost: 14 Million (USD)
Robot Technology
Positioning and 3D Mosaicking
Integrated System
Water Treatment
International Standardization
Regulations & Laws
STR
TAS GLOBAL
S&SYS
KOMERI
KTR
KR


TAS GLOBAL
HULL CLEANING ROBOT
Thank You
ys.kim@usmtas.com
PAST
FUTURE

DR. PAN-MOOK LEE

Korea Research Institute of Ships & Ocean Engineering (KRISO)

Republic of Korea

He received the B.E. degree from Hanyang University, Seoul, Korea, and the M.E. and Ph.D. degrees from the Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea, in 1983, 1985, and 1998, respectively, all in mechanical engineering. Since 1985, he has been a principal researcher with the Ocean and Maritime Digital Technology Research Division of the Korea Research Institute of Ships and Ocean Engineering (KRISO), Daejeon, Korea. He was a visiting researcher with the University of Hawaii at Manoa between 1998 and 1999. He was an adjunct professor of the Ocean Engineering Division of the University of Science and Technology (UST) of Korea between 2004 and 2017. His research interests include navigation, guidance, and control of unmanned underwater vehicles such as remotely operated vehicles (ROV), autonomous underwater vehicles (AUV) and hull cleaning robot (HCR). He has published 146 technical papers of international and/or domestic journals. Dr. Lee was a technical board member of the Korean Society of Ocean Engineers (KSOE) and the Society of Naval Architect of Korea (SNAK), and a member of the Oceanic Engineering Society of IEEE. He served as the director of the ocean engineering division of KRISO between 2008 and 2011, and between 2020 and 2021.

Overview of KRISO's R&D on biofouling management technology

The Korea Research Institute of Ships and Ocean Engineering (KRISO) is a government-supported institute for the science and technologies of ships and offshore structures. One of the major roles and responsibilities (R&R) of KRISO is to improve ship's performance and to develop intelligent underwater/surface robotic vehicles. Bio-fouling management technology corresponds to the R&R of KRISO, and the research activities of the institute on the topic include the followings.

- Technologies to estimate the hull cleaning cycle of ships through the risk assessment of ships in operation: KRISO is developing biofouling assessment technologies based on operational performance assessment according to marine environmental factors and operating conditions of ships.

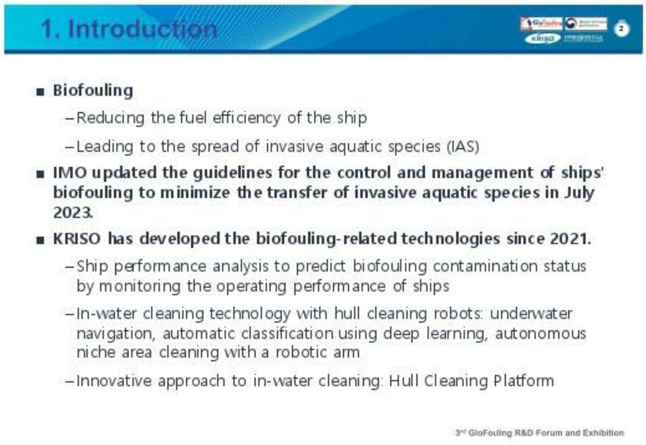
- Integrated underwater navigation technology of hull cleaning robots assisted by acoustic positioning system: KRISO has developed a modeling technology on the characteristics of statistical error of underwater acoustic positioning signals, which is efficient to remove outlier of acoustic positioning.

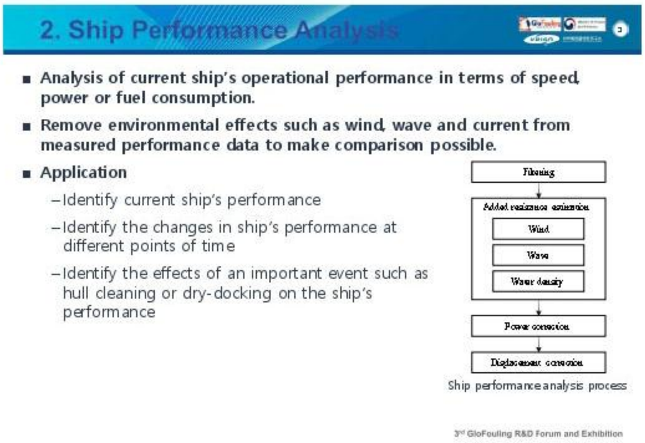
- In-water cleaning technologies for ships' niche areas using underwater robot arms: KRISO is focusing on the development of robot arm-based automatic cleaning technology for proactive/reactive cleaning of niche areas. In-water cleaning in test basin was conducted to confirm automatic cleaning of a propeller and recovery performance of cleaning debris. In the experiment, the control performance and the cleaning and recovery performance were analyzed by attaching analogous artificial organisms to the propeller with an adhesion force of grade 2 or higher.

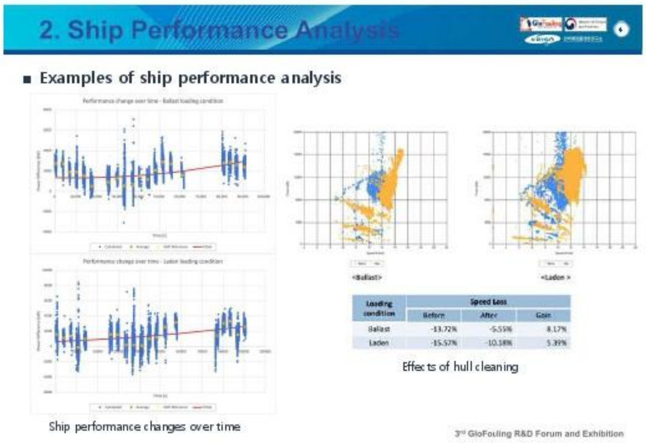
- Artificial intelligence technologies to identify the biofouling level of ships and to classify aquatic invasive species: KRISO is developing an identification technology of biofouling level and aquatic invasive species based on GoogleNet transfer learning from the image streams of hull cleaning robots.

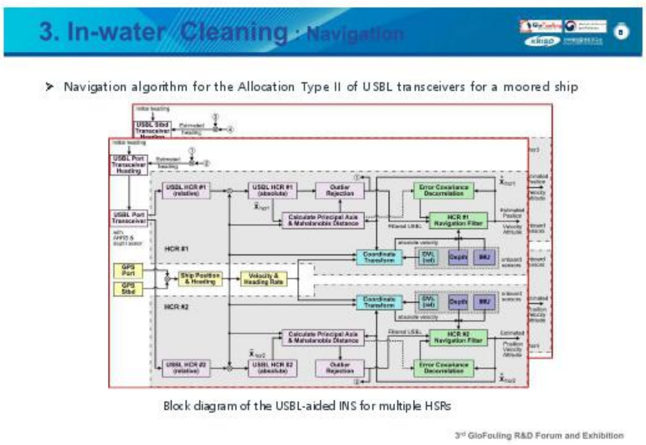
This presentation will introduce the KRISO's R&D activities related to the biofouling management technologies.

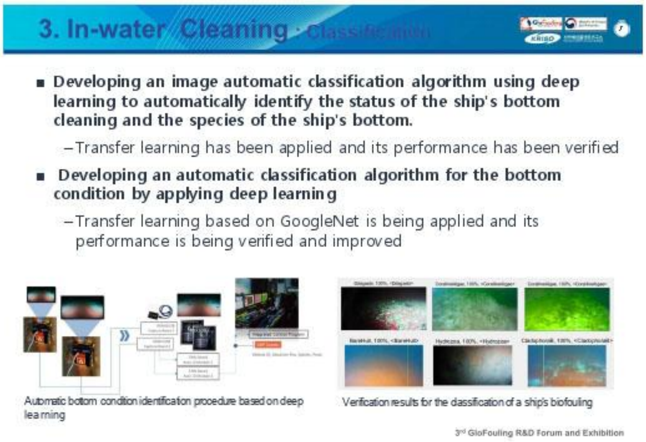
Presentation slides

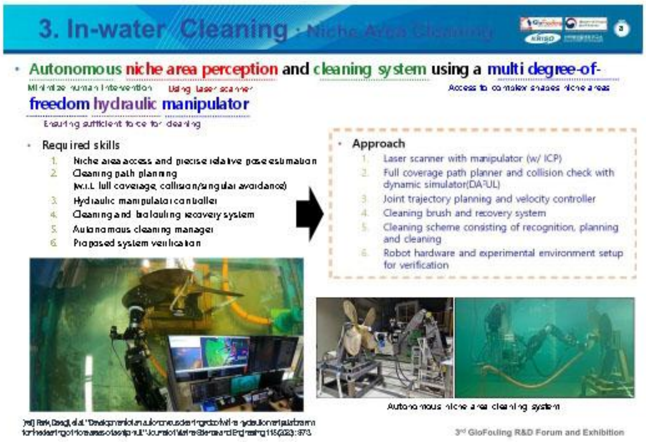




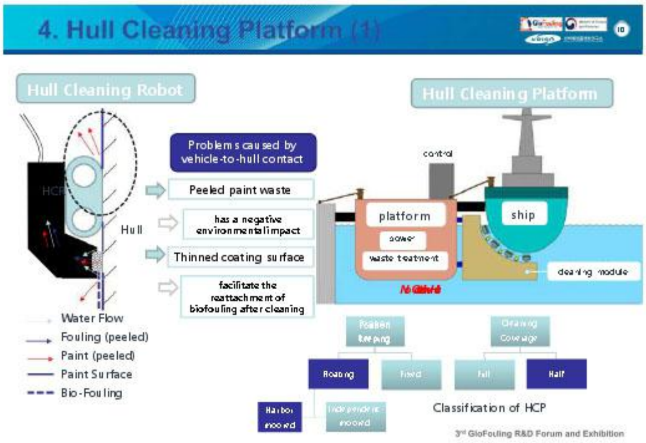




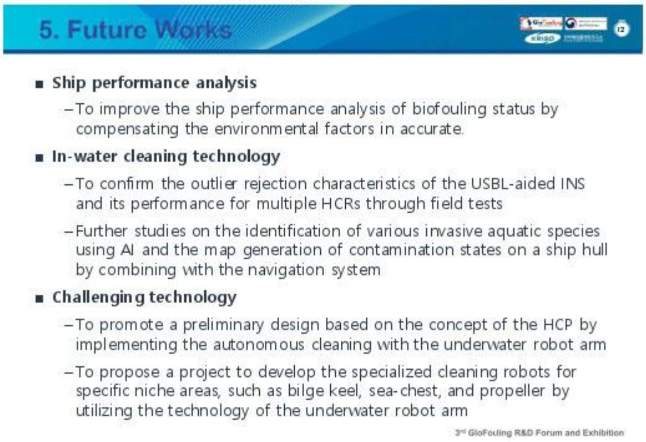

3. In-water Cleaning : Classification
■ Developing an image automatic classification algorithm using deep learning to automatically identify the status of the ship's bottom cleaning and the species of the ship's bottom.
–Transfer learning has been applied and its performance has been verified
■ Developing an automatic classification algorithm for the bottom condition by applying deep learning
–Transfer learning based on GoogleNet is being applied and its performance is being verified and improved
Automatic bottom condition identification procedure based on deep learning
Verification results for the classification of a ship's biofouling
3rd GloFouling R&D Forum and Exhibition


3. In-water Cleaning : Niche Area Cleaning
• Autonomous niche area perception and cleaning system using a multi degree-of-freedom hydraulic manipulator
Minimize human intervention
Using laser scanner
Access to complex shapes niche areas
Ensuring sufficient force for cleaning
• Required skills
1. Niche area access and precise relative pose estimation
2. Cleaning path planning (w.r.t. full coverage, collision/singular avoidance)
3. Hydraulic manipulator controller
4. Cleaning and biofouling recovery system
5. Autonomous cleaning manager
6. Proposed system verification
• Approach
1. Laser scanner with manipulator (w/ ICP)
2. Full coverage path planner and collision check with dynamic simulator(DARUL)
3. Joint trajectory planning and velocity controller
4. Cleaning brush and recovery system
5. Cleaning scheme consisting of recognition, planning and cleaning
6. Robot hardware and experimental environment setup for verification
Autonomous niche area cleaning system
3rd GloFouling R&D Forum and Exhibition


3. In-water Cleaning : Niche Area Cleaning
• Experimental environment
Hydraulic Power Unit
Flowmeter
Propeller
Biofouling Filter
Manipulator Arm
Suction Motor
Suction Hose
3rd GloFouling R&D Forum and Exhibition


4. Hull Cleaning Platform (1)
Hull Cleaning Robot
Hull Cleaning Platform
Problems caused by vehicle-to-hull contact
Peeled paint waste
has a negative environmental impact
Thinned coating surface
facilitate the reattachment of biofouling after cleaning
Hull
Water Flow
Fouling (peeled)
Paint (peeled)
Paint Surface
Bio-Fouling
control
platform
power
waste treatment
ship
cleaning module
Floating
Fixed
Full
Half
Harbor moored
Independent moored
Classification of HCP
3rd GloFouling R&D Forum and Exhibition


4. Hull Cleaning Platform (2)
Floating Hull Cleaning Platform
moored in a harbor with half-hull coverage
3rd GloFouling R&D Forum and Exhibition


5. Future Works
■ Ship performance analysis
–To improve the ship performance analysis of biofouling status by compensating the environmental factors in accurate.
■ In-water cleaning technology
–To confirm the outlier rejection characteristics of the USBL-aided INS and its performance for multiple HCRs through field tests
–Further studies on the identification of various invasive aquatic species using AI and the map generation of contamination states on a ship hull by combining with the navigation system
■ Challenging technology
–To promote a preliminary design based on the concept of the HCP by implementing the autonomous cleaning with the underwater robot arm
–To propose a project to develop the specialized cleaning robots for specific niche areas, such as bilge keel, sea-chest, and propeller by utilizing the technology of the underwater robot arm
3rd GloFouling R&D Forum and Exhibition

DR. MAN SOO CHOI

SLM Global

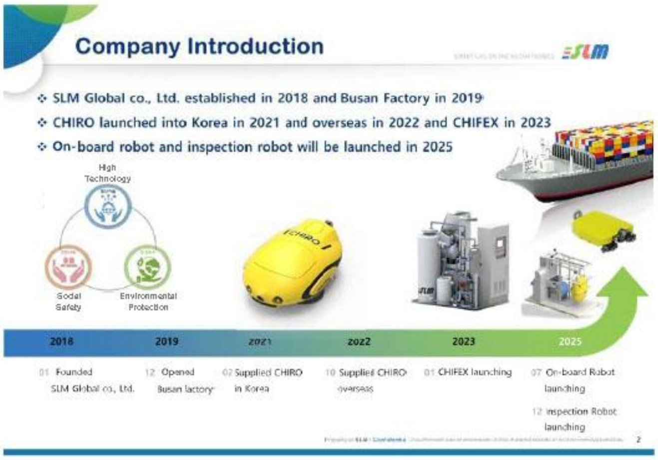
Republic of Korea

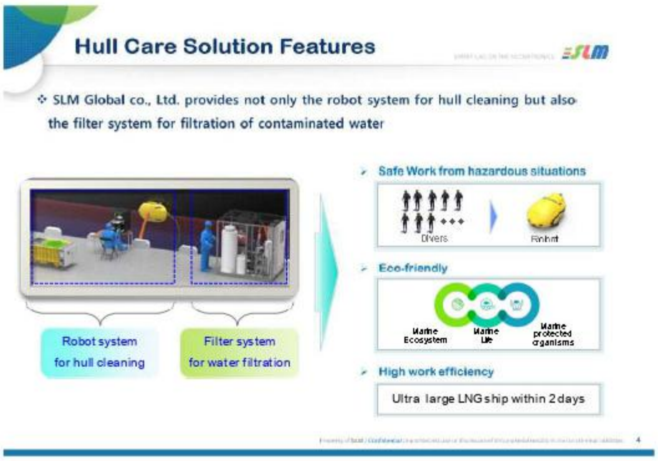
Hello, How are you? My name is Man Soo Choi.

I majored in precision mechanical engineering especially precision generator for future windmill at university. and, On the development of robots and automation systems at Samsung Heavy Industries during about 16 years. Now, I work for SLM Global company developing and spreading hull cleaning robot. It is very proud of me. because I am sure it will make the Global clean.
Our company and I will continue to strive for the environment of the Earth and human safety. Thank you.

Hull Cleaning Robot and Filter System for Marine Environmental Protection

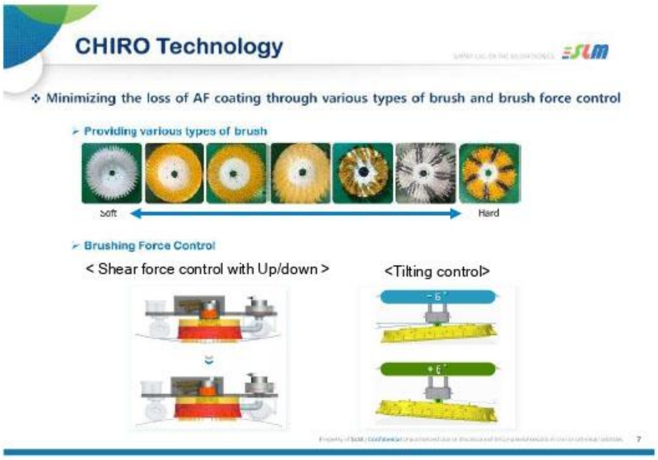
Presentation slides





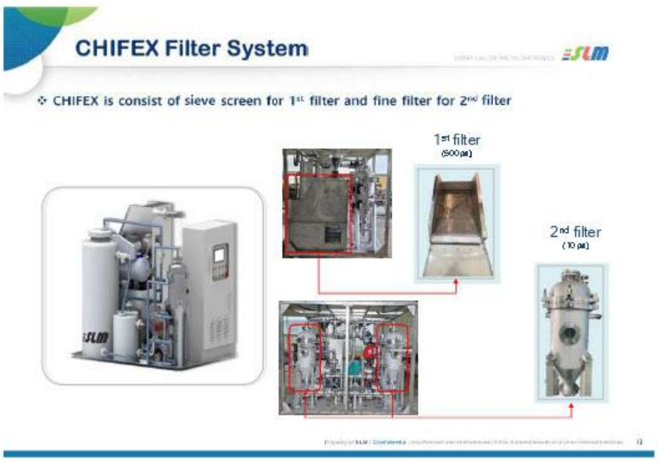

Technology Introduction
SLM Global has two systems of CHIRO and CHIFEX which are the most compact solution
CHIRO
Robot System for hull cleaning
CHIFEX
Filter system for contaminated water
Size (m) | Weight (kg) | Working Speed (m/sec) | Current Speed (knots)
1.6 x 0.3 x 0.6 | 250 | 0.5 (1 knot) | 3 max.
Size (m) | Weight (kg) | Capability (ton/hrs.) | Filter Availability (μm)
2.2 x 1.6 x 2.0 | 1,500 | 15 max. | 10 min.

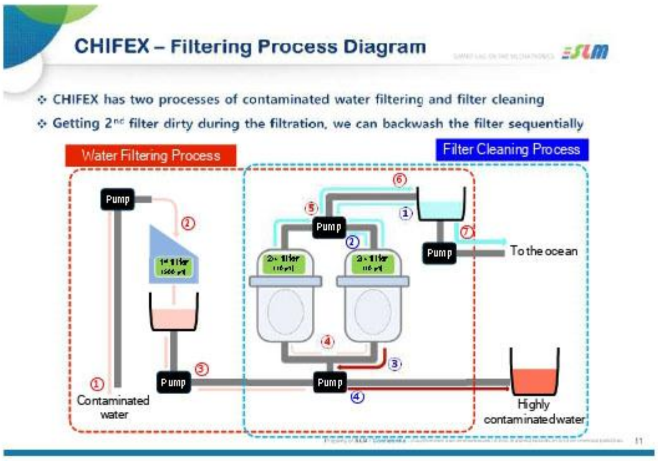

CHIRO Technology
Working stably in fast current
Monitoring the location, path and status in real time
Reporting overall work results
Stable Working in fast current(3 knots)
Front Current
Lateral Current
Force
3 Knots
Monitoring the location, path and status in real time with various sensors.
Front camera
Rear camera
Communication status
Robot operation status
Robot Location
<Console Screen>
Reporting overall work results.

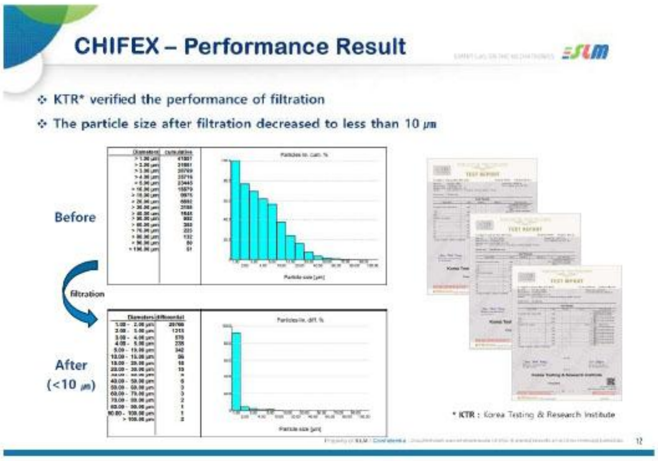

CHIRO Technology
Minimizing the loss of AF coating through various types of brush and brush force control
Providing various types of brush
Soft
Hard
Brushing Force Control
< Shear force control with Up/down >
<Tilting control>


CHIRO Technology
Major paint maker confirmed the loss of AF coating acceptable(less than 5μm)
Initial State
Measuring Initial DFT*
625 points
(Qnix 7500 DFT gauge)
Immersion
Seawater Immersion
For 1 year
Cleaning
Measuring Final DFT
After cleaning and drying
* DFT: Dry Film Thickness
APPROVAL OF HULL CLEANING COMPANY
SLM GLOBAL


CHIRO Technology
Maximizing debris collection with the optimized design of skirt and collection module
Preventing debris spread
Analysis of skirt strength
Brush Rotation
Skirt Module
Debris Collection Module
Debris path
Outlet
Pump
Duct
Inlet
(Contaminated water)
Brush


CHIFEX Filter System
CHIFEX is consist of sieve screen for 1st filter and fine filter for 2nd filter
1st filter
(500 μm)
2nd filter
(10 μm)


CHIFEX – Filtering Process Diagram
SLM
CHIFEX has two processes of contaminated water filtering and filter cleaning
Getting 2nd filter dirty during the filtration, we can backwash the filter sequentially
Water Filtering Process
Filter Cleaning Process
Pump
Pump
Pump
Pump
Pump
To the ocean
Contaminated water
Highly contaminated water
11


CHIFEX – Performance Result
SLM
KTR* verified the performance of filtration
The particle size after filtration decreased to less than 10 ㎛
Before
filtration
After
(<10 ㎛)
* KTR : Korea Testing & Research Institute
12


History of Hull Cleaning
SLM
SLM Global has been providing Hull Care Solutions to major customers in Korea
History
Year
Customer
Number of cleaning ships
2021
S company
10
2022
S company
15
2023
S company
16
2024
S company
17
H company
2
Photos of Working
Type of ships
Containers
Oil Tankers
LNG Carriers
Navy Ships
13


Vision
SLM
Providing the world best robot systems
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14

COLIN HENEIN

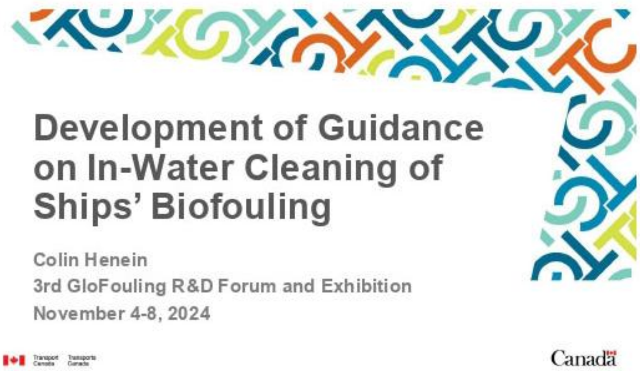
Director, Marine Protection, Environment Policy

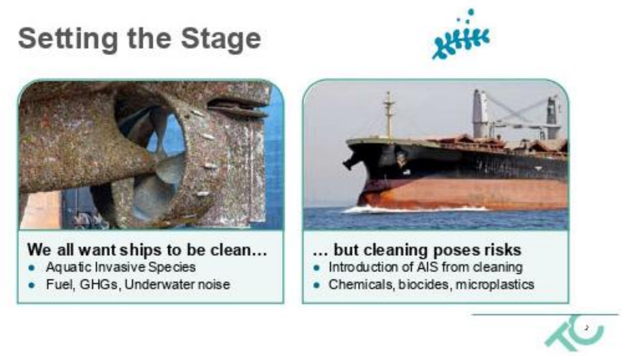
Transport Canada, Canada

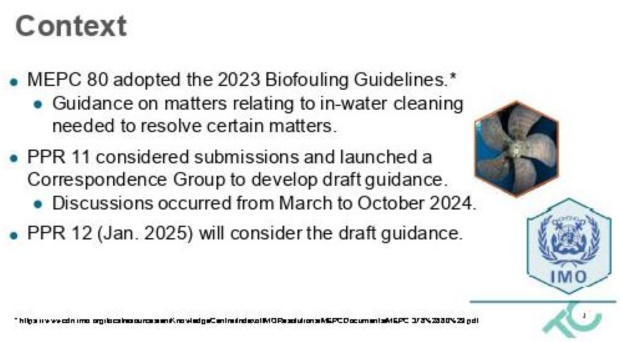
Colin Henein is the Director of Marine Protection within Transport Canada's Environmental Policy directorate. His policy responsibilities relate to biofouling, ship recycling, vessel garbage, marine protected areas as well as abandoned and derelict vessels. Colin is a longstanding member of Canada's delegation to the environmental committees of the International Maritime Organization (IMO). In 2024 he led the IMO's correspondence group on in-water cleaning of ships. Prior to accepting his current position, Colin spent 13 years at Transport Canada in positions of increasing responsibility regarding the ballast water of ships, water levels and flows, and work towards a network of Green Shipping Corridors. Colin holds an honours bachelor's degree in Computer Science and a Ph.D. in Cognitive Science. Outside of work, Colin is a community radio broadcaster and chairs the board of a local multicultural organisation that promotes the arts in schools and the community.

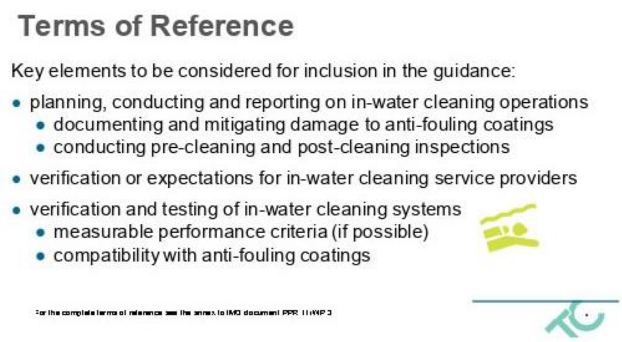
International Guidance on In-Water Cleaning

Presentation slides









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APPENDIX: In-Water Cleaning Request Form

Key Issues

- In-Water Cleaning Operations
- Approval of Cleaning Operations
- Minimum Performance Standard
- System Approval
- Coating Compatibility

In-Water Cleaning Operations

- Information on arranging and preparing cleaning, pre- and post-cleaning inspections, conduct of cleaning, and reporting and record-keeping
- Pre- and post-cleaning inspections may be conducted simultaneously with cleaning, if appropriate
- New concept of a **cleaning plan** to prepare for cleaning, to be developed by the service provider with input from the ship
- Plan may be approved by a relevant authority if required by local regulations and requirements

Approval of Cleaning Operations

- Considerations for relevant authorities that approve:
  - **In-Water Cleaning Service Providers**
    (Testing, locations, safety, training, etc.)
  - **Ship Cleaning Requests**
    (Coating, operational profile, fouling, records, etc.)
- Annexed *In-Water Cleaning Request Form*

Minimum Performance Standard

- Clean surfaces having a fouling rating ≤ 1
- Not visibly damage compatible coating types
- Cleaning without capture:
  - not significantly increase dissolved biocides, particulate biocides, plastics or microplastics near the cleaning unit, relative to ambient levels
- Cleaning with capture:
  - not significantly increase TSS, dissolved biocides, particulate biocides, plastics or microplastics near the cleaning unit, relative to ambient levels
  - only release captured particles, including organisms, that are less than 10 μm

Further discussion is expected on the meaning of "ambient levels", and whether specific scientific methods should be developed to assess the standard.

System Approval

- Guidance proposes a multi-phase assessment:
  - Readiness
  - Planning
  - Testing
  - Evaluation and Reporting
- Provides guidance to relevant authorities that choose to approve in-water cleaning systems
- Recommends independent, science-based decision making

Further discussion is expected on whether to reference scientific methods in ISO 20679, which are in development.

Coating Compatibility

- Compatibility of IWCS with ship coatings, considering the fouling rating.
- Recommended process for providing assurance of compatibility, and what data and testing this assurance should be based upon.
- Guidance outlines the roles and responsibilities of:

Coating Manufacturers | IWCS Manufacturers | Service Providers | Ships

Further discussion is expected on whether to develop a specific scientific method to test the compatibility between IWCS and coating types.

Next Steps

Finalization at PPR 12

- A Working Group should discuss the issues noted above, and:
  - Disinfection of IWCS effluent
  - Cleaning local macrofouling from hard non-biocidal coatings without capture
  - Duration of video storage onboard ship
  - Keeping the Guidance under review

Current Knowledge Gaps

- Data to support matters such as:
  - protectiveness of a 10 µm particle size limit
  - quantitative limits for other substances that may be released during cleaning
  - quantifying acceptable coating wear

Thank you

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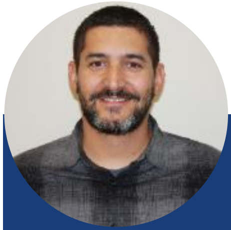
CHAIR OF THE SESSION

JON STEWART

Moderator

GloFouling R&D Forum



CHRIS SCIANNI

Environmental Program Manager, Marine Invasive Species Program

California State Lands Commission, the United States

Chris Scianni is the Environmental Program Manager for the California State Lands Commission's Marine Invasive Species Program, managing and providing support for the science policy and data management teams while coordinating with field inspectors spread across California. Chris is also the chair of the Coastal Committee of the Western Regional Panel on Aquatic Nuisance Species and helps to facilitate collaborative discussions between invasive species prevention, management, and control programs across the western United States.

In-Water Cleaning (IWC): Implications for Environmental Stewardship

Chris Scianni, Mario Tamburri, Ralitsa Mihaylova and Eugene Georgiades

Biofouling of ship submerged surfaces directly impacts vessel performance and fuel efficiency and can have negative environmental consequences, including the increases in exhaust emissions and the release of non-indigenous species (NIS). While various approaches are used to manage ship biofouling (e.g., anti-fouling coatings, marine growth prevention systems, and vessel maintenance regimes), the approaches themselves may also pose environmental risks through the release of biofouling-associated NIS and coating-associated biocides and microplastics.

Focusing on ship in-water cleaning (IWC) as a vessel biofouling management activity, this presentation will highlight recent advances and current knowledge gaps and propose a more holistic framework for environmental stewardship related to commercial shipping.

Keywords: biofouling, in-water cleaning, non-indigenous species, environmental risks

Presentation slides

Lots of IWC Guidance/Regulatory Activity

- IMO Biofouling Guidelines (2023)
- IMO IWC Guidelines (in preparation)
- ISO Standards in development (ISO TC 8/SC 2/WG 13)
  - Conducting IWC (ISO 6391, in preparation)
  - Testing IWC (ISO 20679, near-final)
- Australia AF and IWC Guidelines (exposure draft)
- Norway IWC regulations (in preparation)
- U.S. EPA VIDA (final rule adopted in September)

What are our goals?

Biofouling

- Reduce economic, environmental, and human health consequences
- Facilitate the operation of clean and efficient ships

What are our goals?

In-Water Cleaning

- Avoid environmental degradation
  - Decouple the consequences from the action
- Enable responsible IWC operations
- Facilitate technology innovation by being transparent and predictable
- Regulators need to be aware of the full suite of consequences when setting policy

Consequences of In-Water Cleaning

Nonindigenous species/Biosecurity

- Spawning, larvae, fragmentation, intact organisms, pathogens
- Removal, capture, treatment

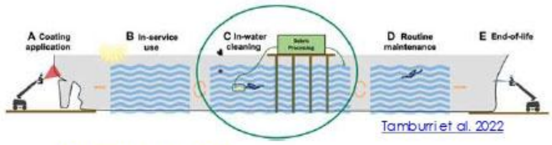
Consequences of In-Water Cleaning

Biocides/Water Quality

- Tamburri et al. 2020 (1 vessel)
  - *Macrofouling*; After filtration (5 μm)
  - Dissolved Cu: 273.3 μg/L
  - Dissolved Zn: 1,354 μg/L
- Soon et al. 2021 (4 vessels)
  - *Mostly microfouling*; no filtration
  - Dissolved Cu: 63.7 – 365 μg/L
  - Dissolved Zn: 224.4 – 3,821 μg/L
- Soon et al. 2023 (5 vessels)
  - *Microfouling*; after filtration (1-10 μm)
  - Dissolved Cu: 12.3 – 314 μg/L
  - Dissolved Zn: 35.4 – 2,195 μg/L

Consequences of In-Water Cleaning

Microplastics/Water Quality



- Tamburri et al. 2022
- Soon et al. (in review)

Consequences of In-Water Cleaning
Sediment Quality


'Clamshell dredging in New York and New Jersey Harbor' by USACE NY is licensed under CC BY 2.0

- Accumulation of biocides/microplastics
- Dredging operations
  - Resuspension
  - Redistributing
  - Depth limits leading to increased frequency

Consequences of In-Water Cleaning
Facilitating NIS establishment

Creating conditions that are conducive to establishment of nonindigenous species

- Copper contaminated ports facilitate success of copper tolerant species
  - Piola and Johnston 2006, 2007

Consequences of In-Water Cleaning
Coating Damage and Vessel Efficiency Loss

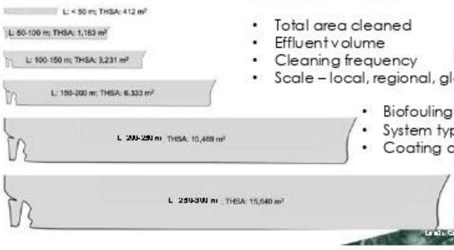
- Oliveira and Granhag 2020
- Tamburri et al. 2020
- Swain et al. 2022

Tamburri et al. 2020

Consequences of In-Water Cleaning
Human Health Impacts

- Diver safety
  - Ship traffic
  - Recesses
  - Suction
  - Visibility
  - Swell
  - Low clearance

Factors that Influence Risk

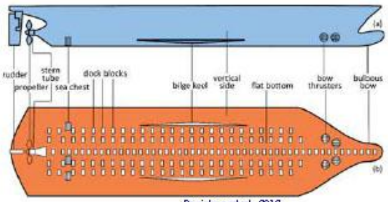


- Total area cleaned
- Effluent volume
- Cleaning frequency
- Scale – local, regional, global
  - Biofouling extent
  - System type
  - Coating age/condition

Types of In-Water Cleaning

Reactive | 1° treatment | 2° treatment
Proactive | Without capture | With capture
Proactive with biocide-free coating | Diver-driven | In-transit
Remotely operated | Others
Autonomous | Brushes | Water jets | Offshore

Niche Areas



Davidson et al., 2018

Policy Implications

- Existing approaches = varying levels of risk reduction
  - Some may reduce risk for once concern at expense of another
- Policymakers need to be aware of full suite of risks to make fully informed and transparent decisions

Policy Implications

- Embracing gains now based on current technologies can reduce risks in real time
- Continue making progress by incentivizing innovation

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THANK YOU & QUESTIONS

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I am engaged in research on marine robotics, with a particular focus on underwater robots. My work has involved various studies on perception and cognition in underwater environments, utilizing these capabilities for localization and SLAM (Simultaneous Localization and Mapping). Building on this foundation, I have conducted research on the autonomous control and operation of box-type and torpedo-type underwater vehicles.
Recently, my research has expanded to explore the interaction between robots and underwater environments. This includes work on force control in underwater manipulation, the locomotion control of hexapod robots, and remote control systems for underwater operations.

Development of an Autonomous Cleaning Method Based on a Manipulator for the Niche Area of Ship Hull

Daegil Park, Jong-Boo Han, Teakyeong Yeu, Su-gil Cho, Seongsoon Kim, Hyungwoo Kim, Yeongjun Lee

Fouling organisms reduce the fuel efficiency of ships and disrupt the ecosystem.

As a result, the International Maritime Organization (IMO) and many countries have enacted legislation requiring regular hull cleaning to remove fouling organisms. However, the crevice area of a hull is very difficult to clean. Due to its complex shape, it is difficult to apply antifouling paint and clean with a hull cleaning robot, but about 80% of fouling organisms are concentrated in the crevice area. To solve this problem, this study proposes an autonomous cleaning robot with a multi-joint robot arm to clean the crevice area of a hull.

This study proposes an underwater cleaning robot method using the position control of a hydraulic manipulator and a force control technique using an electric manipulator.

The hydraulic manipulator can access the complex-shaped hull crevice using a multi-joint arm. It is designed to scan the area to be cleaned, make a cleaning plan, and clean it accordingly. The robot autonomously cleans a propeller blade, a typical hull crevice, to verify the applicability of this system.

As an ongoing research, an electric manipulator is conducting a study on cleaning the hull by using force control as a method to solve the problem of inaccurate recognition underwater. By using the manipulator's torque control to push and clean the hull with a constant force, we confirmed stable hull surface tracking performance even in an environment where the hull recognition conditions are unclear.

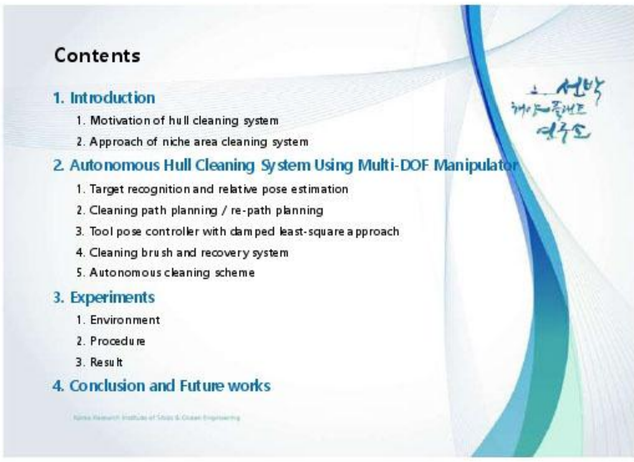
The hydraulic manipulator has a multi-joint arm to access the complex hull crevice. It is designed to scan the area to be cleaned, create a cleaning plan, and clean it accordingly. The robot autonomously cleans a propeller blade, a typical hull crevice, to verify the applicability of this system.

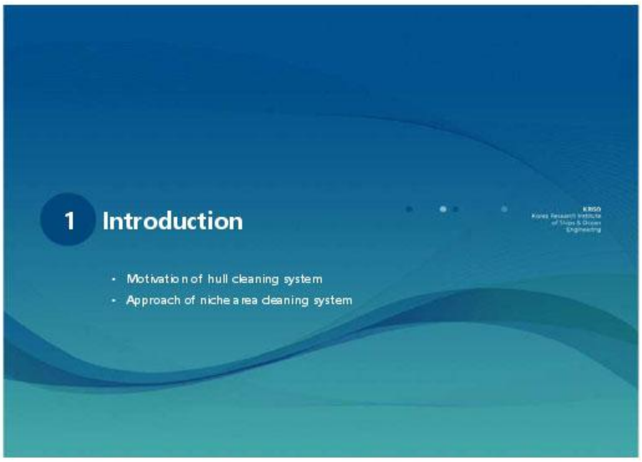
Ongoing research is investigating an electric manipulator to follow the hull section using force control in an imprecise hull detection environment as a way to solve the underwater precision detection problem.

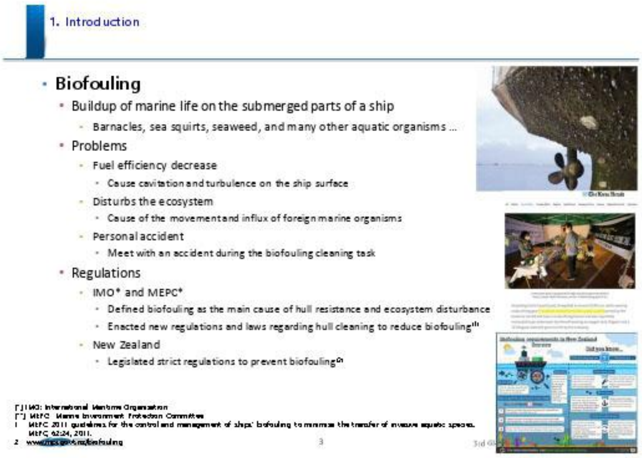
Figure 1. Multi-degree-of-freedom manipulator-based hull crevice cleaning system

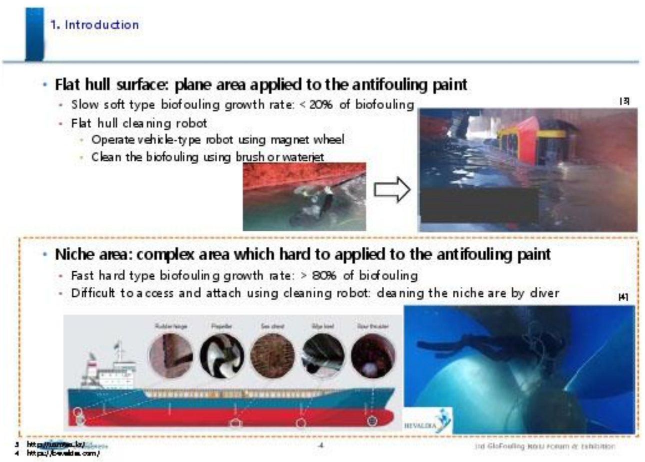
Keywords: biofouling; hydraulic manipulator; autonomous cleaning system; path planning; ship; hull niche area; laser scanning.

Presentation slides

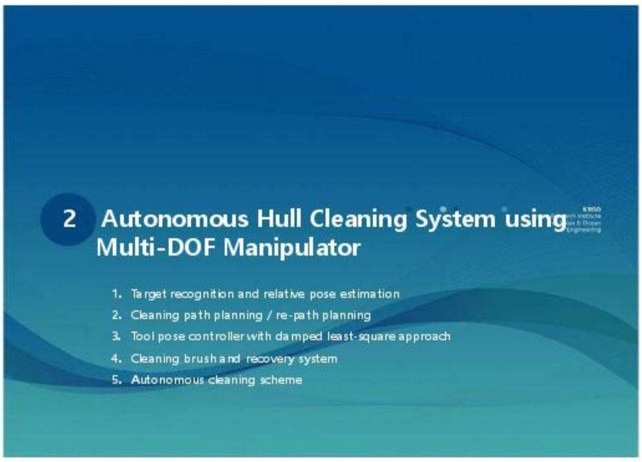


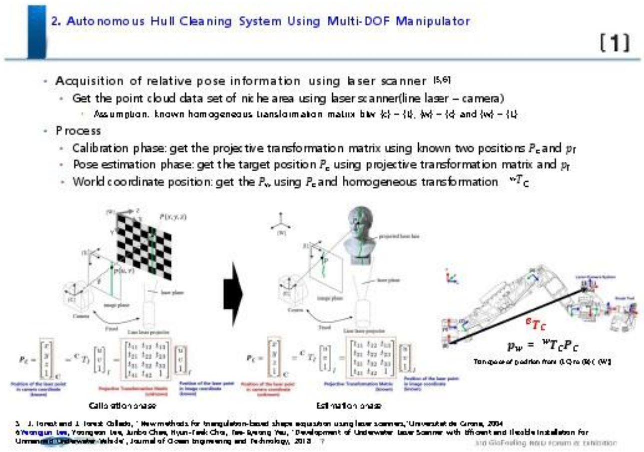


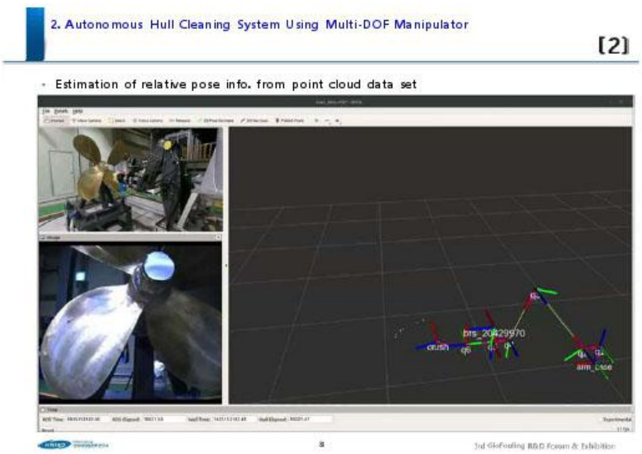


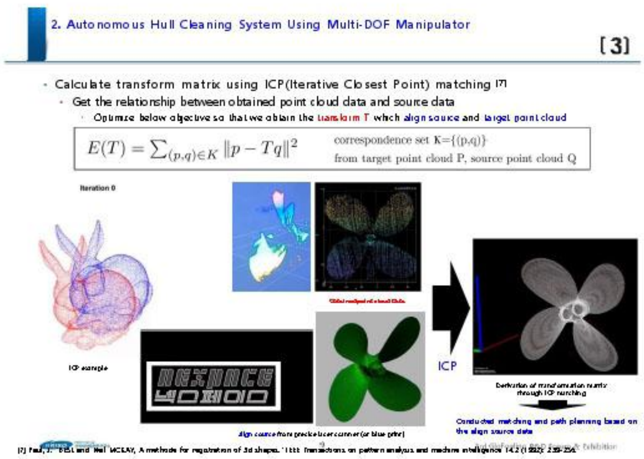

1. Introduction
Flat hull surface: plane area applied to the antifouling paint
Slow soft type biofouling growth rate: < 20% of biofouling
Flat hull cleaning robot
Operate vehicle-type robot using magnet wheel
Clean the biofouling using brush or waterjet
[3]
[redacted]
Niche area: complex area which hard to applied to the antifouling paint
Fast hard type biofouling growth rate: > 80% of biofouling
Difficult to access and attach using cleaning robot: cleaning the niche are by diver
[4]
4 https://hevaldia.com/


1. Introduction: Approach
Autonomous niche area perception and cleaning system using a multi degree-of-freedom hydraulic manipulator
Minimize human intervention
Access to complex shapes niche areas
Ensuring sufficient force for cleaning
Required skills
1. Niche area access and precise relative pose estimation
2. Cleaning path planning (w.r.t full coverage, collision/singular avoidance)
3. Hydraulic manipulator controller
4. Cleaning and biofouling recovery system
5. Autonomous cleaning manager
6. Proposed system verification
Approach
1. Laser scanner with manipulator (w/ ICP)
2. Full coverage path planner and collision check with dynamic simulator(DAFUL)
3. Joint trajectory planning and velocity controller
4. Cleaning brush and recovery system
5. Cleaning scheme consisting of recognition, planning and cleaning
6. Robot hardware and experimental environment setup for verification
Autonomous niche area cleaning system


2 Autonomous Hull Cleaning System using Multi-DOF Manipulator
1. Target recognition and relative pose estimation
2. Cleaning path planning / re-path planning
3. Tool pose controller with damped least-square approach
4. Cleaning brush and recovery system
5. Autonomous cleaning scheme

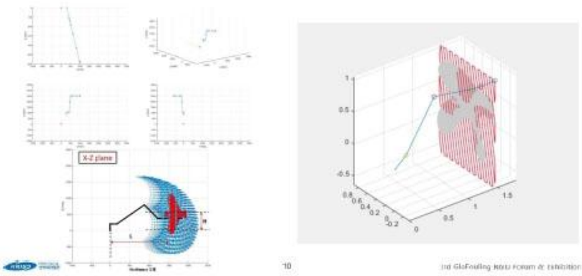

2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator
[1]
Acquisition of relative pose information using laser scanner [5,6]
Get the point cloud data set of niche area using laser scanner(line laser – camera)
Process
Calibration phase: get the projective transformation matrix using known two positions P_c and p_I
Pose estimation phase: get the target position P_c using projective transformation matrix and p_I
World coordinate position: get the P_w using P_c and homogeneous transformation ${}^{w}T_C$
$p_w = {}^{w}T_C P_C$
Calibration phase
Estimation phase
5. J. Forest and J. Forest Collado, "New methods for triangulation-based shape acquisition using laser scanners," Universitat de Girona, 2004
6 Yeongjun Lee, Yeongwon Lee, Junbo Choi [?], Hyun-Taek Choi, Tae-Kyeong Yeu, "Development of Underwater Laser Scanner with Efficient and Flexible Installation for Unmanned Underwater Vehicle", Journal of Ocean Engineering and Technology, 2018


2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator
[2]
Estimation of relative pose info. from point cloud data set


2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator
[3]
Calculate transform matrix using ICP(Iterative Closest Point) matching [7]
Get the relationship between obtained point cloud data and source data
Optimize below objective so that we obtain the transform T which align source and target point cloud
$E(T) = \sum_{(p,q)\in K} \|p - Tq\|^2$
correspondence set K={(p,q)}
from target point cloud P, source point cloud Q
Iteration 0
ICP example
ICP
Derivation of transformation matrix through ICP matching
Conducted matching and path planning based on the align source data
Align source from precise laser scanner (or blue print)
[7] Paul, J. BESL and Neil MCKAY, A methode for registration of 3d shapes. IEEE Transactions on pattern analysis and machine intelligence 14.2 [illegible]: 239-256.

2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator [1]

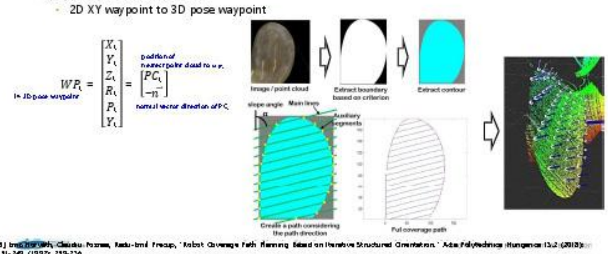
- Workspace analysis
  - Forward kinematics analysis for workspace
    - Print the end-effector position along to the each joint angle
  - Inverse kinematics analysis for workspace
    - Controllability check using inverse kinematics for the desired pose with constraints
  - Get the relative length and height between robot base and target niche area



2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator [2]

- ROI extraction and full coverage path planning
  - Extract Region of Interest (ROI)
    - Contour-based boundary extraction (criterion: depth, color)
  - Full coverage path planning [3]
    - Setup the main line angle and interval
    - Checking the cross point with margin
    - Connecting the nearby mainlines considering the cleaning direction
  - Waypoint dimension extension
    - 2D XY waypoint to 3D pose waypoint

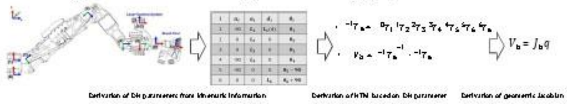
$$WP_i = \begin{bmatrix} X_i \\ Y_i \\ Z_i \\ R_i \\ P_i \\ Y_i \end{bmatrix} = \begin{bmatrix} PC_i \\ -\vec{n} \end{bmatrix}$$



[3] Imre Horváth, Claudiu Pozna, Radu-Emil Precup, "Robot Coverage Path Planning Based on Iterative Structured Orientation." Acta Polytechnica Hungarica 15.2 (2018): 231-249. (1992): 230-236.

2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator [3]

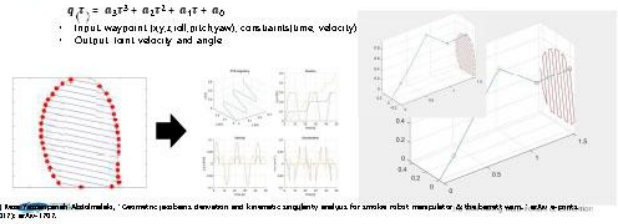
- Joint space trajectory generation
  - Derivate Homogeneous Transformation Matrix (T), Jacobian matrix (J_b, J_b^{-1})) [4]



  - Cubic polynomial trajectory planning : 4 coefficients > 3th order polynomial.

$$q(\tau) = a_3\tau^3 + a_2\tau^2 + a_1\tau + a_0$$

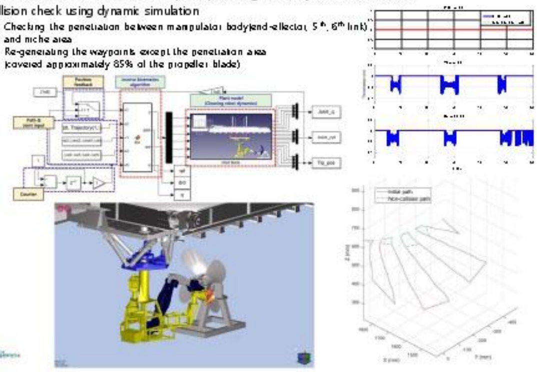
- Input: waypoint (x,y,z,roll,pitch,yaw), constraints(time, velocity)
- Output: Joint velocity and angle



[4] Reza Yazdanpanah Abdolmalaki, "Geometric Jacobians derivation and kinematic singularity analysis for smokie robot manipulator & the barrett wam." arXiv e-prints (2017): arXiv-1707.

2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator [4]

- Collision check and non-collision path planning with dynamic simulation
  - Collision check using dynamic simulation
    - Checking the penetration between manipulator body(end-effector, 5th, 6th link) and niche area
    - Re-generating the waypoints except the penetration area (covered approximately 85% of the propeller blade)



2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator

- Velocity controller design
  - Joint space velocity controller

$$V_b = J_b \dot{q}$$

$$\dot{q} = J_b^{-1}\left\{\begin{pmatrix} R^T \dot{r}_d \\ R^T R_d \Omega_d \end{pmatrix} - \begin{pmatrix} R^T K_t (r - r_d) \\ B(\tilde{\epsilon}) K_r \tilde{\epsilon} \end{pmatrix}\right\}$$

$$\begin{pmatrix} R^T \dot{r} \\ \Omega \end{pmatrix} = \begin{pmatrix} R^T \dot{r}_d \\ R^T R_d \Omega_d \end{pmatrix} - \begin{pmatrix} R^T K_t (r - r_d) \\ B(\tilde{\epsilon}) K_r \tilde{\epsilon} \end{pmatrix}$$

- Translation
  $(\dot{r} - \dot{r}_d) + K_t (r - r_d) = 0$
- Orientation
  $\Omega - R^T R_d \Omega_d + B(\tilde{\epsilon}) K_r \tilde{\epsilon} = \dot{\tilde{\epsilon}} + K_r \tilde{\epsilon} = 0$

- Joint – workspace translation
  - $V_w = \begin{bmatrix} R & 0 \\ 0 & B \end{bmatrix} J_b(q) \dot{q}$
  - $\dot{q} = \begin{bmatrix} R^T & 0 \\ 0 & B^{-1} \end{bmatrix} J_b(q)^{-1} V_w$
  - World Angular velocity

$$\begin{pmatrix} \Omega_1^b \\ \Omega_2^b \\ \Omega_3^b \end{pmatrix} = \begin{bmatrix} 1 & 0 & -\sin\theta \\ 0 & \cos\phi & \cos\theta\sin\phi \\ 0 & -\sin\phi & \cos\phi\cos\theta \end{bmatrix} \begin{pmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{pmatrix}$$

$$\underset{\dot{q}}{Find} \|\dot{p} - J(q)\dot{q}\|, \quad \text{Sol.} : \dot{q} = J(q)^{-1}\dot{p}$$

2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator

- SVD approach to solve singular problem (Damped LS solution)
  - Singularity check using singular value decomposition (SVD) to prevent infeasible joint velocities near singular configurations when calculating the inverse kinematics of the manipulator
    - Singularity check using SVD

Controller: $\underset{q}{Find} \|\dot{p} - J(q)\dot{q}\|$ Sol. : $\dot{q} = J(q)^{-1}\dot{p}$

Where, Jacobian matrix can be decomposed

$J = U\Sigma V^{-1}$

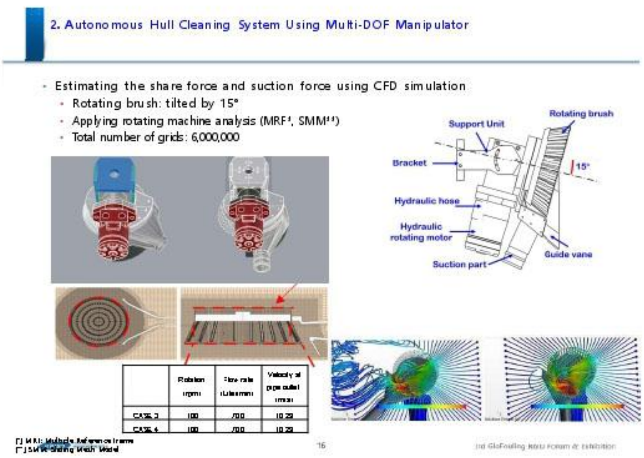
$J^{-1} = V\Sigma^{-1}U^{-1}$

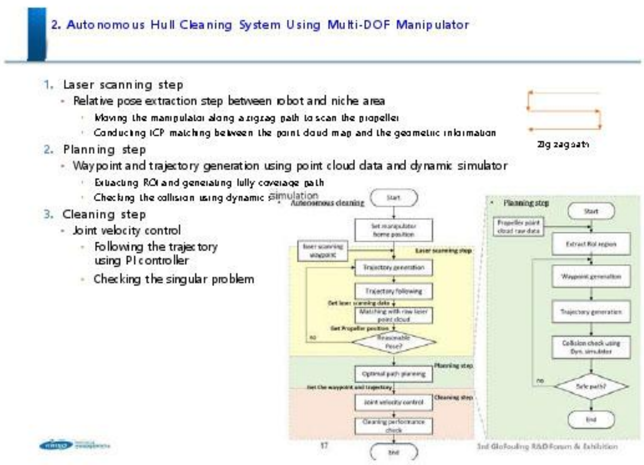
rectangular diagonal matrix

- Damped LS solution approach: change the solution to converge the joint velocity input $\dot{q}$

$$\underset{q}{Find} \|\dot{p} - J(q)\dot{q}\| + \lambda^2 \|\dot{q}\|$$

- Prevent the divergence using damped LS solution


2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator
Estimating the share force and suction force using CFD simulation
Rotating brush: tilted by 15°
Applying rotating machine analysis (MRF*, SMM**)
Total number of grids: 6,000,000
Support Unit
Rotating brush
Bracket
15°
Hydraulic hose
Hydraulic rotating motor
Suction part
Guide vane
16
3rd GloFouling R&D Forum & Exhibition


2. Autonomous Hull Cleaning System Using Multi-DOF Manipulator
1. Laser scanning step
Relative pose extraction step between robot and niche area
Moving the manipulator along a zigzag path to scan the propeller
Conducting ICP matching between the point cloud map and the geometric information
Zig zag path
2. Planning step
Waypoint and trajectory generation using point cloud data and dynamic simulator
Extracting ROI and generating fully coverage path
Checking the collision using dynamic simulation
3. Cleaning step
Joint velocity control
Following the trajectory using PI controller
Checking the singular problem
Autonomous cleaning
Planning step
Start
Set manipulator home position
Laser scanning step
Trajectory generation
Trajectory following
Reasonable Pose?
Optimal path planning
Joint velocity control
Cleaning step
Cleaning performance check
End
Extract RoI region
Waypoint generation
Trajectory generation
Collision check using Dyn. simulator
Safe path?
17
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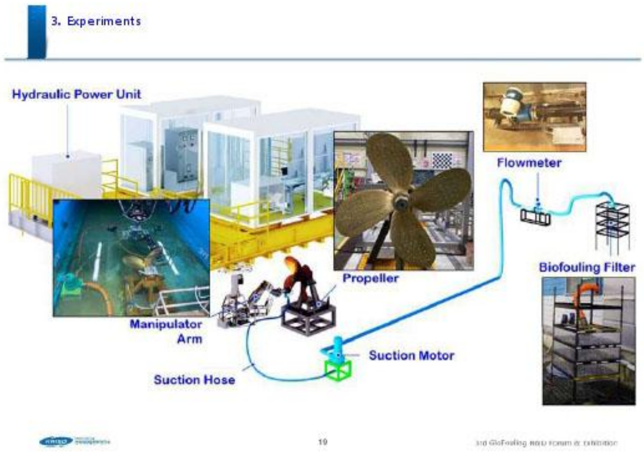
3 Experiments
1. Environment
2. Procedure
3. Result


3. Experiments
Hydraulic Power Unit
Flowmeter
Biofouling Filter
Propeller
Manipulator Arm
Suction Motor
Suction Hose
19
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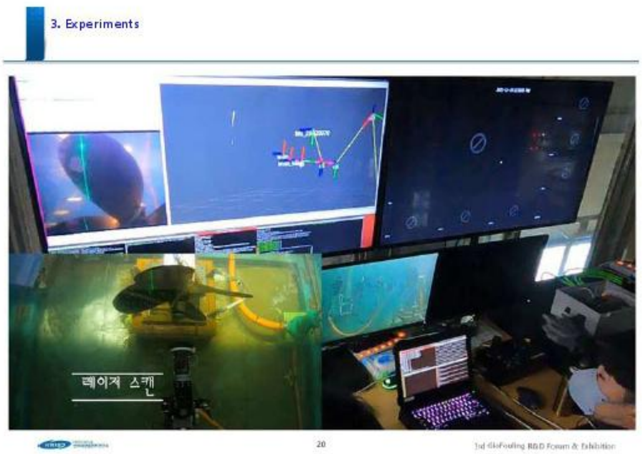
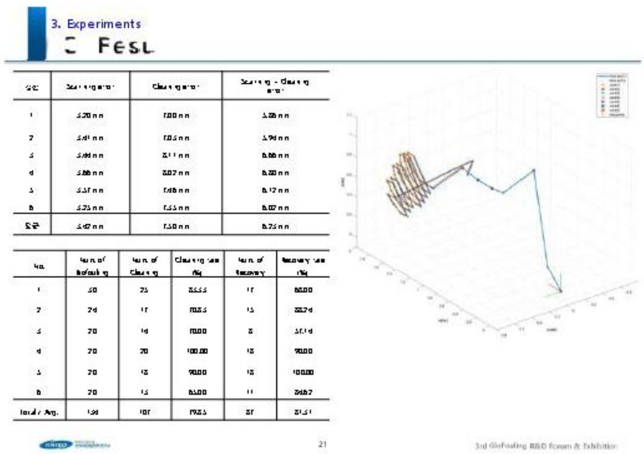
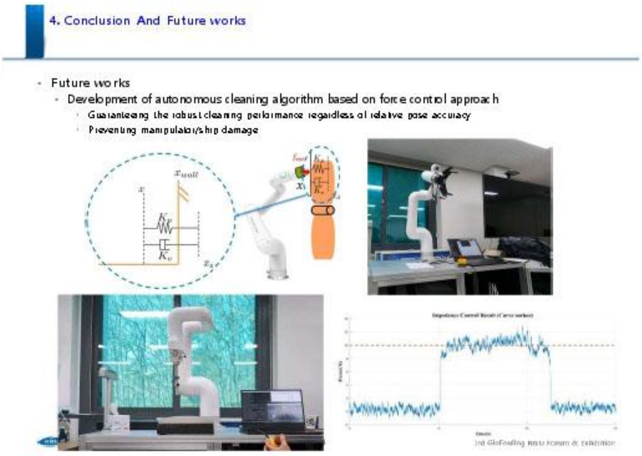
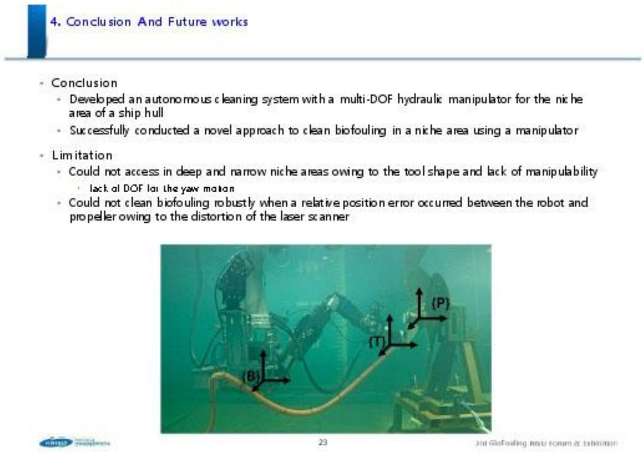

3. Experiments
레이저 스캔
20
3rd GloFouling R&D Forum & Exhibition


3. Experiments
21
3rd GloFouling R&D Forum & Exhibition


4. Conclusion And Future works
Future works
Development of autonomous cleaning algorithm based on force control approach
Guaranteeing the robust cleaning performance regardless of relative pose accuracy
Preventing manipulator/ship damage
3rd GloFouling R&D Forum & Exhibition


레이저 스캔
Thank you


4 Conclusion And Future Works


4. Conclusion And Future works
Conclusion
Developed an autonomous cleaning system with a multi-DOF hydraulic manipulator for the niche area of a ship hull
Successfully conducted a novel approach to clean biofouling in a niche area using a manipulator
Limitation
Could not access in deep and narrow niche areas owing to the tool shape and lack of manipulability
lack of DOF for the yaw motion
Could not clean biofouling robustly when a relative position error occurred between the robot and propeller owing to the distortion of the laser scanner
{P}
{T}
{B}
23

ÅGE HØJMARK

CEO

Shipshave, Norway

Åge Højmark holds both an MSc in engineering and an MBA. He has 15 years experience in the Maritime industry.

Serving in various international senior leadership roles both with vessel owner/operators and equipment suppliers including Seadrill and Rolls-Royce Marine have provided an in-depth understanding of the industry.

He is genuinely interested in the transition to a sustainable future and the green transition within shipping and is currently serving as the Chief Executive Officer of Shipshave.
In this role the primary focus is on vessel performance optimization and the challenges associated with biofouling.

Hull performance, going from extrapolation and interpretation to big data

Rune Freyer

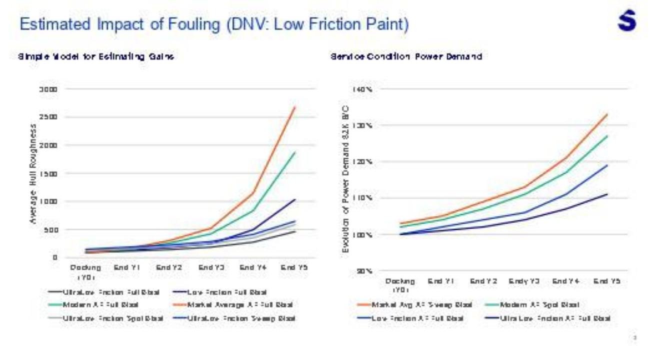
Ship operators interprets hull performance through multiple inaccurate measurements, sometimes noon reports corrected for current, wind, waves, engine conditions and trim. Other times assessments are based on blurry videos from ROVs without scale and with subjective interpretations. A 330meters long, 250.000ton ship guzzling 80ton of fuel a day has less accurate energy management than the Authors Tesla car. The key in operational performance management is the roughness of the surface. To prepare for information driven management with clean data, a new submerged roughness sensing methodology was proven.

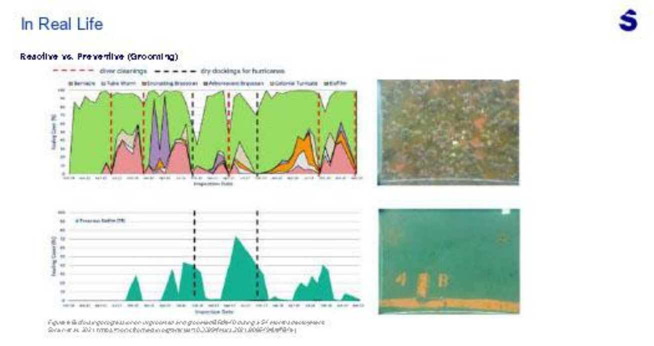
In a case study a hull cleaning method of a newly diver cleaned Handymax vessel was evaluated. 216,000 roughness measurements were successfully made of the submerged surface and analyzed. Normally the industry would expect the paint roughness to increase after cleaning.

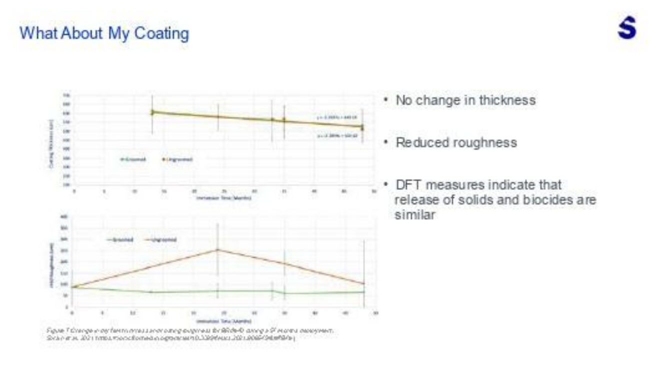
An unpredicted outcome was that the hull paint itself had reduced roughness after being cleaned, meaning that the hull cleaning had a polishing effect. This will reduce the fuel consumption. Neither design processes, lab tests, visual inspections, manual roughness measurements nor traditional fuel efficiency interpretation could capture these findings and create such a holistic data set. Due to the measurement methods ease of use, many other applications can be envisaged, even down to monthly performance management and biofouling management documentation.

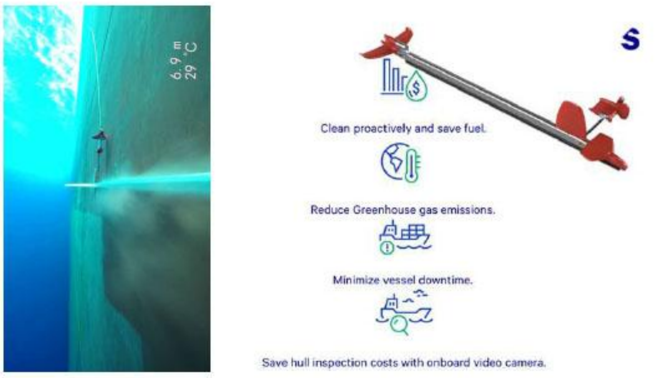
Keywords
Roughness# Big data #hull performance #performance monitoring #fouling #fuel efficiency #in transit hull cleaning

Presentation slides



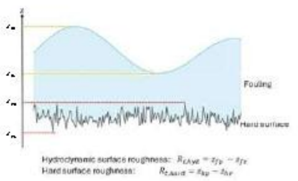






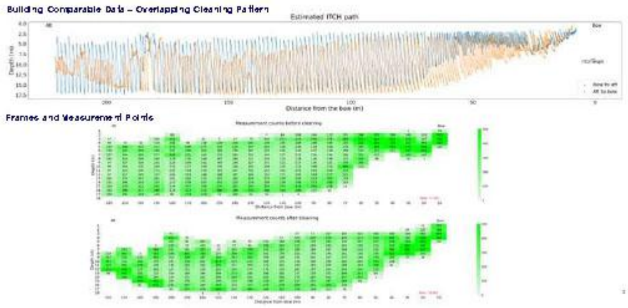
Measuring Roughness

- Hydrodynamic surface roughness
  - Surface in direct contact with water
  - To be validated by further testing and improvement of data models
- Hard surface roughness
  - Surface of paint/metal and calcareous deposits
  - Internally validated by testing



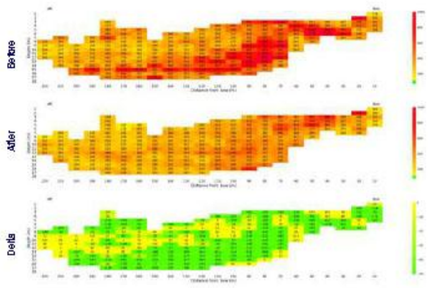
The Law of Large Numbers

Building Comparable Data – Overlapping Cleaning Pattern



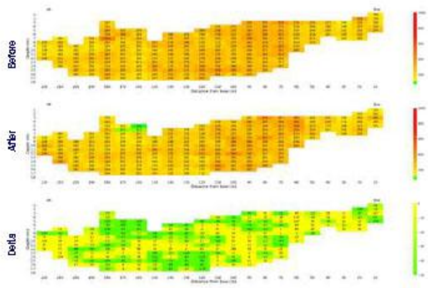
Hydrodynamic Surface Roughness

Average hull roughness		
Before cleaning	After cleaning	Improvement
456 µm	326 µm	[illegible]

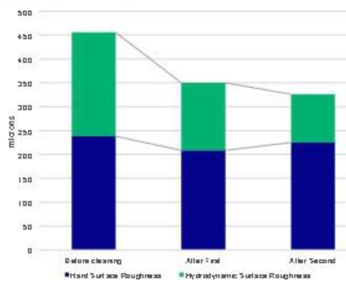


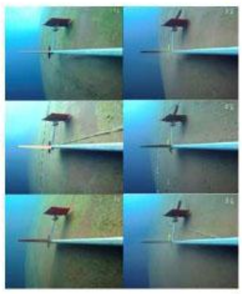
Hard Surface Roughness

Average hull roughness		
Before cleaning	After cleaning	Improvement
238 µm	225 µm	[illegible]



Visual Confirmation





DR. SANG-HO PARK

Team Leader and General Manager

Machinery system team, S & SYS, the Republic of Korea

I hold a Ph.D. in Environmental Engineering and have dedicated many years to research and development in the field of ballast water treatment systems and biofouling management. I have over a decade of experience at Samsung Heavy Industries, where I was responsible for R&D initiatives. Currently, I lead the research and design efforts for ballast water treatment systems and hull biofouling management technologies at S&SYS.

Assessment of Operational Performance to Onshore Treatment Facilities for Ship Biofouling Washing Wastewater

Sangho Park

More than 83% of the world's freight flows is treated through maritime routes.

Every year, the increasing water volume makes it easy for invasive species to invade through ships.

Various marine organisms attached to the surface of ships cause significant damage annually. The attachment of marine organisms to ships increases resistance during navigation, leading to an increase in fuel consumption.

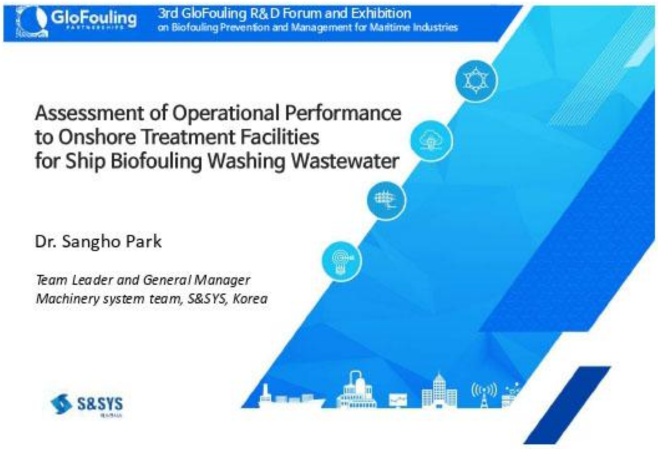
Consequently, more carbon is emitted during navigation, causing environmental pollution. The International Maritime Organization (IMO) continues to regulate ballast water and hull biofouling to prevent the invasive aquatic species in each port and maritime area. IMO has recently initiated revisions to guidelines for controlling and managing hull fouling, while New Zealand and California in the United States already regulate hull fouling management through national laws.

Technologies are needed in shipping companies and ports to remove various marine organisms attached to ships. Recently, various underwater cleaning technologies have been developed to remove organisms attached to hulls.

Cleaning robots effectively remove marine organisms attached to the surfaces of ships, which are currently under active research and development.

Subsequently, large amounts of wash wastewater containing marine organisms are generated. In this study, wash wastewater generated by cleaning robots is collected and transferred to onshore treatment facilities, where marine organisms contained within the wash water are effectively sterilized. The performance of onshore treatment facilities for ship wash wastewater is evaluated, and optimal treatment methods are proposed.

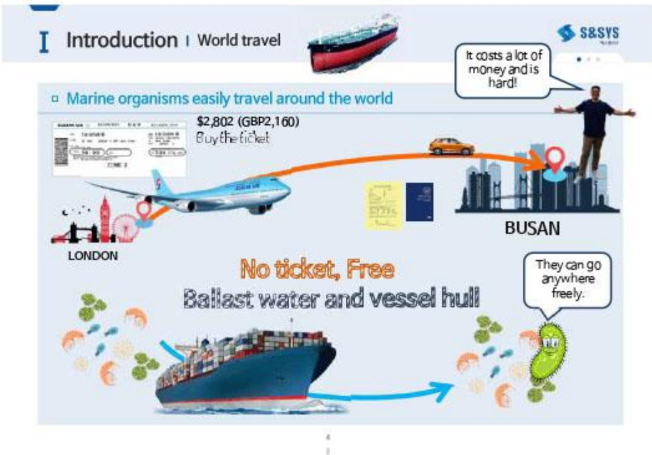
Keywords: Ballast water, Biofouling, Invasive Aquatic Species, Underwater Cleaning, IMO



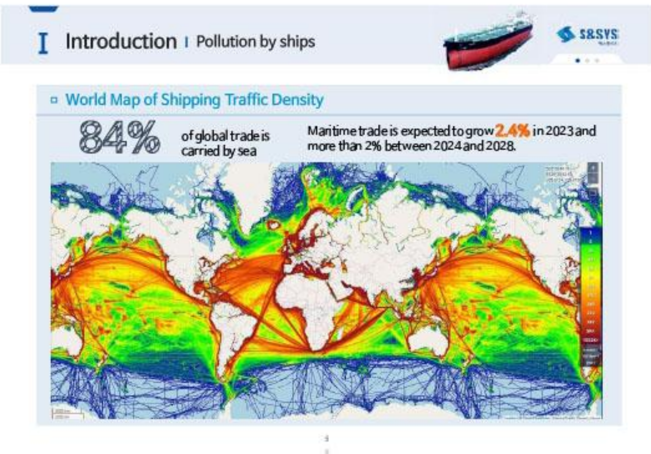
GloFouling
3rd GloFouling R&D Forum and Exhibition
on Biofouling Prevention and Management for Maritime Industries
Assessment of Operational Performance
to Onshore Treatment Facilities
for Ship Biofouling Washing Wastewater
Dr. Sangho Park
Team Leader and General Manager
Machinery system team, S&SYS, Korea
S&SYS

S&SYS
CONTENTS
CHAPTER I Introduction
CHAPTER II Methodology
CHAPTER III Results and discussions
CHAPTER IV Conclusion

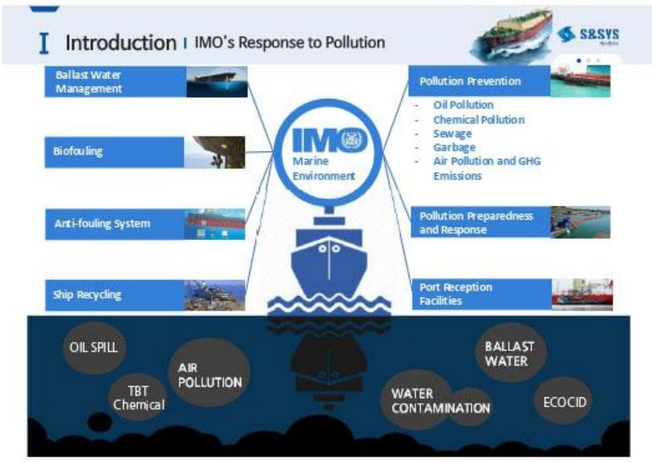
I Introduction | Dr. Sangho Park
S&SYS
WORK EXPERIENCE
S&Sys, 2018~Present : General Manager / Team Leader
Charge of Design and Development Part
(30 researchers and designers, More than 40 patents registered)
SAMSUNG HEAVY INDUSTRIES, 2007~2017 : Senior Manager
Charge of Development line (25 researchers and designers)
Managed 10 Projects (Ballast Water Management System, MGPS, Ballast Tank Paint Corrosion Test, Filter development, Electrolysis improve etc.)
Registration of a patent 41 (10-1122294 etc.)
Successfully deployed on a commercial scale : BWMS, Filter, Electrolysis etc.
Collaborated with marketing/PR agencies to promote major conferences
Korea Maritime University, 2006~2007 : Research professor
Carry out research projects : National Research Foundation of Korea
Lecture on Chemistry and Environmental Engineering to a class
SAMSUNG HEAVY INDUSTRIES
KOREA MARITIME AND OCEAN UNIVERSITY
EDUCATION
1994~2000 Korea Maritime University, Busan, KOREA Environmental Engineering, Faculty course
2000~2002 Korea Maritime University, Busan, KOREA Environmental Engineering, Master course
2002~2006 Korea Maritime University, Busan, KOREA Environmental Engineering, Doctor course
2019~2020 Korea Maritime University, Busan, KOREA Maritime Finance, Master course
ACHIEVEMENTS
Received the Korean Intellectual Property Office Award, 2022
SAMSUNG HEAVY INDUSTRIES : Wine prizes in SHI, 2012
SHI CEO Award of Honor 2011 and Patent MVP 2013
3



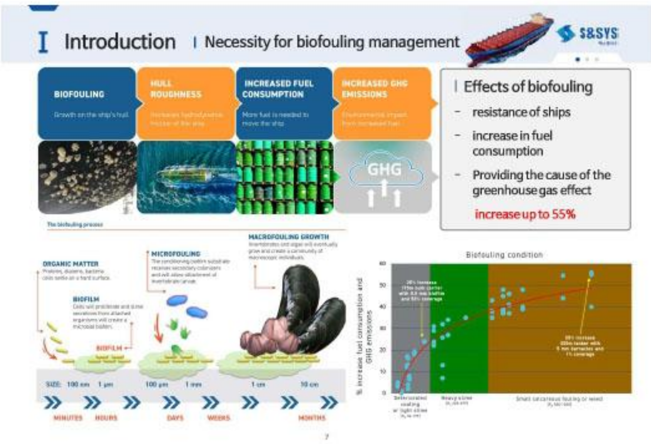
I Introduction | World travel
S&SYS
It costs a lot of money and is hard!
Marine organisms easily travel around the world
$2,802 (GBP2,160)
Buy the ticket
LONDON
BUSAN
No ticket, Free
Ballast water and vessel hull
They can go anywhere freely.
4

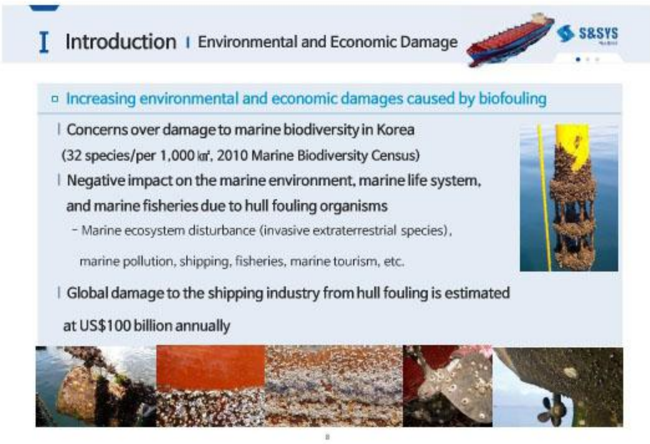


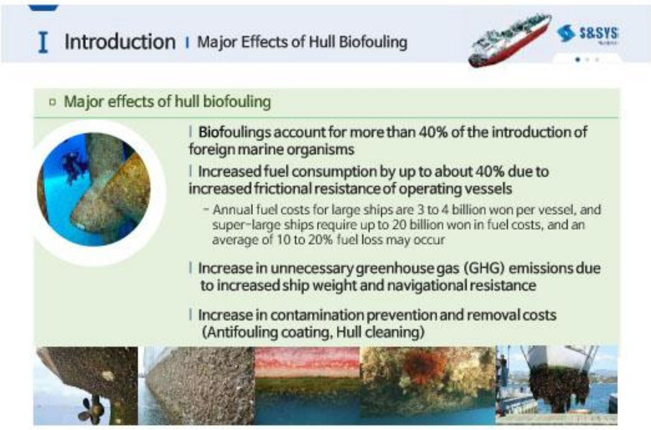
I Introduction | Pollution by ships
S&SYS
World Map of Shipping Traffic Density
84% of global trade is carried by sea
Maritime trade is expected to grow 2.4% in 2023 and more than 2% between 2024 and 2028.



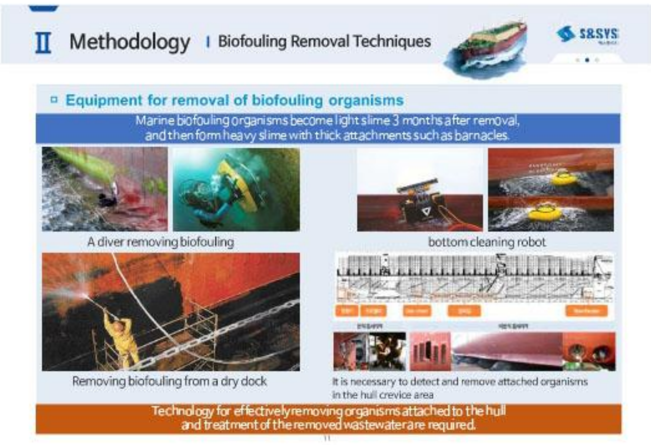
I Introduction | IMO's Response to Pollution
S&SYS
Ballast Water Management
Biofouling
Anti-fouling System
Ship Recycling
IMO
Marine Environment
Pollution Prevention
- Oil Pollution
- Chemical Pollution
- Sewage
- Garbage
- Air Pollution and GHG Emissions
Pollution Preparedness and Response
Port Reception Facilities
OIL SPILL
TBT Chemical
AIR POLLUTION
WATER CONTAMINATION
BALLAST WATER
ECOCID


Ⅰ Introduction | Necessity for biofouling management
S&SYS
BIOFOULING
Growth on the ship's hull
HULL ROUGHNESS
INCREASED FUEL CONSUMPTION
More fuel is needed to move the ship
INCREASED GHG EMISSIONS
GHG
| Effects of biofouling
- resistance of ships
- increase in fuel consumption
- Providing the cause of the greenhouse gas effect
increase up to 55%
The biofouling process
ORGANIC MATTER
MICROFOULING
MACROFOULING GROWTH
BIOFILM
SIZE: 100 nm 1 μm 100 μm 1 mm 1 cm 10 cm
MINUTES HOURS DAYS WEEKS MONTHS
Biofouling condition
% increase fuel consumption and GHG emissions

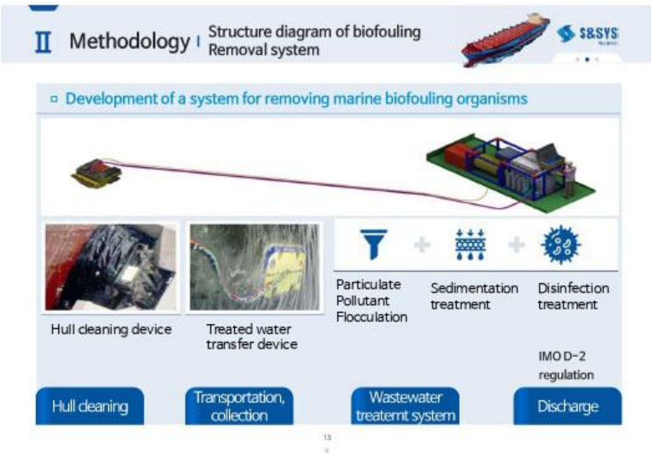

Ⅰ Introduction | Environmental and Economic Damage
S&SYS
□ Increasing environmental and economic damages caused by biofouling
| Concerns over damage to marine biodiversity in Korea
(32 species/per 1,000㎢, 2010 Marine Biodiversity Census)
| Negative impact on the marine environment, marine life system, and marine fisheries due to hull fouling organisms
- Marine ecosystem disturbance (invasive extraterrestrial species), marine pollution, shipping, fisheries, marine tourism, etc.
| Global damage to the shipping industry from hull fouling is estimated at US$100 billion annually

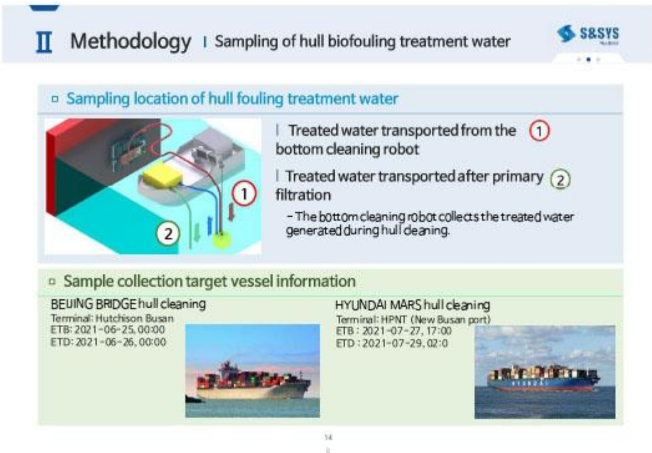

Ⅰ Introduction | Major Effects of Hull Biofouling
S&SYS
□ Major effects of hull biofouling
| Biofoulings account for more than 40% of the introduction of foreign marine organisms
| Increased fuel consumption by up to about 40% due to increased frictional resistance of operating vessels
- Annual fuel costs for large ships are 3 to 4 billion won per vessel, and super-large ships require up to 20 billion won in fuel costs, and an average of 10 to 20% fuel loss may occur
| Increase in unnecessary greenhouse gas (GHG) emissions due to increased ship weight and navigational resistance
| Increase in contamination prevention and removal costs (Antifouling coating, Hull cleaning)


Ⅰ Introduction | Biofouling regulations and discussion trends
S&SYS
□ Regulations and discussion according to the IMO(International Maritime Organization)
The Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines) in July 2011
□ Additional benefits from managing biofouling
Such management practices can also improve a ship's hydrodynamic performance, as hull fouling leads to significant increases in ship resistance, which in turn has a severe impact both on fuel costs and on emissions of air pollutants and greenhouse gases. Therefore, biofouling management can be an effective tool in enhancing energy efficiency and reducing air emissions from ships. This has been recognized by the IMO and is reflected in the 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) (resolution MEPC.282(70)).
CONTROL AND MANAGEMENT OF SHIPS' BIOFOULING
IMO

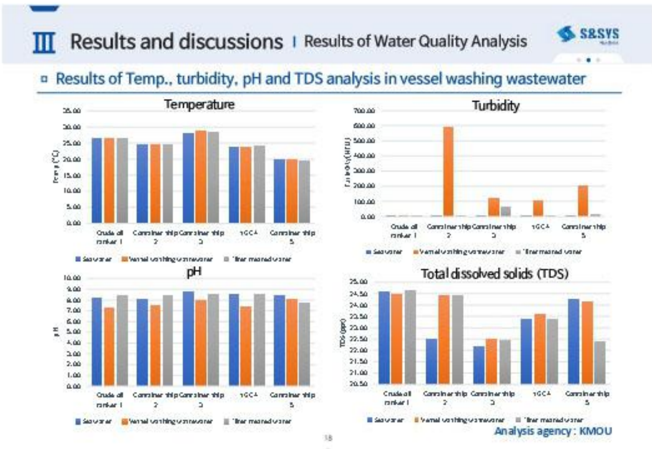

Ⅱ Methodology | Biofouling Removal Techniques
S&SYS
□ Equipment for removal of biofouling organisms
Marine biofouling organisms become light slime 3 months after removal, and then form heavy slime with thick attachments such as barnacles.
A diver removing biofouling
bottom cleaning robot
Removing biofouling from a dry dock
It is necessary to detect and remove attached organisms in the hull crevice area
Technology for effectively removing organisms attached to the hull and treatment of the removed wastewater are required.


Ⅱ Methodology | Joint research and development
S&SYS
20 years
Technological knowhow accumulated over 20 years from Samsung Heavy Industries
No1. Robot Cleaning System
TAS
S&SYS
에스엔시스
40 Countries
With diverse clients in 40 countries worldwide
400 Customers
We provide optimum solutions to over 400 clients.
Korea's leading shipbuilding and marine equipment research institute
KOMERI
A Platform University Pioneering the Ocean's Future





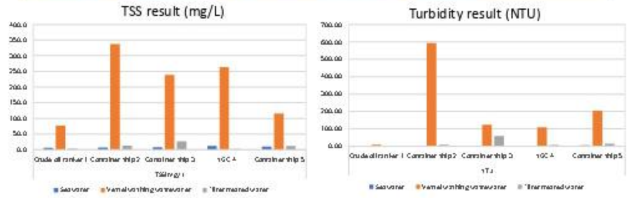
Date of collection	Vessel name	Type	Size	Cleaning time	Wastewater generation	Cleaning Port
June 20, 2023	V.ADVANCE	Crude Oil Tanker	333m × 61m	4-5 hour	17-19 m³/h	Yeosu, Korea
June 23, 2023	ZIM ROTTERDAM	Container Ship	349m × 46m			Busan, Korea
Sept 11, 2023	EDISON	Container Ship	366m × 49m			Busan, Korea
Sept 20, 2023	CLEAN DESTINY	LNGC	300m × 49m			Gwangyang, Korea
Oct. 20, 2023	OSLO TRADER	Container Ship	172m × 29m			Busan, Korea



Ⅲ Results and discussions | Treatment Efficacy for Suspended Solids

S&SYS

▫ Results of TSS and turbidity analysis in vessel washing wastewater



When a primary filtration device was used, the following removal rates were observed.
TSS removal rates were observed as 95.6%, 96.0%, 88.9%, 99.0%, and 89.1%, with an average value of 93.7%.
Turbidity removal rates were observed as 95.3%, 98.5%, 51.2%, 93.5%, and 93.1%, with an average value of 86.3%.
The filtration treatment demonstrated high removal rates for both TSS and turbidity.

Analysis agency : KMOU

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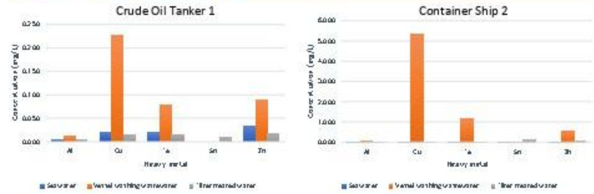
Ⅲ Results and discussions | Heavy Metal Removal Performance

S&SYS

▫ Results of Heavy metal analysis



While specific limits may vary by region, the following guideline concentrations are commonly referenced to protect marine life:
Aluminum (Al): ≤ 0.1 - 1 mg/L, Copper (Cu): ≤ 3 µg/L, Iron (Fe): ≤ 0.3 - 1 mg/L, Tin (Sn): ≤ 0.01 - 0.1 µg/L (for organotin compounds), Zinc (Zn): ≤ 10 µg/L
The concentrations of Cu and Zn exceeded the guideline levels, indicating that continuous monitoring will be required. Additionally, it is necessary to consider implementing processes capable of treating heavy metals.

Analysis agency : KMOU

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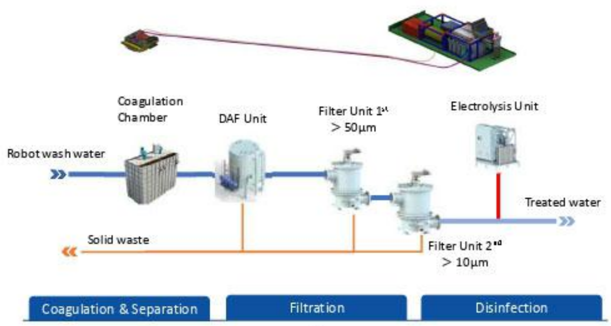
Ⅲ Results and discussions | Wastewater Treatment Technology

S&SYS

▫ Description of hull washing wastewater treatment technology



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Ⅲ Results and discussions | Treatment Facility Photos

S&SYS

▫ Treatment capacity : 5 m³/h

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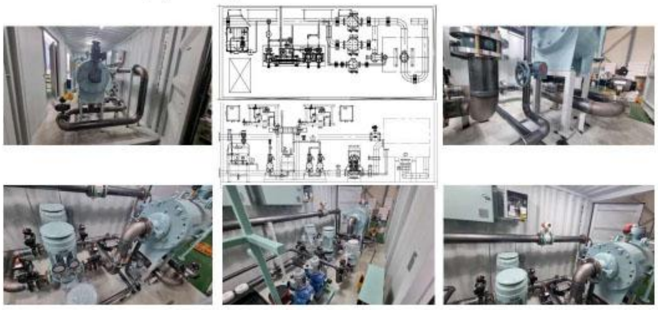
Ⅲ Results and discussions | Containerized Treatment System

S&SYS

▫ Treatment capacity : 100 m³/h

Containerized equipment: easy to move and install



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Ⅲ Results and discussions | Land-based treatment facility

S&SYS

▫ Test result : Influent - treatment capacity : 100 m³/h

Sample name	Test item	Test method	Test result
S&SYS (2310-01)-01	Organisms≥50µm	GENERIC PROTOCOL FOR THE VERIFICATION OF BALLAST WATER TREATMENT TECHNOLOGY EPA/600/R-10/146, 2010 5.4.6 Biological Efficacy(BE) Verification Testing 5.4.6.4 Zooplankton Enumeration, 5.4.6.5 Organisms ≥10 µm and <50 µm (nominally protists)	44,800 cells/m³
S&SYS (2310-01)-02	Organisms≥10µm and <50µm		<1 cells/mL
S&SYS (2310-01)-03	Escherichia coli	EPA Method 1603:2014, (Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar(Modified mTEC))	147 CFU/100 mL
	Intestinal Enterococci	EPA Method 1600:2014, (Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI))	903 CFU/100 mL
	Toxicogenic Vibrio cholerae (O1 and O139)*	ISO 21872-1, Microbioloty of the food chain – Horizontal method for the determination of Vibrio spp.- Part 1: Detection of potentially enteropathogenic Vibrio parahaemolyticus, Vibrio cholerae and Vibrio vulnificus	<1 CFU/100 mL

Test period : November 6~8th 2023

Testing agency : EnCycle

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Ⅲ Results and discussions | Land-based treatment facility

▫ Test result : Treated water – treatment capacity : 100 m³/h

Sample name	Test item	Test method	Test result
S&SYS (2310-01)-01	Organisms≥50 µm	GENERIC PROTOCOL FOR THE VERIFICATION OF BALLAST WATER TREATMENT TECHNOLOGY EPA/600/R-10/146, 2010 5.4.6 Biological Efficacy (BE) Verification Testing 5.4.6.4 Zooplankton Enumeration, 5.4.6.5 Organisms ≥10 µm and <50 µm (nominally protists)	0 cells/m³
S&SYS (2310-01)-02	Organisms≥10 µm and <50 µm		0 cells/mL
S&SYS (2310-01)-03	Escherichia coli	EPA Method 1603:2014, (Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar (Modified mTEC))	18 CFU/100 mL
	Intestinal Enterococci	EPA Method 1600:2014, (Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI))	55 CFU/100 mL
	Toxicogenic Vibrio cholerae (O1 and O139)*	ISO 21872-1, Microbioloty of the food chain – Horizontal method for the determination of Vibrio spp.- Part 1: Detection of potentially enteropathogenic Vibrio parahaemolyticus, Vibrio cholerae and Vibrio vulnificus	<1 CFU/100 mL

Test period : November 6~8th 2023 Testing agency : EnCycle

Ⅲ Results and discussions | Land-based treatment facility

▫ Test result : Influent – treatment capacity : 100 m³/h

Sample name	Test item	Test method	Test result
S&SYS (2310-01)-01	Organisms≥50 µm	GENERIC PROTOCOL FOR THE VERIFICATION OF BALLAST WATER TREATMENT TECHNOLOGY EPA/600/R-10/146, 2010 5.4.6 Biological Efficacy (BE) Verification Testing 5.4.6.4 Zooplankton Enumeration, 5.4.6.5 Organisms ≥10 µm and <50 µm (nominally protists)	61,750 cells/m³
S&SYS (2310-01)-02	Organisms≥10 µm and <50 µm		12 cells/mL
S&SYS (2310-01)-03	Escherichia coli	EPA Method 1603:2014, (Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar (Modified mTEC))	13 CFU/100 mL
	Intestinal Enterococci	EPA Method 1600:2014, (Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI))	350 CFU/100 mL
	Toxicogenic Vibrio cholerae (O1 and O139)*	ISO 21872-1, Microbioloty of the food chain – Horizontal method for the determination of Vibrio spp.- Part 1: Detection of potentially enteropathogenic Vibrio parahaemolyticus, Vibrio cholerae and Vibrio vulnificus	<1 CFU/100 mL

Test period : November 10~12th 2023 Testing agency : EnCycle

Ⅲ Results and discussions | Land-based treatment facility

▫ Test result : Treated water – treatment capacity : 100 m³/h

Sample name	Test item	Test method	Test result
S&SYS (2310-01)-01	Organisms≥50 µm	GENERIC PROTOCOL FOR THE VERIFICATION OF BALLAST WATER TREATMENT TECHNOLOGY EPA/600/R-10/146, 2010 5.4.6 Biological Efficacy (BE) Verification Testing 5.4.6.4 Zooplankton Enumeration, 5.4.6.5 Organisms ≥10 µm and <50 µm (nominally protists)	0 cells/m³
S&SYS (2310-01)-02	Organisms≥10 µm and <50 µm		0 cells/mL
S&SYS (2310-01)-03	Escherichia coli	EPA Method 1603:2014, (Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar (Modified mTEC))	<1 CFU/100 mL
	Intestinal Enterococci	EPA Method 1600:2014, (Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI))	35 CFU/100 mL
	Toxicogenic Vibrio cholerae (O1 and O139)*	ISO 21872-1, Microbioloty of the food chain – Horizontal method for the determination of Vibrio spp.- Part 1: Detection of potentially enteropathogenic Vibrio parahaemolyticus, Vibrio cholerae and Vibrio vulnificus	<1 CFU/100 mL

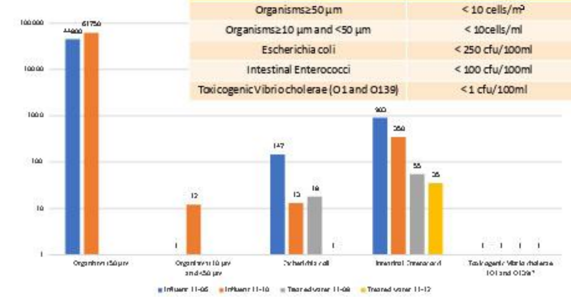
Test period : November 10~12th 2023 Testing agency : EnCycle

Ⅲ Results and discussions | Compliance with IMO Standards

▫ Test result : period 6~8th, 10~12th 2023 Testing agency : EnCycle

Satisfies IMO D-2 standards

Organism Category	IMO Regulation D-2
Organisms≥50 µm	< 10 cells/m³
Organisms≥10 µm and <50 µm	< 10cells/ml
Escherichia coli	< 250 cfu/100ml
Intestinal Enterococci	< 100 cfu/100ml
Toxicogenic Vibrio cholerae (O1 and O139)	< 1 cfu/100ml



Ⅲ Results and discussions

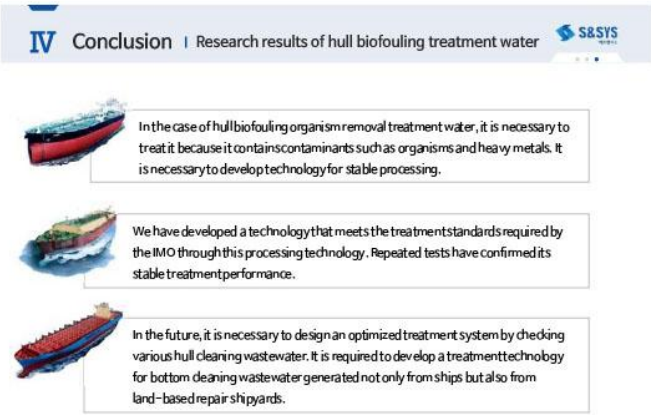
| Land-based biofouling and antifouling paint waste

During the periodic survey conducted every five years, marine organisms and paint particles attached to the vessel hull are removed through water blasting. These residues are then discharged into the surrounding waters near the dry-dock shipyard, leading to marine pollution in the nearby sea.

Ⅲ Results and discussions

| Land-based biofouling and antifouling paint waste : Research on processing methods

As outlined in documents MEPC 82/16/1 and MEPC 82/16/5, the safe handling of invasive aquatic species and waste generated during the removal of anti-fouling coatings from ships is essential. As a researcher who has conducted relevant studies, I support the proposal put forward by CESA.


IV Conclusion | Research results of hull biofouling treatment water
S&SYS
In the case of hull biofouling organism removal treatment water, it is necessary to treat it because it contains contaminants such as organisms and heavy metals. It is necessary to develop technology for stable processing.
We have developed a technology that meets the treatment standards required by the IMO through this processing technology. Repeated tests have confirmed its stable treatment performance.
In the future, it is necessary to design an optimized treatment system by checking various hull cleaning wastewater. It is required to develop a treatment technology for bottom cleaning wastewater generated not only from ships but also from land-based repair shipyards.


ACKNOWLEDGEMENT
S&SYS
Joint research institute
KOMERI
This research was a part of the project titled 'Development of treatment technology of marine bio-fouling on ship hull' and supported by Korea Institute of Marine Science & Technology Promotion(KIMST) funded by the Ministry of Oceans and Fisheries, Korea(20210500).
Ministry of Oceans and Fisheries


THANK YOU
감 사 합 니 다
S&SYS

CHAIR OF THE SESSION

DR. GUILLAUME DRILLET

SGS Marine Services | Chair

Asia-Pacific | Global TestNet, Singapore

Guillaume Drillet draws on his extensive experience in building teams and coordinating projects related to coastal and marine activities to help governments and industries define and meet their environmental health and safety targets. He currently serves as the Asia-Pacific Manager for Global Marine Services at SGS and the Chairman of the Global TestNet.

Guillaume's portfolio covers a wide range of environmental monitoring and risk management services, including coastal waters and sediments, microplastics, aquaculture & invasive species, and national strategies. He also oversees monitoring of discharges incidental to shipping, such as ballast water, gray water, bilge, and wash water, as well as health and safety/living conditions onboard ships, including indoor air, drinking water, noise, and industrial hygiene.

Since 2016, Drillet has chaired the Global TestNet, an NGO with consultative status at the UN-IMO. He also acts as a consultant to the IMO, WMU, and regional bodies on projects involving port surveys, risk management, ballast water, and biofouling. From 2016 to 2023, he served on the boards of the World Aquaculture Society, including a term as President for the Asia-Pacific region from 2016 to 2020.

Guillaume is committed to supporting the sustainable use of oceans through the development of programs and the sharing of information. He holds a PhD in life sciences from Denmark and received the Young Elite Scientist Award from the Danish Ministry of Independent Research in 2011. Guillaume continues to deliver lectures in academia and to global organizations, and he serves as an ambassador to the Singapore Exhibition & Convention Bureau for his commitment to organizing international scientific and technical events.

MOONKO KIM

Principal Research Scientist

Korea Institute of Ocean Science and Technology (KIOST), the Republic of Korea

Moonkoo Kim is a Principal Research Scientist at the Korea Institute of Ocean Science and Technology (KIOST) and a professor of Ocean Science at the Korea University of Science and Technology (UST). He earned his Ph.D. in Oceanography from Texas A&M University and completed a postdoctoral fellowship in Chemistry at Western Michigan University before joining KIOST in 2006. As a marine environmental chemist, his current research primarily focuses on: analyzing antifouling biocides in marine environments and wastewater effluents, assessing the risks of chemical contamination from ship maintenance operations, such as in-water hull cleaning and ship hull hydroblasting, and investigating microplastics derived from ship paint, including estimation of their environmental emissions.

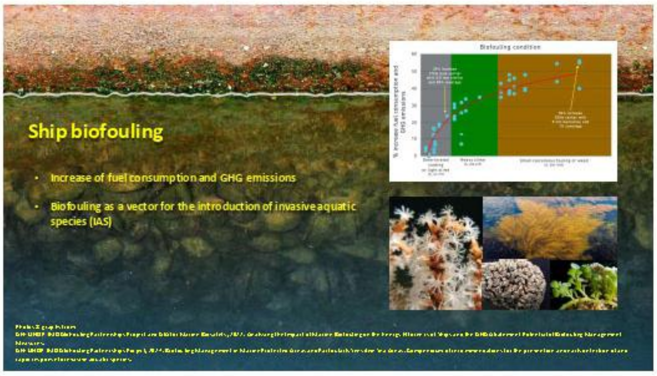
Predicting environmental concentration of metals released by in-water hull cleanings in an international harbor - considering the contribution from paint particles.

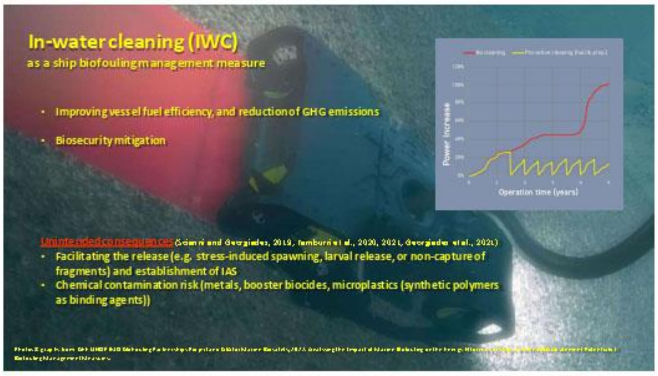
Moonkoo Kim, Zhi Yang Soon, Taekhyun Kim, Je Hyeok Kang, Gi Beum Kim, Kyoungsoon Shin

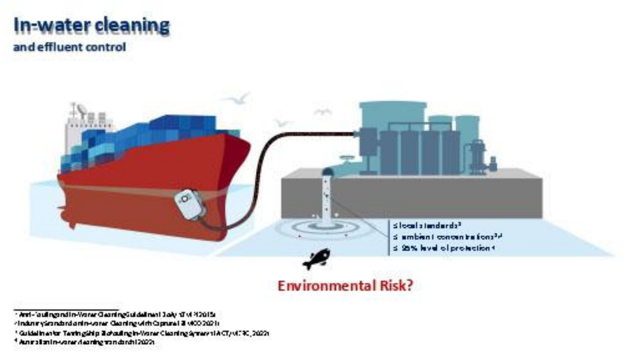
In-water cleaning (IWC) is employed to remove fouling from ship hulls, aiming to prevent the spread of non-indigenous species and reduce hull friction, thus minimizing fuel consumption. The increased adoption of IWC has led to the need to assess the environmental risks associated with the discharge of cleaning effluents, which may contain hazardous residues from antifouling paints. This study seeks to understand the potential chemical contamination risk posed by IWC, considering both the direct release of untreated effluents and the environmental leaching of metals from paint particles. Environmental concentrations were predicted using MAMPEC with worst-case release rates of 8.07 and 11.7 µg/cm2 for dissolved Cu and Zn, derived from local IWC trials. The contribution of particulate metal emission was accounted for in the model by evaluating the leaching of metals from paint particles released into the water column, estimating values of 268 µg Cu and 2209 µg Zn from a gram of paint particles. The maximum demand for IWC at the port was estimated based on the average number of vessels berthing per day over the past ten years, categorized by vessel size, from vessel statistics provided by the local port authority. Our risk assessment reveals that while the environmental risks associated with IWC vary depending on the scale of hull cleaning activities, adverse effects are evident unless effluents are recovered or treated prior to discharge. Since most harmful substances have a strong affinity towards paint particles in effluent, effective removal of particles is crucial to mitigate environmental impacts.

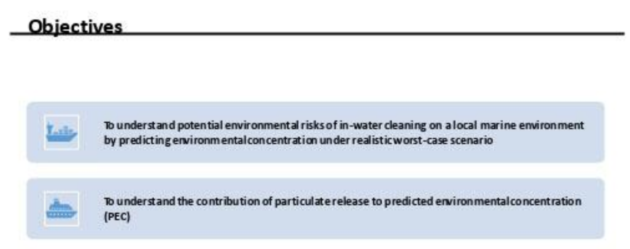
Antifouling; biofouling; particulate metals; risk assessment; marine environment

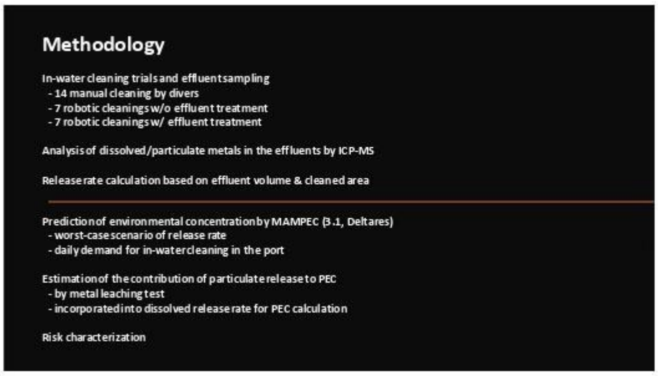
Presentation slides

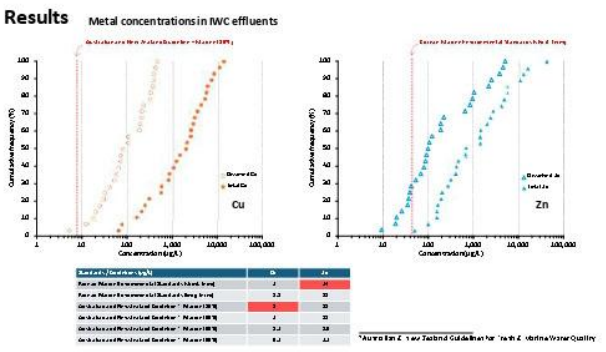


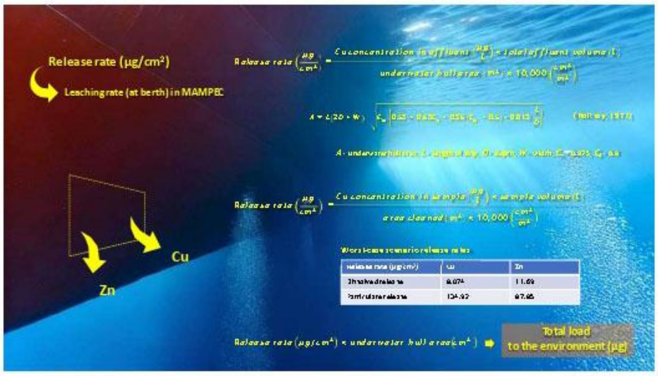


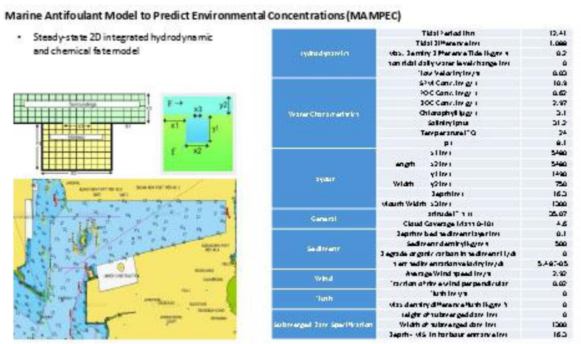


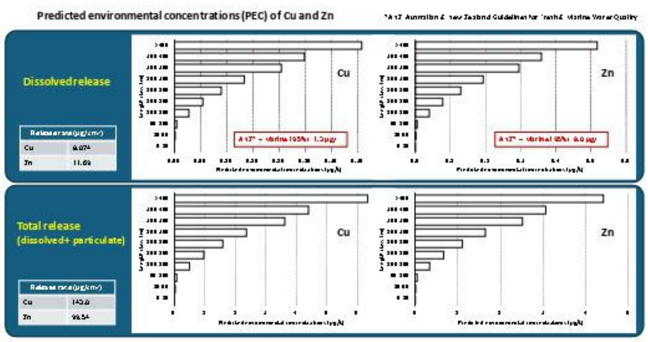


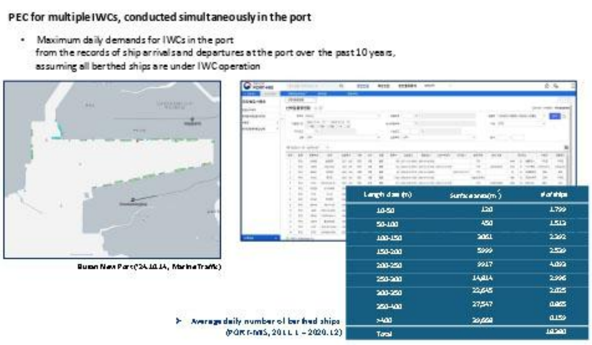


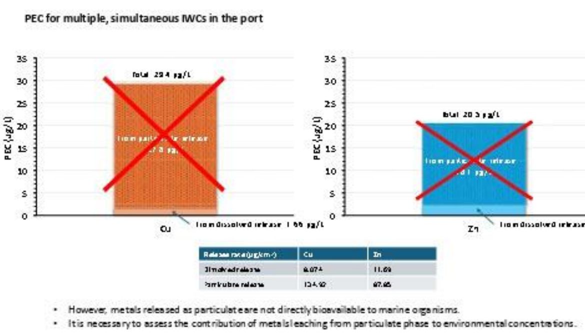

Results
Metal concentrations in IWC effluents
Cu
Zn
Concentration (µg/L)
Cumulative frequency (%)
Dissolved Cu
Total Cu
Dissolved Zn
Total Zn

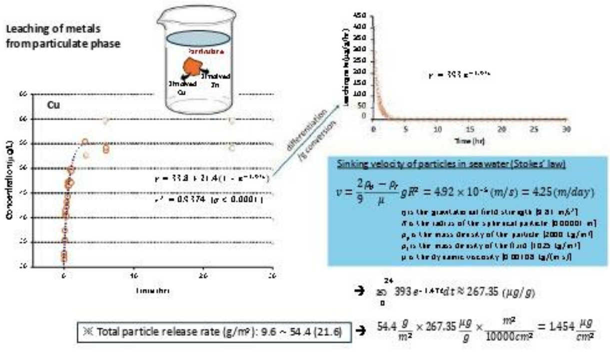

Release rate (µg/cm²)
Leaching rate (at berth) in MAMPEC
Cu
Zn
Worst case scenario release rates
Release rate (µg/cm²) | Cu | Zn
Dissolved release | 6.074 | 11.69
Particulate release | 104.92 | 67.65
Total load to the environment (µg)

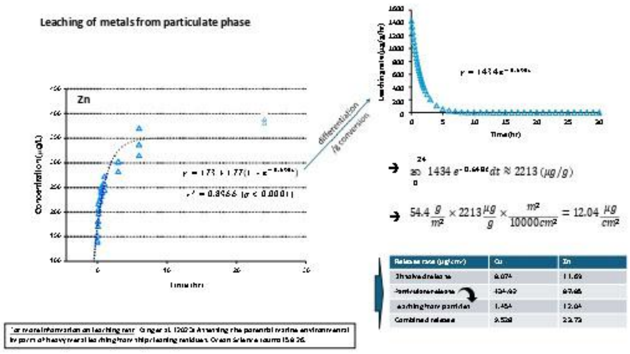

Marine Antifoulant Model to Predict Environmental Concentrations (MAMPEC)
Steady-state 2D integrated hydrodynamic and chemical fate model


Predicted environmental concentrations (PEC) of Cu and Zn
Dissolved release
Total release (dissolved+ particulate)
Cu
Zn
Release rate (µg/cm²)
Cu | 6.074
Zn | 11.69
Cu | 143.0
Zn | 98.54

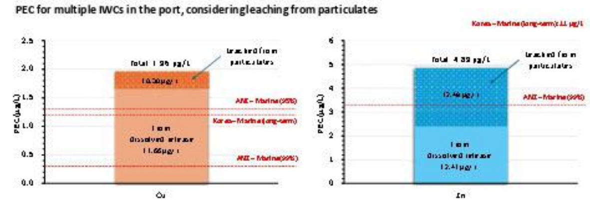

PEC for multiple IWCs, conducted simultaneously in the port
Maximum daily demands for IWCs in the port
from the records of ship arrivals and departures at the port over the past 10 years,
assuming all berthed ships are under IWC operation
Busan New Port ('24.10.14, MarineTraffic)
Average daily number of berthed ships
Length class (m) | Surface area (m²) | # of ships
10-50 | 120 | 1.799
50-100 | 450 | 1.512
100-150 | 2061 | 2.392
150-200 | 5999 | 2.529
200-250 | 9917 | 4.093
250-300 | 14,814 | 2.996
>400 | 29,888 | 0.159
Total


PEC for multiple, simultaneous IWCs in the port
PEC (µg/l)
Cu
Zn
Release rate (µg/cm²) | Cu | Zn
Dissolved release | 6.074 | 11.69
Particulate release | 104.92 | 67.65
However, metals released as particulate are not directly bioavailable to marine organisms.
It is necessary to assess the contribution of metals leaching from particulate phase to environmental concentrations.





PEC for multiple IWCs in the port, considering leaching from particulates



Risk characterization ratio (RCR) = PEC / PNEC

RCR_{Cu} = PEC / PNEC = 1.96 / 1.2 = 1.63

RCR_{Zn} = 4.89 / 11 = 0.44

Risk characterization

✓ **PEC / PNEC ≥ 1: possible risk to the marine environment**

✓ **PEC / PNEC < 1: low risk to the marine environment**

Antifouling paints
- Metals
- Booster biocides
- Microplastics (synthetic polymers as binding agents)

Cumulative RCR

= RCR_{Cu} + RCR_{Zn} + $RCR_{biocides}$ + RCR_{MP} + ...

= 1.63 + 0.44 + ... + ... >>1

Possible risk to marine ecosystem!

Conclusions

- A **single hull cleaning** may **not harm** the marine environment, but **assessing single cleaning event is insufficient** for risk management in a port. **Multiple IWCs** should be considered in risk assessments.
- Discharging IWC effluents **without removing particles** is likely to pose **clear risks to the marine environment**, due to the combined release of metals (dissolved release + leaching from particulate phase).
- Even when particles are removed from the effluents before discharge, the **dissolved release of Cu** alone may still **negatively impact** the marine ecosystem.
- Our predictions highlight the **potential environmental risks posed by IWC**, especially under realistic worst-case scenarios.
- The scale of cleaning activities should be regulated based on risk assessments that account for the specific conditions of each local port environment.
- Effluent treatment technologies must also be **capable of removing dissolved metals** to mitigate these risks effectively.

Limitations

- **Background contributions** from other sources should be considered.
- **Contributions from other metals and substances**, as well as their **combined (additive or synergistic) effects**, may increase the potential risks of IWC.
- A risk assessment **criteria** (e.g., predicted no-effect concentration; PNEC) should be developed **site-specifically**.
- Release rates can be **highly variable** depending on the type and age of coating, the fouling conditions, and the type of cleaning method used. Results from the worst-case scenario may differ from real-world situations.
- More comprehensive case studies under various conditions are required to fully understand the environmental risks posed by IWCs.


South Sea Research Institute, KIOST
Thank you !
Contact: Moonkoo Kim, mkim@kiost.ac.kr

JOAPE GINIGINI

Senior Scientific Officer | Project Manager at Institute of Applied Sciences
Pacific Islands Marine Bioinvasions Alert Network (PacMAN) | University of South Pacific, Fiji

Education *- BSc Bio/Chem USP, MSc USP*
Academic Awards- *Best Masters of Science by thesis, 2013 Career Awards- 'He for She' and 'She Champions' by the SPC's Maritime Technology Cooperation Centre (MTCCs) under the Test Biofouling project for IMO*
Membership to Scientific and Academic bodies and networks - *Indigenous Science Network, Natural Resource Food Science (USP Thematic Group), Association of Common Wealth Universities, Oceans expert (UNESCO-IOC, IODE), Deep Ocean Science Initiative (DOSI), ONet IPBES.*
Research Interests *- Microbiology, Molecular biology, Natural Products research, ABS regime, Deep sea research, Ocean acidification monitoring, Blue Carbon, Invasive species detection*

Ocean Science, Early Warning Systems and Hazards

Ginigini, J, Vuiyasawa, M; Appeltans, W; Suominen, Provoost, P; Brodie, G; Obst, M; Sherman, C.D.H.; Davis, N; Meyer, C; Buttigieg, P.L; Hablutzel, P; Bax, N; Muller-Karger, F; and Ginigini, J.

Invasive Alien Species has been identified as one of the major drivers of biodiversity loss next to Climate change (Bellard et al.; 2016).

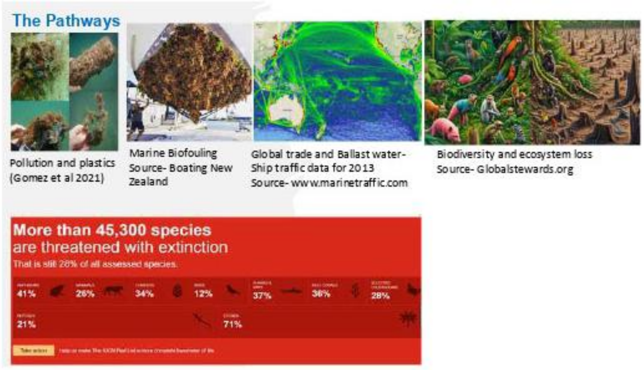
The increasing movement of goods and services across the globe has enhanced the risk of invasive species throughout the world. Currently, the information on local marine biodiversity and consequently marine invasive alien species (MIAS) is lacking in the Pacific Islands at large. Fiji is considered a hub of marine traffic among the Pacific Islands, and therefore is highly susceptible to high-risk invasive species incursions in the region. This means that the rate at which foreign organisms are establishing in ports worldwide has increased dramatically.

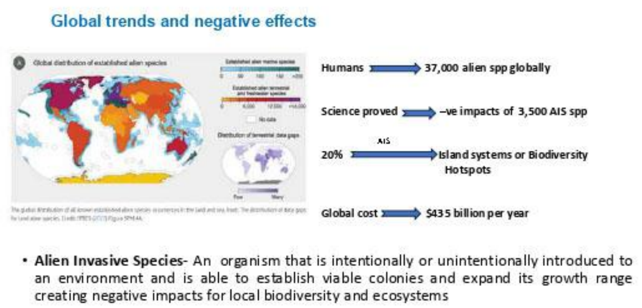
New estuarine and marine species have been establishing once every 32 (San Francisco Bay) to 85 weeks in six studied ports in the US, Australian and NZ, and the rate of establishment appears to be increasing (Hewit et al.; 2003). Eradicating and managing established invasive species is difficult and costly thus proactive early detection of high risk of species is vital. The Pacific Islands Marine Bioinvasions Alert Network (PacMAN) is a project lead by The University of the South Pacific and awarded by the United Nations Decade of Ocean Science for Sustainable development program in 2020 with funding assistance from UNESCO-IOC.

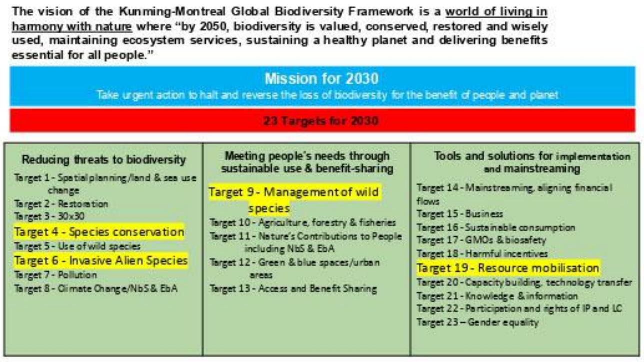
It is a three-year pilot project that develops the on ground tools and expertise to implement a marine invasive species monitoring program for the Fiji Islands with a potential to increase its efforts to other Pacific Islands. The program uses environmental DNA (eDNA) to identify potential invasive species and provides a valuable biodiversity baseline for the area. The main objective is to develop a marine "high risk" non-native invasive species-monitoring plan as well as create an easy to use (desktop) early warning decision support tool based on eDNA sequence data and high throughput bioinformatics analyses. An assemblage of renown experts in the field of marine invasive species taxonomy, DNA analyses and data analysts have been actively involved as part of the projects scientific advisory group to assist with the design of a user friendly monitoring plan and a decision support tool which may be reusable later in other small island states with existing laboratories. This collaborative approach allows PacMAN to establish Fiji's first exhaustive baseline overview of marine taxonomic groups currently present at the Suva harbor and more importantly identify problematic invasive alien species and cryptogenic marine organisms.

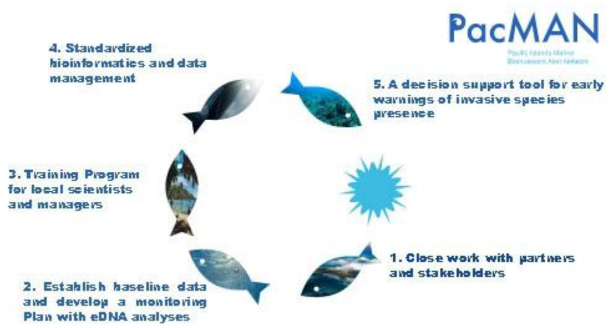
Keywords: eDNA, marine invasive species, biodiversity

Presentation slides

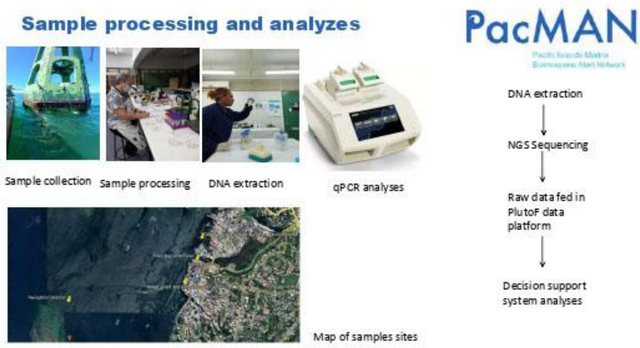


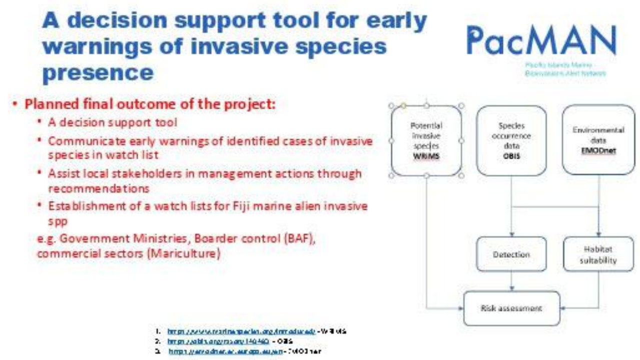


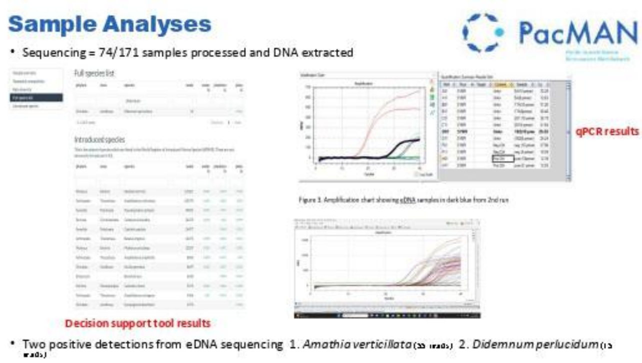



PacMAN
4. Standardized bioinformatics and data management
5. A decision support tool for early warnings of invasive species presence
3. Training Program for local scientists and managers
1. Close work with partners and stakeholders
2. Establish baseline data and develop a monitoring Plan with eDNA analyses


Training Program for local scientists and managers
PacMAN
Two training workshops planned for Nov 2022 and November 2024
First training workshop: To train local experts on the monitoring methods as well familiarize them with qPCR and eDNA analyses
Blended mode of virtual through OTGA and Face to face through USP
OTGA


Sample processing and analyzes
PacMAN
Sample collection
Sample processing
DNA extraction
qPCR analyses
Map of samples sites
DNA extraction
NGS Sequencing
Raw data fed in PlutoF data platform
Decision support system analyses


A decision support tool for early warnings of invasive species presence
PacMAN
Planned final outcome of the project:
A decision support tool
Communicate early warnings of identified cases of invasive species in watch list
Assist local stakeholders in management actions through recommendations
Establishment of a watch lists for Fiji marine alien invasive spp
e.g. Government Ministries, Boarder control (BAF), commercial sectors (Mariculture)
Potential invasive species WRIMS
Species occurrence data OBIS
Environmental data EMODnet
Detection
Habitat suitability
Risk assessment


Sample Analyses
PacMAN
Sequencing = 74/171 samples processed and DNA extracted
Full species list
Introduced species
qPCR results
Figure 1 Amplification chart showing eDNA samples in dark blue from 2nd run
Decision support tool results
Two positive detections from eDNA sequencing 1. Amathia verticillata 2. Didemnum perlucidum


Acknowledgements
IMO INTERNATIONAL MARITIME ORGANIZATION
SPREP
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
USP THE UNIVERSITY OF THE SOUTH PACIFIC
MSAF MARITIME SAFETY AUTHORITY OF FIJI
OBIS OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM
BIOSECURITY AUTHORITY FIJI
Flanders State of the Art

DR. YOUNG WOOK KIM

CEO

ProxiHealthcare, the Republic of Korea

Young Wook Kim, Ph.D. is currently founder and CEO of ProxiHealthcare Inc. Korea. His expertise are focused on biocompatible biofilm detection and treatment for various industrial applications including healthcare and ocean field. He published over 40 research articles with 75 patent in the world. He received Ph.D. in Electrical Engineering from the University of Maryland, College Park, USA.

A Real-Time Impedimetric Sensor for Early Detection of Biofouling

Young Wook Kim, JungHyung Lee

Accumulation of marine organisms on vessel and ocean infrastructure, that is known as biofouling, is a global challenge due to the ecosystem disruption and excess emission of carbon dioxide. Total global cost of biofouling is estimated up to $10 billion USD. Therefore, developing an effective management technology is critical.

Biofouling is initiated by forming slime films (biofilms) typically within a month and followed various microorganism attachment. It is known that the biofilms are an initial activation layer of massive biofouling progress. Hence, detection of biofilm is correlated to onset of biofouling and provides a critical management information.

We have developed a highly sensitive electrochemical sensor for ocean biofouling monitoring. The device has been fabricated on flexible substrate and analyzed changes of total impedance through the electric voltage measurement. The electrode design has been focused on the uniform electric field distribution that is important to realize sensitive detection. The system shows in figure 1. Testing of the sensor was conducted in West Sea of Korea at Inchen for 3 weeks that is typical time of biofouling.

The results demonstrated 40% increased impedance in 8 days and additional 10% of changes in 20 days. Overall, the sensor shows 25% signal changes during the biofouling progress. The sensor performed high signal to noise ratio and highly sensitive especially at the beginning of biofouling. The measurement of signal is corelated to image of the sensor where biofouling is on-progress. In conclusion, we demonstrated a successful biofouling monitoring system for the early detection.

Keywords: Biofouling, Biofilms, Impedimetric Sensor

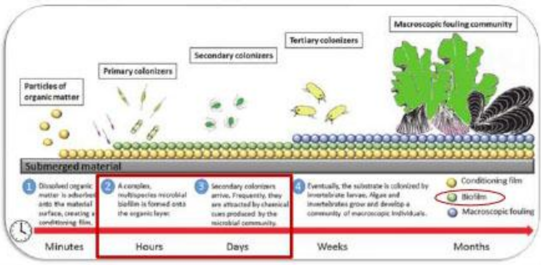
Presentation slides

PROXI

A Real-Time Impedimetric Sensor for Early Detection of Biofouling

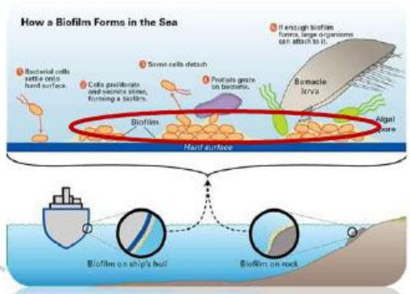
ProxiHealthcare Inc.
CEO/Founder, Young Wook Kim, Ph.D.

Biofouling



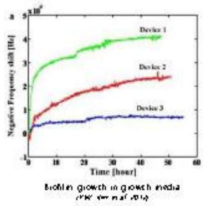
Biof ilmis critical.

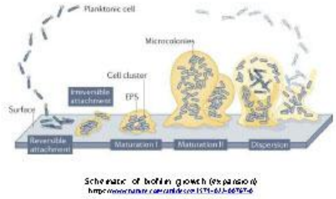
PROXI



Early Detection of Biofouling

- Biofilm Growth within 10 hours





Biofouling Economic Impact

2 bn Vessel in the World

Challenges of Maritime Business

PROXI

90% of the World Trade
$4.2 Trillion Market

25 - 50% Extra CO_2 ↑
Ecosystem Disruption

Problems

1) Hazardous Chemicals
Toxic Environment

2) Human Intensive Work
Inefficient

3) Global Warming
CO_2 Emission

Our solution

Human Intensive Work

Automated Antifouling Solution

Biofilm Sensors

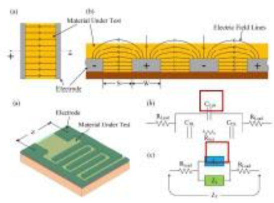
Reliable Operation in Sea Water Condition

Contents	Impedance Sensor	Optical Sensor	Acoustic Wave Sensor
Source	Electric signal (Battery-based device)	Optical source	Electric signal (Battery-less device)
Structure	2D	3D	2D
	255 mV/fF ≈ (10^{-12} g) [illegible]	4 X 10[illegible] cells/mL ≈ (10^{-11} g) [illegible]	3 ag (10^{-18}g) [illegible]

Impedance Sensors

- R_{lead}: total impedance (resistance) of wire
- C_{p}: Capacitance of double layer
- C_{cell}: Capacitance of bacteria cell
- R_{sol}: total impedance (resistance) of media solution

$$C = \varepsilon \frac{A}{d} \qquad Z_{total} = \frac{R_{sol}}{1 + 2\pi f C_{cell} R_{sol}}$$



Equivalent circuit model of interdigitated electrode sensor

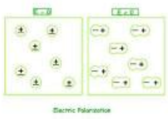
Impedance Sensors

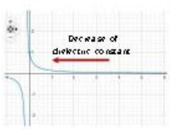
$$C = \varepsilon \frac{A}{d} \qquad Z_{total} = \frac{R_{sol}}{1 + 2\pi f C_{cell} R_{sol}}$$

- ε: dielectric constant
  (electric polarization properties)
  (ex. water: 81, bacterial cell: 2-5)
- A: cross sectional area
- d: distance between two electrodes

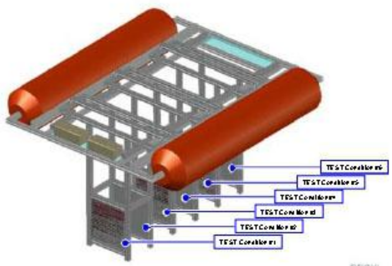
Biofouling progress → dielectric constant ↓
→ Increase of impedance

Increase of voltage drop!!!

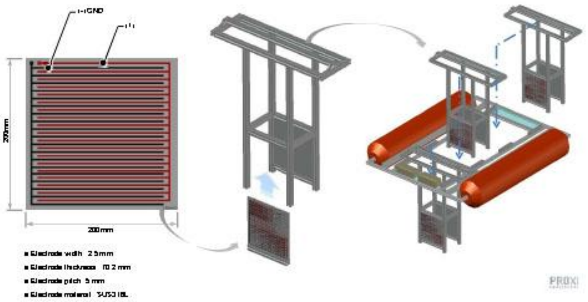




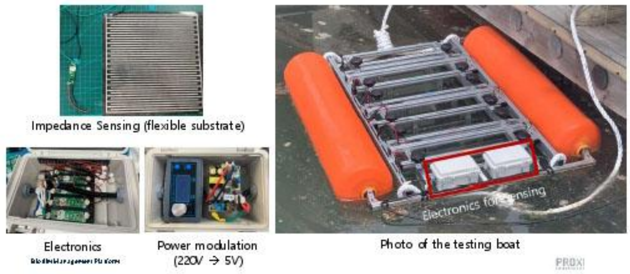
Testing Boat



Testing Boat

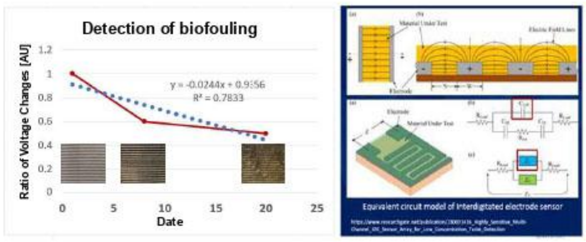


Testing Procedures

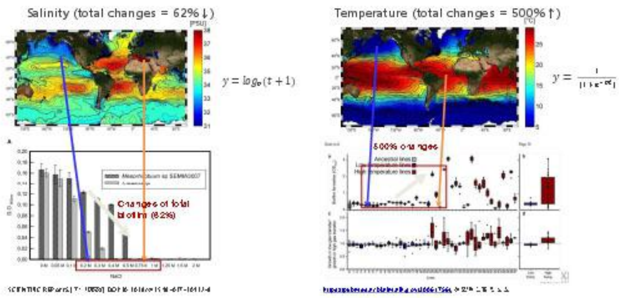


Results of Biofouling Sensing

Sensitive detection of biofouling (>55%)

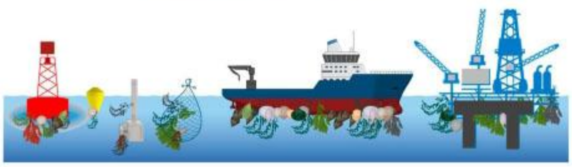


Prediction AI model



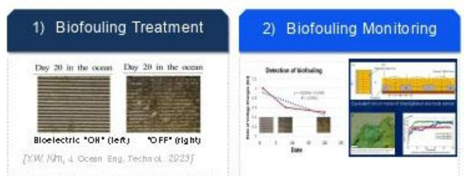
Future Work

Expansion of the sensing applications



Future Work

Automated anti-fouling sensing and treatment



Acknowledgement

목포해양대학교 MOKPO NATIONAL MARITIME UNIVERSITY

KOEM 해양환경공단

한국조선해양기자재연구원 Korea Marine Equipment Research Institute

Ministry of Oceans and Fisheries

Thank You

Bioelectric anti-biofouling management system

ProxiHealthcare Inc.
CEO/Founder, Young Wook Kim, Ph.D.

Internal Vessel Biofouling Problems

- USD7 billion in 2022 to USD 15.57 billion in 2033


Coast Guard Sector Houston-Galveston
Marine Safety Information Bulletin 14-20

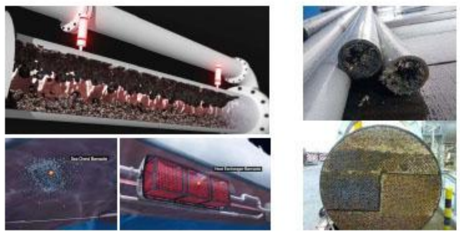
Loss of Vessel Propulsion, Maneuverability and Safety Systems Due to Clogged Sea Strainers

This MSIB is issued to provide awareness for the upcoming Gulf Menhaden seasonal event. Some of the inherent risks to vessels that use sea strainers include loss or reduction in propulsion, reduced maneuverability, and loss of water pressure within the firefighting systems.

Loss or reduction in propulsion continues to occur in the Houston Ship Channel (HSC) complex. One of the causes continues to be accumulation of small fish in vessels' sea strainers. This is typically a seasonal event involving primarily Gulf Menhaden, with May-October being the highest risk (although vessels have reported encountering Menhaden in their sea strainers year round). Gulf Menhaden are found in

Captain, United States Coast Guard
Captain of the Port

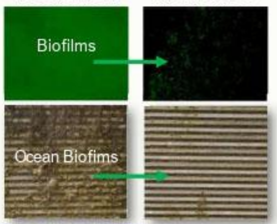
Internal Vessel Biofouling Problems



Biofilm Management

Bioelectric X

Bioelectric O



Patent for Bioelectric pipe

DR. THOMAS VANCE

Chief Operating Officer | Paper Lead Author

PML Applications | Global TestNet, the United Kingdom

Dr Tom Vance is a specialist in marine fouling community ecology, biofouling control, and marine survey. Tom is currently the C.O.O of PML Applications, which provides bespoke environmental consultancy services to industry and gift-aids profits to support the parent charitable organisation, the Plymouth Marine Laboratory. Tom has experience of designing, conducting and interpreting field and laboratory based experiments on marine invertebrate and algal assemblages, both in the U.K and internationally. Tom's practical experience includes diving surveys, field based manipulative experimentation, marine invertebrate taxonomy, advanced image analysis, physiological assessments of fouling species, molecular analysis of biofilms together with multivariate statistics and reporting. Tom has active collaborative partnerships with academics across the U.K, and internationally, together with productive commercial links across a wide range of marine industries, with particular emphasis on the antifouling coating, shipping and marine renewable energy sectors.

Proposed Guidelines for the Evaluation of Efficacy of Marine Growth Prevention Systems (MGPS)

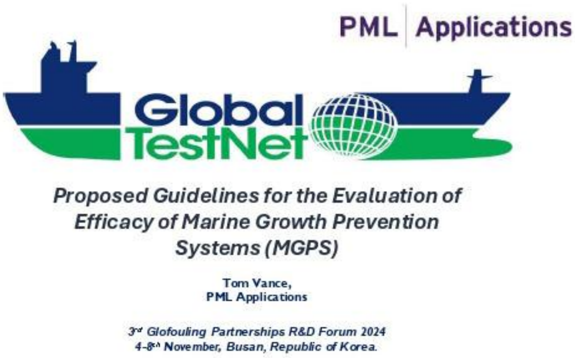
Dr. Thomas Vance

This paper presents information on how to address the lack of standardised test methods to compare the efficacy of different MGPS based on different modes of action, or indeed the efficacy of one mode of action configured in different ways.

However, the relative performance of MGPS, in terms of both their antifouling performance and their impacts on other systems (e.g. coating, anti-corrosion…) is largely driven by empirical experience rather than consistent assessment/evaluation.

These proposed guidelines describe principles and a test methodology that enable direct comparison of the efficacy of different MGPS under comparable conditions. This will allow end users to select the optimum MGPS for a given scenario.

Presentation slides



Biofouling Control

- Antifouling Coatings
  - Great technologies out there!
  - Challenges remain…… cleaning / operational profiles - *PML Applications focus*
- Biofouling control is possible on hull plate ($$$).

That leaves niche areas!!

- Biosecurity & operational ability & fuel consumption
- Other options (design, coatings, operational profile).
- MGPS will be required……….not only for ships….

MGPS – Challenges and Opportunities

- Different types (electro-chlorination, acoustic, UV, etc.).
- Pros & cons, costs, retro-fit options.
- Lack of comparative impartial efficacy data.

How do you choose?!

- Global TestNet entrusted PML Applications to lead the development of efficacy testing guidelines for MGPS, with other members.
- Aim - *enable direct comparison between the efficacy of different MGPS under comparable conditions to assist end users to select appropriate technology.*

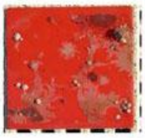
Comparative Efficacy Methods

Not easy!.........

- Draft guidelines - work in progress. Discussion / suggestions welcome.
- Continuous improvement philosophy…….
- One test method will not fit all……..

Scope limited to:

"MGPS systems used within a sea chest to provide antifouling protection to the interior of the sea chest, the outer grating, the first 1-2 m of pipe and the main sea valve".

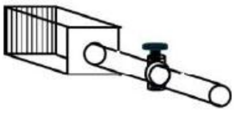


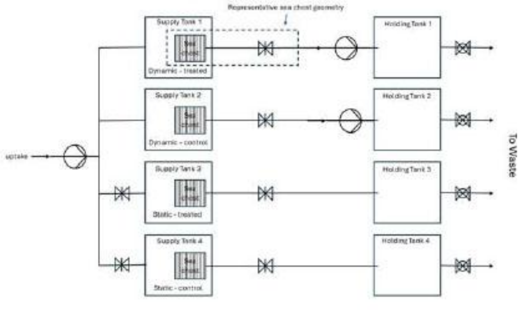
Test Method Overview 1:

- Install MGPS in a waterside test rig, with a known fouling pressure
- Pump raw water through the rig into mimic sea chests and pipework (control & treatment)
- Measure biofouling accumulation on in-line coupons
- Compare static (worst case) and dynamic flow conditions

Test Method Overview 2

- Restricted light – minimise algae – focus on invertebrates
- Fouling pressure - IMO level 3 (medium macro)
- 100% duty cycle (manufacturer guidance)
- Down time (max 10%, 3 consecutive days)
- Static control line (no treatment)
- Static test line (with MGPS treatment)
- Dynamic control line (no treatment)
- Dynamic test line (with MGPS treatment)





Test Method Currently Considers:

- Time scales – duration of test
- Q.A. & reporting template
- Standardised biofouling challenge & test house eligibility criteria
- Performance acceptance criteria
- Interactions with materials & water quality effects on MGPS performance
- Static and dynamic tests
- Coupon type / material
- Acceptable down time
- Raw water uptake position & pump effects on larvae
- Pre-discharge treatment
- Repeated testing, geographic location
- Testing at reduced scale
- Method limitations

Key Questions

- Scope – sea chest, sea valve and 1m of pipe? (not box coolers)
- Flow conditions – static and dynamic? What is dynamic?!

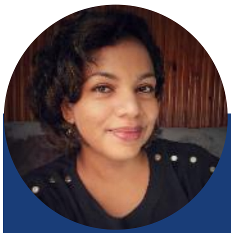
What next?

- Global TestNet Members to vote and agree on the final Guidelines
- Seek comments & contributions from stakeholders
- Coordinate with interested member States and NGOs for the preparation of a submission to the MEPC - intention of proposing development of an IMO Guidance document available to all
- Aim to submit in December for MEPC 83 (Spring 2025). Very tight deadline as submissions are required 2-3 months before the meeting

Thank you !

Contact: Tom Vance, thva@pml.ac.uk **PML | Applications**

CHAIR OF THE SESSION



SARITA KRISSY EMMANUEL

Project Officer

Maritime Technology Cooperation Centre (MTCC) Caribbean, Trinidad and Tobago

Sarita Emmanuel is a wetland ecologist and maritime professional with over 10 years of experience. She serves as a Project Officer at MTCC Caribbean, leading efforts under the IMO-NORAD TEST Biofouling Project in Latin America and the Caribbean. Sarita's work focuses on engaging stakeholders and building regional capacity in sustainable biofouling practices to reduce greenhouse gas emissions and limit the spread of invasive species. With dual Master's degrees in Wetland Science and Maritime Management, and eight years of teaching experience, she brings a strong background in sustainable maritime practices and ecosystem protection.

PETTER KORSLUND

Regulatory Affairs Manager

Performance Coatings, Jotun, Norway

Petter Korslund, Regulatory Affairs Manager Performance Coatings Jotun AS.
BSc from University of Plymouth UK in Maritime Business with Maritime Law.
Been with Jotun since 2015, started in the maritime industry in 2001. More than 20 years of marine paint experience.

Biofouling management through digital solutions

Petter Korslund

The shipping industry is contending with significant decarbonization challenges along with ecological issues, in particular the transfer of invasive aquatic species that are closely linked to global shipping activities. Jotun has a clean shipping commitment to continuously innovate and develop advanced products and solutions designed to protect biodiversity, cut carbon emissions and preserve fuel to support global sustainability ambition and achieve cleaner operations with a clean hull.

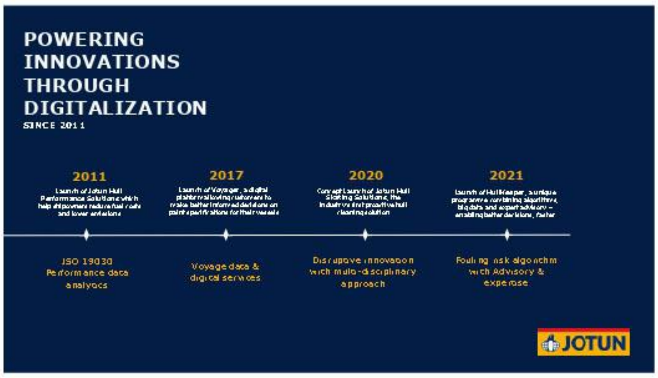
One of Jotun's key solutions comes in the form of digital solution, Jotun HullKeeper program.

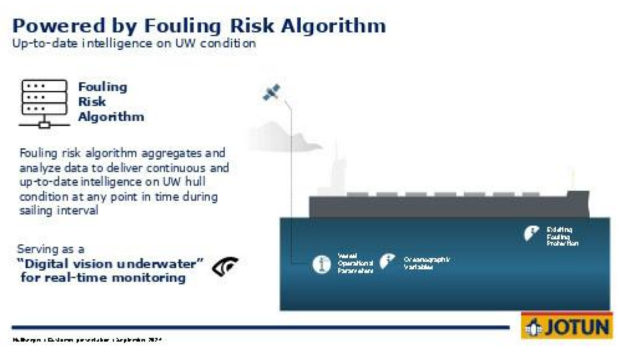
HullKeeper utilizes proprietary fouling risk algorithm to actively evaluate the underwater hull condition through collating sailing data, oceanographic data and prevailing antifouling properties to provide up-to-date intelligence for users. The utility of this digital solution is to provide better understand of the potential fouling risk and provide users to gain control to make informed decision to maintain a clean hull.

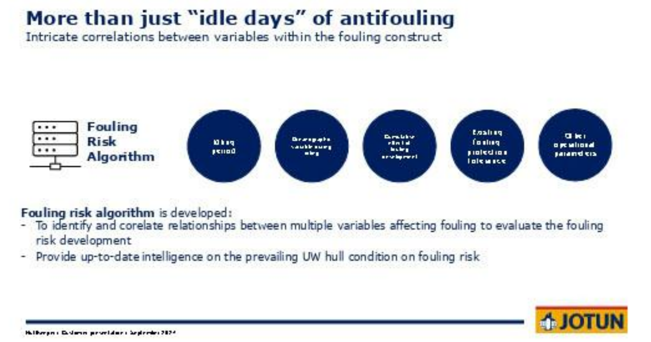
The notion of active hull condition monitoring is a crucial aspect of hull performance that has been overlooked. The ability to identify fouling risks through big data analytics can help avoid fouling to become a bigger problem. This concept can play an integral role in effective biofouling management planning. By implementing effective biofouling planning and informed decision to clean early (preferably in IMO biofouling rating 1), vessels will minimize the rate of degradation of hull and maintain the intended protection throughout their intended sailing interval. HullKeeper will be an enabler of control and planning as part of having an effective biofouling management plan.

KEYWORDS:
-Fouling prediction
-Biofouling management Plan
-Digital solutions
-Clean Shipping Commitment

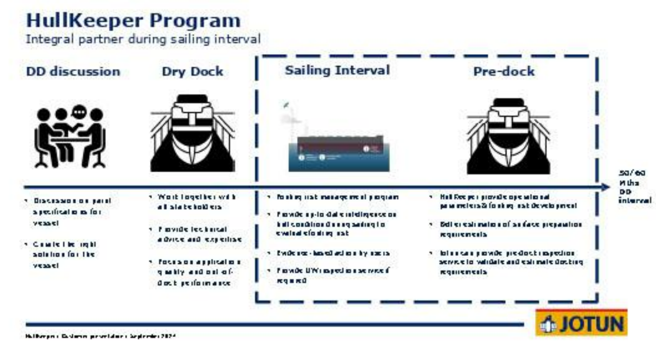
Presentation slides



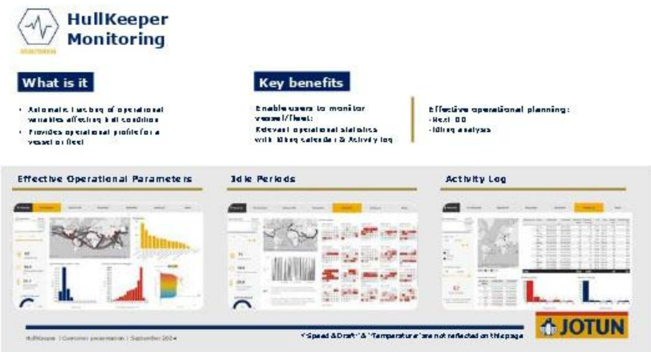



More than just "idle days" of antifouling
Intricate correlations between variables within the fouling construct
Fouling Risk Algorithm
Fouling risk algorithm is developed:
- To identify and corelate relationships between multiple variables affecting fouling to evaluate the fouling risk development
- Provide up-to-date intelligence on the prevailing UW hull condition on fouling risk
JOTUN

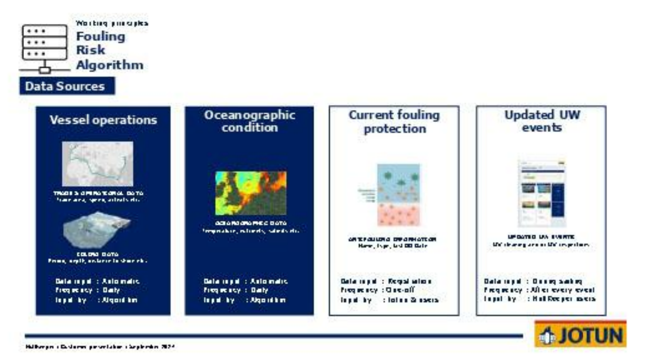

Contribute to Cleaner shipping
Positive contribution towards CII ratings
Timely recommendation and action to intervene fouling risks can alter performance trajectory, contribute positively towards CII ratings over time
Active intervention ensures preserving of fuel, cut carbon emission & protect biodiversity
JOTUN

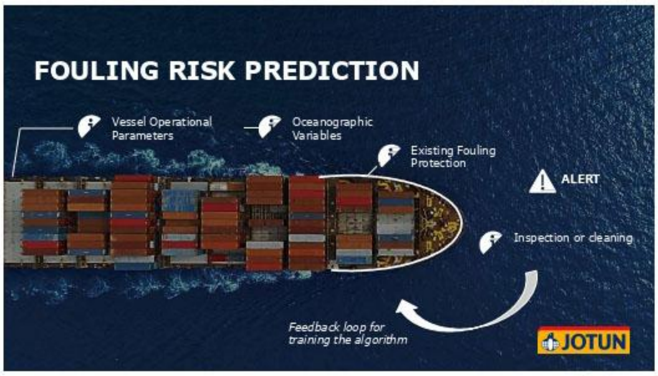

HullKeeper Program
Integral partner during sailing interval
DD discussion
Dry Dock
Sailing Interval
Pre-dock
JOTUN

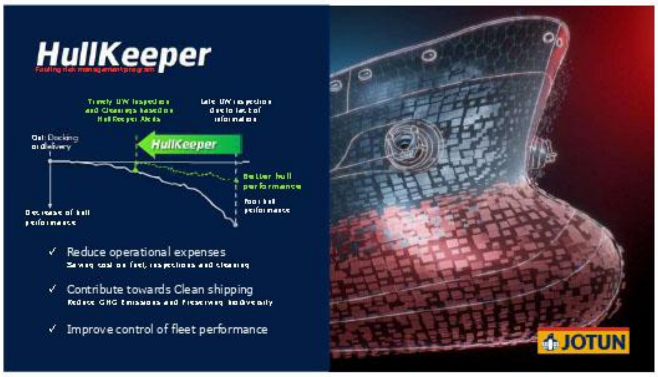

HullKeeper
Digital services
MONITORING
ALERTS
JOTUN


HullKeeper Monitoring
What is it
Key benefits
Effective Operational Parameters
Idle Periods
Activity Log
JOTUN


HullKeeper Alerts
What is it
Understanding
Fouling Risk Algorithm
Risk Periods Overview
Alerts Dashboard
Single Vessel Analysis
JOTUN


Fouling
Risk
Algorithm
Data Sources
Vessel operations
Oceanographic condition
Current fouling protection
Updated UW events
JOTUN


FOULING RISK PREDICTION
Vessel Operational Parameters
Oceanographic Variables
Existing Fouling Protection
ALERT
Inspection or cleaning
Feedback loop for training the algorithm
JOTUN


HullKeeper
HullKeeper
Better hull performance
Reduce operational expenses
Contribute towards Clean shipping
Improve control of fleet performance
JOTUN


Thank you for your attention!
JOTUN

NEIL OXTOBY

AkzoNobel

The United Kingdom

Dr Neil Oxtoby, a chemist by background, is an R&D technical specialist in the area of Fouling Control Coatings within AkzoNobel / International Paint. He has worked in the industry for 18 years developing and supporting a global product range. Since 2021, he has chaired the World Coatings Council Anti-fouling Coating Committee and represents AkzoNobel on the IMO GloFouling Global Industry Alliance.

Next steps in the development of UV-C as the ultimate fouling prevention technology

N. Oxtoby, C. Price, K. Reynolds, C. Cairns, C. Taylor, B. Salters, M. Wijnen, J.den Breejen, K. Hageman, I.Bonetto Beytia, I Robinson, G. Barker, M. Winfield

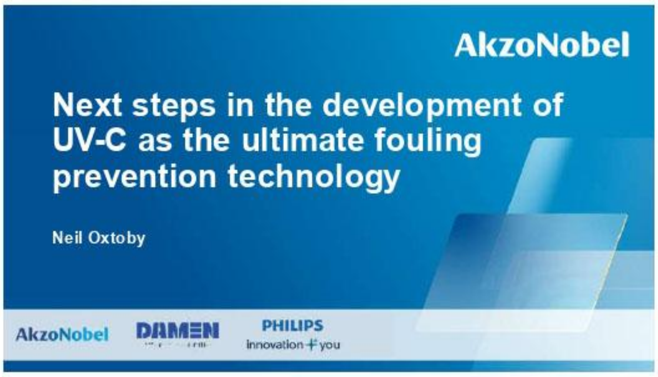
An essential aspect in reducing the risk from invasive species and CO2 emissions within the shipping industry is managing biofouling on ships' hulls. Biofouling, the accumulation of organisms on hulls, increases surface roughness, leading to greater hydrodynamic drag. Consequently, ships consume more fuel to maintain speed, resulting in higher CO2 emissions.

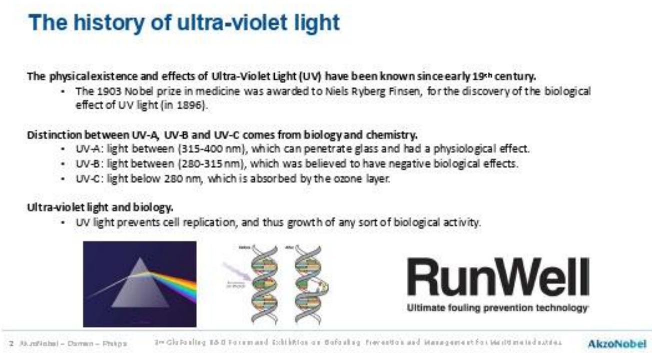
To counter this problem, AkzoNobel, Royal Philips and Damen Shipyards are developing a revolutionary fouling prevention technology utilizing Ultraviolet Light Emitting Diodes (UV-LEDs). This technology integrates UV-LEDs into a protective coating, emitting UV-C light from the surface to prevent biofouling accumulation. This innovative, economically viable, solvent free and biocide-free solution aims to offer complete fouling prevention.

In this presentation we will update on developments towards a vessel demonstration trial which integrates large arrays of preformed UV-C tiles onto the hull of a commercial vessel at new building stage. Aspects of the technical challenges associated with upscaling, application and vessel integration will be discussed. In addition, although it has been demonstrated that low intensity UV-C light can keep a submerged surface completely free of biofouling, for a prolonged period of time, the impact on non-target organisms is yet to be extensively studied. In this presentation, the results from our initial investigations to demonstrate the safe use of UV-C in the aquatic environment will be shared.

Keywords: UV-C, Fouling Prevention, New Technology

Presentation slides

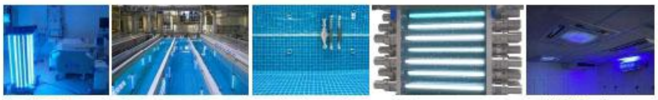




The biological effect of ultra-violet light

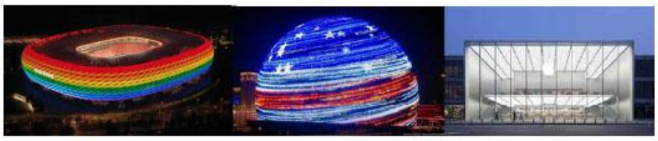
Since the discovery of the anti-microbial effect of UV light, numerous applications have been developed for surface disinfection and water purification.

- Non-chemical.
- Non-toxic.
- No by products.



Hospital room cleaning | Sewage water treatment | Swimming pool & Aquarium water treatment | Ballast water treatment systems (IMO regulation - BMW, 2017) | HVAC Air Purification

The present day; Large area light distribution & luminous surfaces



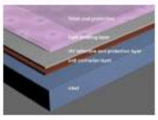
Allianz Arena Munich, Germany | **Sphere** Nevada, United States | **Apple Store** Hangzhou, China

Seamless luminous surfaces powered by LEDs are increasingly being used in terrestrial settings for aesthetics.

Can UV-C LEDs be used to harness the biological effect to keep immersed surface biofouling free?

Total fouling prevention.

Total Fouling Prevention



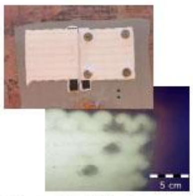
Concept:
A "wallpaper" or "tiles" that emits UV-C light.
- Keeps the surface spotlessly clean.
- Active against all fouling organisms.
- Functions when stationary, at slow or high speeds.

- **Total fouling prevention.**
- Adaptive to vessel operations and fouling challenge.

Development – vessel testing of individual tiles

Tiles attached to 10+ vessels (since 2016)

Sailing Vessel: Northern Europe
One 30x30cm "Tile"
Totally clean after 2 years – Trial Ended



Cruise: Caribbean & Mediterranean
Two 50x50cm "Tiles"
Mostly clean after 2 years – Trial ended
Edges fouling as LEDs come to end of life

LNG: Global
Two 50x50cm "Tiles" + Dummy tiles
Totally clean after 1 year – Ongoing
Due to dry dock in 2025

Next phase – production scale up and vessel integration

Scale up:
- Production simplification and manufacture time.

Lifetime up:
- LED improvements – size, cost, lifetime, efficiency.

Cost down
- Moving from a proof-of-concept prototype to a market ready product.

Next phase installation:
- 25 m².
- 5+ year lifetime.
- Commercial operation & linked to vessel monitoring system.
- Large scale in yard installation.
- Class society approvals.

Damen – Shoalbuster Trial – 2024/2025

Damen Shoalbuster
Multifunctional, oceangoing, versatile tug.
Integration of UV-C Fouling prevention system at new build.

- 25m² test area.
- Minimal number of cables.
- Scalable hull penetration design.
- Internal electronics housed in engine room.
- Bridge control.
- Remote monitoring.
- Class society approval.
- Deliberate selection of non-curved areas.

Production scale-up

Improvements in efficiency of the "tile" will be achieved via LED developments and engineering design choices.

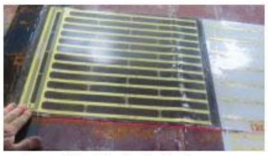
- 2020 – 1 tile (0.25m²) per week – Handmade
- 2024 – 8 tiles (2m²) per week – Batch process – Scalable to 150 per week with more filling carts

Also happening are developments towards mass production to satisfy the 10K+ tiles needed for large commercial vessels.

- Mobile filling cart

- 4 tiles undergoing silicone infusion (4 carts)

Trial application



- Laser marking tool used to align first tiles
- Subsequent tiles use the first ones as reference points

- 12 tiles (3m2) in yard installation trial

In yard trial using mock up and prototype tiles to show:
- How good tile alignment can be achieved – alignment tooling used to ensure correct placement.
- That welds seems are not a problem.
- The time taken to install tiles vs. current antifouling coatings – untrained installers took approx. 1 hour for 3m².
    - Much faster speeds can be achieved with process familiarity.

Tile Alignment - Hydrodynamics

CFD studies into the frictional effects of tiles

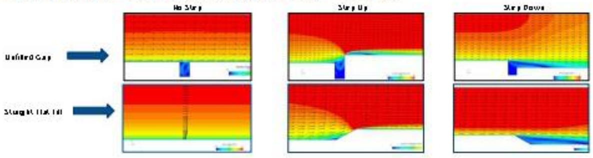
Quantifying the impact of uniform gaps and non-uniformities due to height profile changes.
Initial study:

- 17 simulations: Flat, step-up, and step-down profiles
- Compared to idealised welds.

TCOMS

Tile Alignment - Hydrodynamics

CFD studies into the frictional effects of tiles – Results

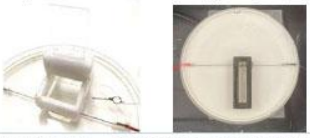


- Different tile gap profiles result in different drag penalties; gap filling is advantageous.
- Filled gaps and non-uniformities likely won't increase the overall drag comparing with the traditional BAF coating surface with welding seams.
- Further modelling at larger scale and for 3D structures needed to draw definitive quantitative conclusions on the impacts of different profiles on real life ship's hydrodynamics.
- Future developments towards larger tiles reduces the number of gaps.

Environmental impact of UV-C

The effects of UV-C anti-fouling treatment on target and non-target organisms.

- Research on the environmental effects of UV-A and UV-B began in the 1970's.
    - But with a gap in the literature studying UV-C.
- Studies have begun to determine the safe use of UV-C LEDs as a fouling prevention solution against non-target organism.
- In a pilot study the phototactic responses of zooplankton (*Artemia franciscana, Daphnia pulex, Harpacticoida* copepods) were measured.
    - Zooplankton were exposed to non-lethal doses of UV-C in a choice chamber.
    - A negative phototactic response was seen – avoidance behaviour limiting the exposure dose.
- Comprehensive further work is needed to get a complete picture.



University of BRISTOL

Other areas that are being worked on…

Vessel operator and Class society feedback has identified other questions / areas of potential focus:

- Safety to humans and the environment
- Operating cost/electricity consumption
- Adhesion – will it stay on?
- Impact damage
- Repairing
- End of life – Recycling
- Weight
- Steel inspection


Current Status & Future Outlook
Market drivers (sterilisation and disinfection) are resulting in smaller, longer lifetime, lower cost LEDs.
Application on small vessel areas achieved with simple tooling using manual techniques - high accuracy achieved.
Manufacture of UV-C tiles at pilot scale has been demonstrated.
Roadmaps for rapid, efficient manufacture at vessel scale.
Tile alignment has no impact on hydrodynamic drag if appropriately filled.
Tile smoothness gives a drag benefit; Total fouling prevention ensures it is maintained.
Preliminary studies show no adverse effects of UV-C on non-target organisms.
Follow up and broader scope studies are needed.
Vessel trial (Damen Shoalbuster) to demonstrate vessel integration and operation at scale.
Proof of concept at system level & Class society discussions
Application on large vessels.
Engineering solutions in parallel markets for large format displays, glazing and building cladding.
Proof of concept has been demonstrated; focus now on commercialisation
the immediate next step is a large area installation on a vessel
15 AkzoNobel – Damen – Philips
AkzoNobel


AkzoNobel
Thank You For Listening
Neil.Oxtoby@akzonobel.com
AkzoNobel
DAMEN
PHILIPS
innovation + you

PERNILE BOHN

Business Area Manager

DHI, Denmark

Pernille Bohn is an environmental chemist testing technologies relevant for prevention or mitigation of marine biofouling. She also works with technologies applied in water treatment of drinking water or ballast water and with studies on effect of chemicals in the environment, based on literature studies as well as field or laboratory test results.

Efficacy and Biological Side Effects of Ultrasonic Transducers

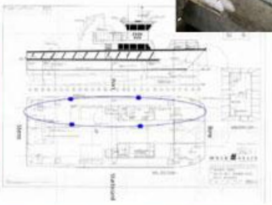
Pernille Bohn, Torben Madsen, Jonas Vendel, Pankaj Porwal

Biofouling on ships increases fuel consumption and transfers non-indigenous species between habitats. Ultrasonic antifouling technologies have the potential to address areas not effectively controlled by conventional technologies. This Danish Maritime Fund-funded study tests the efficacy of an ultrasonic system and investigates the potential side effects on marine mammals.
In the first half of 2024, ultrasonic transducers were installed and then inspected regularly to assess the biofouling level within the ship surface area protected by the ultrasonic waves compared to area protected by conventional technologies.
Ultrasonic transducers were installed on the propeller, cooling system and on part of the hull of an oil tanker as well as on the hull of a diving vessel.
Underwater sound measurements were recorded to model each sound source and its propagation into the environment. The potential impact of the ultrasonic frequencies on marine mammals such as whales, dolphins, and porpoises was then evaluated by comparing the generated sound spectrum to the spectrum of their hearing ability at the relevant frequencies.

Antifouling, testing, efficacy, impact, ultrasonic, technology

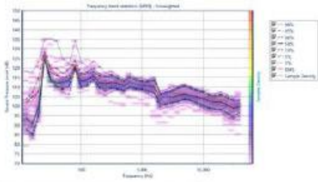
Presentation slides

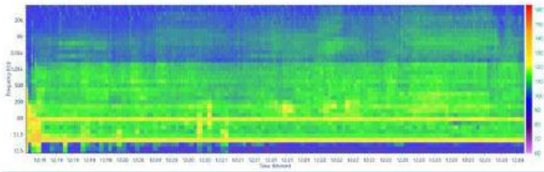
Installation in diving vessel (catamaran)



Transducers OFF, depth 5m, protected side

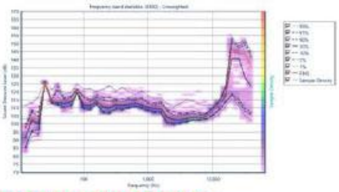
- Genset/machine noise recorded

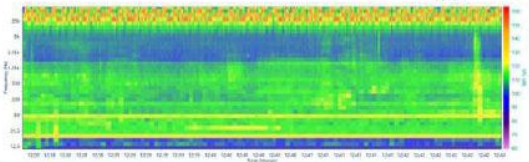




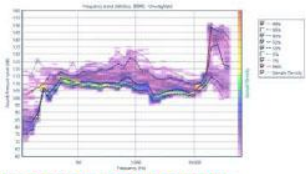
Transducers ON, depth 5m, protected side

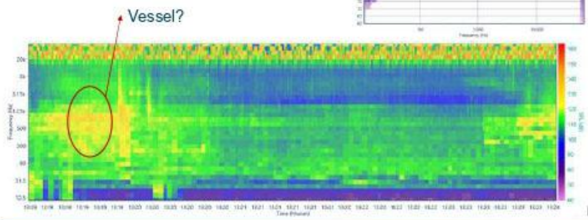
- Pulse from transducer can be captured clearly but with some genset/machine noise





Transducers ON, depth 5m, front

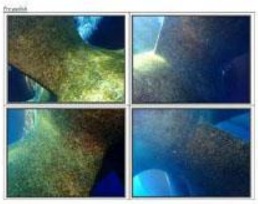




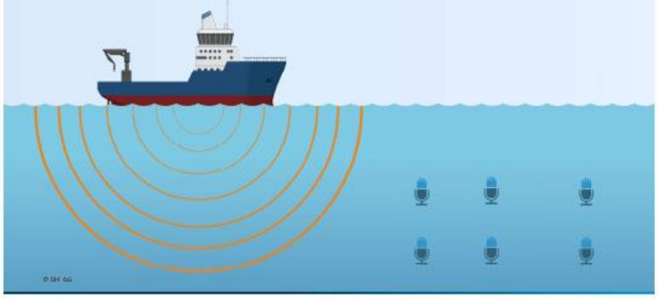
Installation in Hafnia oil tanker

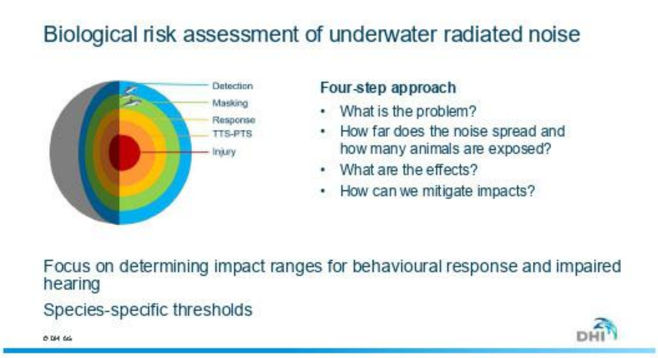
- Internal waterways: cooling system
- Propeller

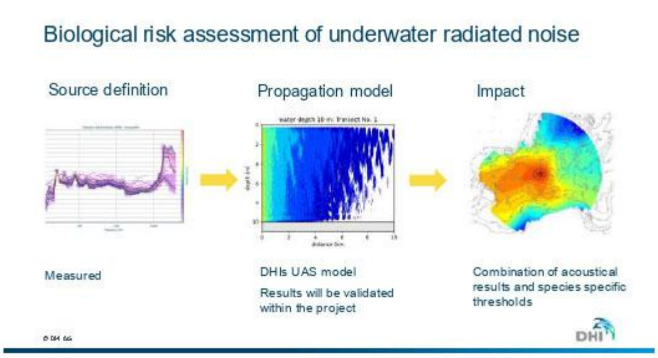
Vessel's four-bladed propeller assembly was examined in detail by diver in end of September concluding doubtful protection.



Measuring ultrasonic emissions in the field




Biological risk assessment of underwater radiated noise
Detection
Masking
Response
TTS-PTS
Injury
Four-step approach
• What is the problem?
• How far does the noise spread and how many animals are exposed?
• What are the effects?
• How can we mitigate impacts?
Focus on determining impact ranges for behavioural response and impaired hearing
Species-specific thresholds
DHI


Biological risk assessment of underwater radiated noise
Source definition
Propagation model
Impact
Measured
DHIs UAS model
Results will be validated within the project
Combination of acoustical results and species specific thresholds
DHI


Thank you
Pernille Bohn
PEBO@dhigroup.com / +45 4516 9508
DHI

KARL LANDER

Environmental Services Director

Subsea Global Solutions

Karl Lander is the Environmental Services Director for Subsea Global Solutions. He has over 25 years of diverse maritime experience, including the past 8 years in the fields of subsea robotics and biofouling management. He is a leader in the development of emerging global industry standards for in-water hull inspection and cleaning, with a focus on robotic and automated solutions, working closely with both the IMO and ISO. Karl previously served in the US Coast Guard, as a diver, Naval Engineer and Cutterman, retiring as a Commander following over 20 years of service, with almost 10 years at sea.

Advanced Hull Cleaning Technology Transport Canada Performance Verification Study

Presentation slides


SUBSEA GLOBAL
Environmentally Complaint
Cleaning all degrees of biofouling
Equipment & Process
Subsea Global Solutions Environmental Solutions shall test three (3) different underwater vehicles equipment with In water Capture systems
All three (3) underwater vehicles shall be tested with the Whale Shark water filtration and processing system filtering particulates (organic and in organic) to one (1) micron and substantially removing soluble metals
In water Cleaning With Capture (IWCC) efficiency as well as ecological water impacts shall be tested
Remora
✓ Diver driven cleaning vehicle
✓ In Water Cleaning with Capture capable to clean all types of coatings with all degrees of biofouling
C-ROV
✓ Cleaning Remote Operated Vehicle
✓ In Water Cleaning with Capture capable to clean all types of coatings with all degrees of biofouling
Beluga
✓ Diver operated Niche Cleaning and Propeller polishing
✓ In Water Cleaning with Capture capable to clean all types of coatings with all degrees of biofouling
Local Regulatory Checklist
Vessel Type ✓
Vessel Trade Route ✓
Applied Coating/Paint ✓
Local Environmental Regulations ✓
Marine Biological Growth ✓
Underwater Maintenance & Record Evaluation ✓
Intellectual Property of Subsea Global Solutions, LLC - All Rights Reserved


SUBSEA GLOBAL
Demonstration Requirements
Performance on different levels of Biofouling
Demonstration Requirements
Specific testing milestones must be met to meet demonstration requirements.
Close coordination between Transport Canada and Subsea Global Solutions necessary.
Vessel Selection ✓
Pre-Cleaning Activities ✓
Demo / Water Sampling ✓
Post-Cleaning Activities ✓
Data Management ✓
Reporting ✓
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SUBSEA GLOBAL
Milestone Schedule
Demonstration to be completed within 2-years.
Three (3) bespoke coatings to be tested within term
First coating type was testing last month; possible completion of additional tests before ice season at testing site.
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SUBSEA GLOBAL
We are Proud of our success
Thank you for your attention.
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CHAIR OF THE SESSION

DR INTI KEITH

Principal Investigator

Marine Biodiversity Research, Charles Darwin Foundation, Galapagos Islands, Ecuador

Dr Inti Keith is a HSE part IV commercial diver, a Scientific Diver and PADI instructor and has dedicated her career to the conservation of marine ecosystems. Inti has worked all around the world from the remote islands of Orkney in Scotland to the Great Barrier reef in Australia. Inti joined he Charles Darwin Foundation in 2010 and worked on shark tagging sea turtle monitoring and subtidal ecological monitoring before completing her PhD on Marine Invasive Species in the Galapagos Marien Reserve. She now leads the Marine Invasive Species and the long term Subtidal Ecological Monitoring Programmes as well as being the science group coordinator for the Eastern Tropical Pacific Marine Corridor initiative (CMAR).

Her research portfolio revolves around the role humans play in changing the natural world, particularly in marine ecosystems, and how science can influence management and policy. In recent years she has focused her research on marine invasions in Marine Protected Areas. She is particularly interested in both the consequences of invasions as well as the informed interventions to prevent and mitigate the impacts of these species and other anthropogenic impacts such as climate change.

WILL GRIFFITHS

Technical Project Analyst

GloFouling Partnerships project, IMO

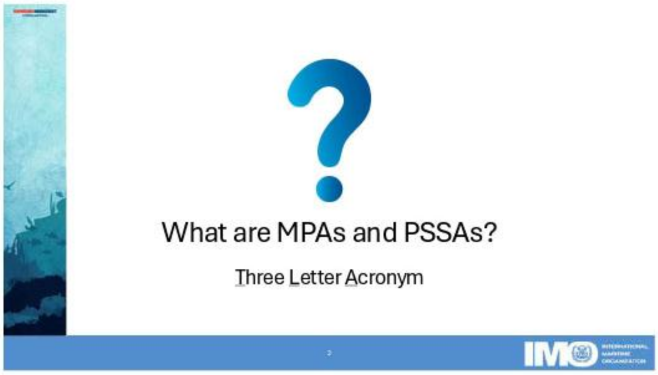
Will Griffiths holds a BSc in Marine Biology and an MSc in Marine Science, Policy and Law. He spent 8 years at Oil Spill Response Limited (OSRL) where he responded to oil spills across Europe, Africa, Asia and the Middle East, from managing beach clean-up operations and offshore response to providing incident management support to private companies as well as governments.

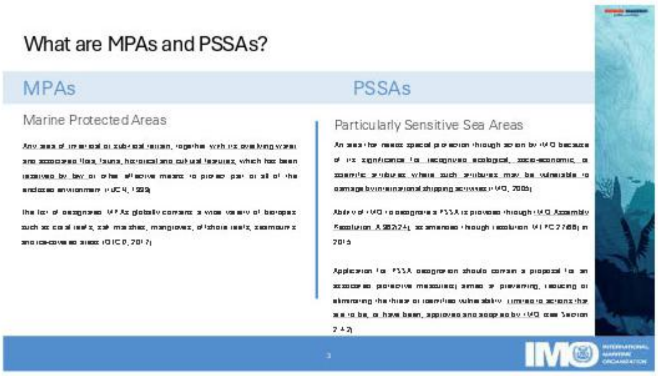
In addition to response, Will also has extensive experience supporting preparedness activities, developing contingency plans, delivering training and conducting preparedness reviews. In 2022, Will joined the International Maritime Organization, a specialised agency of the United Nations as the Technical Officer responsible for the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 90) and its Protocol on Hazardous and Noxious Substances (HNS). In this position he assisted IMO Member States with issues pertaining to marine spills of oil and chemicals to increase international levels of preparedness.

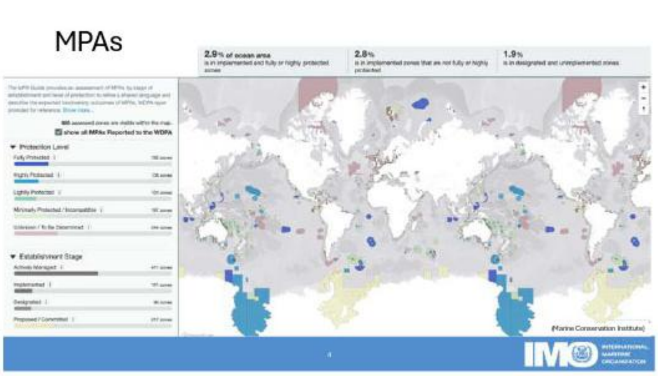
In 2024, Will returned to his Marine Biology roots as he took up the role of Project Technical Analyst in the GloFouling Partnerships project. In this role, he analyses technical aspects of the project, including data related to biofouling management strategies and technologies, to support the project's goals including collaboration with researchers, industry experts, and government agencies.

Biofouling Management in Marine Protected Areas and Particularly Sensitive Sea Areas: State of Play

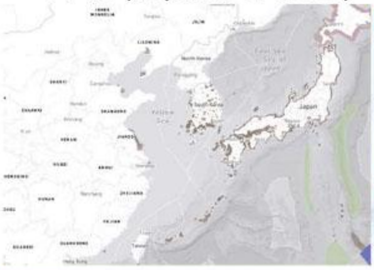
Presentation slides







MPAs (Republic of Korea)



PSSAs

As of 2024, 18 PSSAs have been identified and designated

Examples and measures include

Great Barrier Reef, Australia (1990)
- compulsory pilotage
- Mandatory reporting

Galapagos Islands, Ecuador
- Area to be avoided

Baltic Sea
- Mandatory reporting
- Traffic route
- Deep-water route
- Western traffic separation schemes
- localised compulsory pilotage
- Deep-water route
- Two areas to be avoided

Why is biofouling management important in these areas?

Protected and managed areas provide the core to efforts to protect the ocean.

Increasingly recognized as essential providers of ecosystem services and biological resources, key components in climate change mitigation strategies, and, in some cases, tools for protecting threatened human livelihoods

IAS often have negative impacts on:

- Biodiversity, habitats or ecological processes (ecological impacts);
- Economic activities and infrastructure (economic impacts); and
- Sociocultural impacts (including to human health)

LEATHERY SEA SQUIRT (*Styela clava*)

Is native to the Pacific Coast of Asia but is now known to be in Australasia, the Pacific, Europe and North America. As a fouling species, it is common on rocks and pylons and can reach densities of 500 to 1500 individuals per square metre. It can attach itself to concrete, wood, vessel hulls, pontoons and reefs.

MPAs – Biofouling management

?

How prevalent is Biofouling Management in MPAs?

Managing Risks

"THE PRIMARY FOCUS FOR MPA MANAGERS SHOULD BE IN PREVENTING THE ARRIVAL OF A FOULED VESSEL IN THE FIRST PLACE."

Management measures can be implemented for each stage of the invasion pathway.

Management measure can take the form of:

- effectively preventing biofouling growth on a vessel, maintaining the hull of the vessel as clean as possible; or
- excluding fouled vessel(s); or
- monitoring, controlling and eradicating the species if an IAS has been introduced

Important to take into account the ability to monitor and enforce

IMO's guidelines not mandatory - guidance

Need for regulatory instruments that

(i) establish binding rules and standards against which to measure compliance; and

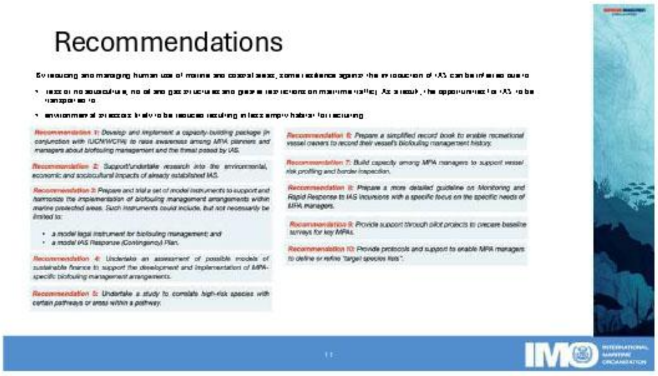
(ii) (ii) define the penalties that will be imposed for any non-compliant actions. In this way, vessel owners will be incentivized to ensure they meet the relevant biofouling management requirement

Ideally each MPA will have a Management plan

Managing Risks - Regulatory approaches

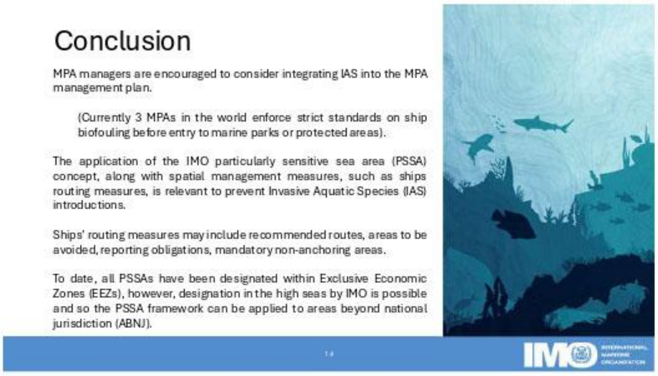
"THE FURTHER ALONG THE INVASION PATHWAY THE DESTINATION IS MADE, THE MORE DIFFICULT IT BECOMES TO PREVENT THE ESTABLISHMENT OF AN INVASIVE FOULING ORGANISM"

	Ecuador (Galapagos Marine Reserve)	Hawaii, USA (Papahānaumokuākea Marine National Monument)	New Zealand (Kermadec and Sub Antarctic Islands)


Recommendations
Recommendation 1: Develop and implement a capacity-building package (in conjunction with IUCN/WCPA) to raise awareness among MPA planners and managers about biofouling management and the threat posed by IAS.
Recommendation 2: Support/undertake research into the environmental, economic and sociocultural impacts of already established IAS.
Recommendation 3: Prepare and trial a set of model instruments to support and harmonize the implementation of biofouling management arrangements within marine protected areas. Such instruments could include, but not necessarily be limited to:
• a model legal instrument for biofouling management; and
• a model IAS Response (Contingency) Plan.
Recommendation 4: Undertake an assessment of possible models of sustainable finance to support the development and implementation of MPA-specific biofouling management arrangements.
Recommendation 5: Undertake a study to correlate high-risk species with certain pathways or areas within a pathway.
Recommendation 6: Prepare a simplified record book to enable recreational vessel owners to record their vessel's biofouling management history.
Recommendation 7: Build capacity among MPA managers to support vessel risk profiling and border inspection.
Recommendation 8: Prepare a more detailed guideline on Monitoring and Rapid Response to IAS incursions with a specific focus on the specific needs of MPA managers.
Recommendation 9: Provide support through pilot projects to prepare baseline surveys for key MPAs.
Recommendation 10: Provide protocols and support to enable MPA managers to define or refine "target species lists".


Good News!
GloFouling
BIOFOULING MANAGEMENT IN MARINE PROTECTED AREAS AND PARTICULARLY SENSITIVE SEA AREAS
Output of an international workshop in Galapagos Islands, Ecuador, June, 2023
Provides MPA managers and policymakers with information to assist in biofouling-vectored IAS management
Compiles and presents existing practices that can be used by MPA managers to protect MPAs
3 Parts (8 Chapters):
I- Overview and Context
1 - Introduction
2 – Context and Problem Definition
II- Management Approaches
3 – Governance Arrangements
4 - Prevention
5 – Managing Risk
6 – Monitoring, Control and Eradication
III – R&D Needs
7 - Recommendations
8 – References


Good News!
GloFouling
BIOFOULING MANAGEMENT IN MARINE PROTECTED AREAS AND PARTICULARLY SENSITIVE SEA AREAS
Contributions from (and thanks to):
• Biofouling Solutions PTY Ltd;
• Fundación Charles Darwin;
• Government of Australia (Department of Agriculture Fisheries and Forestry);
• Government of Hawai'i (Papahānaumokuākea Marine National Monument);
• International Maritime Organization (Marine Environment Division);
• New Zealand (Department of Conservation and Ministry for Primary Industries)
• Orkney Harbours
• Parque Nacional Galapagos; and
• UNESCO - Intergovernmental Oceanographic Commission


Conclusion
MPA managers are encouraged to consider integrating IAS into the MPA management plan.
(Currently 3 MPAs in the world enforce strict standards on ship biofouling before entry to marine parks or protected areas).
The application of the IMO particularly sensitive sea area (PSSA) concept, along with spatial management measures, such as ships routing measures, is relevant to prevent Invasive Aquatic Species (IAS) introductions.
Ships' routing measures may include recommended routes, areas to be avoided, reporting obligations, mandatory non-anchoring areas.
To date, all PSSAs have been designated within Exclusive Economic Zones (EEZs), however, designation in the high seas by IMO is possible and so the PSSA framework can be applied to areas beyond national jurisdiction (ABNJ).


Thank you for listening
Get in touch: Glofouling@imo.org / wgriffiths@imo.org

SONIA ANGÉLICA JURADO CAICEDO

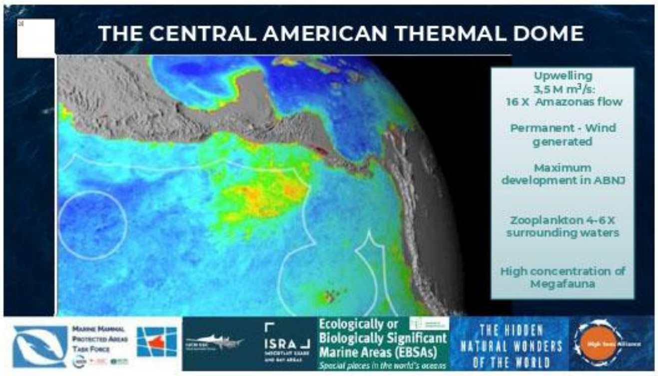
Sargadom Thermal Dome Project *Coordinator*

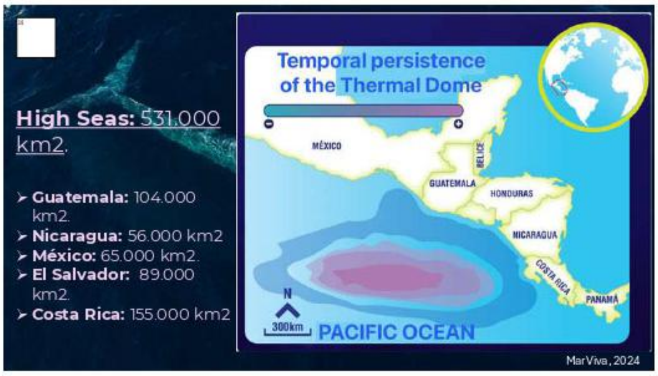
MarViva, Colombia

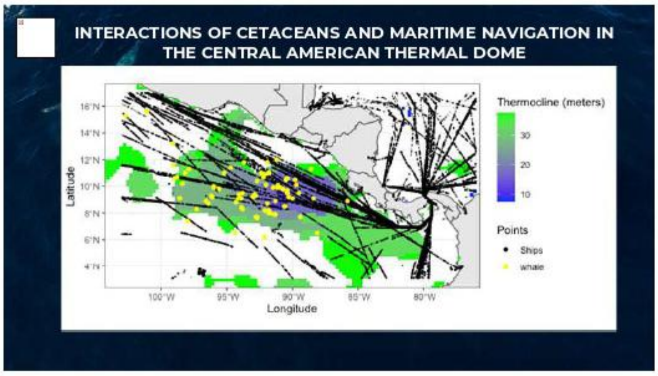
Sonia is a lawyer with a Master's Degree in International Affairs from the University Externado de Colombia. Since 2016, she has been working in the field of international affairs, environmental multilateralism, ocean governance and sustainable development. Sonia joined the SARGADOM project in May 2023 and currently holds the role of Project Manager. As a consultant, she works with governments, NGOs, and International Organizations to design marine conservation and management policies in the High Seas. She is passionate about achieving effective agreements that enable the conservation and sustainable use of the ocean. From 2016 to 2023, she worked for the Ministry of Foreign Affairs of Colombia, where she led the ocean international agenda and environmental affairs in regional and global scenarios. From there, she led the development of public policy for marine conservation and prioritized ocean issues in the national and international agenda.

The journey towards declaring the Thermal Dome as a Particularly Sensitive Sea Area (PSSA)

Presentation slides







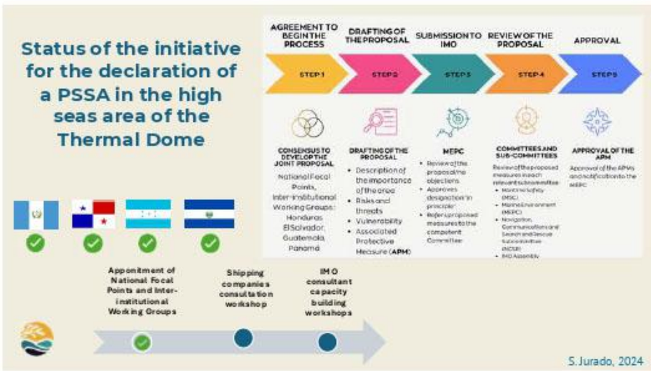

Area Based Management Tools (ABMT)
IMO
BBNJ
MÉXICO
BELICE
GUATEMALA
HONDURAS
NICARAGUA
COSTA RICA
PANAMÁ
300km
PACIFIC OCEAN
While the BBNJ Treaty enters into force:
S. Jurado, 2024


Regional Workshop
Maritime Navigation in the Thermal Dome: Impacts, Management Measures and Governance Options for the Dome
COCATRAM
→Creation of the Technical Liassons Committe for the PSSA on the Thermal Dome
July, 2023
San José, Costa Rica
MarViva, 2024


First international workshop of PSSAs on the High Seas
November 13-15, 2023
San José, Costa Rica.
MarViva, 2024


High-level side event 'Beyond Boundaries: PSSAs a complementary tool for BBNJ, the 30x30 and SDG 14 Agendas'
June 7, 2024
San José, Costa Rica, in the framework of the United Nations Ocean Conference UNOC.
MarViva, 2024


Dissemination and awareness generation sessions:
Honduras April 2, 2024.
Panama May 9, 2024.
El Salvador May 22, 2024.
Guatemala July 17, 2024.
ROCRAM July 22, 2024
MarViva, 2024


Status of the initiative for the declaration of a PSSA in the high seas area of the Thermal Dome
AGREEMENT TO BEGIN THE PROCESS
DRAFTING OF THE PROPOSAL
SUBMISSION TO IMO
REVIEW OF THE PROPOSAL
APPROVAL
CONSENSUS TO DEVELOP THE JOINT PROPOSAL
National Focal Points, Inter-institutional Working Groups: Honduras, El Salvador, Guatemala, Panamá
DRAFTING OF THE PROPOSAL
Description of the importance of the area
Risks and threats
Vulnerability
Associated Protective Measure (APM)
MEPC
COMMITTEES AND SUB-COMMITTEES
APPROVAL OF THE APM
Appointment of National Focal Points and Inter-institutional Working Groups
Shipping companies consultation workshop
IMO consultant capacity building workshops
S. Jurado, 2024


Thanks for your attention
ATLAS:
THE THERMAL
DOME of Costa Rica
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AND SUSTAINABLE USE OF
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UBO

DR INTI KEITH

Principal Investigator

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Assessing the Risk of Non-Indigenous Species in Marine Protected Areas: A Framework for the Eastern Tropical Pacific

Inti Keith

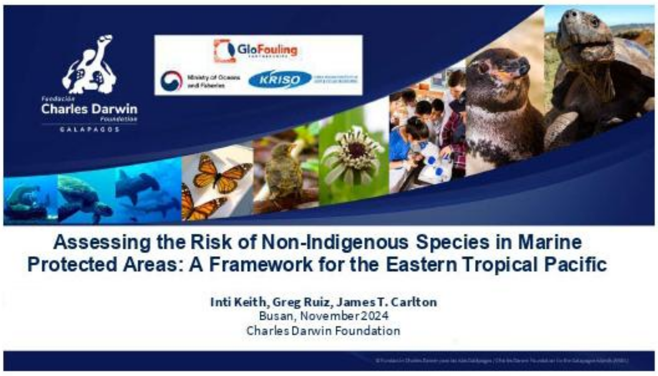
Non-Indigenous Species (NIS) are a growing threat to marine ecosystems worldwide due to globalization and the fact that many species are tolerant of a broad range of environmental conditions, which allows them to extend their distribution to other oceanic regions outside their native range.

Furthermore, NIS hold the potential to enter Marine Protected Areas (MPAs) and maintain populations, which could have cascading effects on native ecosystems, including reduced native biodiversity and changes in native ecosystem structure and functioning. Affected ecosystems may result in adverse socio-economic impacts to coastal communities, such as reduced commercial species, increased biofouling, and reduction in tourism. While biological invasions are often thought to be a threat primarily to urban coastal areas, due to marine traffic and pollution in highly developed areas, recent research reveals that a surprising number of marine species have invaded MPAs, including the iconic Galapagos Islands. Thus, understanding transportation pathways is pivotal to predicting where the next introduction may be likely to arrive via human-mediated transfers, whether intentional or accidental.

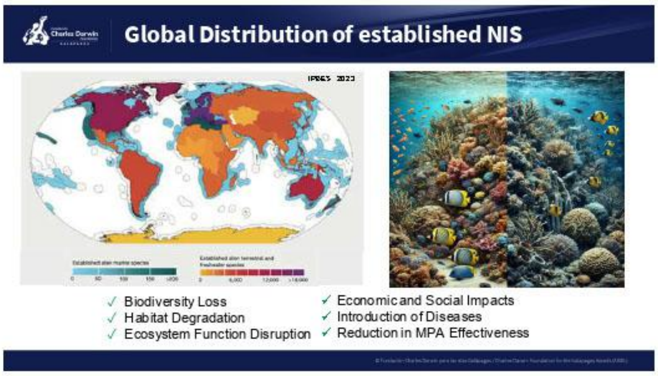
This research provides a framework to assess the risk that NIS pose to MPAs in the Easter Tropical Pacific by promoting standardized monitoring of species and pathways as well as promoting significantly increased biosecurity based on prevention, early detection and rapid response protocols and working alongside MPA managers creating a regional alert system. More broadly, we aim to understand the risk (extent and impact) of NIS already established, as a model to evaluate invasion dynamics and management strategies for island ecosystems and MPAs.

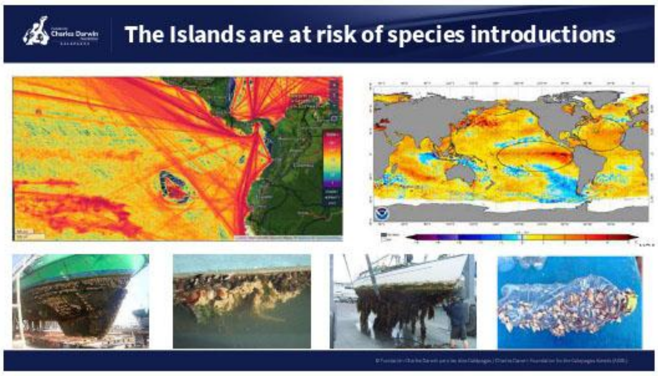
Keywords
Non-Indigenous Species, MPAs, Ecosystems, Bioinvasions, Pathways, Biosecurity

Presentation slides


GloFouling
Ministry of Oceans and Fisheries
KRISO
Fundación Charles Darwin Foundation
GALAPAGOS
Assessing the Risk of Non-Indigenous Species in Marine Protected Areas: A Framework for the Eastern Tropical Pacific
Inti Keith, Greg Ruiz, James T. Carlton
Busan, November 2024
Charles Darwin Foundation


Marine Invasive species are a global problem
✓ The introduction of exotic species has been identified as the second most important cause of biodiversity loss worldwide, after habitat destruction.
✓ Exotic species not only cause effects in ports in urban coastal areas due to maritime traffic, but they also have dramatic effects on isolated ecosystems (islands) and are one of the main causes of species extinction.
Corredor Marino del Pacífico Este Tropical
CMAR


Global Distribution of established NIS
IPBES 2023
✓ Biodiversity Loss
✓ Habitat Degradation
✓ Ecosystem Function Disruption
✓ Economic and Social Impacts
✓ Introduction of Diseases
✓ Reduction in MPA Effectiveness


The Islands are at risk of species introductions


The Galapagos population
Population increase in the inhabited islands
+30,000
Visitor arrivals 2019 - 2023
Number of visitors
271K
73K
136K
267K
329K
2019
2020
2021
2022
2023
Year


Marine Biosecurity

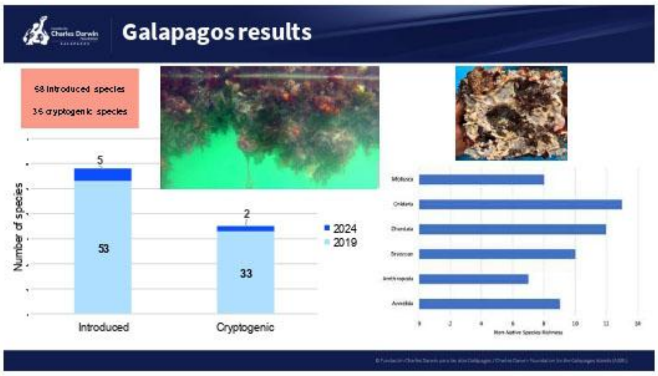

Local level - Management plans
Plan de Manejo de Especies Invasoras para Galápagos 2019-2029
ECUADOR
Parque Nacional GALÁPAGOS
2014
Plan de Manejo de las Áreas Protegidas de Galápagos para el BUEN VIVIR


National and international level
IMO
GloFouling PARTNERSHIPS
BIOFOULING MANAGEMENT
Biofouling Management in Marine Protected Areas and Particularly Sensitive Sea Areas
Charles Darwin Foundation
ECUADOR
Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos
Parque Nacional GALÁPAGOS Ecuador


Global level
Convention on Biological Diversity
THE BIODIVERSITY PLAN
For Life on Earth
Target 6
Reduce the Introduction of Invasive Alien Species by 50% and Minimize Their Impact
Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands.
TARGET 6
Eliminating, minimizing, reducing or mitigating the impacts of invasive alien species
Identifying and managing pathways to preventing their introduction and establishment
Eradicating or controlling invasive alien species that have been introduced and established
1. Identify invasive alien species
2. Identify and manage pathways
3. Prevent introduction and establishment
4. Prioritize pathways, sites and invasive alien species
5. Eradicate or control invasive alien species

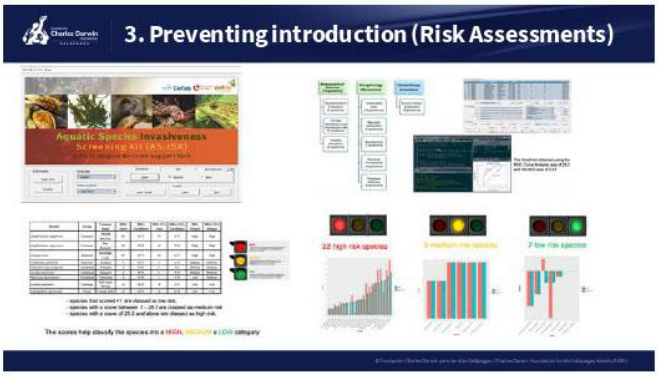

Charles Darwin
Framework for Galapagos

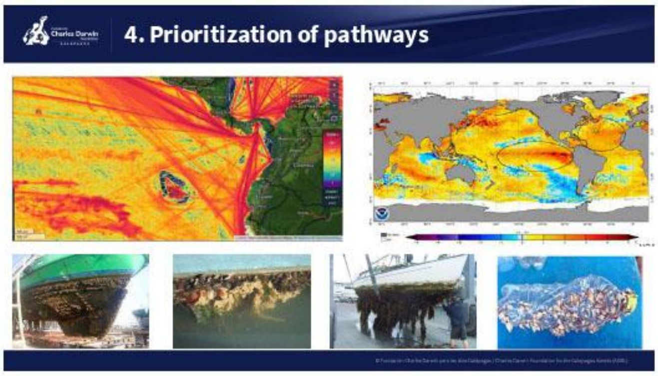

1. Identifying Invasive Alien Species in the GMR
Smithsonian
Species diversity
Voucher collections
Metabarcoding
+
eDNA


Galapagos results
68 introduced species
36 cryptogenic species
Number of species
5
53
2
33
2024
2019
Introduced
Cryptogenic


Online portal
Welcome to GalNEMO!
Select Galapagos NEMESIS species profiles
Bugula neritina
Description

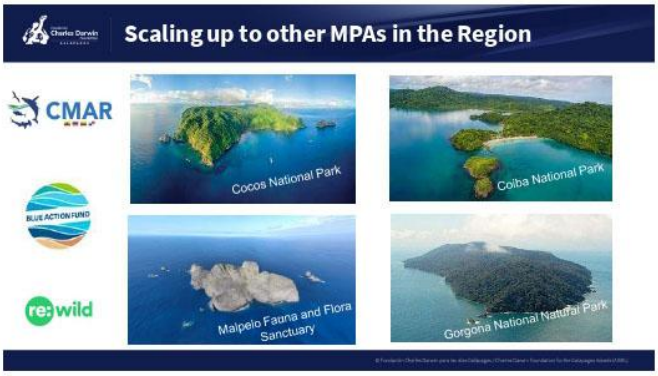

2. Identify and manage pathways
ECUADOR
Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos
All ships entering the GMR are inspected by the ABG
If biofouling is present, the vessel must leave the GMR to clean the hull and return for further inspection.
The GNPD and the Ecuadorian Navy supervise the process
Prevention
Early Detection
Rapid Response

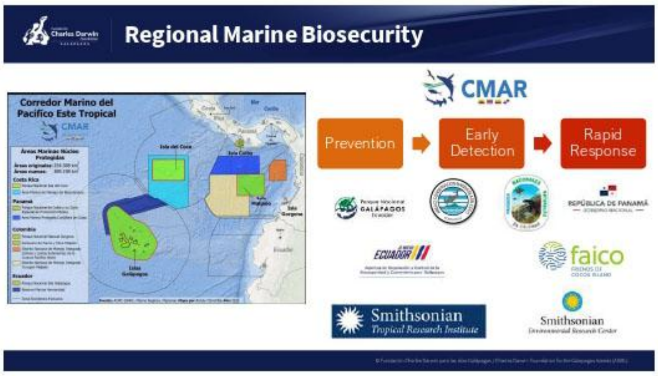

3. Preventing introduction (Risk Assessments)
Aquatic Species Invasiveness Screening Kit (AS-ISK)
22 high risk species
6 medium risk species
7 low risk species


4. Prioritization of pathways


5. Eradicating or controlling
ECUADOR
Parque Nacional GALÁPAGOS Ecuador
SE BUSCA
ESPECIE INTRODUCIDA
BRIOZOO ESPAGUETI
Amathia verticillata
¿DE DÓNDE VIENE?
¿DESDE CUANDO ESTÁ EN GALÁPAGOS?
¿QUÉ PROBLEMAS CAUSA?
2015
2016
¿CÓMO LO IDENTIFICO?
¡CONTÁCTANOS!


Scaling up to other MPAs


Scaling up to other MPAs in the Region
CMAR
re:wild
Cocos National Park
Coiba National Park
Malpelo Fauna and Flora Sanctuary
Gorgona National Natural Park


Regional Marine Biosecurity
Corredor Marino del Pacífico Este Tropical
CMAR
Prevention
Early Detection
Rapid Response
faico
Smithsonian Tropical Research Institute
Smithsonian Environmental Research Center


Coastal & Ocean Marine Biosecurity: International Network of the Americas (COMBINA)
Galapagos, June 2019
Panama, March 2024


Coastal & Ocean Marine Biosecurity: International Network of the Americas (COMBINA)
Our Goal:
• Prevent Invasions & Impacts
--- Local to Continental Scale ---
Accelerate Knowledge Exchange & Capacity-Building Mechanisms:
• Annual regional meeting
• Training workshops
• Student exchanges and internships
Mobilize Shared Tools & Resources
• Standardized Protocols
• Non-native Species Databases
• Alert System
• Risk Prediction
• Detection and Response Framework


Global Goals
Convention on Biological Diversity
THE BIODIVERSITY PLAN
SUSTAINABLE DEVELOPMENT GOALS
The challenge is not just to promote biosecurity in a single location, but to implement a coordinated regional marine biosecurity approach across countries.
2021 2030 United Nations Decade of Ocean Science for Sustainable Development
Challenge 2
Protect and restore ecosystems and biodiversity


Our Donors
USAID
re:wild
MOORE
KFW
ecoventura
Houston Zoo
IGTOA
STEFANO RICCI
QUASAR
FOUNDATION
Metropolitan Touring

Fundación
Charles Darwin
Foundation
GALÁPAGOS

Thank you!
¡Gracias!

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Puerto Ayora, Santa Cruz, Galápagos, Ecuador.

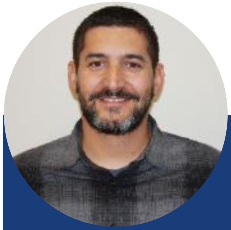
CHAIR OF THE SESSION

COLIN HENEIN

Director

Protection Environment Policy, Transport Canada, Canada

Colin Henein is the Director of Marine Protection within Transport Canada's Environmental Policy directorate. His policy responsibilities relate to biofouling, ship recycling, vessel garbage, marine protected areas as well as abandoned and derelict vessels. Colin is a longstanding member of Canada's delegation to the environmental committees of the International Maritime Organization (IMO). In 2024 he led the IMO's correspondence group on in-water cleaning of ships. Prior to accepting his current position, Colin spent 13 years at Transport Canada in positions of increasing responsibility regarding the ballast water of ships, water levels and flows, and work towards a network of Green Shipping Corridors. Colin holds an honours bachelor's degree in Computer Science and a Ph.D. in Cognitive Science. Outside of work, Colin is a community radio broadcaster and chairs the board of a local multicultural organisation that promotes the arts in schools and the community.



CHRIS SCIANNI

Environmental Program Manager, Marine Invasive Species Program

California State Lands Commission, the United States

Chris Scianni is the Environmental Program Manager for the California State Lands Commission's Marine Invasive Species Program, managing and providing support for the science policy and data management teams while coordinating with field inspectors spread across California. Chris is also the chair of the Coastal Committee of the Western Regional Panel on Aquatic Nuisance Species and helps to facilitate collaborative discussions between invasive species prevention, management, and control programs across the western United States.

Lessons learned from 6+ years of enforcing biofouling management regulations in California

Chris Scianni

The California State Lands Commission's Marine Invasive Species Program has been enforcing biofouling management regulations for commercial vessels arriving at California ports for more than 6 years since adoption in late 2017. The implementation timeline for these regulations was based on each vessel's delivery date or dry docking schedule, resulting in a relatively small number of vessels required to comply during the first year, but increasing annually over the next several years. Between 2019 and 2023, Marine Invasive Species Program staff performed 4,653 biofouling inspections on vessels arriving at California ports. Annual violations per inspection have decreased since inspections began, likely due to increased awareness of the regulatory requirements over time and the dedicate outreach of our inspection teams. This presentation will highlight the most common deficiencies encountered over time, and the effectiveness of a phased implementation followed by a 60-day grace period provision to ease the transition to this new regulatory world in 2017.

Keywords: Biofouling regulations, compliance, inspections, violations

Presentation slides

California's Biofouling Management Regulations

2017

2018

- Phased Implementation – Dry dock or delivery on or after 1 January 2018:
  - Biofouling Management Plan
  - Biofouling Record Book
  - Biofouling Management
    - Hull and niches
  - Extended residency periods

Easing the Transition

2011: Voluntary IMO Biofouling Guidelines
- Biofouling Management Plan not mandatory
- Biofouling Record Book not mandatory

2018: New Zealand CRMS
- BFMP/BFRB not mandatory but one way to be compliant

2018: California Biofouling Management Regulations
- BFMP/BFRB *are mandatory*

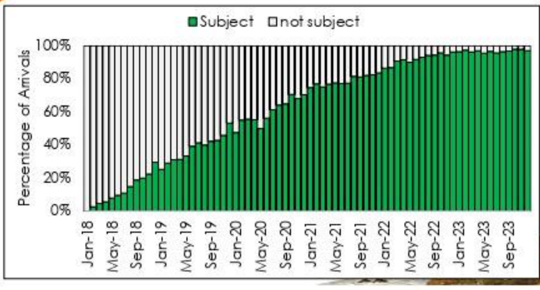
Easing the Transition: 60-day Grace Periods

Deficiency → 

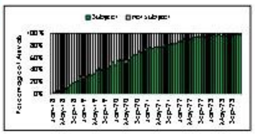
→ Compliance?

- Less punitive
- Encourage compliance

Phased Implementation



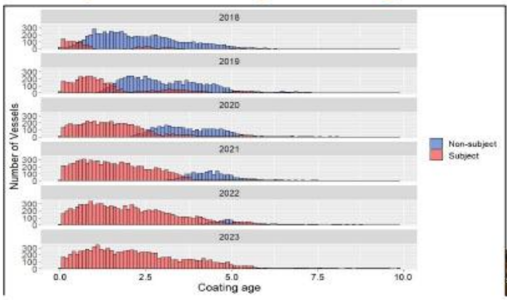
Phased Implementation



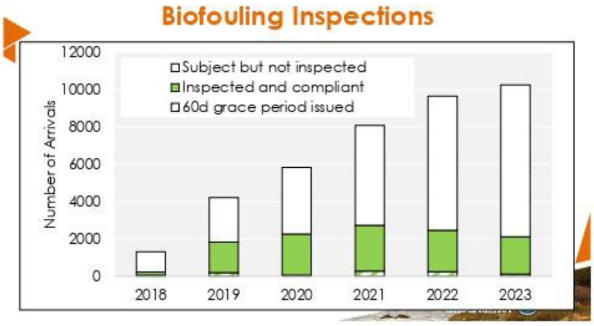
Lesson: Phased implementation was beneficial for:

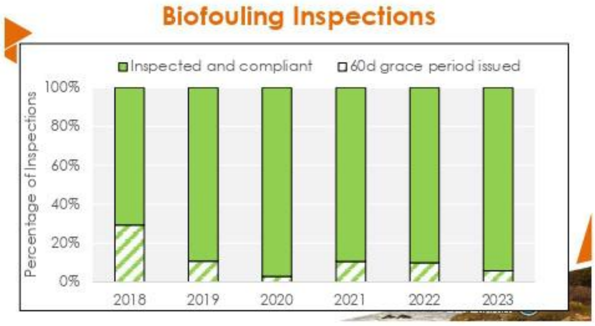
- Industry: Time to create BFMPs and align with drydocking
- MISP: Time to develop inspection and enforcement regime

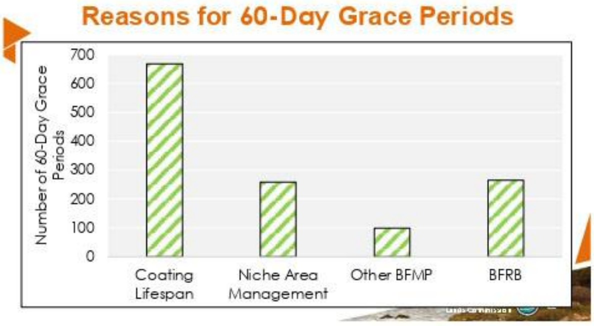
Vessel Populations: Subject to Regulations?




Enforcement: Inspections


Biofouling Inspections
Subject but not inspected
Inspected and compliant
60d grace period issued
Number of Arrivals
12000
10000
8000
6000
4000
2000
0
2018
2019
2020
2021
2022
2023


Biofouling Inspections
Inspected and compliant
60d grace period issued
Percentage of Inspections
100%
80%
60%
40%
20%
0%
2018
2019
2020
2021
2022
2023


Reasons for 60-Day Grace Periods
Number of 60-Day Grace Periods
700
600
500
400
300
200
100
0
Coating Lifespan
Niche Area Management
Other BFMP
BFRB


Lessons Learned: Implementation
- Phased implementation worked
- 60-day grace periods proved useful to increase compliance with the new regulatory regime


Lessons Learned: Enforcement
- Variable quality of Biofouling Management Plans
- Violations: what can we improve with better outreach?
- Coating lifespans
- OOWSSs
- Messages need to make it to owners/operators (plan development) and crew (implementation)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THANK YOU & QUESTIONS
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DR. YASMIN GABAY

Ministry of Primary Industries

New Zealand

Dr. Yasmin Gabay is a Senior Advisor at Biosecurity New Zealand, Ministry for Primary Industries (MPI), specializing in biofouling management and regulatory framework for international vessels. With over five years of advisory experience, she plays a pivotal role in shaping policies that protect New Zealand's unique marine ecosystems.

Holding a PhD in marine biology from Victoria University of Wellington, Dr. Gabay's research focused on the ecological and physiological effects of climate change on the marine environment.

As a representative of New Zealand in international discussions, Dr. Gabay collaborate with a wide range of stakeholders to promote sustainable practices in maritime industries. She has led numerous workshops and webinars, where she discussed New Zealand biofouling regulations and best practices.

Dr. Gabay is committed to advancing maritime biosecurity strategies that ensure a sustainable future for both the environment and maritime operations.

Driving Change on a Global Scale: New Zealand's vessel biofouling requirements

Dr. Greer Whiting

The New Zealand Ministry for Primary Industries (MPI) has been at the global forefront of biofouling requirements since 2018, when they began enforcement of the world's first nationally consistent biofouling standard.

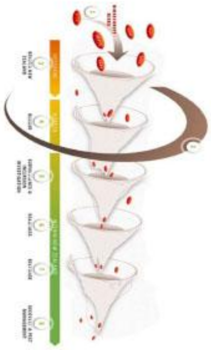
Six years on MPI has reviewed and updated the biofouling requirements.

A quick summary of MPI's updated requirements will give insight into enforcing rules that exist nowhere else in the world.

MPI also holds unique knowledge and lessons learned from the challenges that come with driving change in a newly regulated area. Find out how New Zealand's biofouling requirements are going, the trends they are seeing and their plans to increase the quality and efficacy of global biofouling management in future.

Keywords: biofouling, requirements, policy, compliance, management, New Zealand, global, lessons, trends, future

Presentation slides



New Zealand Biofouling – Overview

- MPI commissioned research to better understand the biosecurity risks from vessels arriving in New Zealand
- Craft Risk Management Standard for Biofouling (*CRMS-BIOFOUL*) published in 2014
- The world's first to target biofouling and apply to all vessels arriving in NZTW
- Prevention is the most effective option to manage vessel biofouling
- Four-year lead-in period for industry to adapt
- Enforcement in 2018

Ministry for Primary Industries

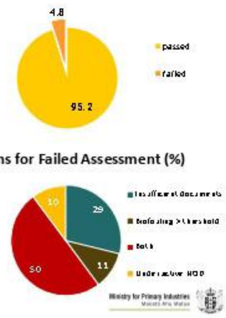
Working Together with Industry to Adapt

- Required the shipping industry to develop new operational practices to manage biofouling on all surfaces
- Cleaning for biosecurity purposes rather than operational
- MPI undertook an intensive communications campaign to raise awareness of the requirements
- Both the shipping industry and MPI experienced a learning curve
- Continued communication and ongoing education is a strong contributor to the high compliance

Ministry for Primary Industries

Vessel Compliance

- Efforts to comply are high
- Reasons for non-compliance:
  - Fouling present over thresholds
  - Insufficient evidence
    - Hull inspection missing/overdue
    - Incomplete reporting on hull
    - AFC expired
  - Both
  - Under active Notice from previous voyages



Ministry for Primary Industries

Biofouling Reporting Issues

- Insufficient documents is a major reason for non-compliance
- MPI sees a large variation in the quality of vessel biofouling inspection reports
- Causes operational delays during clearance
- Leaves vessel operator without evidence to show that they are meeting the biofouling requirements
- Does not allow for accurate self-assessment

Ministry for Primary Industries

Congestion and Post-Covid Issues

- Global supply chain issues have been exacerbated by Covid-19
- Congestion issues at international and domestic ports
- Caused many vessels to go over their short stay allowance

Ministry for Primary Industries

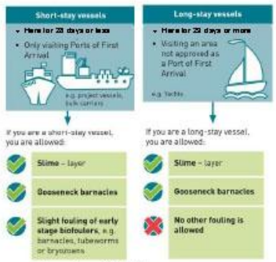
Craft Risk Management Standard for Vessels

- Re-issued in October 2023
- Includes requirements for topside (above water) and biofouling biosecurity risk
- The short stay threshold was increased to 28 days
- Introduced minimum evidence requirements for vessel biofouling inspections

Ministry for Primary Industries
Manatū Ahu Matua

Biofouling Requirements

The definition of "clean hull" depends on the vessels' itinerary within New Zealand



- 1% coverage allowed on flat hull,
- 5% coverage allowed in niche areas

- MPI reduces biosecurity risk by requiring preventative measures for biofouling
- Most commercial vessels fall into the "short-stay" category

Ministry for Primary Industries
Manatū Ahu Matua

Minimum Evidence Requirements for Vessel Biofouling Inspections

- Details how to build a report and the minimum information needed
- Schedule 2 outlines general requirements, capturing evidence requirements and reporting requirements
- Schedule 3 lists the areas that must be covered in an inspection report
- Setting a baseline to:
  - Provide a clear target
  - Smooth out clearance processes
  - Enable informed hull management
  - Reduce biosecurity risks

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Manatū Ahu Matua

In-Water Cleaning

- In-water cleaning (IWC) as a tool for meeting the clean hull requirement
- IWC poses biosecurity risks
- Complicated work with many components that requires holistic perspective
- New Zealand is committed to continue working on this topic with the end goal of creating IWC legislation that safely manages biosecurity risk
  - Part of the IMO IWC guidance development
  - Research
  - Engaging with industry

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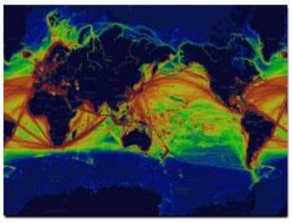
Manatū Ahu Matua

Our Strategy – Thinking Global

- New Zealand is committed to be part of the solution
- Communication - Influencing global trend of biofouling management
- IMO work – driving change
- Supporting other nations developing biofouling regulations



Ministry for Primary Industries
Manatū Ahu Matua

SVEINUNG OFTEDAL

Director

Ministry of Climate and Environment, Norway

Chief Negotiator on Green Shipping in the Norwegian Ministry of Climate and Environment with focus on international negotiations on environmental requirements for the maritime sector.

He started in the Ministry in 1996, but has also executed these tasks for 6 years in the Norwegian Maritime Authority (2000-2006). He started his career as Project Manager in the Norwegian Society for Conservation of Nature in 1990.

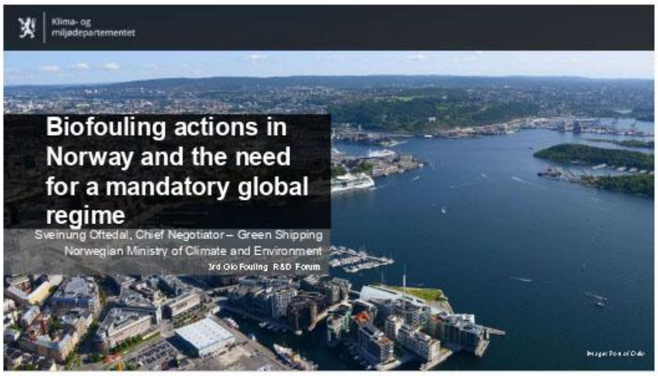
He has been heavily involved in negotiations on the hot topics at the IMO such as Greenhouse Gas Emissions, Air Pollution and other issues addressed in MARPOL, Ship Recycling, Ballast Water Management, Ships biofouling, Antifouling Systems and other environmental issues for over two decades.

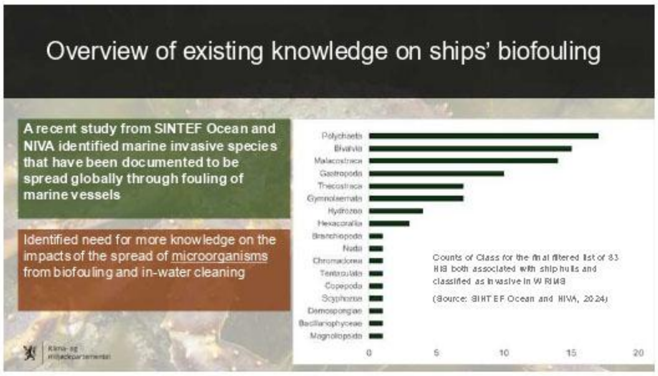
In addition to his role for establishing the environmental framework for global shipping at the IMO, he has played a key role in developing Norwegian green shipping policies for domestic and short sea shipping.

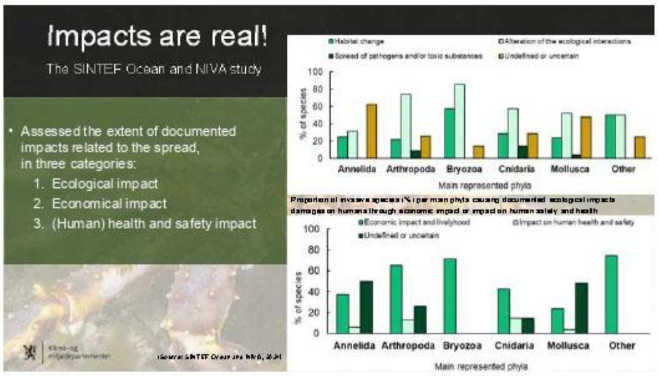
Vice Chair of the IMO BLG Sub-Committee (2002-2009). Chair of the IMO BLG and PPR Sub-Committee (2010 – 2019). Chair of the IMO Working Group on Greenhouse Gas emissions (2017 – present).

Biofouling actions in Norway and the need for a mandatory global regime

Presentation slides





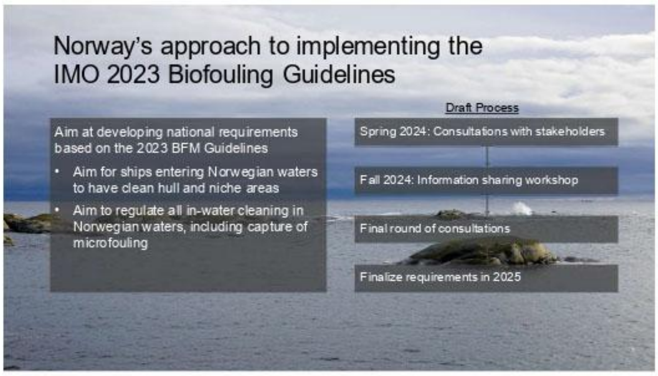


Impacts are real!
The SINTEF Ocean and NIVA study
• Assessed the extent of documented impacts related to the spread, in three categories:
1. Ecological impact
2. Economical impact
3. (Human) health and safety impact
Habitat change
Alteration of the ecological interactions
Spread of pathogens and/or toxic substances
Undefined or uncertain
% of species
Annelida Arthropoda Bryozoa Cnidaria Mollusca Other
Main represented phyla
Economic impact and livelyhood
Impact on human health and safety
Undefined or uncertain
% of species
Annelida Arthropoda Bryozoa Cnidaria Mollusca Other
Main represented phyla
Klima- og miljødepartementet

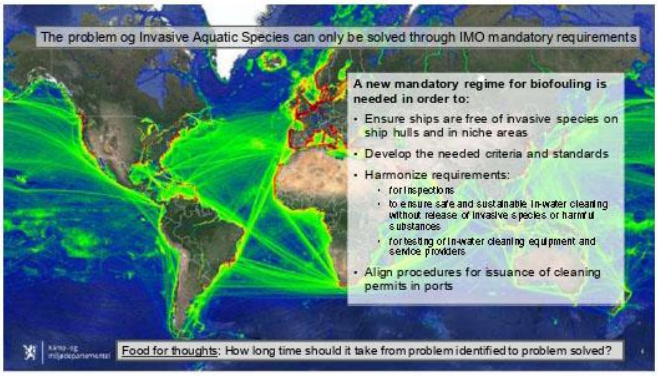
What do we know about the introduction of invasive acquatic species in Norway?
MONITORING MARINE ALIEN SPECIES IN NORWAY
"Biofouling on vessels coming into the Norwegian coast is thus considered to be the most important vector for marine introduction of new species."
Didemnum vexillum was identified in a Norwegian harbour in 2020. This is identified as an high risk invasive species which quickly spreads and establish in Norwegian habitats
"An analysis of preferred habitat of established alien species and potential doorknockers which will create a basis for the choice of methods"
"Methods used followed the recommendations in the HELCOM protocol, which is developed for the Baltic Sea, but also included beach survey, video survey, dredging and extensive use of DNA-methods"
"A total of 33 alien species were detected and DNA analysis indicates that several new doorknocker species are already present in Norwegian waters"
Klima- og miljødepartementet

Monitoring in Norway
✓ National programmes for mapping and monitoring potential new non-indigenous species
✓ Systematic monitoring of spread of already established invasive species
✓ Database for alien doorknockers and assessment of risk

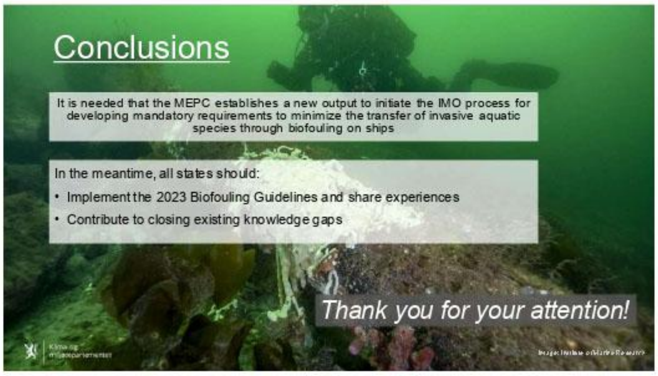
Approval of in-water cleaning in ports
Port of Oslo and Port of Bergen:
• Procedures for approval of service providers and equipment for cleaning in port
• Test procedure:
✓ Ex-situ testing with special focus on capture efficiency of live organisms
✓ In-situ testing with water sampling during cleaning events
• Third-party approval of test results
• Issue cleaning permits to approved providers
Aligned with the draft IMO guidance on in-water cleaning
Klima- og miljødepartementet



Norway's approach to implementing the IMO 2023 Biofouling Guidelines
Aim at developing national requirements based on the 2023 BFM Guidelines
• Aim for ships entering Norwegian waters to have clean hull and niche areas
• Aim to regulate all in-water cleaning in Norwegian waters, including capture of microfouling
Draft Process
Spring 2024: Consultations with stakeholders
Fall 2024: Information sharing workshop
Final round of consultations
Finalize requirements in 2025



The problem og Invasive Aquatic Species can only be solved through IMO mandatory requirements
A new mandatory regime for biofouling is needed in order to:
• Ensure ships are free of invasive species on ship hulls and in niche areas
• Develop the needed criteria and standards
• Harmonize requirements:
• for inspections
• to ensure safe and sustainable in-water cleaning without release of invasive species or harmful substances
• for testing of in-water cleaning equipment and service providers
• Align procedures for issuance of cleaning permits in ports
Klima- og miljødepartementet
Food for thoughts: How long time should it take from problem identified to problem solved?


Conclusions
It is needed that the MEPC establishes a new output to initiate the IMO process for developing mandatory requirements to minimize the transfer of invasive aquatic species through biofouling on ships
In the meantime, all states should:
• Implement the 2023 Biofouling Guidelines and share experiences
• Contribute to closing existing knowledge gaps
Thank you for your attention!

DR. BEV MACKENZIE

Head of Intergovernmental Organization (IGO) Engagement

The Baltic and International Maritime Council (BIMCO), the United Kingdom

Dr Mackenzie is Head of Intergovernmental Engagement at BIMCO, the world's largest direct-entry membership organisation for the shipping industry. She is the London-based Representative at the International Maritime Organization and also provides the link between BIMCO and IMO and other intergovernmental organisations, particularly those within the UN Ocean family, across the globe to ensure that BIMCO's technical expertise can be best utilised by decisions makers- to support practical and harmonised regulation for the shipping industry.

She has a degree in chemical oceanography and a PhD in physical oceanography from the University of Liverpool, UK and applies that scientific knowledge to help understand the science-engineering-policy interface. She has expertise in operational oceanography and ocean observing and issues relating to maritime industries and the environment including issues such as sea-based sources of marine plastics, biofouling management, climate change and air pollution and marine pollution.

She is on the board for the UK's Net Zero Oceanographic Capability programme and is a Trustee of Plymouth Marine Laboratory. She is a Fellow of the IMarEST and of the Marine Biological Association of the UK and a Chartered Scientist and Chartered Marine Scientist.

Application of the 2023 Biofouling Guidelines - Industry insights

Dr. Bev Mackenzie

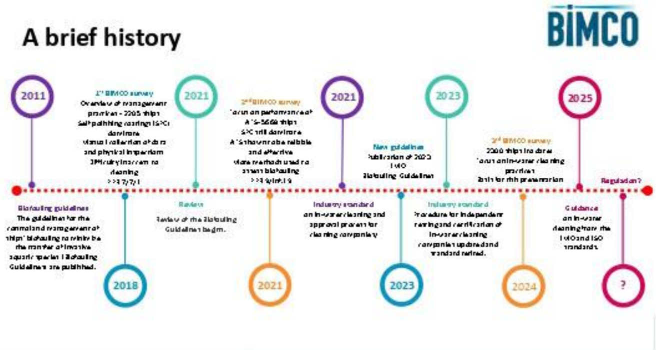
Previous industry surveys carried out by BIMCO in 2018 and 2021 have yielded vital insights into the practical aspects of biofouling management and existing practices- exploring the ways and means ships undertake performance monitoring and inspections through to the efficacy of antifouling systems and their lifetimes compared to claimed lifetimes. The gathering of such information is essential to determine whether or not the 2023 Guidelines and other management measures can be both effective and adopted widely by the industry.

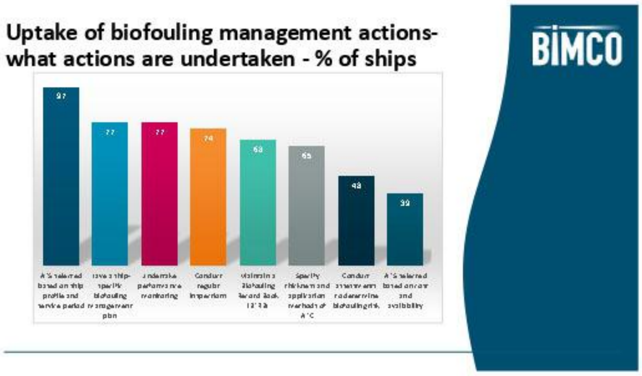
The 2024 shipowner survey will determine whether management practices have changed over the past 6 years (since the first survey) as a result of raised awareness of the relationship between good biofouling management and greenhouse gas reductions. Additionally, it will take a deep dive into a number of specific management scenarios. For example, what actions would a ship take if performance monitoring indicates biofouling? What are the usual practices for cleaning- in-water or in dry dock? What are the potential pitfalls and challenges that may arise? It will also seek to shine a light on the frequency and practical aspects of propellor polishing and look at the adoption of proactive cleaning (hull grooming).

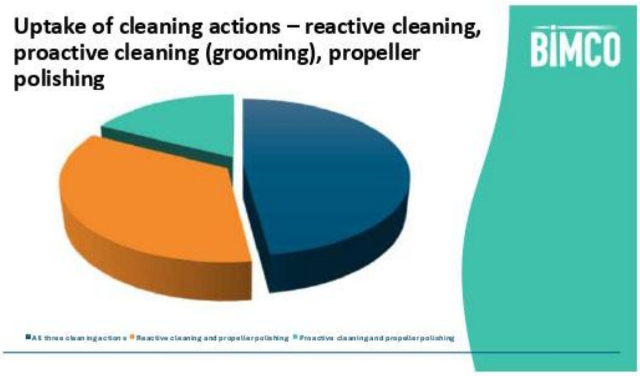
The results of the survey will be presented at the R&D forum- giving attendees a first and comprehensive look into the current state of play in industry biofouling management.

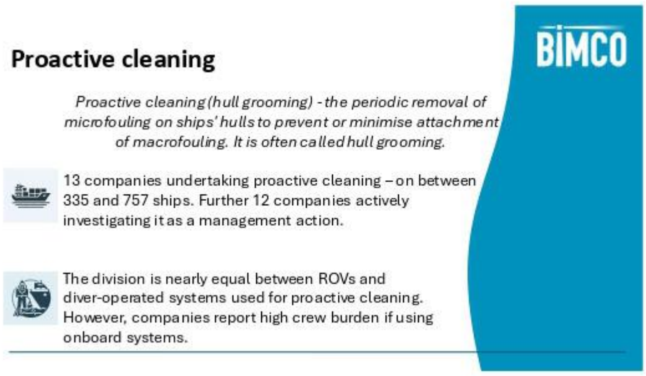
Keywords: Industry, Guidelines, Performance Monitoring, Inspection, In-Water Cleaning

Presentation slides









Propeller polishing

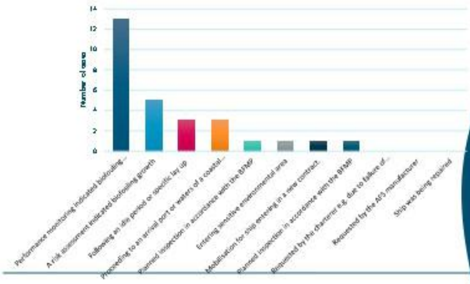
Propeller polishing is the process of cleaning and smoothing a ship's propeller blades. This technique helps reduce drag and enhances the propeller's efficiency.

80% of companies are regularly undertaking propeller polishing with two thirds undertaking propeller polishing once or less than once per year.

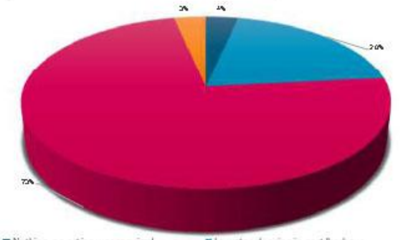
Average GHG savings estimated on average at being just over 6 %

Is propeller polishing being used to full effect or are there barriers?

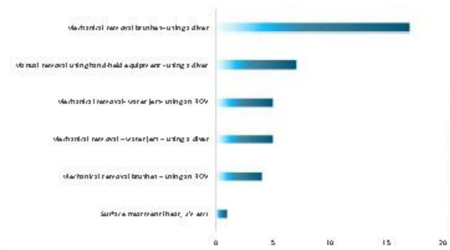
Case studies of reactive cleaning- why?



Case studies of reactive cleaning- what happened as a result of the inspection?

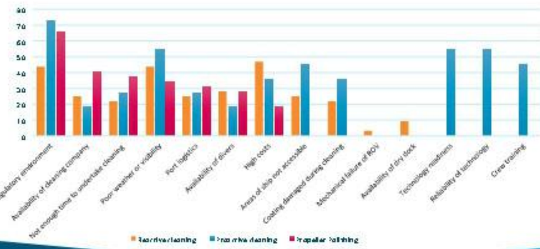


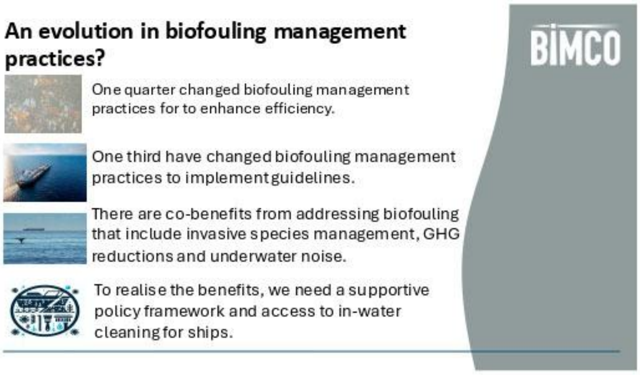
Case studies of reactive cleaning- how was cleaning carried out?



26 out of the 28 cases where GHG emissions were quantified reported that the cleaning decreased their emissions.

What are the barriers to cleaning?




An evolution in biofouling management practices?
BIMCO
One quarter changed biofouling management practices for to enhance efficiency.
One third have changed biofouling management practices to implement guidelines.
There are co-benefits from addressing biofouling that include invasive species management, GHG reductions and underwater noise.
To realise the benefits, we need a supportive policy framework and access to in-water cleaning for ships.


BIMCO
Stay in touch
Contact BIMCO: www.bimco.org
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Contact bm@bimco.org

IRENE ØVSTEBØ TVEDTEN

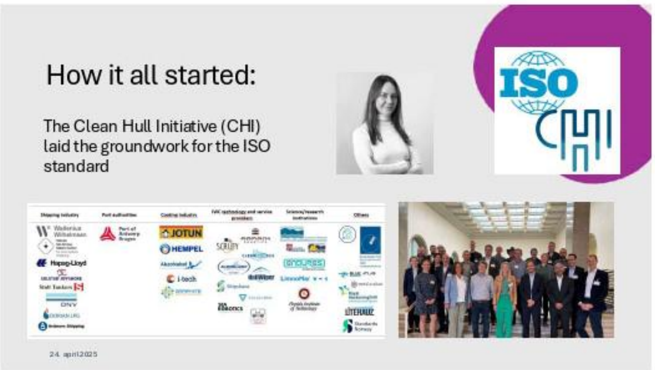
Senior Advisor Maritime

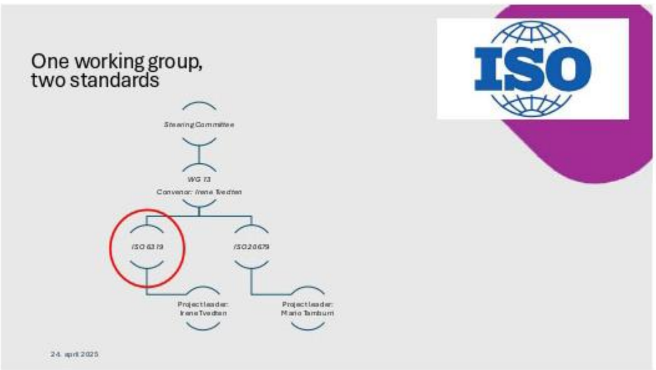
The Bellona Foundation, Norway

Irene Øvstebø Tvedten is a Senior Advisor Maritime in the Bellona Foundation, which is an environmental NGO with main office in Oslo. Tvedten has a PhD in Science and Technology Studies from the University of Oslo. In Bellona, Tvedten works on the Clean Hull Initiative (CHI) to promote frequent and safe in-water cleaning, aiming to stop the spread of invasive aquatic species and reduce greenhouse gas emissions from shipping. Tvedten is also the project leader of a new ISO standard on in-water cleaning.

Updates on the development of ISO Standards related to In-Water Cleaning

Presentation slides





The working group

- Comprised of subject matter experts
- Represents 12 countries (and a liaison organization).
- Includes over 60 experts
  - IWC service providers and technology developers, academic researchers, the coating industry, the port sector and regulatory agencies, the shipping industry, testing organizations and NGOs.

24. april 2025

Title of ISO 6319

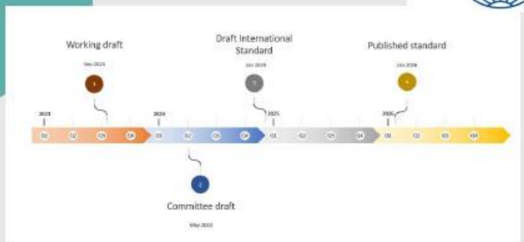
Ships and marine technology — Marine environment protection — Conducting and documenting in-water cleaning of ships' biofouling

ISO 6319 aims to

- Harmonise stakeholder requirements.
- Help ports and other jurisdictions evaluate requests for in-water cleaning.
- Help shipowners ensure that cleaning services are performed in a specific way regardless of location.
- Provide an agreed "best practice" for IWC.

24. april 2025

Timeline for ISO 6319



Scope

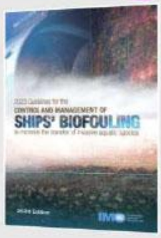
- This document provides best practices for **planning and conducting** in water cleaning (IWC) operations **safely, efficiently and in an environmentally sound manner.** Additionally, this document provides best practices for **reporting on the effectiveness** of IWC operations.
- This document addresses all forms of IWC of external submerged surfaces, which are **hull and niche areas, all types and levels of biofouling**, which means biofilms, microfouling and macrofouling, conducted both **with or without capture**. It does not address internal piping.
- The document has been **established to inform** ports, regulatory agencies, ship biofouling IWC service providers, inspection service providers, IWC equipment manufacturers, coating manufacturers, shipowners, ship managers, ship operators and other relevant stakeholders.

24. april 2025

Aligned with the IMO

Table 1: Rating scale to assess the extent of fouling on inspection areas

Rating	Description	Macrofouling cover of area inspected (visual estimate)	Recommended cleaning
0	**No fouling** Surface entirely clean. No visible biofouling on surfaces.	-	-
1	**Microfouling** Submerged areas partially or entirely covered in microfouling. Metal and painted surface may be visible beneath the fouling.	-	Proactive cleaning may be recommended as further specified in paragraph 9.4.
2	**Light macrofouling** Presence of microfouling and multiple macrofouling patches. Fouling species cannot be easily wiped off by hand.	1-15% of surface	Cleaning with capture is recommended as further specified in paragraph 9.9. It is recommended to shorten the interval until the next inspection. If the AFS is significantly deteriorated, dry-docking with maintenance and reapplication of the AFS is recommended.
3	**Medium macrofouling** Presence of microfouling and multiple macrofouling patches.	16-40% of surface	
4	**Heavy macrofouling** Large patches or submerged areas entirely covered in macrofouling.	41-100% of surface	



24. april 2025

Introduction

Through a stepwise approach, this standard describes the IWC process chronologically. First, all relevant, preparatory aspects—such as general preparations, the assessment of the hull prior to the IWC operation, and preparations associated with any single cleaning event—are considered, then the cleaning operation itself is discussed, which is followed by considerations of post-cleaning processes and reporting. Questions of *why* and *when* cleaning is necessary, including the establishment of proactive or reactive cleaning regimes, are beyond the scope of this document. Rather, this document focuses on the questions of *how* the IWC preparations and operations should take place, and how they should be documented.

24. april 2025

General preparations

24. april 2025

Assessment of hull condition prior to cleaning

24. april 2025

Preparations prior to cleaning events

24. april 2025

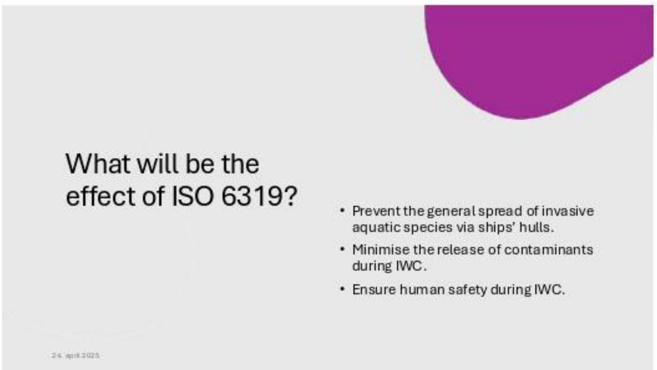
In-water cleaning operations

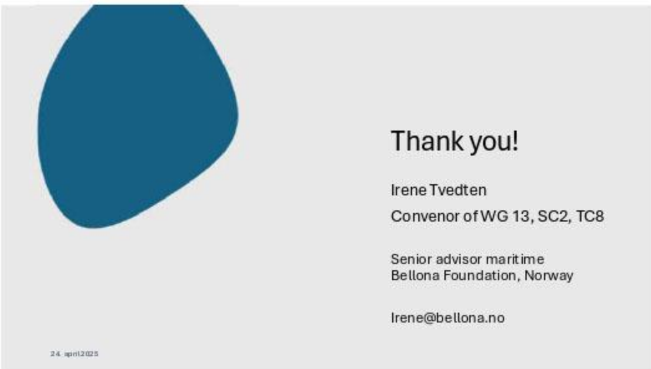
24. april 2025

Post-cleaning reporting and documentation

24. april 2025


What ISO 6319 does not go into
Does not describe IWC regimes.
Does not set criterias for:
Capture rates.
Water quality test results.
ISO 6319 refers to other standards on the following topics:
Testing: ISO 20679
Inspection: SP21487-2021
Evaluation of fouling degree: SP21421-2017


What will be the effect of ISO 6319?
Prevent the general spread of invasive aquatic species via ships' hulls.
Minimise the release of contaminants during IWC.
Ensure human safety during IWC.


Thank you!
Irene Tvedten
Convenor of WG 13, SC2, TC8
Senior advisor maritime
Bellona Foundation, Norway
Irene@bellona.no

DR. MARIO TAMBURRI

Professor

University of Maryland, the United States

Director of the Alliance for Coastal Technologies

Director of the Marine Environmental Resource Center

Recent Awards:

2015 University of Maryland Center for Environmental Science President's Award for Science Application

2017 University System of Maryland Regents Faculty Award for Excellence in Public Service

Areas of Expertise

- *Sustainable urban waterfronts*
- *Environmental technologies and observing*
- *Chemical ecology of aquatic organisms*
- *Invasive species ecology, prevention and management*

Education

- *B.A. Marine Sciences, University of California, Santa Barbara*
- *M.S. Biology, University of Alabama*
- *Ph.D. Biology and Marine Sciences, University of South Carolina*

Updates on the development of ISO Standards related to In-Water Cleaning

Dr. Mario Tamburri

Biofouling of anthropogenic surfaces in natural waters, and the resulting spread of non-indigenous species (NIS), have received substantial attention from researchers, regulators, and the private sector focused on understanding processes and consequences and developing sustainable management approaches. This presentation will provide updates on two related international efforts.

In 2020, the UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) established Working Group 44 to build a broader understanding of the introduction and spread of NIS via biofouling across all maritime industries (e.g., shipping, aquaculture, fishing, and ocean energy). WG44's initial efforts resulted in the 2024 "Biofouling: Non-Indigenous Species and Management Across Sectors" report.

This review found that various strategies and tools to prevent, reduce, or manage biofouling have been developed and adopted but there is no single 'best solution'. Various combinations of policies, regulations, and innovations are still needed for the effective prevention or control of biofouling NIS, and effective frameworks (with adequate monitoring and compliance) need to be established as additional knowledge/solutions become available. The International Organization for Standards (ISO) has also established ISO TC8/SC2/WG 13 on In-Water Cleaning of Ship's Biofouling, which includes ISO 20679 on ship in-water cleaning (IWC) systems verification testing. This standard provides detailed and rigorous methods for performance testing for all forms of IWC (proactive and reactive, with or without debris capture), types of biofouling (microfouling and macrofouling), and surfaces (hull and niche areas). ISO 20679 was developed to support IMO and broader biofouling management efforts and is now being implemented in assessments of IWC systems.

Keywords: GESAMP, ISO, Non-Indigenous Species, In-Water Cleaning

Presentation slides

ISO 20679
Testing of Ship Biofouling In-Water Cleaning Systems

International Organization for Standardization

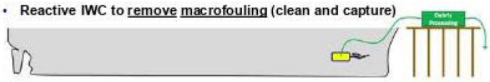
Mario Tamburri, Project Lead
University of Maryland Center for Environmental Science
tamburri@umces.edu, +1-410-326-7440

In-Water Cleaning of Ship Biofouling

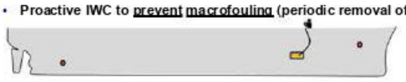
- Long history

Testing In-Water Cleaning Systems

- New generation of in-water cleaning (IWC) technologies and systems
- Reactive IWC to remove macrofouling (clean and capture)

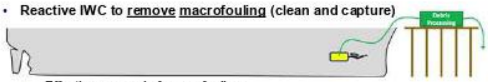


- Proactive IWC to prevent macrofouling (periodic removal of biofilms)

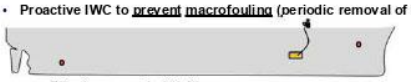


Testing In-Water Cleaning Systems

- New generation of in-water cleaning (IWC) technologies and systems
- Reactive IWC to remove macrofouling (clean and capture)



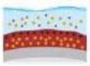
  - Effective removal of macrofouling
  - Effective capture and disposal of debris removed
  - Measurable environmental impacts
  - Measurable coating impacts
- Proactive IWC to prevent macrofouling (periodic removal of biofilms)



  - Effective removal of biofilms
  - Effective prevent of macrofouling
  - Measurable environmental impacts
  - Measurable coating impacts

In-Water Cleaning of Ship Biofouling

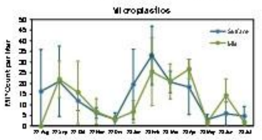
- Ship biofouling is an open system, material is released from surfaces independent of IWC.

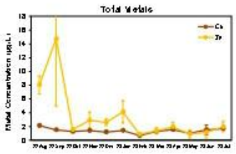


In-Water Cleaning of Ship Biofouling

- Ship biofouling is an open system, material is released from surfaces independent of IWC.

- Ports commonly have measurable and variable background levels of contaminants.
  - Monthly samples at Dundalk Terminal, Port of Baltimore





ACT/MERC Testing of IWC Systems

- Tested a reactive IWC with capture system in 2018

- Tested a proactive IWC system in 2020-2021

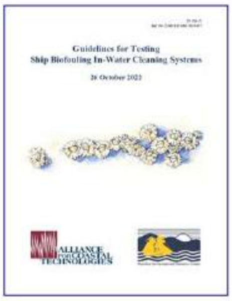
- Ongoing assessments of additional IWC systems

ACT/MERC IWC System Testing Guidelines

- 2021

Technical Considerations for Development of Policy and Approvals for In-Water Cleaning of Ship Biofouling

- 2022



Guidelines for Testing Ship Biofouling In-Water Cleaning Systems

28 October 2022

ISO Standards Related to In-Water Cleaning of Ships' Biofouling

Ships and marine technology – Marine environment protection – In-water cleaning of ships' biofouling ISO/TC 8/SC 2/WG 13

ISO 6319 – Performing and documenting in-water cleaning of ships' biofouling (by 2026)

ISO 20679 – Testing ship biofouling in-water cleaning systems (by end 2024)

- In support of the IMO 2023 *Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species*, new IMO CG on IWC, and other related efforts.
- WG 13 is comprised of subject matter experts from 12 countries (and a liaison organization) who represent the shipping industry, IWC service providers, regulatory agencies, academic researchers, testing organizations, and other stakeholders.

ISO 20679 Testing of Ship Biofouling In-Water Cleaning Systems

Scope

This document provides detailed and rigorous procedures for the independent performance testing of all forms of ship in-water cleaning (IWC), including on all types of biofouling (i.e. biofilms/microfouling and macrofouling), all external submerged surfaces (i.e. hull and niche areas), and both proactive and reactive IWC systems with or without the capture, processing, and disposal of debris. This document also includes testing protocols and describes how to produce data and report on the efficacy and safety of IWC systems to clean various ship surfaces and for the capture and disposal of cleaning debris.

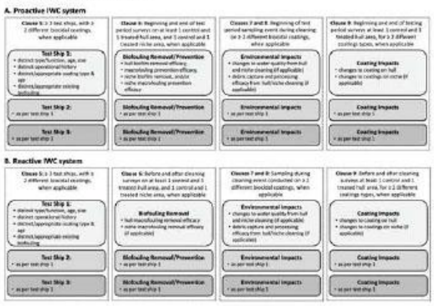
The development of specific IWC performance requirements, criteria, or standards is outside the scope of this document and is the responsibility of individual authorities, agencies, or administrations. Similarly, while some methods and approaches described here can apply to other ship biofouling management approaches, systems designed to kill or prevent biofouling on external surfaces without removal (i.e. without in-water cleaning), and systems that remove or treat biofouling on internal surfaces (e.g. seawater pipes) or external surfaces of intricate mechanical components (e.g. external parts of propeller shaft seal), are also outside the scope of this document.

ISO 20679 Testing of Ship Biofouling In-Water Cleaning Systems

- Table of Contents
  - Forward
  - Introduction
  - Scope
  - Terms and definitions
  - Fundamental information needed for testing IWC systems
  - Test experimental design (for proactive and reactive IWC)
  - Quantification of biofouling removal and/or prevention
  - Quantification of changes to water quality
  - Quantification of debris processing and effluent
  - Quantification of IWC impacts on ship coatings
  - Data management
  - Quality assessments
  - Human health and environmental safety
  - Test reports
  - Annex A - Example of biofouling surveys
  - Annex B - Optional additional determination of IWC impacts on ship coatings
  - Bibliography

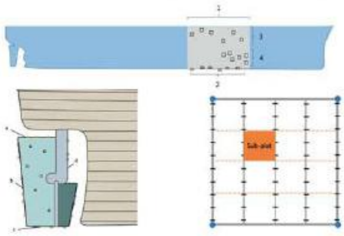
ISO 20679 Testing of Ship Biofouling In-Water Cleaning Systems

- Test experimental design



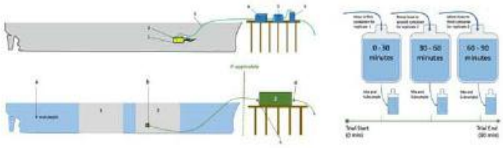
ISO 20679
Testing of Ship Biofouling In-Water Cleaning Systems

- Quantification of biofouling removal and/or prevention
  - Utilizes current/proven best available method (before and after diver biofouling photographic surveys) but allows for new approaches (e.g., automated ROV video surveys) to be incorporated as they are developed and accepted.



ISO 20679
Testing of Ship Biofouling In-Water Cleaning Systems

- Quantification of changes to water quality
- Quantification of debris processing and effluent
  - Comparisons of ambient background, ships coating background (away from IWC), cleaning unit during IWC, and when applicable waste treatment influent and effluent
  - Biofouling organisms (TSS, PSD, POC, and DOC as proxies)
  - Particulate and dissolved biocides
  - Microplastics (polymers associated with coatings and IWC system)



ISO 20679
Testing of Ship Biofouling In-Water Cleaning Systems

- Status
  - Draft International Standard review was completed in September 2024.
  - WG 13 accepted DIS edits and the final WG version was sent to ISO for final editing, formatting, and public release (planned for December 2024).

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Testing of Ship Biofouling In-Water Cleaning Systems

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- Possible Next Steps
  - Capacity building and implementation ISO 20679, including demonstrations and training.

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Testing of Ship Biofouling In-Water Cleaning Systems

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  - WG 13 accepted DIS edits and the final WG version was sent to ISO for final editing, formatting, and public release (planned for December 2024).
- Possible Next Steps
  - Capacity building and implementation ISO 20679, including demonstrations and training.
  - Supplement, expand, or adapt ISO 20679 for other ship IWC approaches (e.g., IWC while underway) and other IWC applications (e.g., offshore platforms and aquaculture pens).

SAHAN ABEYSEKARA

Lloyds Register

The United Kingdom

Sahan is an experience Marine professional with extensive experience on marine environmental technology, marine engineering and marine strategy development. He represented IACS at IMO for Marine Biosecurity. Sahan is LR representative to Global Industry Alliance of IMO-GEF-UNDP GloFouling partnership-. Sahan is an author and speaker representing LR in various conferences and workshops. He is leading Environmental policy at Technical Directorate of Lloyd's Register. Responsible for strategy and implementation for future environmental regulations, provide 'thought leadership' to the industry. He was a Chief engineer sailing on board ship before join LR. Sahan is a Fellow at Institute of Chartered Shipbrokers, Engineering council and member of IMarEST. Sahan holds Master's degree from City University, London.

Clean Hull Notation - Achieving best of both worlds

Heather Hughes, Sahan Abeysekara

Biofouling has been identified as a vector for transfer of invasive aquatic species. Biofouling also has a major impact on the hull/propeller efficiency resulting in higher fuel consumption thus an increase of the operational costs and GHG emissions.

Never before has vessel performance been more important than today, as new regional legislation in the form of the EU ETS (Emissions Trading Scheme) and international regulations such as the IMO Carbon Intensity Indicator (CII) rating system come into play, affecting charter party agreements and placing renewed emphasis on efficient operations. It can be argued the performance of AFC's is now part of various regulatory compliances.

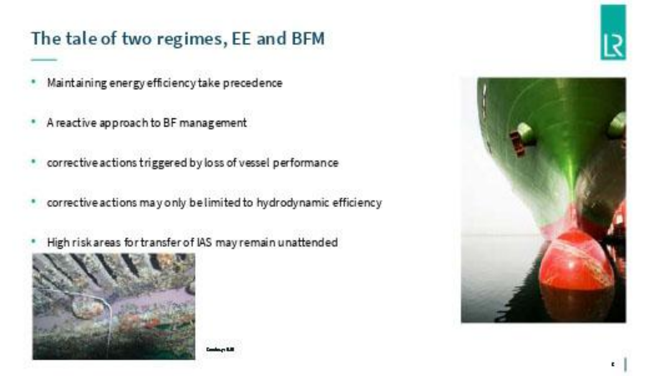
Maintaining a clean hull being the objective, LR explored the possibility of providing framework for ship operators and stakeholders. The process includes Enhanced approval for AFC (beyond AFS convention), compatibility of cleaning equipment and coatings, quality of service suppliers for cleaning and BF inspection, operational practices for the ship to proactively identify and managed the hull fouling.

It is expected the CH Notation provide ships with the recognition for maintaining a near clean hull and access to approved list of suppliers, more visibility of the available AFC and their recommended cleaning processes. It provides AFC's/ AFS's, Cleaning equipment manufacturers, service providers with independent verification of their product/services. More importantly It highlights the synergies of, otherwise isolated regulatory regimes, IMO GHG strategy and prevention of Invasive Aquatic Species.

Keywords
Bio Fouling Management, Green House Gas emissions, Anti Fouling Coatings, In-water Hull Cleaning, Bio Fouling Inspection, Ship Operations, Hull Management

Presentation slides


Achieving best of
both worlds –
LR Clean Hull Notation
Sahan Abeysekara
3rd BioFouling R&D Forum, Korea

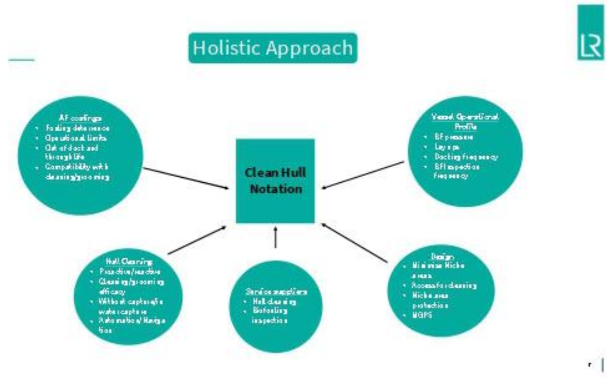

The tale of two regimes, EE and BFM
Maintaining energy efficiency take precedence
A reactive approach to BF management
corrective actions triggered by loss of vessel performance
corrective actions may only be limited to hydrodynamic efficiency
High risk areas for transfer of IAS may remain unattended


Is future looks brighter for BFM?
Unit cost of energy is increasing
Different reporting requirements
Meeting UN SDG obligations
Evolving regulatory landscape and legal prejudices
Climate change
Biodiversity loss
Pollution


The Synergy
Reduction of GHG emissions and Biofouling management
Digitalisation
Better connectivity
Robotics and AI

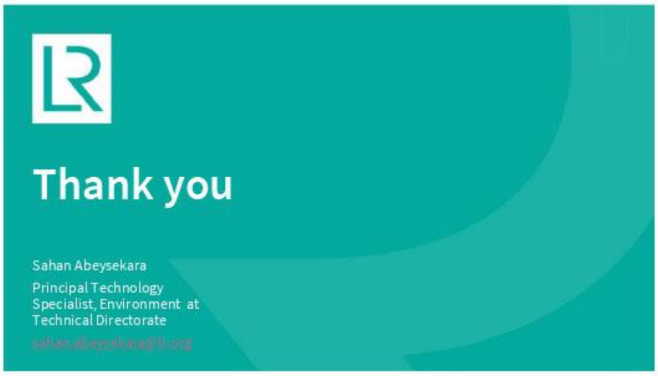

Clean Hull
Notation


Clean Hull notation provides recognition of various hull management practices and quantifies it to a surveyable output. As its name suggests, the intention of the CH notation is to always maintain the hull at near cleaned condition. To obtain and maintain it requires a close relationship with hull management and vessel performance monitoring systems. The proactive identification of hull condition is by means of frequent biofouling inspections and fouling prediction modelling
AFS
BFMP
BFRB
CLEANING
INSPECTION


Holistic Approach
AF coatings
Fouling deterrence
Operational limits
Out of dock and through life
Compatibility with cleaning/grooming
Vessel Operational Profile
BF pressure
Lay ups
Docking frequency
BF inspection frequency
Clean Hull Notation
Hull Cleaning
Proactive/reactive
Cleaning/grooming efficacy
Without capture/with capture
Automation/Navigation
Service suppliers
Hull cleaning
Biofouling inspection
Design
Minimise Niche areas
Access for cleaning
Niche area protection
MGPS


Assign and forget ? No
Assignment of Clean Hull notation include use of approved service suppliers, approved technologies, approved coatings and rigorous reporting/monitoring.
Efficacy of Anti fouling Systems
Compatibility of Antifouling coating with Cleaning technologies , MGPS technologies
Proactive Biofouling inspections (clear & frequent digital reports)
Compatible vessel performance monitoring system
Approved Biofouling management plan which details proposed actions of Hull management.
BF record keeping (BFRB)
LR will conduct review of BFMP, initial survey and periodic survey to verify ship meets the notation requirements. BFMP will be re-reviewed after every docking cycle or major changes to ship operation.
Photo Credit: JOTUN


Where it will be making a difference
Clean Hull notation is exceeding IMO BF guidelines. It's a more proactive approach to BF management.
It merges otherwise isolated two regulatory regimes EE and BFM
CH being part of ECO notation enhances stakeholder confidence by demonstrating a commitment to corporate social responsibility(ESG reporting) and sustainable development. This can lead to stronger relationships with investors, insurers, customers, and communities.
ECO notation signifies that a ship exceeds minimum environmental standards. This included lower emissions of GHGs, reduced air and water pollution, and prevents transfer of AIS.
Foster collaboration: Ship owners, shippers, ports and technology developers
Future proofing: foster Compliance by Design with BF management requirements.
Chapter 11:
Arrangements and Equipment for Environmental Protection (ECO Class Notation)
3.3 Bio-fouling – CH character
3.4 Main character


Thank you
Sahan Abeysekara
Principal Technology Specialist, Environment at Technical Directorate

CHAIR OF THE SESSION

AMELIA BOLA

Maritime GHGH Officer

Maritime Technology Cooperation Centre (MTVV) Pacific, Fiji

Amelia Bola serves as the Maritime Greenhouse Gas (GHG) Officer for the Pacific Maritime Technology Cooperation Centre (MTCC-Pacific), under the Pacific Community (SPC). She specializes in integrating GHG emissions data into maritime policies and strategies to promote pollution prevention and combat climate change across Pacific Island Countries and Territories (PICTs).

With a Master of Arts in Marine Affairs and a Bachelor of Science in Marine Science from the University of the South Pacific (USP), Amelia brings a wealth of knowledge in sustainable sea shipping, environmental management, renewable energy technologies, and PICTs' seafaring heritage. Her experience spans the tourism shipping sector, where she honed her skills in vessel fleet operations, management, and ship safety. An active member of the Fiji Women in Maritime Association (FIJI WIMA), Amelia is a passionate advocate for empowering women in the maritime sector and fostering gender-inclusive solutions for sustainable maritime practices.

BEOM JIN PARK

Principal Research Engineer

Advanced Ship Research Division, Korea Research Institute of Ships & Ocean Engineering, the Republic of Korea

Mr. Park has been working in KRISO (Korea Research Institute of Ships and Ocean Engineering) since 2001. He is now principal research engineer and are expert in the field of risk assessment, ship operational performance analysis and speed trial analysis.

Effects of Hull Cleaning on the Ship Performance

Beom Jin Park, Joon-Hyong Lee, Myoung-Soo Kim

Before biofouling and periodic hull cleaning began to be discussed in terms of preventing aquatic invasive species, ship owners and operators were already employing hull cleaning as a means to improve ships' performance when it is degraded due to biofouling and increase in frictional resistance.

This paper introduces a method to measure the effects of hull cleaning on ships' performance by analysing ship operational data. First, from measured operational data and weather information, added resistance due to environmental conditions are estimated. Then measured consumed power is corrected with added resistance estimation to obtain power consumption in calm waters so that it can be compared with each other on the same reference condition. Corrected power consumption before and after hull cleaning is compared to draw conclusion on the effect of hull cleaning on the ship's performance. Using this method, ship operators will be able to quantify the gain from hull cleaning. While hull cleaning is being discussed as an effective strategy to stop aquatic invasive species from spreading, if a performance gain can be quantified, it will be an added incentive for ship owners and operators to introduce periodic hull cleaning.

Keywords: Hull Cleaning, performance analysis, Biofouling, performance increase, performance degradation.

Presentation slides

Introduction

- CSC (Clean Shipping Coalition) report in 2011 IMO MEPC
  - Average speed loss per year : 2.63%
  - Cumulative speed loss for typical length of sailing interval (54 months) : 10.6%
  - Corresponds to 16% loss in vessel efficiency.
- Generally, 15~20% loss in vessel efficiency is observed over a sailing period.

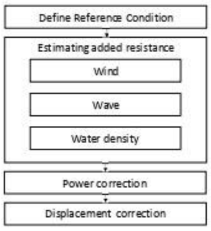
- Ship operators has been using hull cleaning as a means to increase vessel efficiency rather than preventing aquatic invasive species.

Introduction

- Difficulties in hull cleaning decision-making
  - Everyone know hull cleaning increase ship efficiency in terms of speed-power performance
  - The question is how much?
  - (cost) Hull cleaning cost + potential risk for hull and painting damage vs (benefit) less operational cost due to less fuel consumption
- If effects of hull cleaning can be accurately predicted this is easy decision to make
  - Identify current ship performance
  - Identify the effect of hull cleaning on ship performance
  - Predict decrease of ship performance
  - Predict the effects of hull cleaning

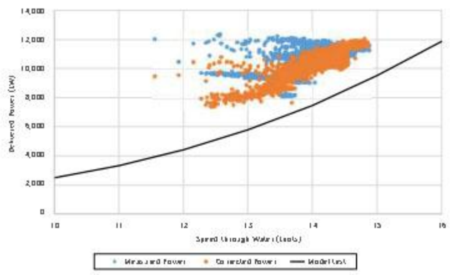
Ship Performance Analysis

- To identify current speed-power performance in reference condition from measured data
  - Measured data
    - Onboard measured data : speed, power, rpm, etc.
    - Weather data : wind, wave, temperature
  - Reference condition
    - Typical operating condition : ballast, laden
    - Reference data is available : tank test results, etc.
    - No environmental effect : wind, wave, tec



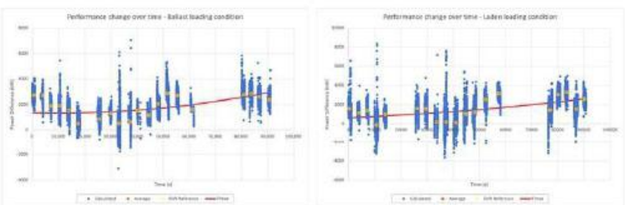
Ship Performance Analysis

- Performance analysis results



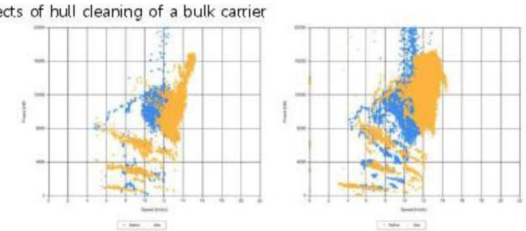
Case Studies

- Ship performance analysis of a Bulk carrier
  - Trends in power increase between dry dockings
  - Increase is not always consistent with time



Case Studies

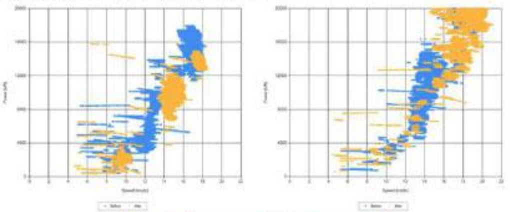
- Effects of hull cleaning of a bulk carrier



Loading condition	Speed Loss		
	Before	After	Gain
Ballast	-15.72%	-5.55%	8.17%
Laden	-15.57%	-10.18%	5.39%

Case Studies

- Effects of hull cleaning of a container carrier



Loading condition	Speed Loss		
	Before	After	Gain
Design	-4.40%	-2.08%	2.32%
Ballast load	-2.50%	-0.58%	1.23%

Conclusions

- Ship performance analysis can:
  - identify current ship performance in terms of speed-power
  - identify increase in performance after hull cleaning
- Hull cleaning increases vessel efficiency.
- Increase in vessel efficiency is directly related to fuel consumption, so a very strong incentive for ship operators.
- This should be considered when making requirements for hull cleaning even if the baseline is to prevent aquatic invasive species

Thank You

Contact: baracude@netopia.re.kr

PROF. I KETUT ARIA PRIA UTAMA

Professor of Hydrodynamics

Department of Naval Architecture, Institut Teknologi SEPULU Nopember (ITS) Indonesia

I Ketut Aria Pria Utama is a professor of marine hydrodynamics at the Institut Teknologi Sepuluh Nopember (ITS) since 2007. His research focus includes the resistance and seakeeping analysis of mono- and multi-hull vessels, study into the correlation of biofouling growth against ship resistance, powering, and ship energy efficiency, development of ocean renewable energy focusing on the investigation of vertical axis ocean current turbine and floating solar farming, and maritime education.

He received his B.Eng. from ITS in 1991, MSc and PhD from the University of Southampton in 1996 and 1999, respectively. He has maintained his research activities via collaboration with UK universities including Southampton. Newcastle, Strathclyde, Cranfield, and University College London (UCL), and in Australia with the University of Melbourne and Australian Maritime College (AMC). He received the Newton Fund Grant 3 (three) times with different types of focus, namely: 1 on Researcher Link Scheme with the University of Strathclyde and 2 on the Institutional Links with the University of Southampton and UCL. The recent and ongoing work with UCL entitled "Ensuring the safety of Indonesian seafarers and fishers in the time of COVID-19 and beyond" has received considerable attention from scientists and practices around the world since the investigation of the pandemic is less on sea transportation and fishing vessels. Part and the very important of this research are the development of mobile application (Apps) on fishing vessel stability called Kora-Kora, has received the very prestigious award called "2023 RINA – LR Maritime Safety Award." Furthermore, his work on the development of hydrophobic anti-fouling coating has been selected as one of the invited papers (speakers) on the 2nd Glofouling R&D Forum on 11th to 14th October 2022 held in London by the International Maritime Organization (IMO). Very recently, Prof Utama and his colleagues (in collaboration with Cranfield University) receive funding from Innovate UK on the development of floating solar farming to be implemented in Indonesia.

Prof Utama has published more than 115 papers indexed by Scopus and cited more than 760 times as well as being a reviewer for many high-impact international journals. He also has 3 granted patents and one of it is the development of dredger with bucket elevator system (granted in 2017). His outstanding non-academic achievements include being a Fellow of the Royal Institution of Naval Architects – one of the biggest professional maritime associations in the world – since 2006, Chartered Engineer (CEng) from the UK Engineering Council since 2006, Fellow of the Indonesian Academy of Sciences (AIPI) since 2015, Vice President of the Royal Institution of Naval Architects (RINA) – Regional Asia since 2019, and Head of Marine-Earth Science and Technology Research Centre (of ITS) from 2020 to 2024.

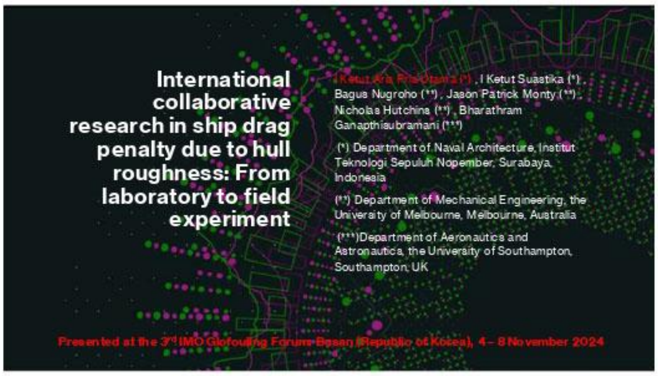
International collaborative research in ship drag penalty due to hull roughness: From laboratory to field experiment

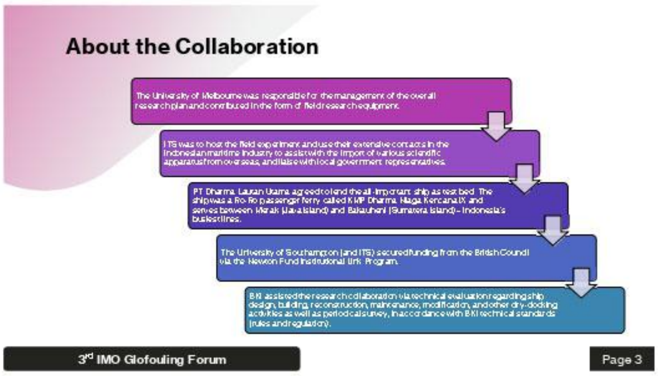
I Ketut Aria Pria Utama, I Ketut Suatika, Bagus Nugroho, Jason Patrick Monty, Nicholas Hutchins, Bharathram Ganapthisubramani

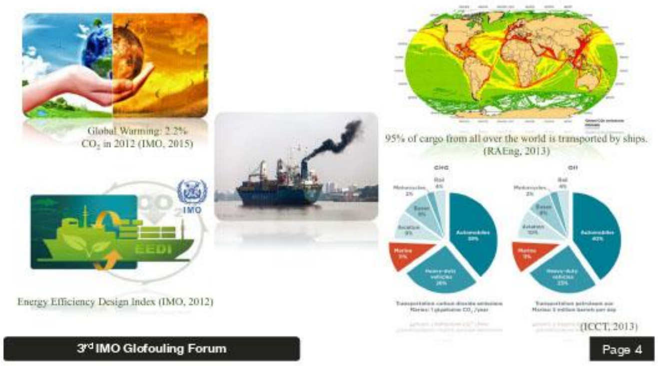
This study investigates the impact of hull roughness on the hydrodynamic performance of recently cleaned and coated ship hulls. Surface scanning and wind tunnel experimentation reveal an "orange-peel" roughness pattern with a sand-grain roughness height (ks) of 0.101 mm. Using integral boundary layer evolution, we predict a significant increase in the average coefficient of friction and total hydrodynamic resistance during operation. To complement the laboratory experiment, a novel non-intrusive measurement technique utilizing Laser Doppler Anemometer (LDA) measurements is employed to assess the rough surface drag penalty of the same ship during steady. Preliminary results show a significant increase in skin-friction drag for recently cleaned ship hulls compared to hydrodynamically smooth surfaces. These approaches provide insights into the practical implications of hull roughness on ship performance and offers valuable methods for drag estimation and measurement, and its correlation to green-house gas (GHG) emissions.

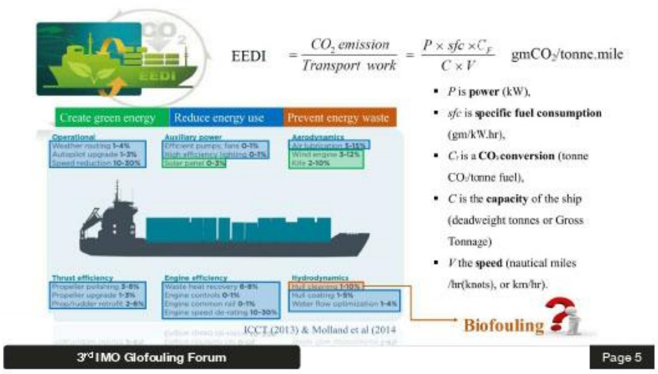
Keywords: hull-roughness effects, Laser Doppler Anemometer, wind tunnel, ship drag.

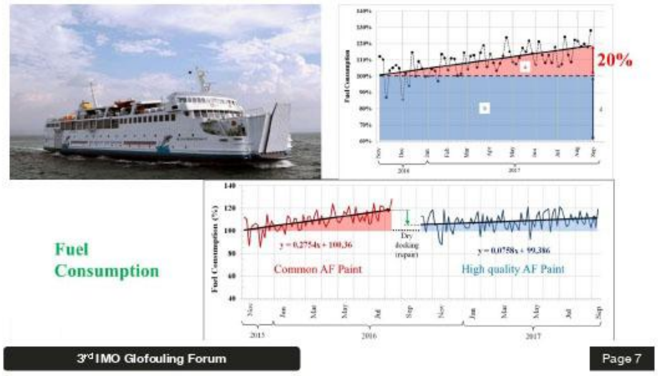
Presentation slides



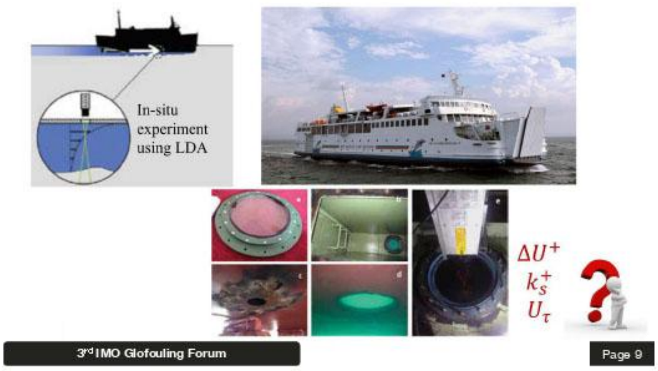







20%
Fuel Consumption
Common AF Paint
High quality AF Paint
3rd IMO Glofouling Forum
Page 7


Wind Tunnel Experiment
ΔU^+
k_s^+
U_τ
3rd IMO Glofouling Forum
Page 8


In-situ experiment using LDA
ΔU^+
k_s^+
U_τ
3rd IMO Glofouling Forum
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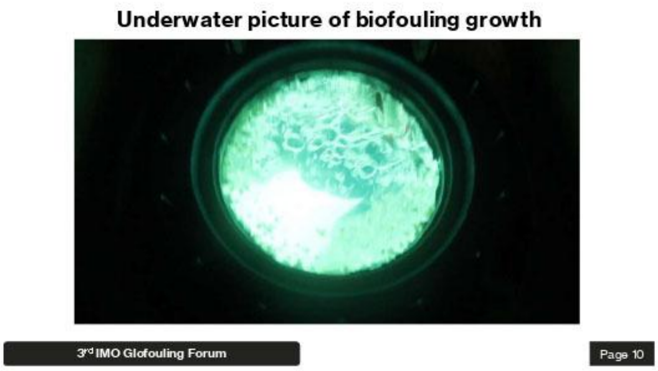
Underwater picture of biofouling growth
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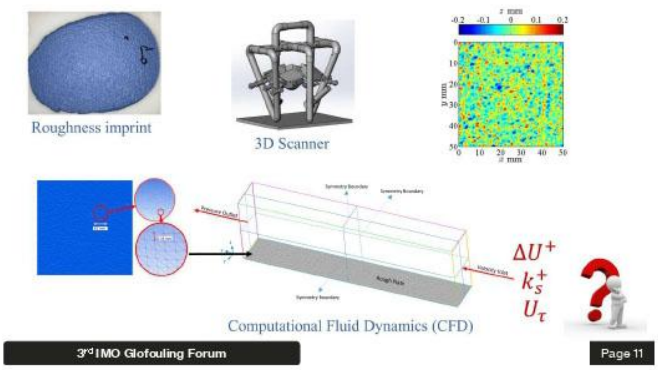
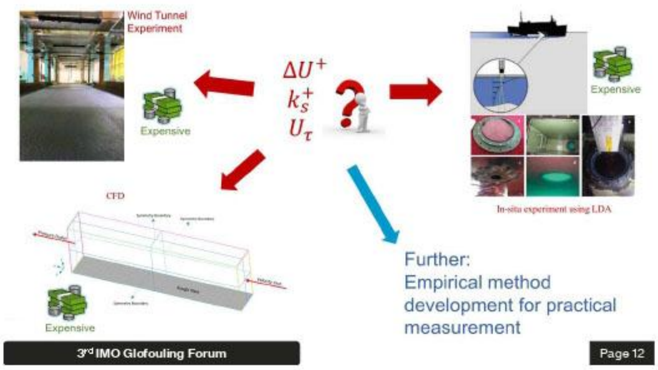

Roughness imprint
3D Scanner
Computational Fluid Dynamics (CFD)
ΔU^+
k_s^+
U_τ
3rd IMO Glofouling Forum
Page 11


Wind Tunnel Experiment
Expensive
ΔU^+
k_s^+
U_τ
Expensive
CFD
Expensive
In-situ experiment using LDA
Further:
Empirical method development for practical measurement
3rd IMO Glofouling Forum
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Paper Published
IOP Conference Series: Earth and Environmental Science
PURPOSE-LED PUBLISHING
Investigation of fuel consumption on an operating ship due to biofouling growth and quality of anti-fouling coating
Investigation of fuel consumption on an operating ship due to biofouling growth and quality of antifouling coating
doi:10.1088/1755-1315/339/1/012037
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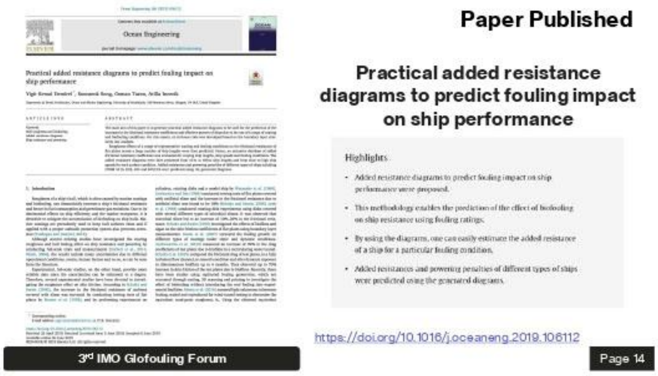
Paper Published
Ocean Engineering
Practical added resistance diagrams to predict fouling impact on ship performance
Highlights
Added resistance diagrams to predict fouling impact on ship performance were proposed.
This methodology enables the prediction of the effect of biofouling on ship resistance using fouling ratings.
By using the diagrams, one can easily estimate the added resistance of a ship for a particular fouling condition.
Added resistances and powering penalties of different types of ships were predicted using the generated diagrams.
https://doi.org/10.1016/j.oceaneng.2019.106112
3rd IMO Glofouling Forum
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Paper Published
Ocean Engineering
A practical empirical formula for the calculation of ship added friction-resistance due to (bio)fouling
Highlights
A practical empirical formula is proposed for the calculation of ship added friction-resistance due to (bio)fouling.
The formula was developed based on data derived from Demirel et al.'s diagrams.
The formula involves power functions with coefficients and powers determined from a nonlinear optimization method.
https://doi.org/10.1016/j.oceaneng.2023.113744
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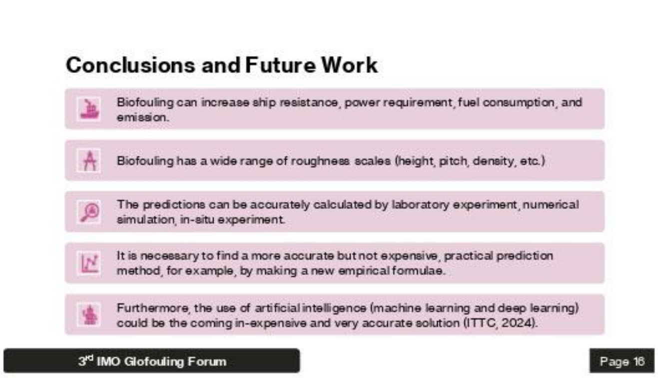
Conclusions and Future Work
Biofouling can increase ship resistance, power requirement, fuel consumption, and emission.
Biofouling has a wide range of roughness scales (height, pitch, density, etc.)
The predictions can be accurately calculated by laboratory experiment, numerical simulation, in-situ experiment.
It is necessary to find a more accurate but not expensive, practical prediction method, for example, by making a new empirical formulae.
Furthermore, the use of artificial intelligence (machine learning and deep learning) could be the coming in-expensive and very accurate solution (ITTC, 2024).
3rd IMO Glofouling Forum
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Future work?
Empirical method development for practical measurement
3rd IMO Glofouling Forum
Page 17


THANK YOU
merci
gracias
danke
dziękuje
dank u
takk
obrigado
kiitos
terima kasih
köszönöm

DR. BAGUS NUGROHO

Lecturer

The University of Melbourne, Australia

Dr Bagus Nugroho is a Lecturer at the Dept of Mechanical Engineering, The University of Melbourne, and part of the fluid mechanics research group. Dr Nugroho's research interest is in fundamental fluid mechanics (both in experiment and numerical simulation), particularly on high Reynolds number turbulent flows, flow controls, drag reduction mechanisms, and rough surface flows. He also looks into environmental flows such as at the effects of biofouling on marine engineering applications (large ships and submarine) and high efficient wind turbine.

An assessment of skin-friction drag over a recently cleaned ship under steady cruising via a combination of in-situ laser based measurement, laboratory experiment and empirical estimation.

B. Nugroho, I. ‘Aliman, J. Will, S. Nugroho , R Chin, I. K Suastika, I. K. A. P Utama, B. Ganapathisubramani, N. Hutchins, and J. P. Monty

The hull of a recently dry-docked ship is expected to be relatively smooth; however, closer inspection shows that it can exhibit an “orange-peel” roughness pattern. Here, four different experimental/analytical techniques are applied to estimate the equivalent sand-grain roughness height k_s and the associated drag of a recently cleaned and painted Ro-Ro ferry hull. The four techniques are:

1) In-situ Laser Doppler Anemometer (LDA): A small glass window is placed on the double-bottom hull of the Ro-Ro ferry, allowing the LDA to measure the velocity gradient in the turbulent boundary layer formed over the hull.

2) Laboratory measurement: The surface roughness pattern from a recently cleaned and painted Ro-Ro ferry hull is obtained using an imprint of silicone rubber during dry-docking. The imprint is then scaled and replicated to cover the working section of a wind tunnel for rough-walled boundary layer experiments using a Hot-wire Anemometer.

3) Computational Fluid Dynamics (CFD): The digital scan of the roughness is used for simulation study via the Reynolds-averaged Navier–Stokes (RANS) method.

4) Empirical estimation: The digital scan is applied to two mathematical models: Chan et al. (2015) and Forooghi et al. (2017). Both methods are known to estimate the increase in drag penalty from an orange peel type of roughness.

Initial assessments of the four independent methods show that the hull would experience around 25%-37% increased drag. This result indicates that even a recently cleaned and painted hull would already experience significant drag. This study highlights the sobering challenges facing the shipping industry in dealing with surface roughness.

Chan L, MacDonald M, Chung D, Hutchins N, Ooi A. 2015. A systematic investigation of roughness height and wavelength in turbulent pipe flow in the transitionally rough regime. J Fluid Mech. 771:743–777.

Forooghi P, Stroh A, Magagnato F, Jakirlic S, Frohnapfel B. 2017. Toward a universal roughness correlation. J Fluids Eng. 139: 121201.

Keywords: Turbulent boundary layer, surface roughness, ship drag penalty.

Presentation slides

An assessment of skin-friction drag over a recently cleaned ship under steady cruising via a combination of in-situ laser based measurement, laboratory experiment and empirical estimation.

Bagus Nugroho[1], Jelle Will[1], Isnain Aliman[1], Hendriyadi[2], Trisnadi Mulia[2], I Ketut Suastika[3], I Ketut Aria Pria Utama[3], Jason Monty[1], Nicholas Hutchins[1]

1. The University of Melbourne
2. PT Samudera Indonesia
3. Institut Teknologi Sepuluh Nopember

2024 3rd GloFouling R&D Forum and Exhibition, Busan, the Republic of Korea

Outline

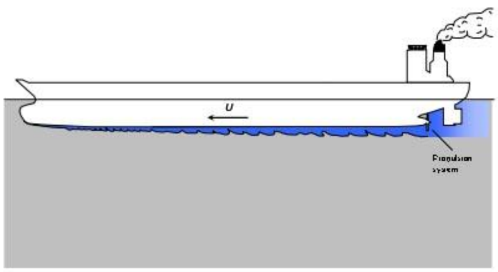
- Background
- Initial research (2015 - 2019)
- Current research (2022 – current)
- Future work

Background

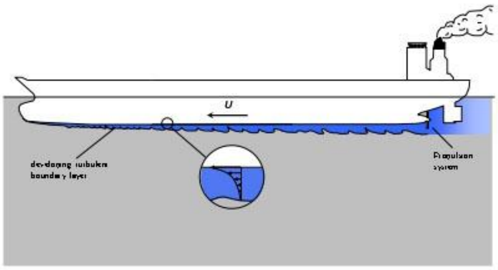
Background

Background

Background

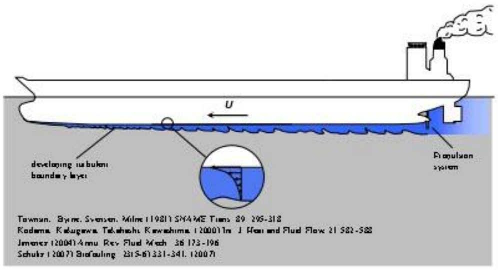


Background



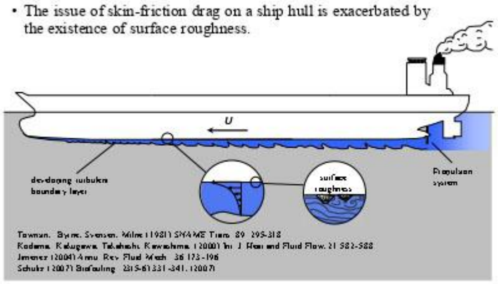
Background

- Up to 80%–90% of the total drag experienced by a large bulk carrier could be due to turbulent skin-friction drag.



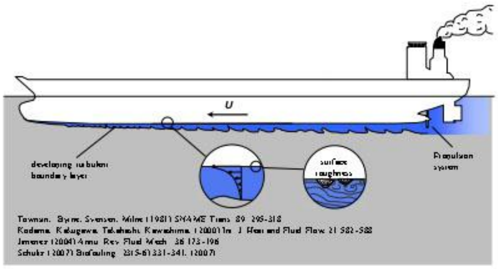
Background

- Up to 80%–90% of the total drag experienced by a large bulk carrier could be due to turbulent skin-friction drag.
- The issue of skin-friction drag on a ship hull is exacerbated by the existence of surface roughness.



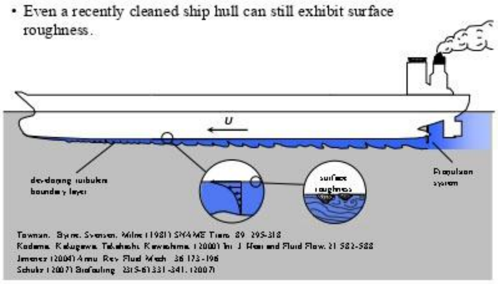
Background

- Surface roughness on a ship hull is generally associated with biofouling or hull imperfections.



Background

- Surface roughness on a ship hull is generally associated with biofouling or hull imperfections.
- Even a recently cleaned ship hull can still exhibit surface roughness.



Background

Background

Background

Laboratory Measurements

Replicate surface in a laboratory facility

Measure the flow over the surface

Background

Laboratory Measurements

Ship-board *in situ* Measurements

Replicate surface in a laboratory facility

Monitor the hull surface state

Measure the flow over the surface

Monitor the velocity gradient in the turbulent boundary layer *in situ*

Background

Laboratory Measurements

Ship-board *in situ* Measurements

Replicate surface in a laboratory facility

Monitor the hull surface state

Measure the flow over the surface

Monitor the velocity gradient in the turbulent boundary layer *in situ*

Analysis

Make predictions for the full-scale ship

Compare with shipboard operations data (fuel consumption, engine power/torque, steaming speed)

Initial research (2015 - 2019)

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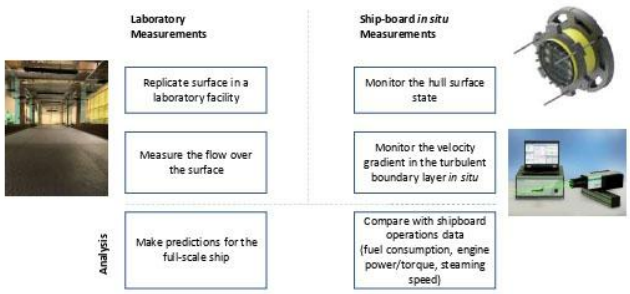
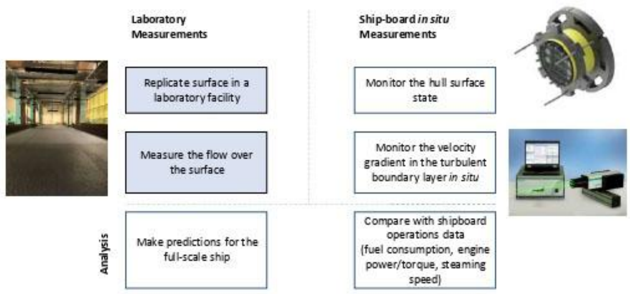


Initial research (2015 - 2019)



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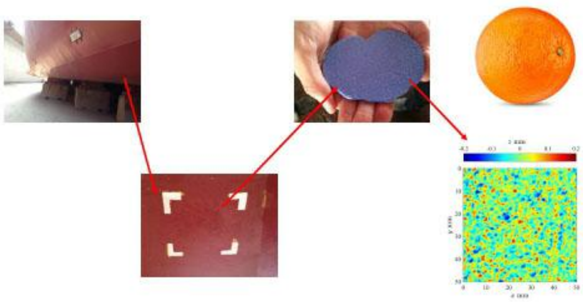

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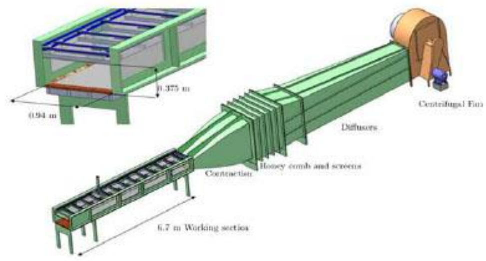

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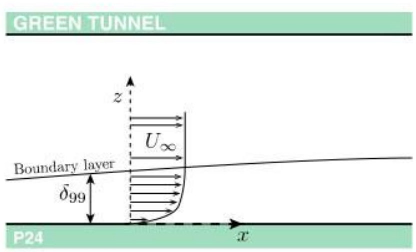

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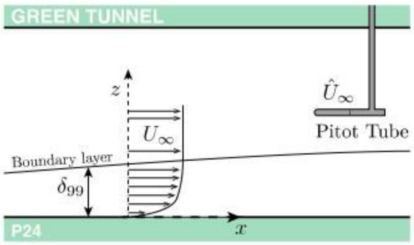

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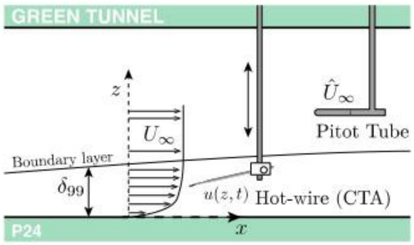

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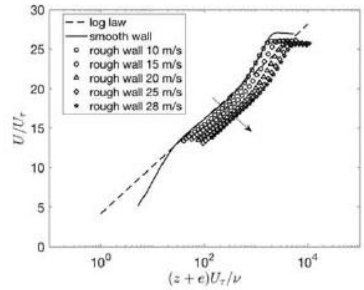

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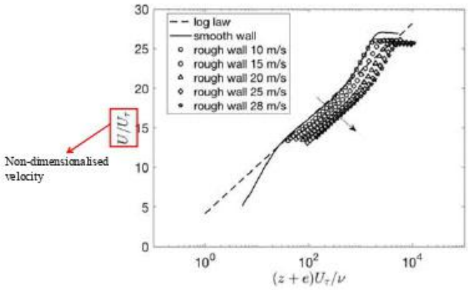

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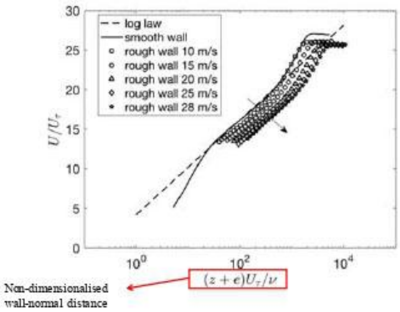

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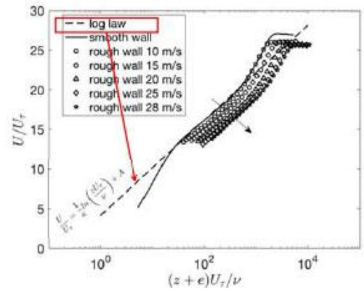

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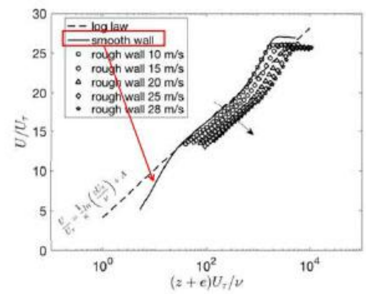

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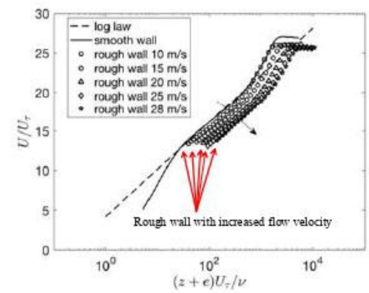

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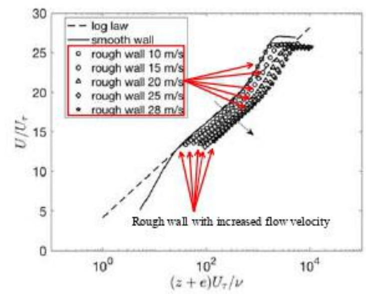

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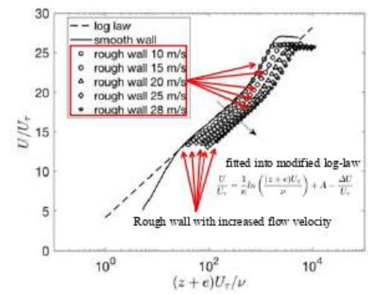

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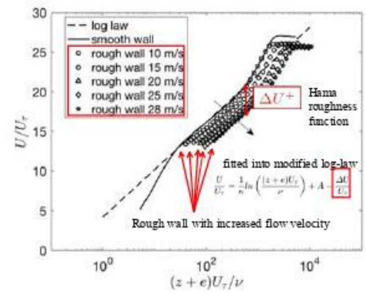

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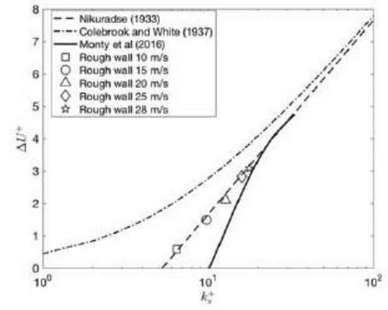

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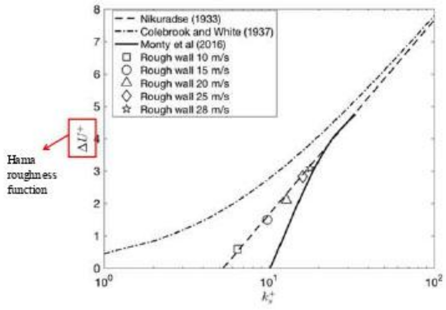

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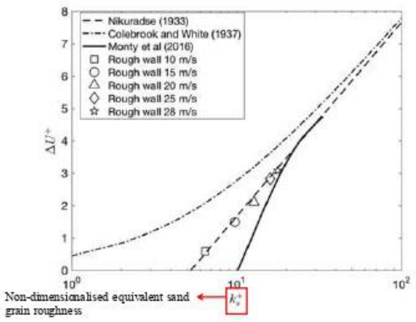

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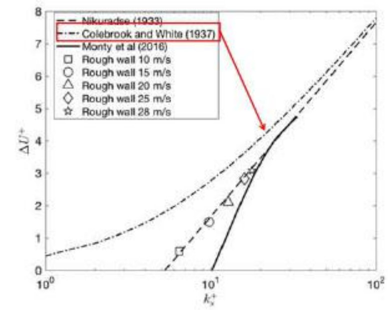

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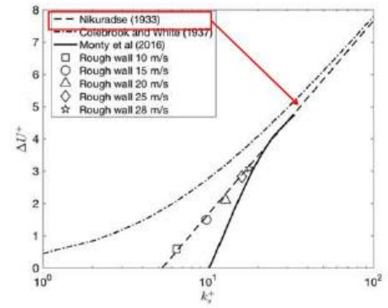

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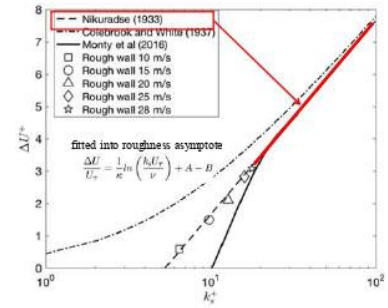

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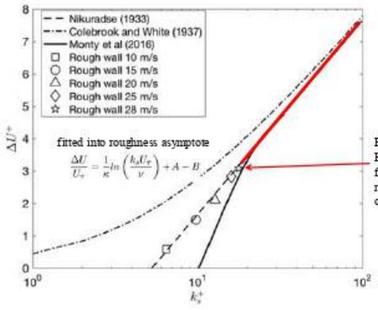

Forcing the highest Hama roughness function to fall under the roughness asymptote to obtain k_s

Initial research (2015 - 2019)

Sand grain equivalent roughness height ks = 0.12 mm

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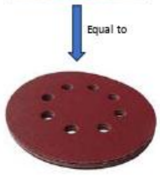

Initial research (2015 - 2019)

Table I. A range of representative coating and fouling conditions. The Naval Ships' Technical Manual (NSTM) rating is a fouling index used by the US Navy based on Naval Ships' Technical Manual (2002). The values of equivalent sand roughness height (k_s) and average coating roughness (Rt_{50}) are based on the measurements of Schultz (2004).

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*NSTM (2002).

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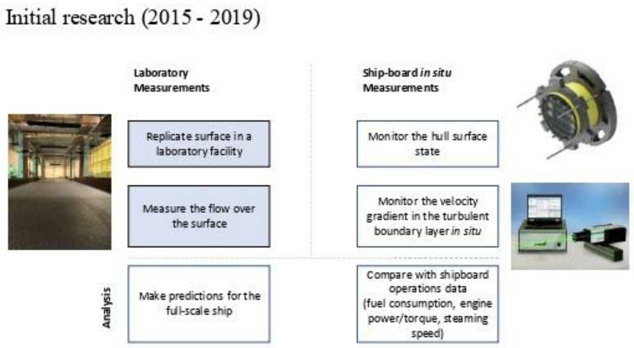
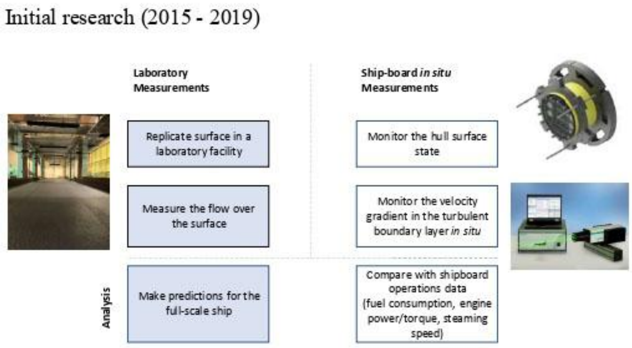

Initial research (2015 - 2019)
Laboratory Measurements
Ship-board in situ Measurements
Replicate surface in a laboratory facility
Measure the flow over the surface
Monitor the hull surface state
Monitor the velocity gradient in the turbulent boundary layer in situ
Analysis
Make predictions for the full-scale ship
Compare with shipboard operations data (fuel consumption, engine power/torque, steaming speed)


Initial research (2015 - 2019)
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Measure the flow over the surface
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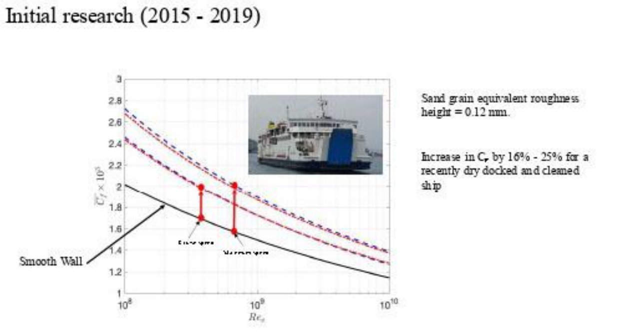
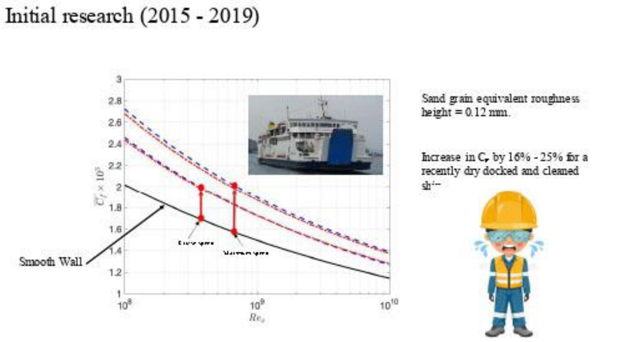

Initial research (2015 - 2019)
Smooth Wall
$\overline{C}_f \times 10^3$
Re_x
Sand grain equivalent roughness height = 0.12 mm.
Increase in C_F by 16% - 25% for a recently dry docked and cleaned ship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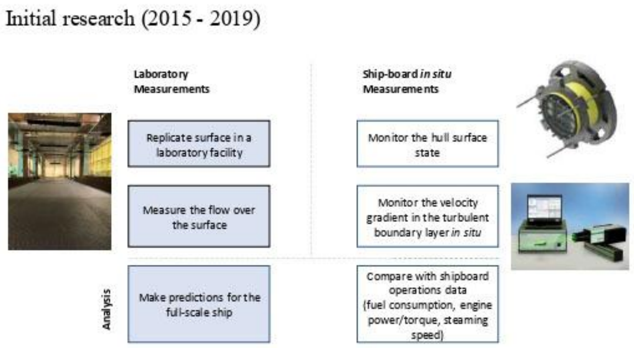
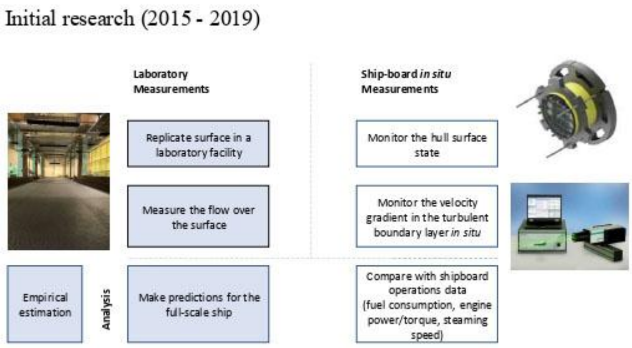

Initial research (2015 - 2019)
Laboratory Measurements
Ship-board in situ Measurements
Replicate surface in a laboratory facility
Measure the flow over the surface
Monitor the hull surface state
Monitor the velocity gradient in the turbulent boundary layer in situ
Analysis
Make predictions for the full-scale ship
Compare with shipboard operations data (fuel consumption, engine power/torque, steaming speed)


Initial research (2015 - 2019)
Laboratory Measurements
Ship-board in situ Measurements
Replicate surface in a laboratory facility
Measure the flow over the surface
Monitor the hull surface state
Monitor the velocity gradient in the turbulent boundary layer in situ
Empirical estimation
Analysis
Make predictions for the full-scale ship
Compare with shipboard operations data (fuel consumption, engine power/torque, steaming speed)

Initial research (2015 - 2019)

Empirical estimation

$$\Delta U^+_{est} = \alpha \log k_a^+ + \beta \log ES + \gamma$$

Only need average height k_a and effective slope ES_x.

Where κ is log law constant 0.4, β and γ is roughness empirical constant 1.47 and 1.12 respectively.

L. Chan, M. MacDonald, D. Chung, N. Hutchins, A. Ooi (2015) J. Fluid Mech. 771 743-777

Initial research (2015 - 2019)

Empirical estimation

Can be obtained via a simple surface scanning or 3D image scanner.

$$\Delta U^+_{est} = \alpha \log k_a^+ + \beta \log ES + \gamma$$

Only need average height k_a and effective slope ES_x.

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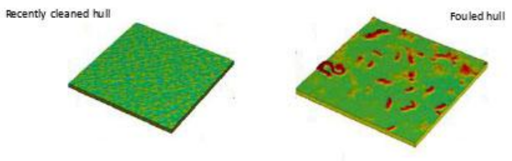

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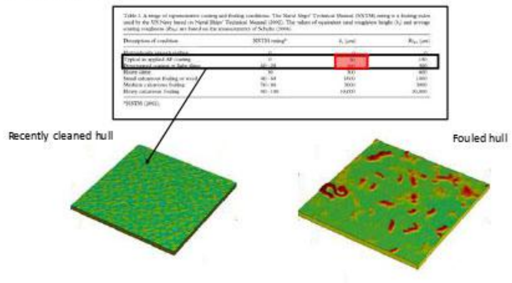

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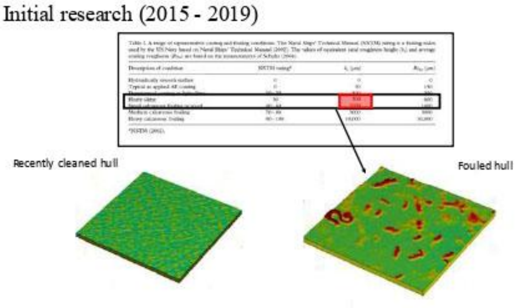

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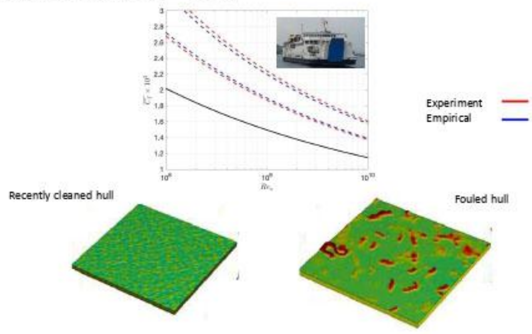

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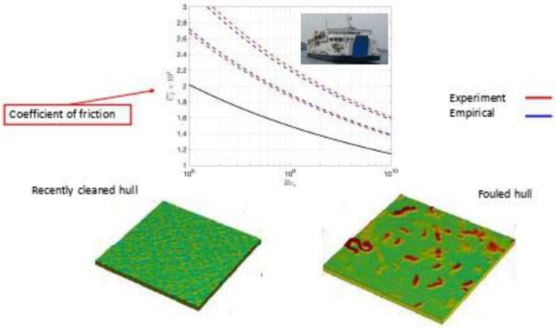

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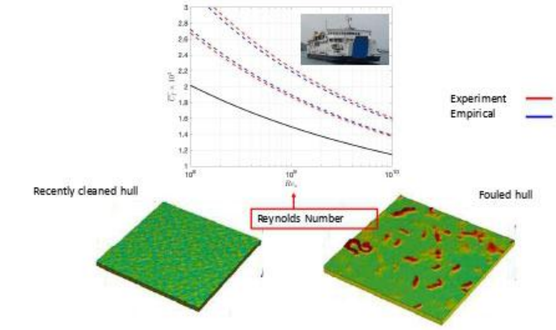

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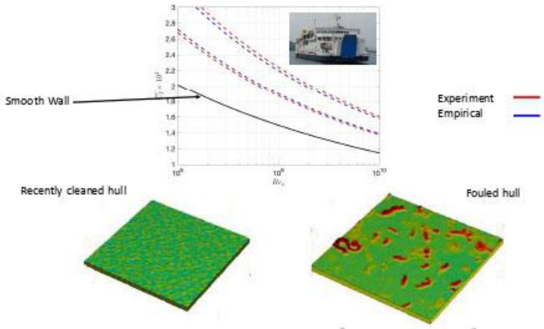

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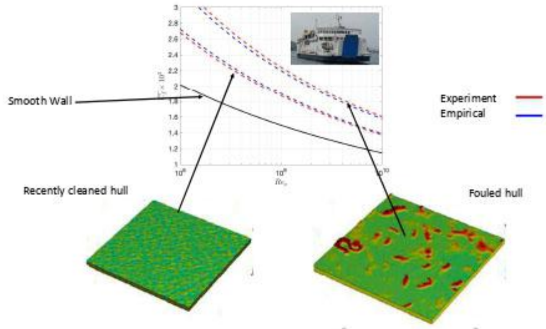

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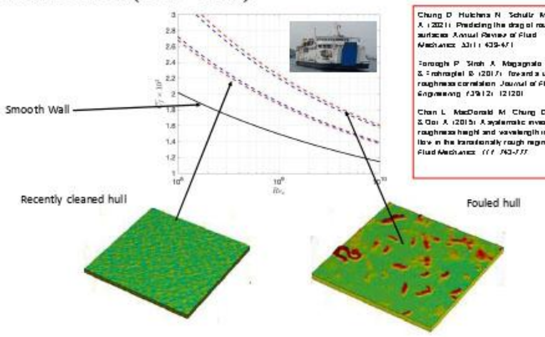

Chung D, Hutchins N, Schultz M P, & Flack K A (2021). Predicting the drag of rough surfaces. Annual Review of Fluid Mechanics, 53(1), 439-471

Forooghi P, Stroh A, Magagnato F, Jakirlić S, & Frohnapfel B (2017). Toward a universal roughness correlation. Journal of Fluids Engineering, 139(12), 121201

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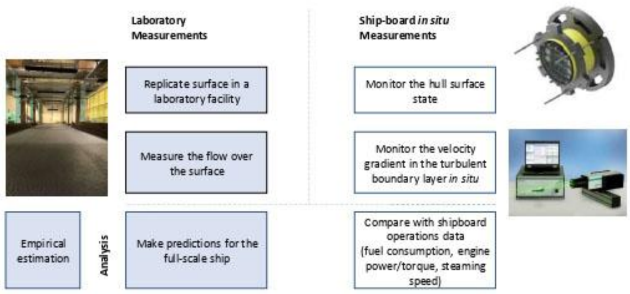

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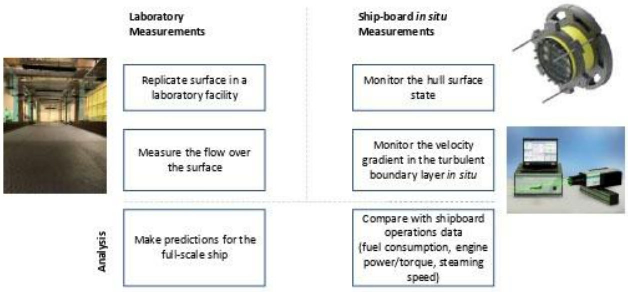

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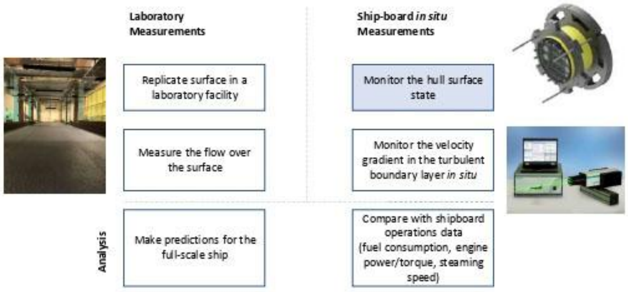

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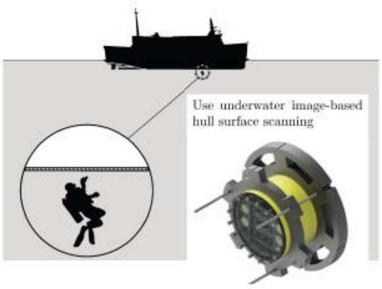

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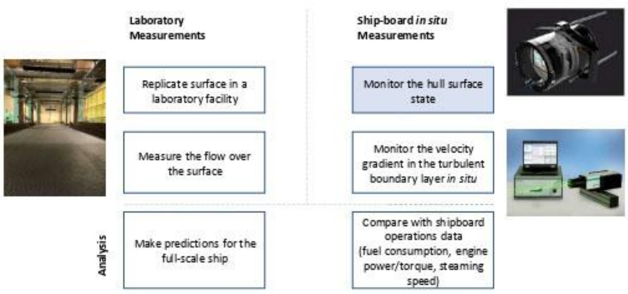

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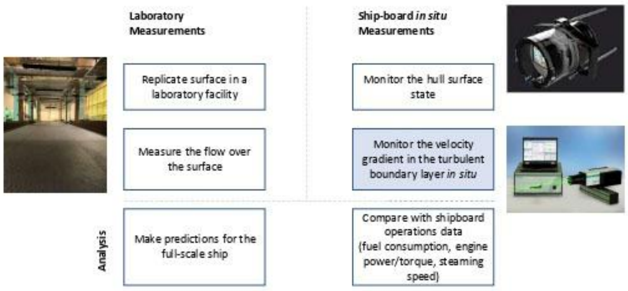

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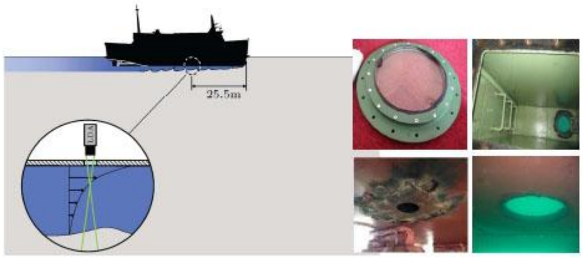

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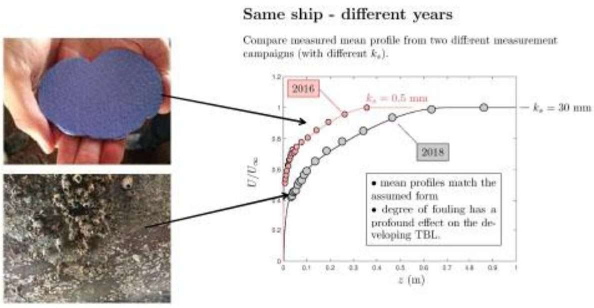

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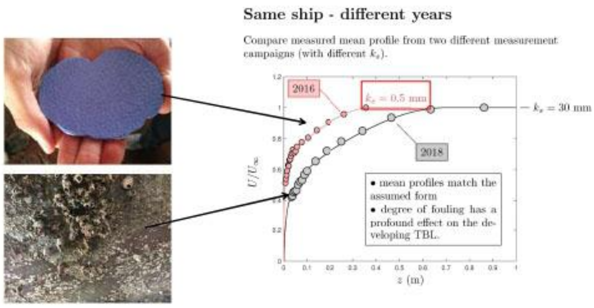
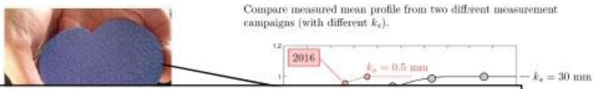


Initial research (2015 - 2019)

Same ship - different years

Compare measured mean profile from two diff:rent measurement campaigns (with different k_s).



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*NSTM (2002).

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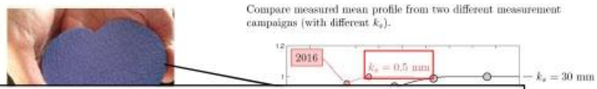
Same ship - different years

Compare measured mean profile from two different measurement campaigns (with different k_s).



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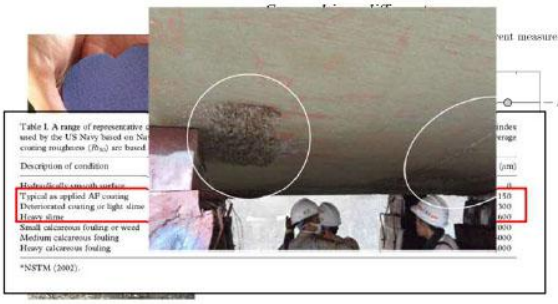

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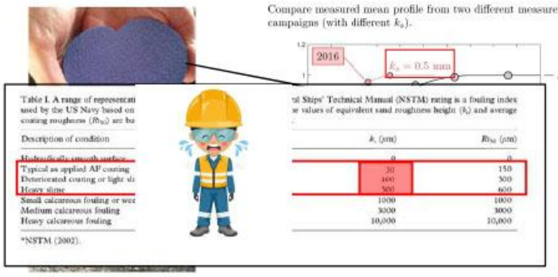

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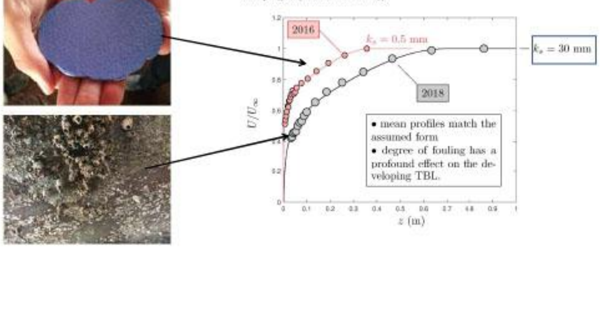

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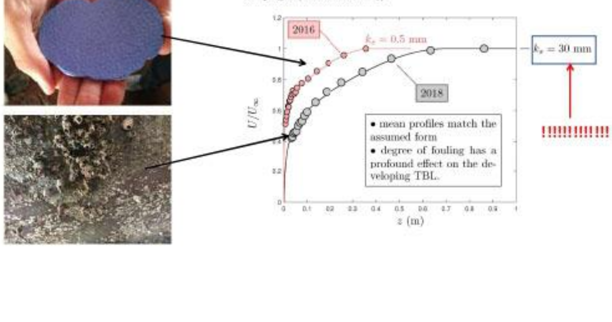
Same ship - different years

Compare measured mean profile from two different measurement campaigns (with different k_s).



Initial research (2015 - 2019)

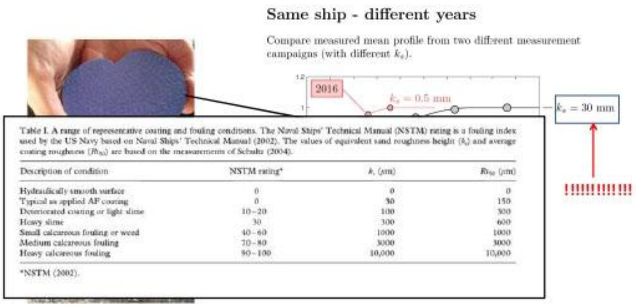
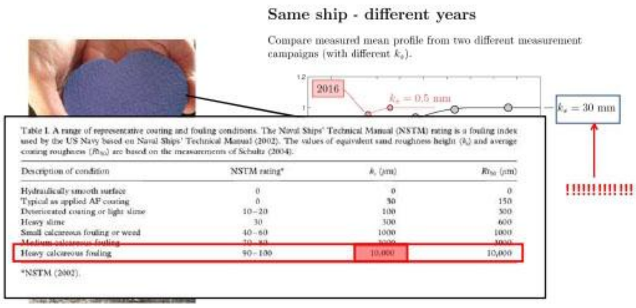


Table I. A range of representative coating and fouling conditions. The Naval Ships' Technical Manual (NSTM) rating is a fouling index used by the US Navy based on Naval Ships' Technical Manual (2002). The values of equivalent sand roughness height (k_s) and average coating roughness (Rt_{50}) are based on the measurements of Schultz (2004).

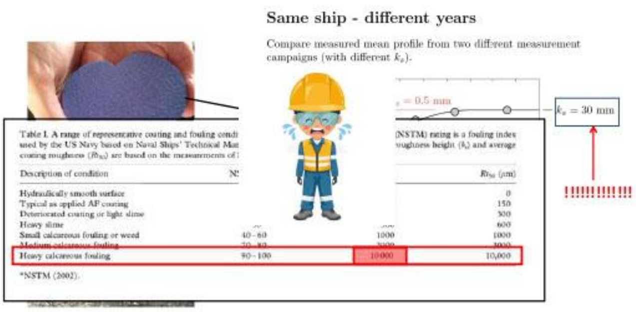
Description of condition	NSTM rating*	k_s (μm)	Rt_{50} (μm)
Hydraulically smooth surface	0	0	0
Typical as applied AF coating	0	30	150
Deteriorated coating or light slime	10–20	100	300
Heavy slime	30	300	600
Small calcareous fouling or weed	40–60	1000	1000
Medium calcareous fouling	70–80	3000	3000
Heavy calcareous fouling	90–100	10,000	10,000

*NSTM (2002).

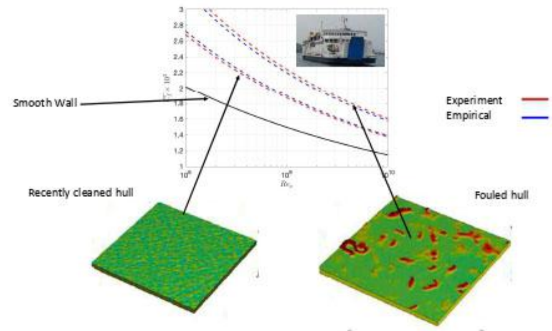
Initial research (2015 - 2019)



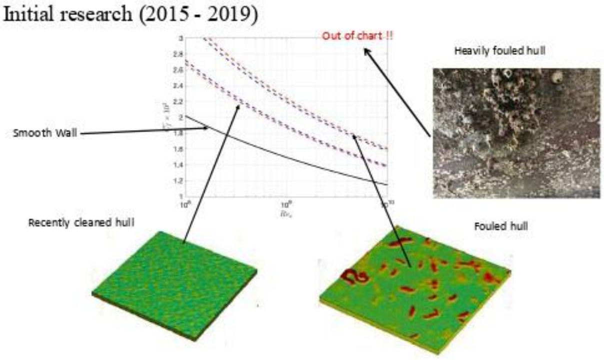
Initial research (2015 - 2019)



Initial research (2015 - 2019)



Initial research (2015 - 2019)



Initial research (2015 - 2019)

Initial research (2015 - 2019)

Please no photo from this slide onwards

Current research (2022 - current)

Current research (2022 - current)

Sinar Morotai

Chemical tanker ship
Samudera Indonesia
Length 95 meter
Draft 5.8 meter
Operational speed 9.7kt (5 m/s)
Flat bottom

Dry-docked 29th March 2022
- Cleaned to bare metal
- Recoated (foul-release)

Current research (2022 - current)

Sinar Morotai

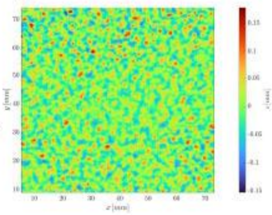
Chemical tanker ship
Samudera Indonesia
Length 95 meter
Draft 5.8 meter
Operational speed 9.7kt (5 m/s)
Flat bottom

Dry-docked 29th March 2022
- Cleaned to bare metal
- Recoated (foul-release)
- Window optical access

Current research (2022 - current)

Initial level roughness level

Imprints during drydocking
(five locations)



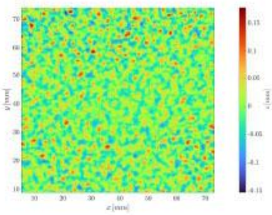
Laser-scanned surface topology

Current research (2022 - current)

Initial level roughness level

Roughness correlation - prediction of k_s^*

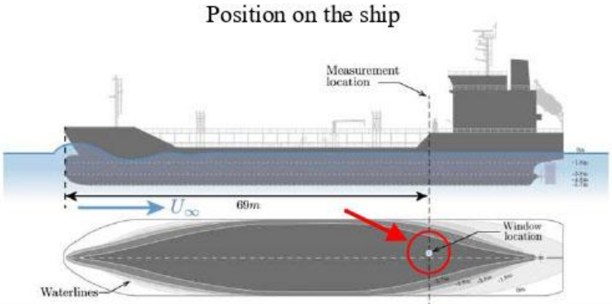
$$k_s(k_{rms}, k_{skew}, ES) \approx 0.1\text{mm}$$



Laser-scanned surface topology

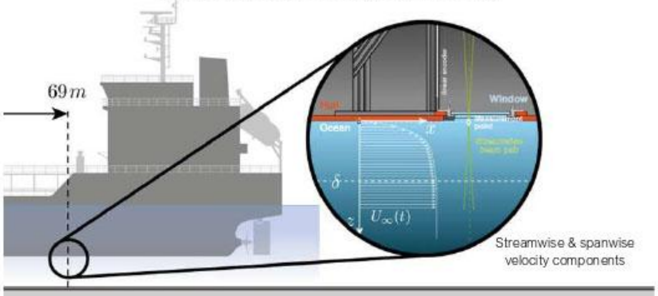
Current research (2022 - current)

Position on the ship



Current research (2022 - current)

Measurement technique (via LDA)



Current research (2022 - current)

Measurements: experimental setup

Current research (2022 - current)

Measurements: experimental setup

Current research (2022 - current)

Roughness Reynolds number: $k_s^+ = 28.5$

$k_s = 0.152$ mm

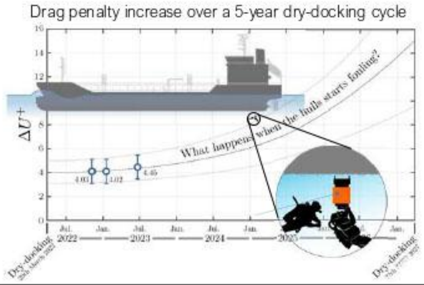
Total drag penalty: $\%\Delta C_D = 28\%$

compared to hydrodynamically smooth

Resulting from painting and cleaning induced roughness!

Current research (2022 - current)

Drag penalty increase over a 5-year dry-docking cycle



Current research (2022 - current)
(extra slides)

Current research (2022 - current)
(extra slides)

Latest Laser Doppler Anemometer results from 21 October – 31 October 2025 Campaign.

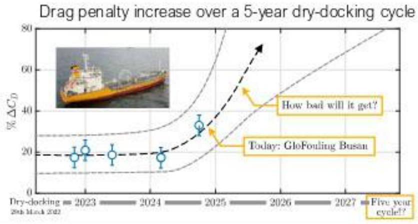
Current drag penalty: $\%\Delta C_D = 33\%$

Additional contribution due to biofouling.

Current research (2022 - current)
(extra slides)

Latest Laser Doppler Anemometer results from 21 October – 31 October 2025 Campaign.

Drag penalty increase over a 5-year dry-docking cycle



Current research (2022 - current)

Conclusion:

Current research (2022 - current)

Conclusion:

Need a better anti fouling application method to minimise orange peel pattern.

Current research (2022 - current)

Conclusion:

Need a better anti fouling application method to minimise orange peel pattern.

Thank goodness it is chemical engineers problem, and not mine.

Current research (2022 - current)

Conclusion:

Need a better anti fouling application method to minimise orange peel pattern.

Thank goodness it is chemical engineers problem, and not mine.

Clean-clean-clean your hull…. PLEASE…!

Current research (2022 - current)

Conclusion:

Need a better

orange peel pattern.

Thank goodne

mine.

Clean-clean-c

Future research

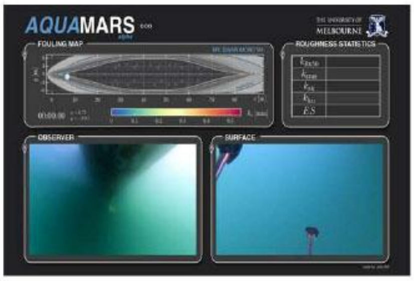
Future research

Latest dive inspections

- Large portions coated in slime
- Some local hard fouling
- More field experiments

Future research

- More lab experiment, removing the effect of weld seam and dry-docking blocks.
- Further developing the 3D image scanner.
- We are open for research collaboration and joint funding application,
- We will gladly poke a hole on your ship's hull…!!!



ABIGAIL ROBINSON

Vice President of Sustainability

ECOsubsea, Norway

Abigail Robinson comes from New Zealand and has a background as an ecologist specialising in Biodiversity Management. She spent 6 years working for the Ministry for Primary Industries - Biosecurity New Zealand. Firstly, she worked as a quarantine officer actively enforcing biosecurity requirements on the front-line, then as a senior adviser working with New Zealand's world-first national biofouling requirements. Following this she moved across to the solution provider side in Europe as VP of Sustainability at ECOsubsea where she is helping to bring sustainable, high-quality hull cleaning services to the mainstream to tackle the biofouling problem.

Quantifying the hull performance impact of biofouling & stopping unnecessary fuel & emissions 'leakage'

Mr. Tor Mikal Østervold

Biofouling growth on hulls adds drag causing elevated fuel burn and CO2 emissions, which can impact ships' CII ratings. However, until now there has been no data quantifying biofouling rate per type of antifouling paint and vessel performance over time. This has made it challenging to assess exactly how often to clean a ship.

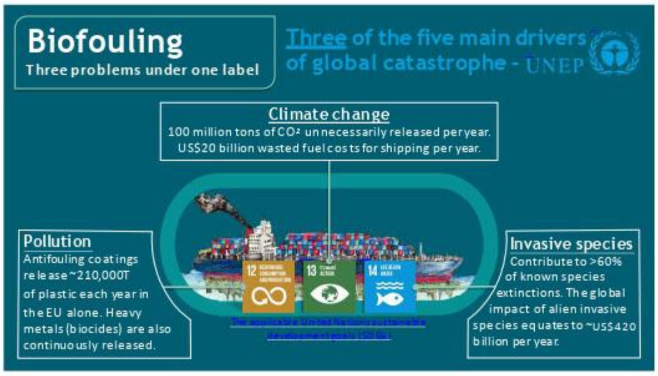
ECOsubsea is the only hull-cleaning company to consistently collect and measure biomass and antifouling debris removed during cleaning. Our constantly expanding dataset clearly shows the benefit of cleaning early to reduce fuel 'leakage' due to biofouling, while also saving money on each clean. It doesn't make sense to delay cleaning as overconsumption increases.

The data also supports coating selection. For example, depending on operational profile there may be a case to choose a coating that fouls fast, but the cost of more frequent cleaning will still be less.

By providing actionable data demonstrating the relationship between cleaning, coatings and performance we can help operators fix the leakage challenge and save money. The saving easily outweighs the overall cost of cleaning. Customers can tap our expertise to decide the optimal cleaning frequency for each vessel depending on trading profile and coating.

There are big numbers at stake; we estimate sustainable hull cleaning can save 10 million tons of fuel worth USD 20 billion every year. As a key corrective strategy on our shared journey to a greener future that can be implemented today, ECOsubsea's long-term vision is to make this service both affordable and available worldwide.

Presentation slides


Biofouling
Three problems under one label
Three of the five main drivers of global catastrophe - UNEP
Climate change
100 million tons of CO² unnecessarily released per year.
US$20 billion wasted fuel costs for shipping per year.
Pollution
Antifouling coatings release ~210,000T of plastic each year in the EU alone. Heavy metals (biocides) are also continuously released.
Invasive species
Contribute to >60% of known species extinctions. The global impact of alien invasive species equates to ~US$420 billion per year.


Biofouling
Three problems under one label
Three of the five main drivers of global catastrophe - UNEP
Climate SDG
Humans
The rest of the SDGs


ecosubsea
Our problem-solving ethos
Clean
Capture
Protect
Everything in nature is connected.
Solutions that exist in nature, for nature, must address the whole picture.
Otherwise, our efforts are wasted.
Humanity cannot afford "solutions" that create more problems.
"In nature, nothing exists alone"
- Rachel Carson, Silent Spring


ecosubsea
Our humble mission statement
Clean
Capture
Protect
13
100,000,000 tons CO2 saved
Approx. 4 million tons of CO² saved for the shipping industry so far...
...and we're just gettin' started!


ecosubsea
Our humble mission statement
Clean
Capture
Protect
100,000,000 tons CO2 saved
Approx. 4 million tons of CO² saved for the shipping industry so far...
...and we're just gettin' started!


But, Abigail,
You JUST said...
Climate SDG
Humans
The rest of the SDGs


ecosubsea
Our to-do list
Clean
Capture
Protect
TARGET 12·4
TARGET 14·1
REDUCE MARINE POLLUTION
TARGET 14·3
REDUCE OCEAN ACIDIFICATION
TARGET 12·5
SUBSTANTIALLY REDUCE WASTE GENERATION
TARGET 14·2
PROTECT AND RESTORE ECOSYSTEMS
TARGET 14·A

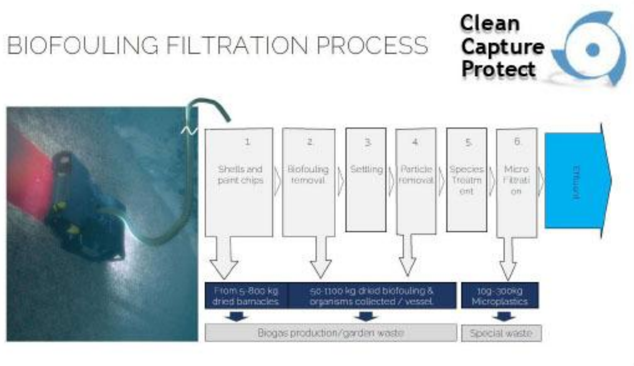

ecosubsea
Our to-do list
Clean
Capture
Protect
ECOsubsea's to do's:
Save the shipping industry 100,000,000 tons of CO2.
Responsibly manage chemicals and reduce waste.
Protect the ocean and ecosystems from invasive species, pollution, and acidification.
Share what we learn and help pave the way for fit-for-purpose regulations.
Our plate


The "norm"
Open-loop hull cleaning with divers
OPEN-LOOP CLEANING RELEASES TO SEA:
MACRO- & MICRO-PLASTICS
HEAVY METALS (BIOCIDES)
INVASIVE SPECIES
DANGEROUS
POLLUTING
INEFFICIENT

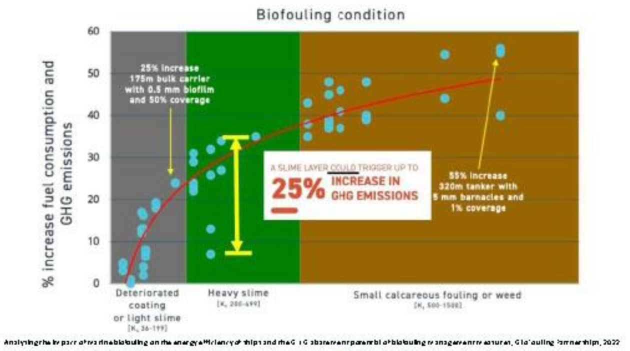

ecosubsea
Three solutions under one innovation
Clean
Capture
Protect
Ocean Robotics

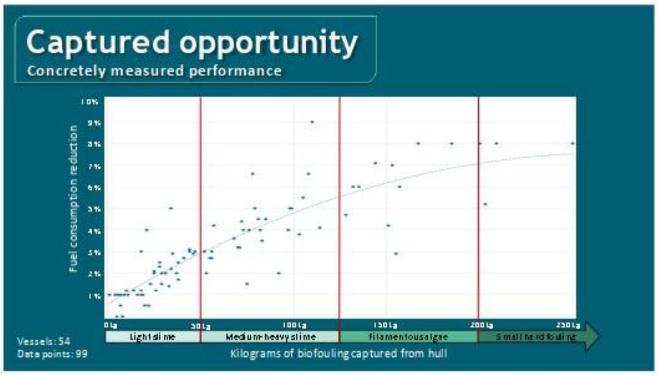

Clean
Capture
Protect

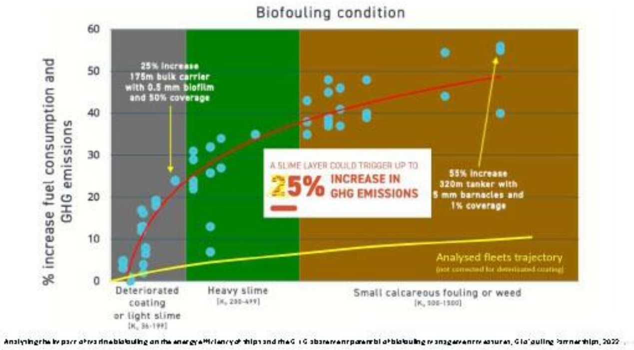

ecosubsea
Cockpit
The Robot
Launch and recovery
Engine
SoftJet Pump
Biofouling Filtration Process
Photo credit: Paul Coken

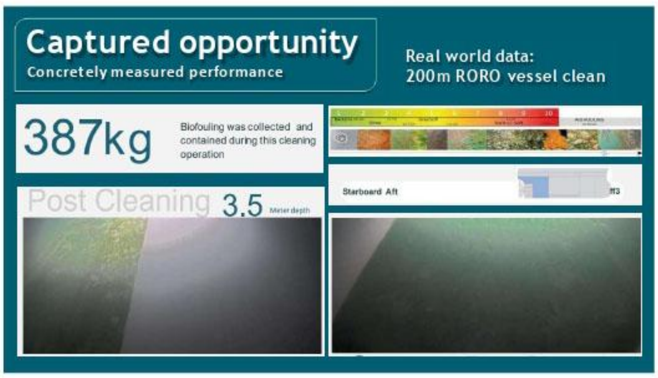

BIOFOULING FILTRATION PROCESS
Clean
Capture
Protect
1
Shells and paint chips
2
Biofouling removal
3
Settling
4
Particle removal
5
Species Treatment
6
Micro Filtration
Effluent
From 5-800 kg dried barnacles
50-1100 kg dried biofouling & organisms collected / vessel
10g-300kg Microplastics
Biogas production/garden waste
Special waste


Captured opportunity
Concretely measured performance
Dirty
Cleaned
Dirty
Dirty
Cleaned


Biofouling condition
% increase fuel consumption and GHG emissions
25% increase 175m bulk carrier with 0.5 mm biofilm and 50% coverage
A SLIME LAYER COULD TRIGGER UP TO
25% INCREASE IN GHG EMISSIONS
55% increase 320m tanker with 5 mm barnacles and 1% coverage
Deteriorated coating or light slime
Heavy slime
Small calcareous fouling or weed


Captured opportunity
Concretely measured performance
Fuel consumption reduction
Vessels: 54
Data points: 99
Kilograms of biofouling captured from hull


Biofouling condition
% increase fuel consumption and GHG emissions
25% increase 175m bulk carrier with 0.5 mm biofilm and 50% coverage
A SLIME LAYER COULD TRIGGER UP TO
25% INCREASE IN GHG EMISSIONS
55% increase 320m tanker with 5 mm barnacles and 1% coverage
Analysed fleets trajectory
Deteriorated coating or light slime
Heavy slime
Small calcareous fouling or weed


Captured opportunity
Concretely measured performance
Real world data:
200m RORO vessel clean
387kg
Biofouling was collected and contained during this cleaning operation
Post Cleaning 3.5
Starboard Aft


Captured opportunity
Concretely measured performance
Real world data:
200m RORO vessel clean
Volume of fouling: 387kg
Est. % fuel reduction: 6.99%
Est. fuel saved (1 yr): 630T
GHG savings:
CO2:1962T
NOx:49T
SOx:30T
Actual % fuel reduction: 7%
USD saved (12m avg. fuel cost):
$432,922
Est. return on investment
9.3 days

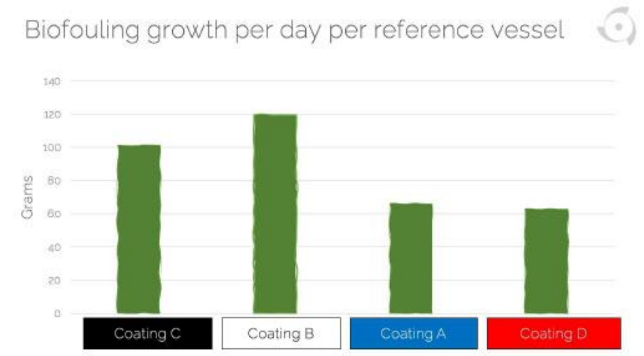

Captured opportunity
Concretely measured performance
Real world data:
What is the impact?
1 day in the office
=
5 years in the forest
~62,000
pines

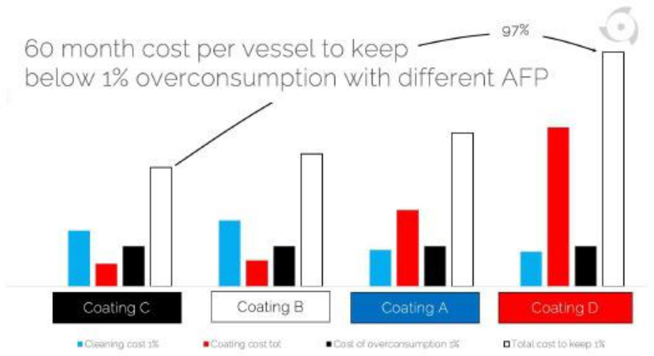

Captured opportunity
Concretely measured performance
Real world data:
What is the potential?
$432,922..?
=
Protect Australia's biodiversity. Forever.
WILDERLANDS
Preserve
12 hectares of
biodiversity
forever


Or...


Captured opportunity
Concretely measured performance
Real world data:
What is the potential?
$432,922..?
=
RESTORING THE OCEAN,
ONE CORAL AT A TIME
CORAL
GARDENERS
Plant 14,497
corals across
1796m² of reef


I digress...
Sustainability leads spotting savings they could spend on nature restoration...
...Their CFO reading their minds

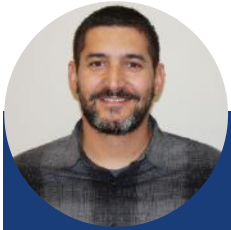

Biofouling growth per day per reference vessel
Grams
140
120
100
80
60
40
20
0
Coating C
Coating B
Coating A
Coating D


60 month cost per vessel to keep
below 1% overconsumption with different AFP
97%
Coating C
Coating B
Coating A
Coating D
Cleaning cost 1%
Coating cost tot
Cost of overconsumption 1%
Total cost to keep 1%


Key takeaways
Capture brings many opportunities
Clean
Capture
Protect
Everything in nature is connected.
Solve problems in all directions, avoid tunnel vision.
Full capture cleaning not only saves the planet, it also saves profit.
Solid data can allow for smart fleet adaptations with large gain.
14
"In nature, nothing exists alone"
- Rachel Carson, Silent Spring
12
13


See the *whole* picture.
Solve the *whole* problem.
Support sustainable solutions.
Abigail Robinson
VP of Sustainability
ecosubsea

CHAIR OF THE SESSION



CHRIS SCIANNI

Environmental Program Manager, Marine Invasive Species Program

California State Lands Commission, the United States

Chris Scianni is the Environmental Program Manager for the California State Lands Commission's Marine Invasive Species Program, managing and providing support for the science policy and data management teams while coordinating with field inspectors spread across California. Chris is also the chair of the Coastal Committee of the Western Regional Panel on Aquatic Nuisance Species and helps to facilitate collaborative discussions between invasive species prevention, management, and control programs across the western United States.

DR. BENJAMIN M VALLEJO JR

Professor of Environmental Science

University of the Philippines Diliman, the Philippines

Professor Benjamin Vallejo is with the Institute of Environmental Science and Meteorology, College of Science, University of the Philippines Diliman. He has degrees in fisheries and marine science from UP and a PhD in Marine Biology from James Cook University, Australia which was awarded in 2004. He worked on coral reef resources, databases, and fisheries policy with WorldFish center prior to his Ph.D. from 1992 to 1998. He did his post-doctoral work in molecular marine biodiversity at Louisiana State University His main area of marine research is on biological invasion. He was an exchange professor at St Norbert College in Wisconsin, USA. He also trained in governmental science advice under the International Network for Governmental Science Advice (INGSA) in Kuala Lumpur, Malaysia in 2017.

He is a writer and authored essays in the science essay genre as well as a book "Between the Coral Tides, A Natural History of Philippine Shores" which was published by the University of the Philippines Press in 2022.

He has over 20 years of experience teaching and research mentoring undergraduate and postgraduate students in marine environmental science and Science, Technology, and Society (STS). He received recognition from the Philippines Government and Civil Society organizations for his work on science policy on the Manila Bay environment, environmental science policy and the COVID-19 pandemic.

Biofouling ecology of tropical anthropized coastal environments in Manila Bay, Philippines

Benjamin M Vallejo Jr , Melody Anne B Ocampo ,Richard Casiguran

Ports and harbors are anthropized (human modified artificial) environments where port structures provide a biological substrate for colonization and habitat structure of marine organisms.

Anthropized communities often have a significant marine non-indigenous species component. As tropical ports and harbors are now important areas for urban renewal with a focus on tourism, many cities are restoring and rehabilitating adjacent natural environments or these no longer exist, create artificial ones with natural features for tourism. Among the artificial environments are mangroves and sandy beaches.

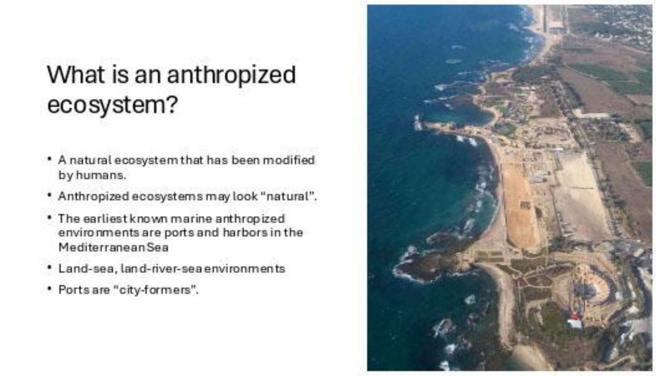
In this study, we present the Port of Manila and the adjacent Dolomite Beach and the Parañaque Las Piñas Wetlands which have a notable level of marine biodiversity but with a significant number of invasive aquatic species (IAS). We present the latest results of studies on their ecology and the use of eDNA to shed light on the ecological and molecular presence of IAS.

Keywords: Ports and Harbors, artificial environments, synthetic communities, invasive aquatic species, urban coastal environments

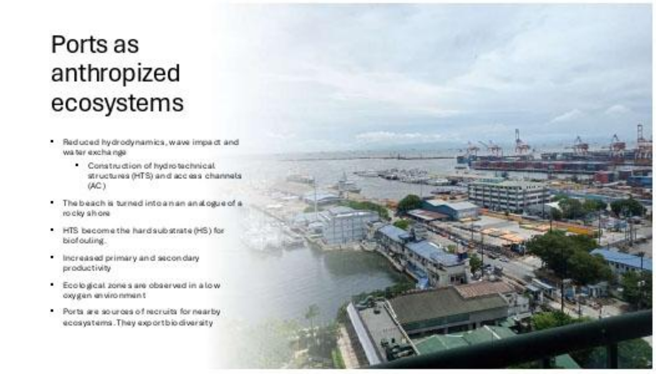
Presentation slides

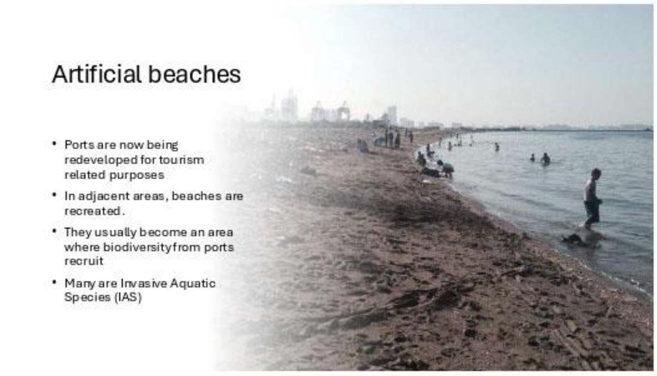

GloFouling
IMO
Biofouling ecology of tropical anthropized coastal environments in Manila Bay, Philippines
SAILS
Benjamin M Vallejo Jr
Melody Anne Ocampo
Richard Casiguran
University of the Philippines
bmvallejo1@up.edu.ph
3rd GloFouling R&D Forum,
Busan, ROK 4-8 Nov 2024

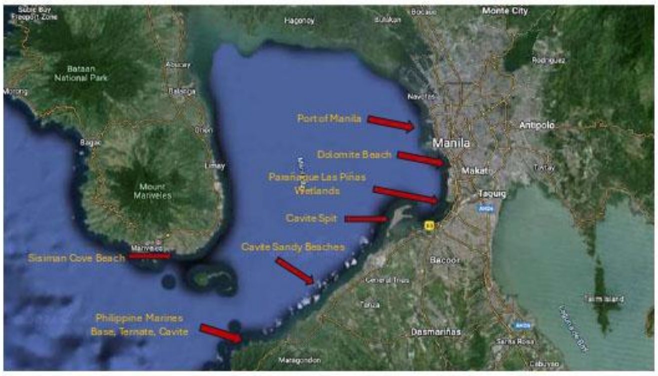

MARINE BIOFOULING
SAILS PORTEC 2021


What is an anthropized ecosystem?
• A natural ecosystem that has been modified by humans.
• Anthropized ecosystems may look "natural".
• The earliest known marine anthropized environments are ports and harbors in the Mediterranean Sea
• Land-sea, land-river-sea environments
• Ports are "city-formers".


Ports, Harbors and Marinas
• From Latin "portus" meaning "passage or refuge"
• Ports and harbors are built on suitable natural geomorphologies
• Bays, estuaries and gulfs
• Artificial modification of coastal geomorphology
• Shallow water geomorphologies such as beaches are removed


Ports as anthropized ecosystems
• Reduced hydrodynamics, wave impact and water exchange
• Construction of hydrotechnical structures (HTS) and access channels (AC)
• The beach is turned into a n an analogue of a rocky shore
• HTS become the hard substrate (HS) for biofouling.
• Increased primary and secondary productivity
• Ecological zones are observed in a low oxygen environment
• Ports are sources of recruits for nearby ecosystems. They export biodiversity


Artificial beaches
• Ports are now being redeveloped for tourism related purposes
• In adjacent areas, beaches are recreated.
• They usually become an area where biodiversity from ports recruit
• Many are Invasive Aquatic Species (IAS)

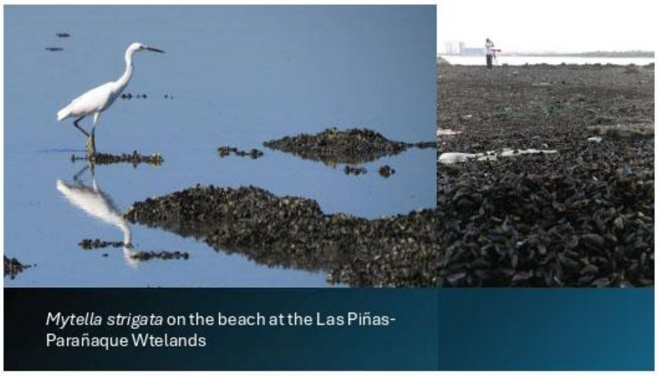


Manila's Dolomite Beach

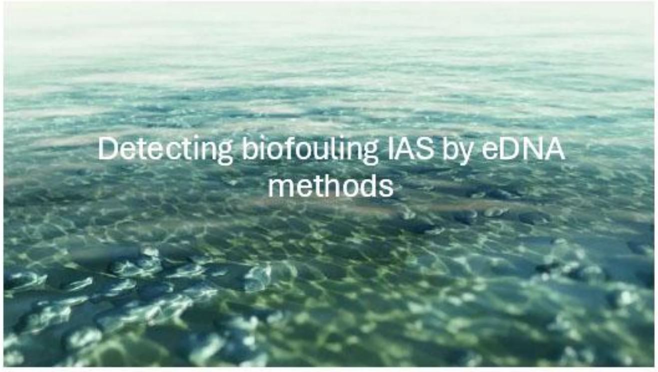
Las Piñas-Parañaque Wetlands

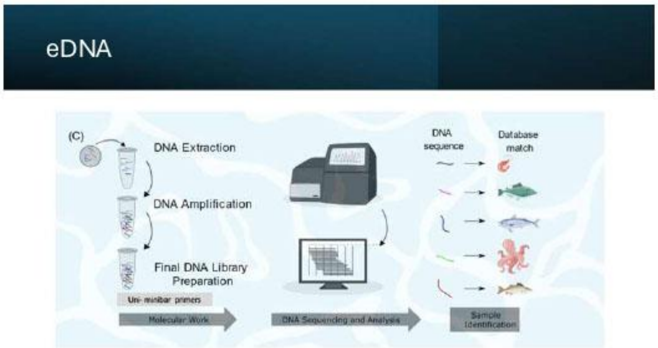
Small scale fisheries on Cavite Sandy Beaches

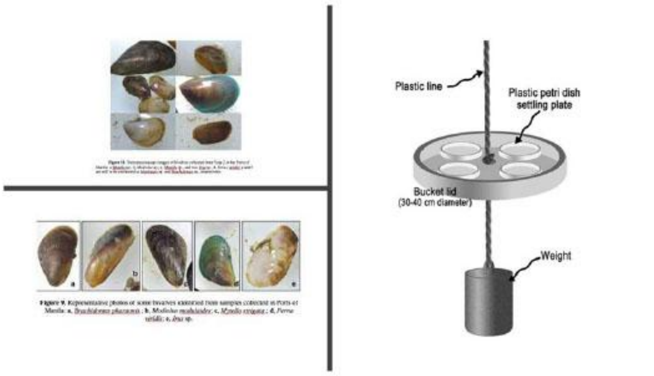
New ecological communities: Dolomite Beach



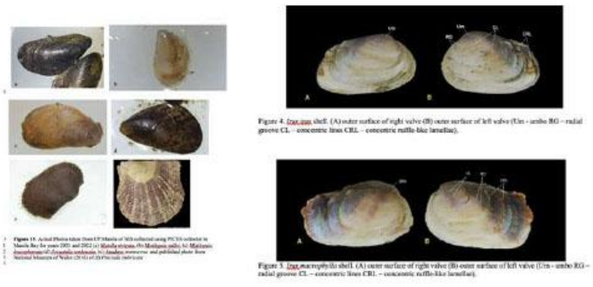
Mytella strigata on the beach at the Las Piñas-Parañaque Wtelands







Phylum	Class	Species	Distribution	Mode of Detection
Mollusca	Bivalvia	Anadara transversa (Say 1822)	Western Atlantic	PICES Collector
Mollusca	Bivalvia	Arcuatula senhousia (Benson, 1842)	Indo-West Pacific, Northern Atlantic, and the Mediterranean	PICES Collector
Mollusca	Bivalvia	Cyrenoida floridana (Dall, 1896)	Western Atlantic	eDNA
Echinodermata	Asteroidea	Luidia foliolata (Grube, 1866)	Eastern Pacific and Western Atlantic: Alaska to Nicaragua	eDNA
Mollusca	Bivalvia	Mytella strigata (Hanley, 1843)	Eastern Pacific and Western Atlantic	PICES Collector
Mollusca	Bivalvia	Mytilopsis leucophaeata (Conrad, 1831)	Atlantic Ocean and Eastern Central Pacific; North America including Mexico	PICES Collector
Mollusca	Bivalvia	Mytilopsis sallei (Recluz, 1849)	Western Atlantic; North America	PICES Collector
Mollusca	Gastropoda	Pinctada imbricata (Roding, 1798)	Western Atlantic: From South Carolina to Uruguay	PICES Collector
Mollusca	Bivalvia	Pinna rudis (Linnaeus, 1758)	Eastern Central Atlantic and the Mediterranean Sea: Cape Verde Island to Congo	eDNA
Annelida	Polychaeta	Polydora websteri (Hartman, 1943)	Western Atlantic and Eastern Pacific.	eDNA
Mollusca	Bivalvia	Tagelus dombeii (Lamarck, 1818)	Eastern Pacific: Panama to Chile	eDNA
Arthropoda	Malacostraca	Upogebia africana (Ortmann, 1894)	Western Indian Ocean Southeast Atlantic: from Langebaan, South Africa to Inhambane, Mozambique	eDNA



How good is eDNA in assessing establishment of biofouling IAS?

- **eDNA can only** on average detect a probability of **44.2%** possible establishment of IAS.
- **eDNA plus morphological taxonomy** using a PICES collector will detect a **54.3 %** chance.
- **eDNA can detect a probability** of **40.05%** probability of the possible establishment of IAS.
- **Morphological taxonomy, eDNA techniques** can detect **59.99%** of establishments.

Is the port suitable for IAS establishment?

- NIS-Invasion Threat Score (NIS-ITS) (Miralles et al, 2021)
- $H_s = S_{depth} \times Temperature \times S_{salinity} \times S_{primaryproductivity} \times S_{iceconcentration} \times S_{landdistance}$
- Values for habitat suitability (Hs) range from 0 (totally unsuitable habitat) to 1 (perfect environmental conditions for the species).

  NIS–ITS= HabitatSuitability+ InvasionHistory+ MaritimeTraffic
- Maximum ITS = 3.0

Habitat suitability models for IAS (using Aquamaps)

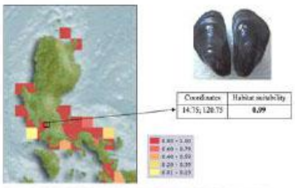


Figure 22. Suitable Habitat Map (Luzon) for Mytella strigata (Habitat Suitability: 0.99).

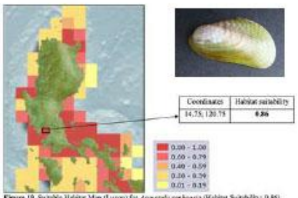
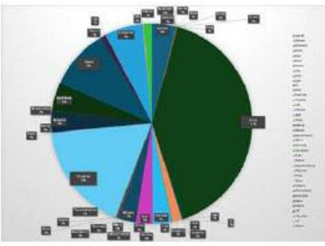


Figure 19. Suitable Habitat Map (Luzon) for Arcuatula senhousia (Habitat Suitability: 0.86).

Relating maritime traffic to biofouling IAS establishment

From where do the ships that call on Manila come from?



FAO Major Fishing Areas		Total KGT	Proportion	Percentage	Presence (Y/N)
77	Pacific, Eastern Central	199.889	0.0014986	0.149859	Y
57	Indian Ocean, Eastern	594.168	0.0044545	0.445453	Y
27	Atlantic, Northeast	130.303	0.0009769	0.097689	Y
67	Pacific, Northeastern	263.561	0.0019759	0.197594	Y
61	Pacific, Northwestern	84927.3037	0.6367081	63.67081	Y
41	Atlantic, Southwest	173.756	0.0013027	0.130267	N
81	Pacific, Southwest	4950.378	0.0371135	3.711345	Y
31	Atlantic, Western Central	4.943	3.706E-05	0.003706	Y
71	Pacific, Western Central	41288.5117	0.3095439	30.95439	Y
51	Indian Ocean, Western	766.509	0.0057466	0.574659	Y
87	Pacific, Southeast	85.676	0.0006423	0.064232	N

Maritime Traffic presence of Arcuatula senhousia in the FAO Major Fishing Areas

	FAO Major Fishing Areas	Total KGT	Proportion	Percentage	Presence (Y/N)
77	Pacific, Eastern Central	199.889	0.0014986	0.149859	Y
57	Indian Ocean, Eastern	594.168	0.0044545	0.445453	Y
27	Atlantic, Northeast	130.303	0.0009769	0.097689	Y
67	Pacific, Northeastern	263.561	0.0019759	0.197594	Y
61	Pacific, Northwestern	84927.3037	0.6367081	63.67081	Y
41	Atlantic, Southwest	173.756	0.0013027	0.130267	N
81	Pacific, Southwest	4950.378	0.0371135	3.711345	Y
31	Atlantic, Western Central	4.943	3.706E-05	0.003706	Y
71	Pacific, Western Central	41288.5117	0.3095439	30.95439	Y
51	Indian Ocean, Western	766.509	0.0057466	0.574659	Y
87	Pacific, Southeast	85.676	0.0006423	0.064232	N

Maritime Traffic presence of *Mytella strigata* in the FAO Major Fishing Areas

Species	Mode of Detection	Habitat Suitability	Invasion History	Maritime Traffic	Total	Proportion	Percentage
Mytella strigata	PICES Collector	0.99	1	0.9913	2.9813	0.993766667	99.3766667
Arcuatula senhousia	PICES collector	0.86	1	0.998	2.858	0.952666667	95.2666667
Polydora websteri	eDNA Technique	0.57	1	0.9942	2.5642	0.854733333	85.4733333
Mytilopsis sallei	PICES Collector	0.53	1	0.952	2.482	0.827333333	82.7333333
Pinctada imbricata	PICES collector	0.26	1	0.9463	2.2063	0.735433333	73.5433333
Mytilopsis leucophaeata	PICES collector	0.81	1	0.3191	2.1291	0.7097	70.97
Anadara transversa	PICES Collector	0.42	1	0.3115	1.7315	0.577166667	57.7166667
Tagelus dombeii	eDNA Technique	0.76	0.2	0.3117	1.2717	0.4239	42.39
Cyrenoida floridana	eDNA Technique	0.67	0.2	0.3131	1.1831	0.394366667	39.4366667
Upogebia africana	eDNA Technique	0.26	0.2	0.3166	0.7766	0.258866667	25.8866667
Pinna rudis	eDNA Technique	0.22	0.2	0.3095	0.7295	0.243166667	24.3166667
Luidia bicolata	eDNA Technique	0.17	0.2	0.3137	0.6837	0.2279	22.79

Invasion Threat Scores of Non-Indigenous Species detected in Manila Bay from 2021 to 2022.

Conclusions

- Biofouling IAS have been detected in the Port of Manila and nearby anthropized environments
- eDNA , morphological taxonomy and ecological detection methods are still the best to determine biofouling IAS establishment (59.99% probability)
- Maritime traffic statistics can be used to estimate IAS establishment

Acknowledgments

- The Philippines Department of Science and Technology
- Philippine Coast Guard
- Maritime Industry Authority, Philippines
- Philippine Ports Authority
- Manila International Container Terminal
- Department of Environment and Natural Resources, Philippines
- Wild Bird Club of the Philippines
- Quantitative Aquatics Inc.

DR. JASMINE FERRARIO

Researcher

University of Pavia, Italy

Jasmine Ferrario is a researcher at the Department of Earth and Environmental Sciences, University of Pavia (Italy). She is a marine ecologist with an expertise in bioinvasions in the Mediterranean Sea. Since her PhD, started in 2012, she focused her research on the study of fouling communities, with the aim to assess the role of recreational boats in spreading non-native species.

Enhancing the biodiversity in ports to limit the introduction of non-native species

Dr. Jasmine Ferrario

Numerous non-native species (NNS) are tolerant and opportunistic organisms, able to survive and establish in variable environmental conditions and resist to various stressors (biological, chemical or physical). One of the major entry points for marine NNS are ports, where harsh conditions and abundance of artificial substrates result in low native species richness and high NNS success.

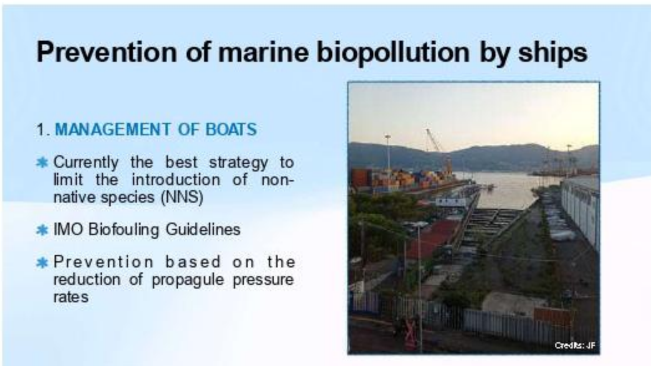
The so-called 'biotic resistance hypothesis' suggests that richness and abundance of native species should act as a barrier for the colonization of NNS, limiting their introduction, but despite important implications for port management, this hypothesis has not been fully proven yet in port fouling communities. Experimental manipulations are scarce, sometimes reaching contrasting results.

One difficulty is given by the fact that propagule pressure of NNS is extremely difficult to manipulate in the field, and even the level of spread of fouling NNS from ports to nearby natural areas is poorly known, because most monitoring efforts focus on ports or other high-risk sites of introduction.

Here we present an overview of current knowledge on the topic and results from preliminary field observations and experiments conducted from recreational ports in the highly invaded Mediterranean Sea. Multiple pieces of evidence suggest that supporting the growth of native communities in ports would have an effect in preventing colonization from introduced NNS.

Keywords: nature-based solutions, biotic resistance hypothesis, marine bioinvasions, fouling communities

Presentation slides



Prevention of marine biopollution in ports

2. **MANAGEMENT OF PORTS**

Enhance biodiversity and ecological functions in urban structures

- Creation of complex habitat in ports
- Transplantation of communities rich in native species
- Prevention based on the biotic resistance hypothesis (Elton, 1958)

E.g., In Sydney Harbour after 1-2 years Living Seawalls support at least 36% more specie. (Bishop et al. 2022 Phil. Trans. R. Soc.B 377: 20210393)

Ports can provide ecological niches suitable for NNS settlement.

The level of spreading of fouling NNS outside ports is still poorly investigated.

Natural substrates are usually complex, three-dimensional and host species-rich communities.

Healthy native communities should be less susceptible to invasion.

Pros and cons of the two strategies

Management of Boats	Management of Ports
+ Application of simple measures (e.g., cleaning and coating)	− Redesign of ports: expensive and difficult to accomplish
− A plethora of boat owners, costs of maintenance and niche areas	+ Interaction only with port authorities or marina managers instead of a multitude of individuals

The synergic use of both strategies would benefit all.

"CLEAN" BOATS + "BIODIVERSE" PORTS

Our case studies

Case study 1: Can ports be NNS-free?

Our case studies

Case study 1: Can ports be NNS-free?

Case study 2: Do natural substrates close to ports host NNS?

Mediterranean case studies

Case study 1: Can ports be NNS-free?

Case study 2: Can natural substrates close to ports host NNS?

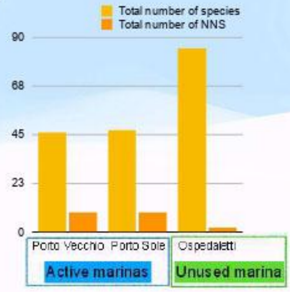
Case study 3: Are fouling communities from natural sites more resistant to NNS settlement?

Can ports be NNS-free?
Case study 1

- Comparison between two active and one unused marina

Can ports be NNS-free?
Case study 1

- Comparison between two active and one unused marina
- The unused marina exhibited a different fouling assemblage with very sporadic NNS
- The limited number of NNS could be assigned to the reduced propagule pressure and low pollution level



Can ports be NNS-free?
Case study 1

Yes, it's possible…but it requires the management of maritime traffic as pathway of NNS introduction

- The sole presence of artificial substrates does not automatically implies NNS settlement
- This confirm the priority of vector management to limit NNS introductions


Estuarine, Coastal and Shelf Science

The influence of recreational boat traffic in the introduction of non-indigenous fouling species in three Ligurian marinas (Mediterranean Sea, Italy)

Do natural substrates close to ports host NNS?
Case study 2

Comparison of fouling communities from **artificial substrates** inside marinas and in closer boulder seawalls (hereafter '**natural substrates**'), to assess the level of spread of NNS over short distances.

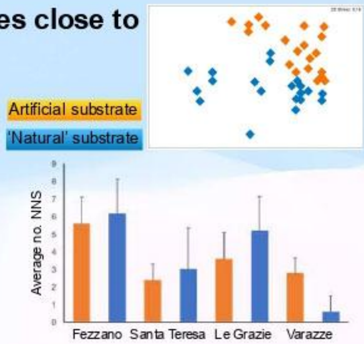
Study conducted in two areas along the Ligurian coast (western Mediterranean Sea, Italy).

Do natural substrates close to ports host NNS?
Case study 2

Distinct fouling communities observed on the two substrates.

Number of total species and NNS were not significantly different between artificial and natural substrates.

In the Gulf of La Spezia the **no. of NNS in natural substrates > artificial substrates.**



Do natural substrates close to ports host NNS?
Case study 2

Yes, they are not exempt from invasion!

- Natural substrates in sheltered areas close to ports are prone to host NNS
- Additional studies in more exposed areas at increasing distances from the selected ports and on rocky shores should be carried out

Are fouling communities from natural sites more resistant to NNS settlement?

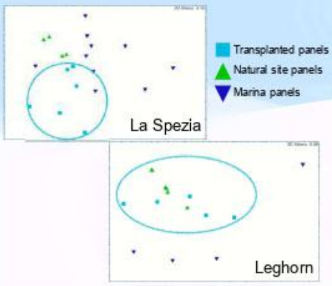
Case study 3

- Transplant experiment to assess the capability of native communities to resist to NNS colonization
- PVC panels immersed for 3 months in low impacted sites (natural) were moved to high impacted sites (marina) and re-immersed for 2 additional months
- Experiment conducted in two areas

Are fouling communities from natural sites more resistant to NNS settlement?

Case study 3

- The number of NNS was significantly lower in the transplanted panels only in Leghorn
- Transplanted panels maintained their own identity
- Native assemblages were not negatively affected by stressful pollution conditions inside the marinas



Are fouling communities from natural sites more resistant to NNS settlement?

Case study 3

- Neither a role of mitigation nor facilitation of native communities on NNS was observed
- The biotic resistance approach is not a static phenomenon and is context dependent


Marine Pollution Bulletin

Biotic resistance of native fouling communities to bioinvasions could not be demonstrated by transplant experiments in Northern Italy

Take home messages

- The importance of biofouling in NNS introduction has been well acknowledged
- Fouling NNS can easily spread in nearby natural areas
- Transplant of communities from natural environments is difficult and its effectiveness is yet to be demonstrated
- **Prioritize the management of biofouling vector**
- Biodiversity enhancement through eco-engineering approaches should be further tested and developed
- Improve communication among different stakeholders and promote awareness raising programs on fouling NNS

Thank you for your attention!

MARION VIAL

PhD Student

Corrosion and Biocorrosion Center, Corrodys and the University of Caen Normandie, France

Marion VIAL is working as a PhD student between industry (CORRODYS, France) and academia (University of Caen Normandy, France) on the study of the biofouling development in French harbours of the English Channel. Her research project BIOSTEM focuses on the monitoring of different coatings in the English Channel to develop standardized tests in laboratory to allow the emergence of more environmentally-friendly coatings. She did her master thesis at the University of Vienna, in Austria, where she studied a newly-discovered gammaproteobacteria with the MICRO-CARD-FISH technique.

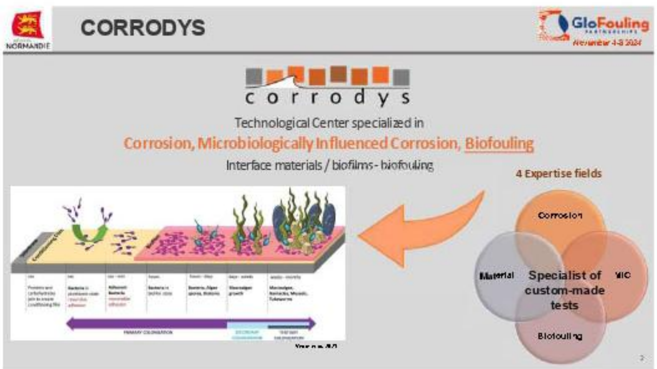
Biofouling in the English Channel: a two-year monitoring on two coatings in the port of Cherbourg (France)

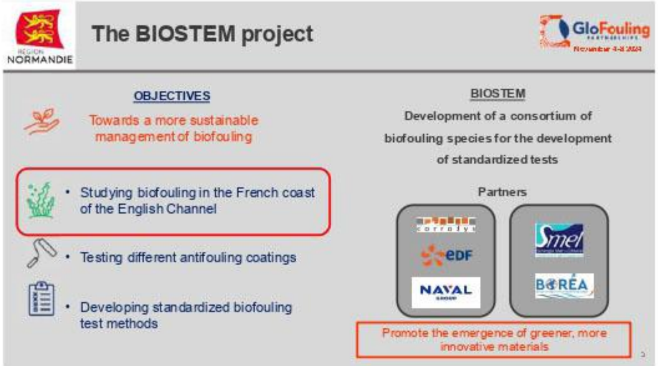
Marion Vial, Christelle Caplat, Katherine Costil, Julie Agogué, Loann Gissat, Hervé Gueuné

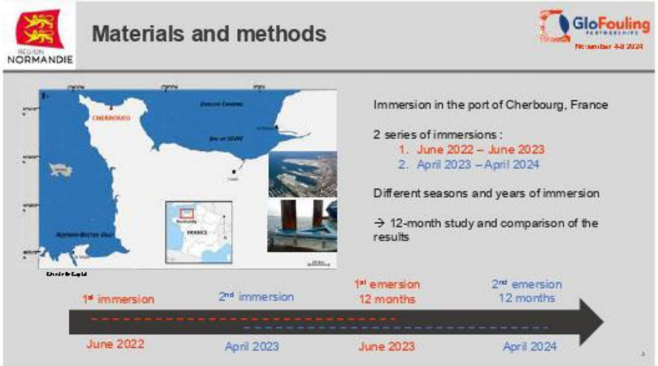
Rising concerns about biofouling are increasing around the world, by reason of the serious damages it has on the industry through the costly impacts of materials and coatings, and on the environment into the introduction of alien species. The English Channel is like a highway for maritime traffic, linking the Atlantic Ocean and the North and Baltic Seas with the rest of the world. However, there are few studies about the impact and the composition of biofouling in this area, which represents an important lack of information in biosecurity. The industrial and commercial port of Cherbourg, located on the French coast of the English Channel, is a stopover for numerous cruise ships and freighters. A two-years monitoring of biofouling on two coatings was performed from June 2022 to April 2024. Various indicators were assessed to study the biofouling developed, such as biomass, covering rate, microalgae concentration, bacteria abundance, floristic and faunal community composition through rRNA16S and rRNA 18S sequencing. Moreover, physico-chemical analyzes were undertaken to establish the features of the port water mass. First results showed significant biofouling differences between coatings, and a seasonal dependance of some indicators, such as macrofouling and microalgae community composition. Microorganisms and microalgae concentrations were comparable between coatings, while macrofouling communities and abundances revealed different. Through the example of Cherbourg, this is the biofouling of the English Channel that is described, giving a state zero before the development of wind farms. This knowledge will be useful to state the emergence of new alien species.

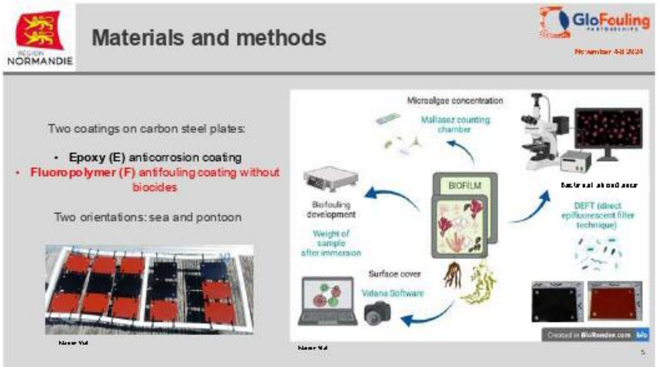
Keywords: Biofouling, port, English Channel, coatings, alien species, biosecurity.

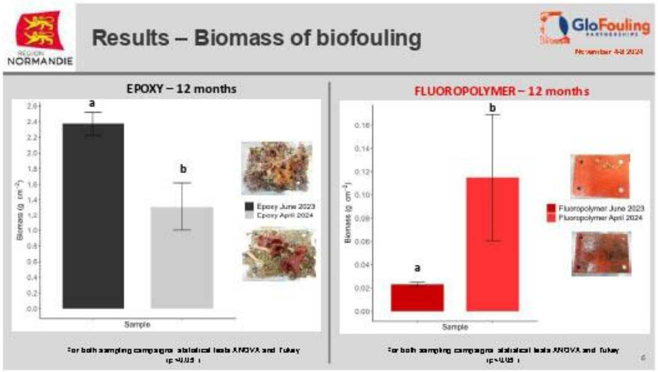
Presentation slides

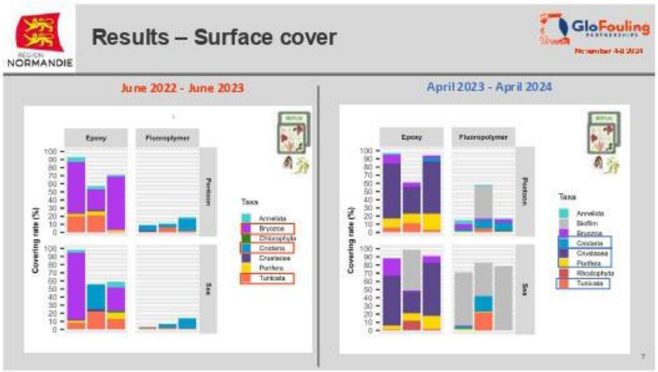


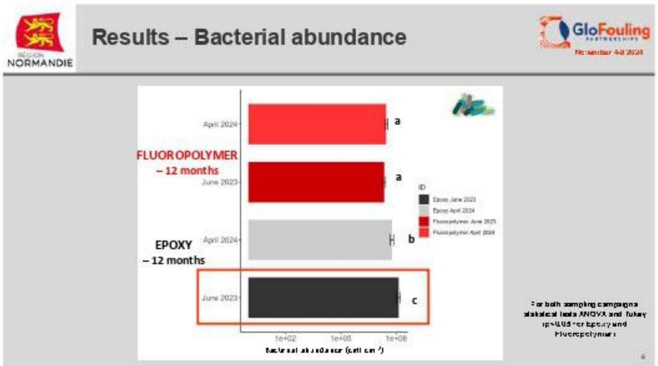

The BIOSTEM project
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
OBJECTIVES
Towards a more sustainable management of biofouling
Studying biofouling in the French coast of the English Channel
Testing different antifouling coatings
Developing standardized biofouling test methods
BIOSTEM
Development of a consortium of biofouling species for the development of standardized tests
Partners
EDF
NAVAL GROUP
Smel
BOREA
Promote the emergence of greener, more innovative materials

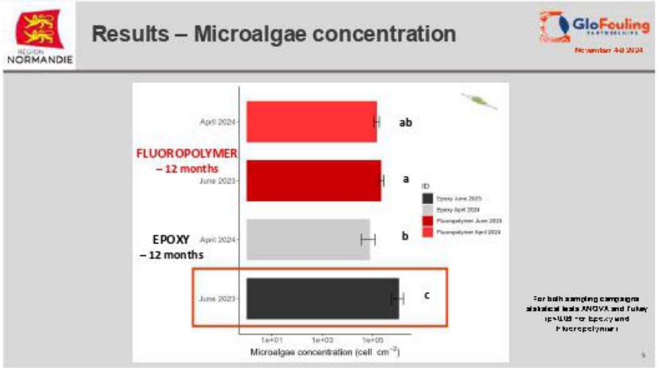

Materials and methods
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
CHERBOURG
FRANCE
Immersion in the port of Cherbourg, France
2 series of immersions :
1. June 2022 – June 2023
2. April 2023 – April 2024
Different seasons and years of immersion
→ 12-month study and comparison of the results
1st immersion
2nd immersion
1st emersion 12 months
2nd emersion 12 months
June 2022
April 2023
June 2023
April 2024


Materials and methods
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
Two coatings on carbon steel plates:
Epoxy (E) anticorrosion coating
Fluoropolymer (F) antifouling coating without biocides
Two orientations: sea and pontoon
Microalgae concentration
Mallassez counting chamber
BIOFILM
Biofouling development
Weight of sample after immersion
Surface cover
Vidana Software
DEFT (direct epifluorescent filter technique)
Created in BioRender.com

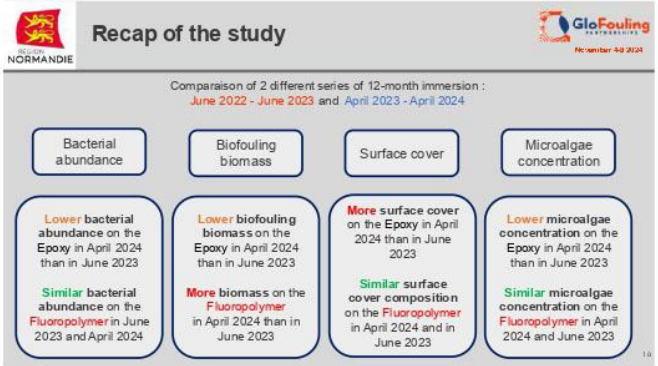

Results – Biomass of biofouling
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
EPOXY – 12 months
FLUOROPOLYMER – 12 months
Biomass (g cm-2)
Sample
Epoxy June 2023
Epoxy April 2024
Fluoropolymer June 2023
Fluoropolymer April 2024


Results – Surface cover
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
June 2022 - June 2023
April 2023 - April 2024
Epoxy
Fluoropolymer
Pontoon
Sea
Covering rate (%)
Taxa
Annelida
Bryozoa
Chlorophyta
Cnidaria
Crustacea
Porifera
Tunicata
Biofilm
Rhodophyta

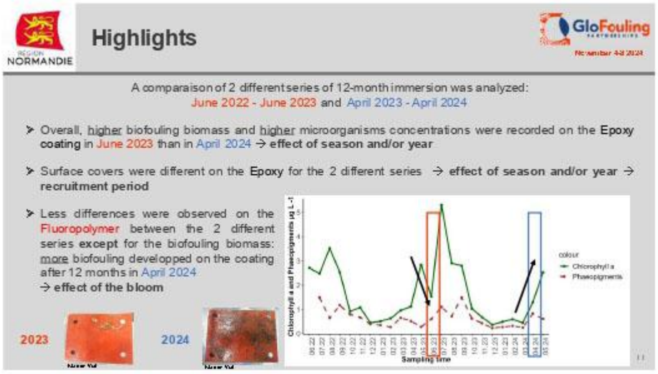

Results – Bacterial abundance
RÉGION NORMANDIE
GloFouling PARTNERSHIPS
FLUOROPOLYMER – 12 months
EPOXY – 12 months
April 2024
June 2023
1e+02
1e+05
1e+08



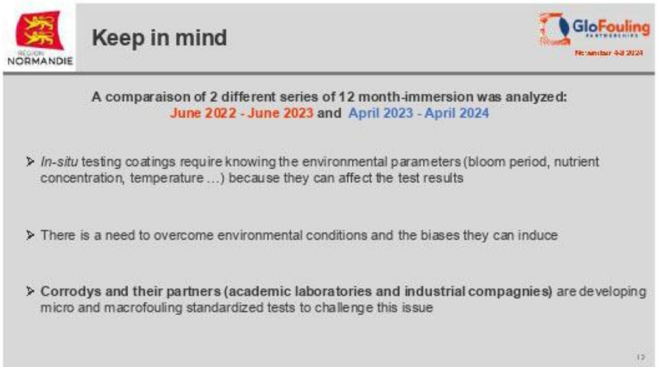
REGION NORMANDIE
Results – Microalgae concentration
GloFouling
FLUOROPOLYMER – 12 months
EPOXY – 12 months
April 2024
June 2023
April 2024
June 2023
ab
a
b
c
ID
Microalgae concentration (cell cm⁻²)
For both sampling campaigns statistical tests ANOVA and Tukey (p<0.05) for Epoxy and Fluoropolymer



REGION NORMANDIE
Recap of the study
GloFouling
Comparaison of 2 different series of 12-month immersion :
June 2022 - June 2023 and April 2023 - April 2024
Bacterial abundance
Biofouling biomass
Surface cover
Microalgae concentration
Lower bacterial abundance on the Epoxy in April 2024 than in June 2023
Similar bacterial abundance on the Fluoropolymer in June 2023 and April 2024
Lower biofouling biomass on the Epoxy in April 2024 than in June 2023
More biomass on the Fluoropolymer in April 2024 than in June 2023
More surface cover on the Epoxy in April 2024 than in June 2023
Similar surface cover composition on the Fluoropolymer in April 2024 and in June 2023
Lower microalgae concentration on the Epoxy in April 2024 than in June 2023
Similar microalgae concentration on the Fluoropolymer in April 2024 and June 2023

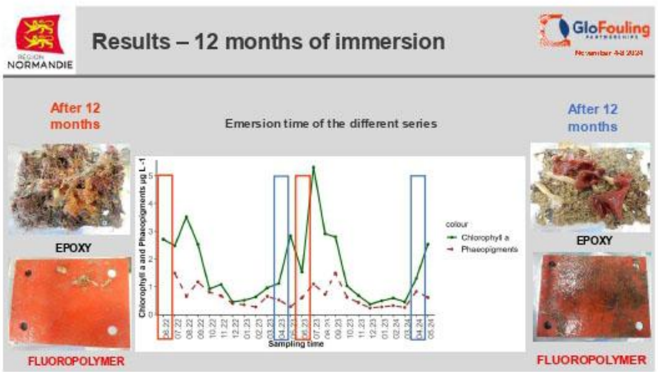


REGION NORMANDIE
Highlights
GloFouling
A comparaison of 2 different series of 12-month immersion was analyzed:
June 2022 - June 2023 and April 2023 - April 2024
➢ Overall, higher biofouling biomass and higher microorganisms concentrations were recorded on the Epoxy coating in June 2023 than in April 2024 → effect of season and/or year
➢ Surface covers were different on the Epoxy for the 2 different series → effect of season and/or year → recruitment period
➢ Less differences were observed on the Fluoropolymer between the 2 different series except for the biofouling biomass: more biofouling developped on the coating after 12 months in April 2024
→ effect of the bloom
2023
2024
Chlorophyll a and Phaeopigments µg L-1
Sampling time
colour
Chlorophyll a
Phaeopigments



REGION NORMANDIE
Keep in mind
GloFouling
A comparaison of 2 different series of 12 month-immersion was analyzed:
June 2022 - June 2023 and April 2023 - April 2024
➢ In-situ testing coatings require knowing the environmental parameters (bloom period, nutrient concentration, temperature ...) because they can affect the test results
➢ There is a need to overcome environmental conditions and the biases they can induce
➢ Corrodys and their partners (academic laboratories and industrial compagnies) are developing micro and macrofouling standardized tests to challenge this issue

corrodys
Your corrosion, biocorrosion and biofouling specialist
https://corrodys.com/
Thank you !
mvial@corrodys.com
SCAN ME



REGION NORMANDIE
Results – 12 months of immersion
GloFouling
After 12 months
After 12 months
Emersion time of the different series
EPOXY
EPOXY
FLUOROPOLYMER
FLUOROPOLYMER
Chlorophyll a and Phaeopigments µg L-1
Sampling time
colour
Chlorophyll a
Phaeopigments

How Industry Can Support IMO's Member States in Biofouling Management?

CHAIR OF THE SESSION

WILL GRIFFITHS

Technical Analyst

GloFouling Partnerships, IMO

AGAMPODI JAGATH MENDIS GUNASEKARA

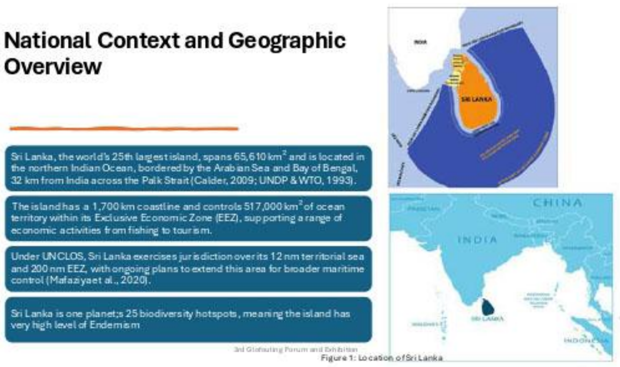
General Manager

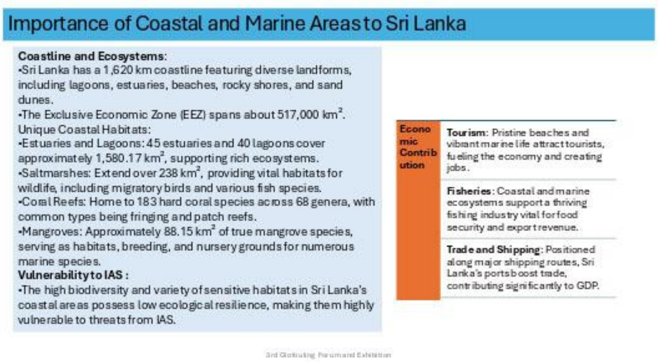
Marine Environment Protection Authority

A.J.M. Gunasekara is the General Manager of the Marine Environment Protection Authority in Sri Lanka, with over two decades of experience in maritime affairs, marine environment protection, and natural resource management. He holds two Master's degrees, including an MSc in Maritime Affairs from the World Maritime University, Sweden, specializing in Marine Environment and Ocean Management. Throughout his career, Gunasekara has led strategic operations and supervised technical functions, He has published numerous research papers on marine pollution and conducted training in oil spill response. His expertise is further recognized through various scholarships and fellowships, alongside significant teaching experience in fisheries, aquatic resource management, and port operations.

Technological Challenges in the Prevention and Management of Biofouling at the National Level

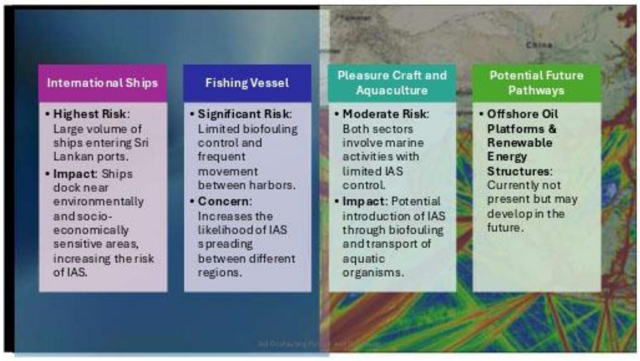
Presentation slides

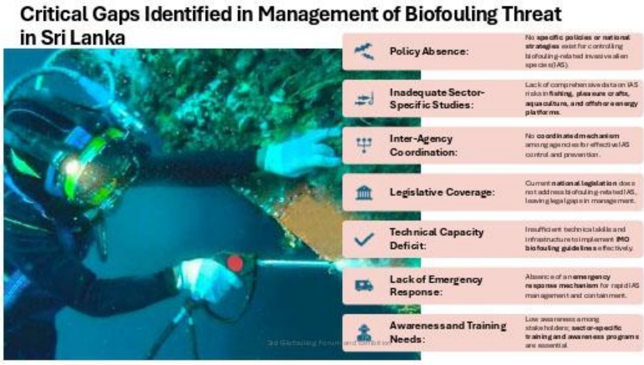




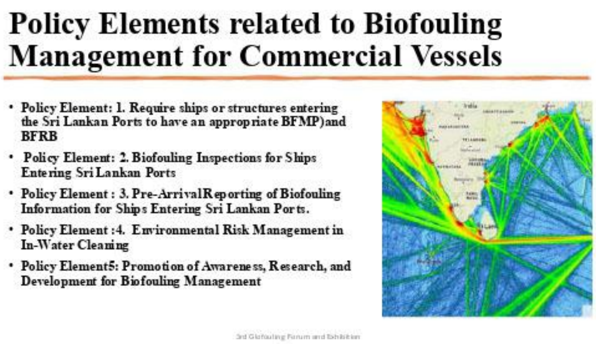

Invasive species found
Colombo Port (9 sepcies)
Musculista senhousia -Asian date mussel , Balanus Amphitrite- Stripped Barnacles
Elminius modestus - Australia acorn barnacle
Mytilus galloprovicialis – Mediterranean mussel
Perna viridis - Asian Green Mussel Crassostrea gigas - pacific Oyster
Ostrea edulis -European flat oyster,
Watersipora subtorquata ,
Membranipora membranacea
Galle - (4 Species)
Perna viridis- Asian green mussel
Crassostrea gigas- Pacific Oyster
Balanus Amphitrite -Stripped Barnacles
Clathria prolifera – Red beard sponge
Trincomalee (5 species)
Rapana venosa -Asian Rapa whelk
Phallusia nigra -Black sea Squirt
Perna perna - Brown Mussel
Brachidontes pharaonis - mussel
Balanus Amphitrite- Stripped Barnacles
Balanus reticulates –Reticulated striped barnacle
Balanus trigonus –Tringle barnacle
Schizoporella errata- Encrusting bryozoan
Hambantota (8 Species)
Rapana venosa -Asian Rapa whelk
Phallusia nigra – Black sea Squirt
Perna perna - Brown Mussel
Brachidontes pharaonis - mussel
Balanus Amphitrite- Stripped Barnacles
Balanus reticulates – Reticulated striped barnacle
Balanus trigonus –Tringle barnacle
Schizoporella errata- Encrusting bryozoan


Biofouling Transfer Pathways in Sri Lanka
There are two pathways identified as primary and secondary pathways.
Primary
Commercial Shipping
Fishing Vessels
Pleasure Crafts
Aquaculture
Secondary
Local Fishing Fleets
Domestic Shipping
Plastic Debris
Aquaculture
Research Vessels and Naval Ships
Oceanographic Instruments and Buoys
Port Structure / offshore structure


International Ships
• Highest Risk: Large volume of ships entering Sri Lankan ports.
• Impact: Ships dock near environmentally and socio-economically sensitive areas, increasing the risk of IAS.
Fishing Vessel
• Significant Risk: Limited biofouling control and frequent movement between harbors.
• Concern: Increases the likelihood of IAS spreading between different regions.
Pleasure Craft and Aquaculture
• Moderate Risk: Both sectors involve marine activities with limited IAS control.
• Impact: Potential introduction of IAS through biofouling and transport of aquatic organisms.
Potential Future Pathways
• Offshore Oil Platforms & Renewable Energy Structures: Currently not present but may develop in the future.
China


Critical Gaps Identified in Management of Biofouling Threat in Sri Lanka
Policy Absence:
No specific policies or national strategies exist for controlling biofouling-related invasive alien species (IAS).
Inadequate Sector-Specific Studies:
Lack of comprehensive data on IAS risks in fishing, pleasure crafts, aquaculture, and offshore energy platforms.
Inter-Agency Coordination:
No coordinated mechanism among agencies for effective IAS control and prevention.
Legislative Coverage:
Current national legislation does not address biofouling-related IAS, leaving legal gaps in management.
Technical Capacity Deficit:
Insufficient technical skills and infrastructure to implement IMO biofouling guidelines effectively.
Lack of Emergency Response:
Absence of an emergency response mechanism for rapid IAS management and containment.
Awareness and Training Needs:
Low awareness among stakeholders; sector-specific training and awareness programs are essential.


Vision
The national vision for biofouling management in Sri Lanka is maintaining a healthy and resilient marine ecosystem that is protected from the threat of IAS, and which supports our economy and social well-being.
Mission:
The mission of the biofouling management policy in Sri Lanka is to protect and maintain healthy and resilient marine ecosystems from biofouling related aquatic invasive species introduction through ships and submerge structures through the integrated and systematic implementation of IMO guidelines and best practices.
Overall Outcome:
The overall outcome of the biofouling management policy is to minimize the amount of biofouling entering Sri Lanka


Policy Elements related to Biofouling Management for Commercial Vessels
Policy Element: 1. Require ships or structures entering the Sri Lankan Ports to have an appropriate BFMP)and BFRB
Policy Element: 2. Biofouling Inspections for Ships Entering Sri Lankan Ports
Policy Element : 3. Pre-Arrival Reporting of Biofouling Information for Ships Entering Sri Lankan Ports.
Policy Element :4. Environmental Risk Management in In-Water Cleaning
Policy Element5: Promotion of Awareness, Research, and Development for Biofouling Management

Policy Elements related to the biofouling management for fishing vessels

- Policy Element: 1. National Guidelines for Fishing Vessel Maintenance and Biofouling Management
- Policy Element: 2. Removal of Biofouling attached to Fishing vessels
- Policy Element: 3. Environmentally Responsible Hull Cleaning Practices
- Policy Element: 4. Antifouling Coating Application
- Policy Element: 5. Removal of Antifouling System
- Policy Element: 6. Inspection of Uncoated Surfaces:
- Policy Element: 7. Mandatory Record-Keeping for Biofouling Management
- Policy Element 8: Environmentally Responsible Vessel Operations and Fishing Practices Minimizing Impact on Marine Ecosystems
- Policy Element: 9. Reporting and Emergency Responses
- Policy Element: 9. Sustainable Hull Cleaning and In-Water Maintenance Practices
- Policy Element 10: Fostering Innovation and Awareness for Effective Biofouling Management.

Policy Elements related to the biofouling management for Recreational Crafts

Policy Element 1: Biofouling Management Records for Recreational Crafts
Policy Element 2: Biofouling Cleaning Techniques for Recreational Craft in Sri Lankan Water
Policy Element 3: Measures to be Taken When Treating Internal Seawater Systems
Policy Element 4: Enhancing education and awareness raising on IAS spreading and management
Policy Element 5: Research and Development for Biofouling Control in Recreational Craft

Policy elements related to the biofouling management for Aquaculture

Policy Element 1: Preventing IAS in Aquaculture
Policy Element 2: Advancement in Antifouling Technologies - Biological Control
Policy Element 3: Aquaculture Infrastructure Cleaning Mechanism
Policy element 4. Inspection and compliance monitoring
Policy Element 5 Empowering Aquaculture Operators through Education and Outreach
Policy Element 6 : Research and Development for Biofouling Management

Policy measures and actions

Prevention | Early Detection | Response

- The policy is structured around three key focus areas essential to effective biofouling management.
- For each policy element, a comprehensive Action Plan has been developed. This plan includes specific actions and cutting-edge technologies should be deployed to ensure efficient and effective implementation. By integrating these technologies, the policy aims to optimize processes, enhance compliance, and achieve sustainable outcomes.

Challenges in Effective Implementation and Required Technological Support

1. IAS Monitoring- a comprehensive monitoring program is essential for effective IAS management, utilizing advanced technologies for precise identification and tracking. This program should incorporate:

- **Identification Techniques**: Employ both morphological character analysis and modern molecular and gene-based technologies for accurate species identification.
- **Data Management and AI Integration**: Use Information Technology to maintain an extensive database, and integrate AI for automated and efficient species identification and pattern recognition

2. The advanced notification of a ship's biofouling management status and risk assessment

- To effectively implement these actions, it is essential to adopt new IT and AI solutions.
- These technologies will enable real-time monitoring, predictive analytics, and automated decision-making, improving the efficiency and accuracy of biofouling management while mitigating associated risks.

In water Cleaning Practices

- including both capture and non-capture methods, are recognized by IMO guidelines as viable options for biofouling management.
- However, there is currently no clear guidance or established protocol for the approval of these technologies. The lack of a standardized approval process makes it challenging to implement these methods effectively. To address this, it is essential to provide the necessary technological support to develop and implement a robust approval protocol. This would ensure that hull cleaning technologies meet environmental, operational, and regulatory standards, fostering their widespread adoption while minimizing ecological risks.
- In water hull cleaning equipment- support to countries to acquire new technologies, through standardization and Industry partnership

Waste Management

- Management of removal waste generated from hull cleaning process
- The waste generated from the above process considers as hazardous waste. However adequate hazardous waste management facilities are not available .

Fishing Boats antifouling system and cleaning system

- Cost effective antifouling paint for fishery vessels
- A cleaning technologies
- specifically designed for fishing boats. To address this gap, there is a pressing need to develop and introduce low-cost, highly efficient cleaning systems tailored to the unique needs of the fishing industry. Offering a sustainable solution for maintaining fishing boats while being cost-effective.


THANK YOU

PATRICIA CARBAJAL

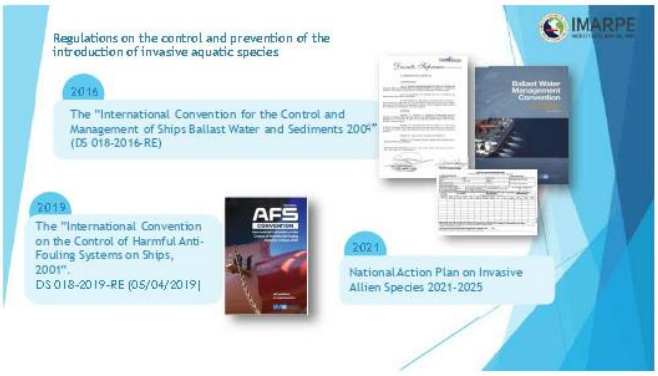
Senior Biologist

Instituto del Mar del Peru, Peru

Patricia Carbajal Enzian works at the Biodiversity Research Department of Instituto del Mar del Peru (Imarpe) and has more than 15 years of working experience in marine biodiversity and conservation topics. She is a biologist with postgraduate studies in aquatic ecosystems and resources, taxonomy and marine ecology. Her primary research is focused on studying the status and variability of marine biodiversity of marine benthic communities in the face of multiple natural and anthropogenic stressors, including fisheries impact, El Niño Event and lately non-indigenous species. She has coordinated the Coastal Marine Biodiversity Technical Group of the Peruvian National Commission for Biodiversity, since 2020, for implementing commitments of the Convention of Biological Diversity. She has participated in different research projects aimed at studying the Peruvian sea biodiversity and elaborated several guides for identifying marine coastal species.

Technological Challenges in the Prevention and Management of Biofouling at the National Level

Presentation slides

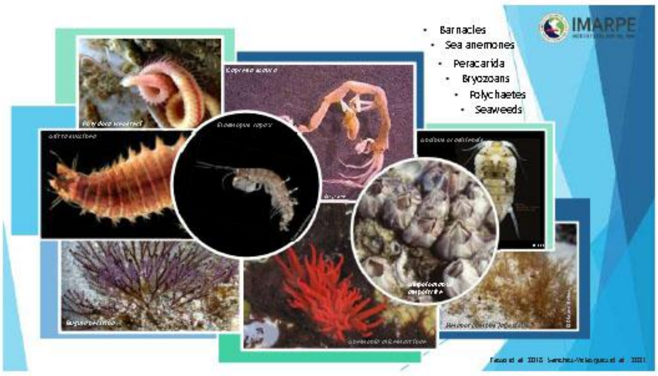



gef
UNDP
IMO
GloFouling PARTNERSHIPS
Galapagos Islands workshop on biofouling management in marine protected areas 2023
The Strategy and Action Plan for preventing invasive species Ecuador, 2022
Peruvian workshops for capacity building of decision makers (2021-2023)
Practical Training Workshop on Port Biological Survey Methodology for the identification of invasive biofouling species. Ecuador, 2022


Non-indigenous species (intentional)
IMARPE
Intentionally transported for aquaculture
"Turbot"
"Pacific oyster"
"Red abalone"


Introduced marine exotic invasive species (unintentional)
Ciona robusta Hoshino & Tokioka, 1967
Major component of fouling communities
Provokes significant losses in scallop aquaculture (Argopecten purpuratus).
Probably introduction through ballast water

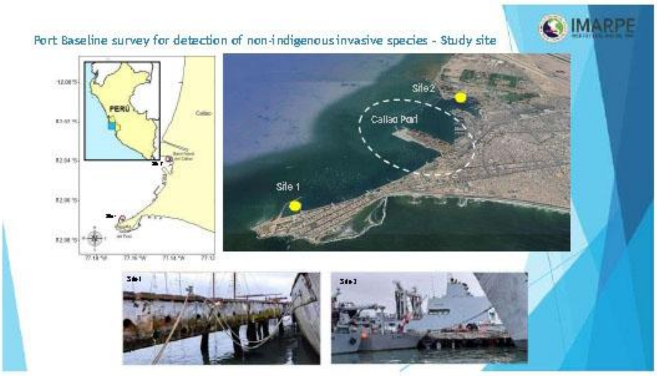

IMARPE
Introduced marine exotic invasive species (unintentional)
Caulerpa filiformis (Suhr) Hering 1841
Original from Africa, first time reported in Peru
It modifies the infaunal and epifaunal community in shallow sandy bottoms
COLOMBIA
ECUADOR
PERU


IMARPE
Barnacles
Sea anemones
Peracarida
Bryozoans
Polychaetes
Seaweeds


IMARPE
Critical issues:
Records of non-indigenous species have increased in the last years.
These introduction events are most likely to be human-mediated through maritime activities.
The ecological and economic impact of establishing non-indigenous species has not been quantified.
Growing marine-related economic activities at a national scale could accelerate the introduction of these species.
The probability of establishing and invading non-indigenous species could increase under the climate change scenario.
Monitoring for early detection and informed management of non-indigenous invasive species is not broadly implemented.

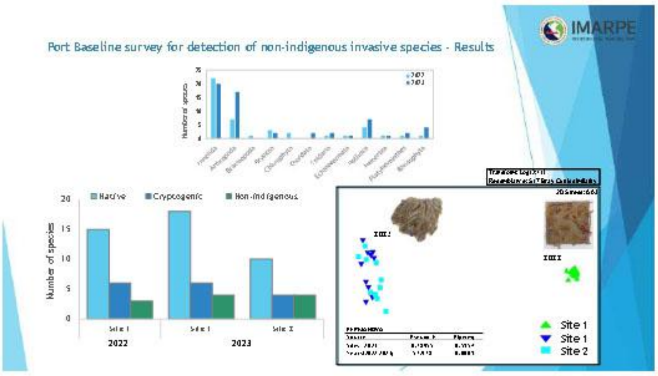

Biological monitoring

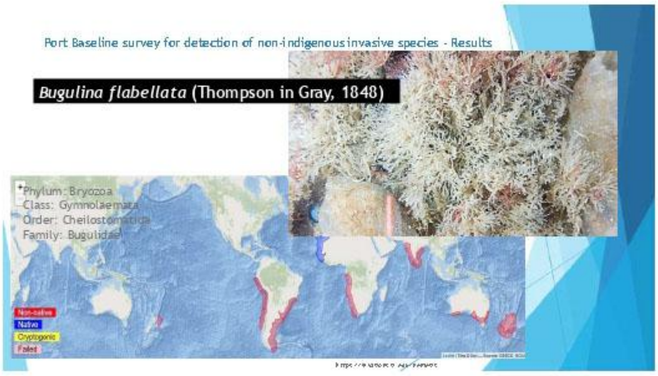

IMARPE
Port Baseline survey for detection of non-indigenous invasive species
This activity aims to perform a basic assessment of the current situation of non-inidgenous species in the Port of Callao, using standardized methodologies (Smithsonian Environmental Research Center).
This project has started with a financial support from IMO-CPPS (Circular CPPS/SE/198/2019).
Monitoring time: 2022 - 2024


IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Study site
PERU
Callao
Site 2
Callao Port
Site 1

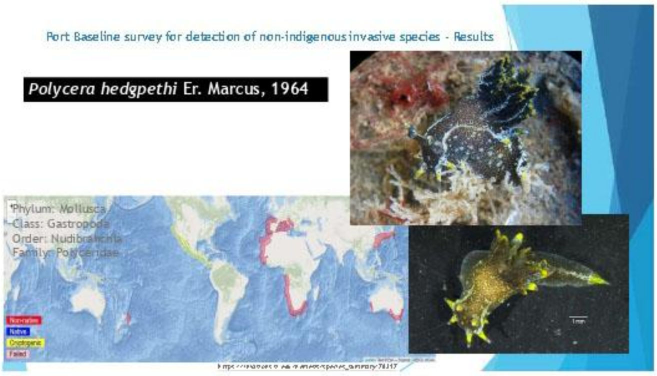

IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Methods
PLATES DEPLOYMENT
PLATES RETRIEVAL


IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Methods
a)
b)
c)
SERC

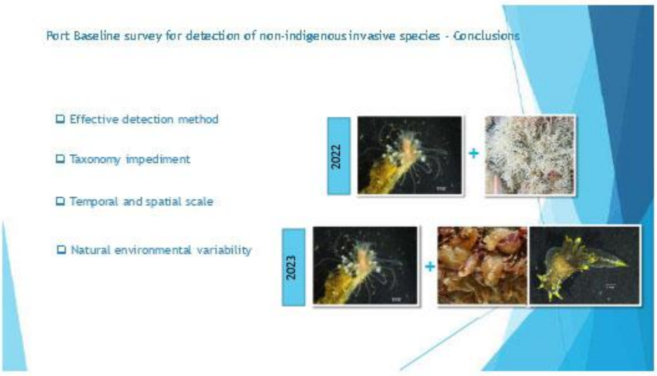

IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Results
Number of species
Native
Cryptogenic
Non-indigenous
2022
2023
Site 1
Site 1
Site 2


Port Baseline survey for detection of non-indigenous invasive species - Results
Bugulina flabellata (Thompson in Gray, 1848)
Phylum: Bryozoa
Class: Gymnolaemata
Order: Cheilostomatida
Family: Bugulidae
Non-native
Native
Cryptogenic
Failed


IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Results
Ectopleura crocea (Agassiz, 1862)
Phylum: Cnidaria
Class: Hydrozoa
Order: Anthoathecata
Family: Tubulariidae
Non-native
Native
Cryptogenic
Failed

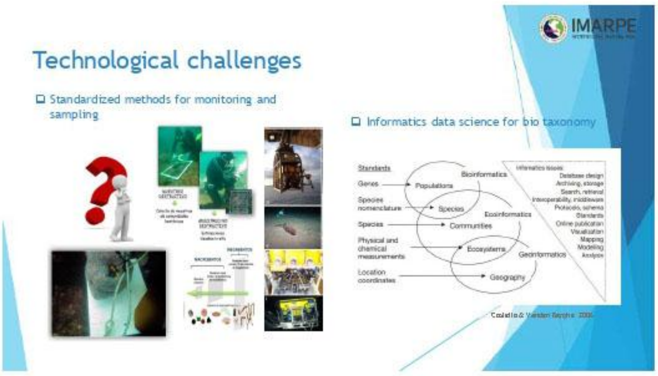

Port Baseline survey for detection of non-indigenous invasive species - Results
Polycera hedgpethi Er. Marcus, 1964
Phylum: Mollusca
Class: Gastropoda
Order: Nudibranchia
Family: Polyceridae
Non-native
Native
Cryptogenic
Failed

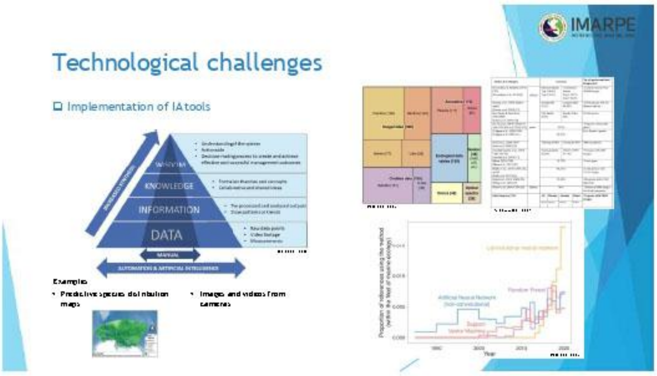

IMARPE
Port Baseline survey for detection of non-indigenous invasive species - Results
Ciona robusta Hoshino & Tokioka, 1967
Non-native
Native
Cryptogenic
Failed


Port Baseline survey for detection of non-indigenous invasive species - Conclusions
Effective detection method
Taxonomy impediment
Temporal and spatial scale
Natural environmental variability
2022
2023


Technological challenges


IMARPE
Technological challenges
Diver-based inspection of vessels
Underwater drones for inspection
Vessel cleaning techniques
TAS GLOBAL
PAST
FUTURE


IMARPE
Technological challenges
Standardized methods for monitoring and sampling
Informatics data science for bio taxonomy
Standards
Genes
Species nomenclature
Species
Physical and chemical measurements
Location coordinates
Bioinformatics
Populations
Species
Ecoinformatics
Communities
Ecosystems
Geoinformatics
Geography


IMARPE
Technological challenges
Implementation of IA tools
WISDOM
KNOWLEDGE
INFORMATION
DATA
Examples
Predictive species distribution maps
Images and videos from cameras


Concluding remarks


GloFouling PARTNERSHIPS
Ministry of Oceans and Fisheries
KRISO
UN DP
IMO
3RD GLOFOULING R&D FORUM AND EXHIBITION
on Biofouling Prevention and Management for Maritime Industries
Patricia Carbajal, Sara Clemente, Rita Orozco, Elisa Goya
Instituto del Mar del Perú
pcarbajal@imarpe.gob.pe
Thank you
2024

RICARDO COUTINHO

Senior Scientist

Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM), Brazil

Doctor (Ph.D) in Biology (Ecology) from the University of South Carolina (1987), with a Post-Doctoral internship at Duke University (2003) and Woods Hole Oceanographic Institute (2004), USA. Full Researcher and Head of the Department of Marine Biotechnology at the Almirante Paulo Moreira Institute of Sea Studies (IEAPM), and CNPq Research Productivity Fellow (IB). Founder and Coordinator of the Postgraduate Program in Marine Biotechnology at IEAPM/UFF. State Scientist by FAPERJ. Coordinator of INCT-PRO-OCEANO which involved 27 national institutions. Scientific Coordinator of the Brazilian Navy, IBAMA and ANP Monitoring Group (GAA), related to the oil spill that hit the northeast coast of Brazil in 2019. Coordinated 2 European and 22 national research projects. He published 152 scientific articles, supervised 46 masters, 36 doctors and 32 post-doctors. National Coordinator of the GEF-UNDP-IMO Glofouling Partnership Project. His research is associated with the Ecology of coastal and oceanic systems, anthropogenic impacts and the recovery and repopulation of aquatic ecosystems, Biofouling and Invasion species. Ricardo Coutinho has 30 years of experience in Ecology and Algae Cultivation. He presided over the Brazilian Society of Phycology (Algae) between 1993-1996, and RedeAlgas (2015-2019) and Organize 15 meeting in Biofouling in Brazil since 1991. Ricardo Coutinho was the President of the 13th ICMCF Conference in Rio de Janeiro in 2006.

Technological Challenges in the Prevention and Management of Biofouling at the National Level

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Presentation slides

The Presentation made by Dr. Ricardo Couthinho is not available for publication yet. It is based on the work of his graduate student and has not yet been published.

For more information about the presentation please Contact Dr. Ricardo Coutinho at : ricardo.coutinho@marinha.mil.br

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CHAIRS OF SESSIONS & PANELISTS

SESSION 3

Panel Discussion on Gender Diversity

Chair of the Session: Dr. Bev Mackenzie

DR. BEV MACKENZIE

Head of Intergovernmental Organization (IGO) Engagement

BIMCO, the United Kingdom

Dr Mackenzie is Head of Intergovernmental Engagement at BIMCO, the world's largest direct-entry membership organisation for the shipping industry. She is the London-based Representative at the International Maritime Organization and also provides the link between BIMCO and IMO and other intergovernmental organisations, particularly those within the UN Ocean family, across the globe to ensure that BIMCO's technical expertise can be best utilised by decisions makers- to support practical and harmonised regulation for the shipping industry.

She has a degree in chemical oceanography and a PhD in physical oceanography from the University of Liverpool, UK and applies that scientific knowledge to help understand the science-engineering-policy interface. She has expertise in operational oceanography and ocean observing and issues relating to maritime industries and the environment including issues such as sea-based sources of marine plastics, biofouling management, climate change and air pollution and marine pollution.

She is on the board for the UK's Net Zero Oceanographic Capability programme and is a Trustee of Plymouth Marine Laboratory. She is a Fellow of the IMarEST and of the Marine Biological Association of the UK and a Chartered Scientist and Chartered Marine Scientist.

PANELLISTS

ERVIN VARGAS WILSON

Director

Maritime Technology Cooperation Centre (MTCC) Latin America, Panama

Accomplished professional with 20+ years of demonstrated leadership experience obtained across the maritime industry. Well-rounded seagoing expertise encompasses container vessels, large crude oil carriers, bulk carrier vessels, chemical tankers and TSHD dredge. Forward-thinking professional with the hands-on knowledge required to lead vessel and port operations see while creating opportunities to further align with the bigger picture. Highly skilled in building and leading successful team that meet the strategic goals and objectives of the organization. I have experience working individually and in teams, supervising others, meeting deadlines, writing reports, teaching, researching, and adjusting my *skills to job demand. Moreover, I firmly believe in education, hard work, commitment, responsibility, respect, loyalty, dedication, adaptability, resilience, and proper use of technology as essential elements for success and personal and professional growth.*

MAYA GUELLNER

Intern

Marine Environment, Technical Directorate, Lloyd's Register, the United Kingdom

Maya is a Master's student in Marine Biology at the University of Southampton. She is currently interning at Lloyd's Register's Technical Directorate, where she focuses on marine environmental policy and the environmental impacts of shipping. Her dissertation explores the establishment of PSSAs in areas beyond national jurisdiction, using the Costa Rican Thermal Dome as a case study. Maya completed a research internship with the IMO on this topic and is collaborating with the MarViva Foundation on the SARGADOM project to develop a PSSA proposal for the Costa Rican Thermal Dome.

RALITSA MIHAYLOVA

Head o Special Projects

Safinah Group, the United Kingdom

Dr Ralitsa Mihaylova is the Head of Special Projects for Safinah Group, a leading independent coating consultancy based in the United Kingdom. Her background is in shipping business and operations with experience in data analysis and machine learning techniques. Ralitsa has a keen interest in sustainable solutions and the regulatory framework governing international shipping. She is actively participating in industry-led initiatives and working groups related to biofouling. At Safinah Group, Ralitsa is responsible for coordinating the company's research and development activities and delivering data-driven solutions and insights to inform strategic decisions.

SUHA NEDHAL KHALIL ABU ZEID

Chartering and Logistics Officer

Jordan National Chapter, Arab Women in Maritime Association (AWIMA)
Jordan

Suha Nedhal Abu Zeid is a dedicated environmental engineer with a passion for sustainable maritime practices. Her obsession with science starts early; since her father gifted her a book as a 9-year-old about Mari Curie, she had a dream to contribute to the science field as Mari did. When she was 16 years old, she participated at the Intel International Science and Engineering Fair in both Reno, USA, and Atlanta, USA, as a finalist. With a BSc in Environmental Engineering, she worked on a project for a pretreatment process for a desalination plant to increase the life of membranes and was awarded as the Best Scientific Youth researcher by the Euro-Arab Organization for Environment, Water, and Desert Research. And by attending multiple courses regarding biofouling, she became aware of the extent of the problem, which encouraged her to think of a natural, sustainable way to reduce fouling species to grow on submerged bodies by studying the color effects, for which she started a research project for two mechanisms to reduce the fouling species naturally.

In addition to her research, she participated in preparing the National Status Assessments on Biofouling Management Report, which was submitted to PERSGA. Lately, she prepared a textbook for the FIATA Accredit Center Jordanian Logistics Association (module 15) FIATA Diploma regarding Sustainability in Freight Industry to teach this module for participants in Jordan.

With over a decade of experience in Maritime Management companies and Agencies, she gained experience in logistics and supply chain management and purchasing as well as project management, relating her experience with her background as an environmental engineer she strongly believe as the maritime transport, accounting for more than 80 percent of global commercial traffic and plays a central role in the international trade, we have to commit with MARPOL annex VI, IMO Biofouling prevention guidelines and ballast convention as maritime industry workers and stockholders to make the change that we are up to for better future and sustainable environment.

As a proud AWIMA-Jordan National Chapter member, she is committed to gender diversity in the maritime sector, which is evident through active participation in the industry. She believes that women can be a very positive aspect in the maritime sector and bring diverse perspectives and skills to the industry with the help of organizations and initiatives dedicated to supporting women in maritime, providing them with networking opportunities, mentorship, and training.

SESSION 8

Biofouling Management in Marine Protected Areas (MPA) and Particularly Sensitive Areas (PSSAs)

Chair of the Session: Dr. Inti Keith

DR INTI KEITH

Principal Investigator

Marine Biodiversity Research, Charles Darwin Foundation, Galapagos Islands, Ecuador

Dr Inti Keith is a HSE part IV commercial diver, a Scientific Diver and PADI instructor and has dedicated her career to the conservation of marine ecosystems. Inti has worked all around the world from the remote islands of Orkney in Scotland to the Great Barrier reef in Australia. Inti joined he Charles Darwin Foundation in 2010 and worked on shark tagging sea turtle monitoring and subtidal ecological monitoring before completing her PhD on Marine Invasive Species in the Galapagos Marien Reserve. She now leads the Marine Invasive Species and the long term Subtidal Ecological Monitoring Programmes as well as being the science group coordinator for the Eastern Tropical Pacific Marine Corridor initiative (CMAR).

Her research portfolio revolves around the role humans play in changing the natural world, particularly in marine ecosystems, and how science can influence management and policy. In recent years she has focused her research on marine invasions in Marine Protected Areas. She is particularly interested in both the consequences of invasions as well as the informed interventions to prevent and mitigate the impacts of these species and other anthropogenic impacts such as climate change.

PANELLISTS

DR. EVANGELINA SCHWINDT

Research Director

Institute of Marine Biology (IBIOMAR – CONICET), Argentina

Dr. Evangelina Schwindt is the Director of the Coastal Environments Ecology Group (GEAC) and a Principal Investigator at IBIOMAR-CONICET, Argentina, based in Patagonia. With over 30 years of experience studying marine invasions, she has published more than 120 articles, book chapters, and reports. Her research focuses on the patterns, processes, and consequences of marine invasions in natural coastal areas, ports and marine protected areas. Given the importance of managing biological invasions, she also studies various prevention and monitoring methods. Dr. Schwindt collaborates with national and international governments to support decision-making processes.

JOAPE GINIGINI

Senior Scientific Officer | Project Manager at Institute of Applied Sciences

Pacific Islands Marine Bioinvasions Alert Network (PacMAN) | University of South Pacific, Fiji

Education *- BSc Bio/Chem USP, MSc USP*
Academic Awards- *Best Masters of Science by thesis, 2013 Career Awards- 'He for She' and 'She Champions' by the SPC's Maritime Technology Cooperation Centre (MTCCs) under the Test Biofouling project for IMO*
Membership to Scientific and Academic bodies and networks - *Indigenous Science Network, Natural Resource Food Science (USP Thematic Group), Association of Common Wealth Universities, Oceans expert (UNESCO-IOC, IODE), Deep Ocean Science Initiative (DOSI), ONet IPBES.*
Research Interests *- Microbiology, Molecular biology, Natural Products research, ABS regime, Deep sea research, Ocean acidification monitoring, Blue Carbon, Invasive species detection*

SHARLOTH FERNANDEZ

Head of Environmental Management Department

National Directorate of Aquatic Spaces (DIRNEA), Ecuador

Education
2015: Bachelor's Degree in Naval Sciences from the Universidad de las Fuerzas Armadas / Naval Officer. Salinas, Ecuador.
2016: Specialization in Surface Operations. Guayaquil, Ecuador.
2018: Postgraduate Degree in Hydrography (Category B) from the Hydrography School of the Oceanographic and Antarctic Institute of the Navy (INOCAR). Guayaquil, Ecuador.
2020: Postgraduate Degree in Observational Oceanography at the POGO Centre of Excellence, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research. Helgoland, Germany.
2024: Diploma in International Maritime Law from Universidad del Pacífico. Guayaquil, Ecuador.

Professional Experience
2019: Director of the Hydrographic and Oceanographic Service of the Insular Region (SHOIAR). Galapagos, Ecuador.
2021: Head of the Marine Geophysics Unit and Project Manager for SUTPLA, responsible for "Defining technical foundations for the extension of the continental shelf and strategic state characterization for the identification and inventory of non-living resources" at the Oceanographic and Antarctic Institute of the Navy (INOCAR). Guayaquil, Ecuador.
2022: Instructor and Thesis Advisor at the Ecuadorian Naval Academy. Salinas, Ecuador.
2023 – Present: Head of the Environmental Management Department at the National Directorate of Aquatic Spaces (Ecuadorian Maritime Authority). The national focal point for the GloFouling, GloLitter,

and Test BioFouling projects under the International Maritime Organization (IMO). National representative for the Regional Task Force on Marine Invasive Species (GTR-EEM) in the Southeast Pacific, under the Permanent Commission for the South Pacific (CPPS).

SONIA ANGÉLICA JURADO CAICEDO

Sargadom Thermal Dome Project *Coordinator*

MarViva, Colombia

Sonia is a lawyer with a Master's Degree in International Affairs from the University Externado de Colombia. Since 2016, she has been working in the field of international affairs, environmental multilateralism, ocean governance and sustainable development. Sonia joined the SARGADOM project in May 2023 and currently holds the role of Project Manager. As a consultant, she works with governments, NGOs, and International Organizations to design marine conservation and management policies in the High Seas. She is passionate about achieving effective agreements that enable the conservation and sustainable use of the ocean. From 2016 to 2023, she worked for the Ministry of Foreign Affairs of Colombia, where she led the ocean international agenda and environmental affairs in regional and global scenarios. From there, she led the development of public policy for marine conservation and prioritized ocean issues in the national and international agenda.

SESSION 9

Policy Developments and Standards

Chair of the Session: Colin Henein

COLIN HENEIN

Director

Protection Environment Policy, Transport Canada, Canada

Colin Henein is the Director of Marine Protection within Transport Canada's Environmental Policy directorate. His policy responsibilities relate to biofouling, ship recycling, vessel garbage, marine protected areas as well as abandoned and derelict vessels. Colin is a longstanding member of Canada's delegation to the environmental committees of the International Maritime Organization (IMO). In 2024 he led the IMO's correspondence group on in-water cleaning of ships. Prior to accepting his current position, Colin spent 13 years at Transport Canada in positions of increasing responsibility regarding the ballast water of ships, water levels and flows, and work towards a network of Green Shipping Corridors. Colin holds an honours bachelor's degree in Computer Science and a Ph.D. in Cognitive Science. Outside of work, Colin is a community radio broadcaster and chairs the board of a local multicultural organisation that promotes the arts in schools and the community.

PANELLISTS

DR. BEV MACKENZIE

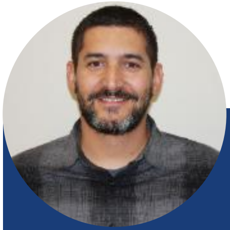
Head of Intergovernmental Organization (IGO) Engagement

BIMCO, the United Kingdom

Dr Mackenzie is Head of Intergovernmental Engagement at BIMCO, the world's largest direct-entry membership organisation for the shipping industry. She is the London-based Representative at the International Maritime Organization and also provides the link between BIMCO and IMO and other intergovernmental organisations, particularly those within the UN Ocean family, across the globe to ensure that BIMCO's technical expertise can be best utilised by decisions makers- to support practical and harmonised regulation for the shipping industry.

She has a degree in chemical oceanography and a PhD in physical oceanography from the University of Liverpool, UK and applies that scientific knowledge to help understand the science-engineering-policy interface. She has expertise in operational oceanography and ocean observing and issues relating to maritime industries and the environment including issues such as sea-based sources of marine plastics, biofouling management, climate change and air pollution and marine pollution.

She is on the board for the UK's Net Zero Oceanographic Capability programme and is a Trustee of Plymouth Marine Laboratory. She is a Fellow of the IMarEST and of the Marine Biological Association of the UK and a Chartered Scientist and Chartered Marine Scientist.



CHRIS SCIANNI

Environmental Program Manager, Marine Invasive Species Program

California State Lands Commission, the United States

Chris Scianni is the Environmental Program Manager for the California State Lands Commission's Marine Invasive Species Program, managing and providing support for the science policy and data management teams while coordinating with field inspectors spread across California. Chris is also the chair of the Coastal Committee of the Western Regional Panel on Aquatic Nuisance Species and helps to facilitate collaborative discussions between invasive species prevention, management, and control programs across the western United States.

YASMIN GABAY

Ministry of Primary Industries

New Zeland

Dr. Yasmin Gabay is a Senior Advisor at Biosecurity New Zealand, Ministry for Primary Industries (MPI), specializing in biofouling management and regulatory framework for international vessels. With over five years of advisory experience, she plays a pivotal role in shaping policies that protect New Zealand's unique marine ecosystems.

Holding a PhD in marine biology from Victoria University of Wellington, Dr. Gabay's research focused on the ecological and physiological effects of climate change on the marine environment.

As a representative of New Zealand in international discussions, Dr. Gabay collaborate with a wide range of stakeholders to promote sustainable practices in maritime industries. She has led numerous workshops and webinars, where she discussed New Zealand biofouling regulations and best practices.

Dr. Gabay is committed to advancing maritime biosecurity strategies that ensure a sustainable future for both the environment and maritime operations.

SVEINUNG OFTEDAL

Director

Ministry of Climate and Environment, Norway

Chief Negotiator on Green Shipping in the Norwegian Ministry of Climate and Environment with focus on international negotiations on environmental requirements for the maritime sector.

He started in the Ministry in 1996, but has also executed these tasks for 6 years in the Norwegian Maritime Authority (2000-2006). He started his career as Project Manager in the Norwegian Society for Conservation of Nature in 1990.

He has been heavily involved in negotiations on the hot topics at the IMO such as Greenhouse Gas Emissions, Air Pollution and other issues addressed in MARPOL, Ship Recycling, Ballast Water Management, Ships biofouling, Antifouling Systems and other environmental issues for over two decades.

In addition to his role for establishing the environmental framework for global shipping at the IMO, he has played a key role in developing Norwegian green shipping policies for domestic and short sea shipping.

Vice Chair of the IMO BLG Sub-Committee (2002-2009). Chair of the IMO BLG and PPR Sub-Committee (2010 – 2019). Chair of the IMO Working Group on Greenhouse Gas emissions (2017 – present).

TEO KARAYANNIS

Head

Marine Biosafety, Sub-Division for Protective Measures, Marine Environment Division, IMO

Dr Theofanis (Teo) Karayannis joined the Marine Environment Division of the IMO Secretariat in March 2014 and since August 2017 holds the position of Head, Marine Biosafety, being in charge of biosafety-related topics (ballast water management, anti-fouling systems and biofouling management) and the associated IMO instruments (the BWM and AFS Conventions and associated guidelines, and the Biofouling Guidelines). He is also the IMO Secretariat's focal point for various ongoing activities, including inter-agency partnerships, related to marine biosafety and biodiversity. Until July 2017 he was also involved with matters related to ship energy efficiency and greenhouse gas emissions from shipping. Prior to joining IMO he worked for Lloyd's Register, as a Senior Specialist in the Strategic Research and Technology Policy Group, and prior to that he held a position in the Marine Pollution Prevention and Cargoes Department of the Greek national maritime Administration. He also has previous experience as a naval architect and marine engineer at a ship design firm; as a university researcher; and as a lecturer at a seafarers' training academy. Dr Karayannis has a Diploma in Naval Architecture and Marine Engineering from the National Technical University of Athens (Greece) and a PhD in Ship Science from the University of Southampton (UK).

SPECIAL PARALLEL SESSION

Industry Panel Discussion

Chair of the Session: Will Griffiths

WILL GRIFFITHS

Technical Analyst

GloFouling Partnerships, IMO

Will Griffiths holds a BSc in Marine Biology and an MSc in Marine Science, Policy and Law. He spent 8 years at Oil Spill Response Limited (OSRL) where he responded to oil spills across Europe, Africa, Asia and the Middle East, from managing beach clean-up operations and offshore response to providing incident management support to private companies as well as governments

.

In addition to response, Will also has extensive experience supporting preparedness activities, developing contingency plans, delivering training and conducting preparedness reviews. In 2022, Will joined the International Maritime Organzation, a specialised agency of the United Nations as the Technical Officer responsible for the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 90) and its Protocol on Hazardous and Noxious Substances (HNS). In this position he assisted IMO Member States with issues pertaining to marine spills of oil and chemicals to increase international levels of preparedness.

In 2024, Will returned to his Marine Biology roots as took up the role of Project Technical Analyst in the GloFouling Partnerships project. In this GEF-UNDP-IMO initiative he analyzes technical aspects of the project, including data related to biofouling management strategies and technologies, to support the project's goals including collaboration with researchers, industry experts, and government agencies.

PANELLISTS

SIMON DORAN

Chair

Global Industry Alliance for Marine Biosafety

Simon has numerous professional qualifications within the subsea industry. He had 19 x years' experience in the UK Military Forces and since 1998 Simon has held various operational and management positions within the subsea industry and on becoming General Manager for UMC in the Middle East Division had overseen the business expansion in the region and development of high profile government contracts with the Royal Navy, US Navy, Omani and Pakistan Navy to name a few and then

Managing Director of HullWiper Ltd based in Dubai. The Main objective of the HullWiper team is to develop the once conceptual Hull Cleaning and inspection ROV platform into the business unit, globally to capture all of the world's shipping market with a safe, sustainable, and environmentally acceptable option to principals
Simons present role is business development (subject matter expert) at International Paint – AKZO NOBEL, establishing supporting subsea services to complement International Paint products

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ABIGAIL ROBINSON

Vice-Chair
Global Industry Alliance for Marine Biosafety

Abigail Robinson comes from New Zealand and has a background as an ecologist specialising in Biodiversity Management. She spent 6 years working for the Ministry for Primary Industries - Biosecurity New Zealand. Firstly, she worked as a quarantine officer actively enforcing biosecurity requirements on the front-line, then as a senior adviser working with New Zealand's world-first national biofouling requirements. Following this she moved across to the solution provider side in Europe as VP of Sustainability at ECOsubsea where she is helping to bring sustainable, high-quality hull cleaning services to the mainstream to tackle the biofouling problem.

AGAMPODI JAGATH MENDIS GUNASEKARA

General Manager
Marine Environment Protection Authority

A.J.M. Gunasekara is the General Manager of the Marine Environment Protection Authority in Sri Lanka, with over two decades of experience in maritime affairs, marine environment protection, and natural resource management. He holds two Master's degrees, including an MSc in Maritime Affairs from the World Maritime University, Sweden, specializing in Marine Environment and Ocean Management. Throughout his career, Gunasekara has led strategic operations and supervised technical functions, He has published numerous research papers on marine pollution and conducted training in oil spill response. His expertise is further recognized through various scholarships and fellowships, alongside significant teaching experience in fisheries, aquatic resource management, and port operations.

PATRICIA CARBAJAL

Senior Biologist

Instituto del Peru, Peru

Patricia Carbajal Enzian works at the Biodiversity Research Department of Instituto del Mar del Peru (Imarpe) and has more than 15 years of working experience in marine biodiversity and conservation topics. She is a biologist with postgraduate studies in aquatic ecosystems and resources, taxonomy and marine ecology. Her primary research is focused on studying the status and variability of marine biodiversity of marine benthic communities in the face of multiple natural and anthropogenic stressors, including fisheries impact, El Niño Event and lately non-indigenous species. She has coordinated the Coastal Marine Biodiversity Technical Group of the Peruvian National Commission for Biodiversity, since 2020, for implementing commitments of the Convention of Biological Diversity. She has participated in different research projects aimed at studying the Peruvian sea biodiversity and elaborated several guides for identifying marine coastal species.

RICARDO COUTINHO

Senior Scientist

Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM), Brazil

Doctor (Ph.D) in Biology (Ecology) from the University of South Carolina (1987), with a Post-Doctoral internship at Duke University (2003) and Woods Hole Oceanographic Institute (2004), USA. Full Researcher and Head of the Department of Marine Biotechnology at the Almirante Paulo Moreira Institute of Sea Studies (IEAPM), and CNPq Research Productivity Fellow (IB). Founder and Coordinator of the Postgraduate Program in Marine Biotechnology at IEAPM/UFF. State Scientist by FAPERJ. Coordinator of INCT-PRO-OCEANO which involved 27 national institutions. Scientific Coordinator of the Brazilian Navy, IBAMA and ANP Monitoring Group (GAA), related to the oil spill that hit the northeast coast of Brazil in 2019. Coordinated 2 European and 22 national research projects. He published 152 scientific articles, supervised 46 masters, 36 doctors and 32 post-doctors. National Coordinator of the GEF-UNDP-IMO Glofouling Partnership Project. His research is associated with the Ecology of coastal and oceanic systems, anthropogenic impacts and the recovery and repopulation of aquatic ecosystems, Biofouling and Invasion species. RC has 30 years of experience in Ecology and Algae Cultivation. He presided over the Brazilian Society of Phycology (Algae) between 1993-1996, and RedeAlgas (2015-2019) and Organize 15 meeting in Biofouling in Brazil since 1991. RC was the President of the 13th ICMCF Conference in Rio de Janeiro in 2006.

CLOSING SPEECHES

LILIA KHODJET EL KHIL

Project Technical Manager

GEF-UNDP-IMO Glofouling Partnerships

Ladies and gentlemen,

As we conclude the 3rd GloFouling R&D Forum and Exhibition here in the vibrant city of Busan, I am filled with pride and gratitude for the incredible week we have just experienced together.
First and foremost, I would like to extend our deepest thanks to the Republic of Korea, our generous host country, for welcoming us to Busan and for providing such a remarkable platform to discuss and advance the cause of biofouling management. The dedication of the Ministry of Oceans and Fisheries and the Korea Research Institute of Ships & Ocean Engineering (KRISO) and their teams has been instrumental in making this event a success. Your efforts have created the best possible conditions for all participants and speakers to fully benefit from this experience.

To our distinguished speakers and expert panelists, thank you for sharing your knowledge, insights, and innovative ideas with us. Your contributions have deepened our understanding and inspired us all to continue working for optimum biofouling management and aquatic invasive species prevention. The dedication and expertise you brought to each session were invaluable to the Forum.
A special thank you also to our exhibitors. The innovative technologies and approaches displayed in your booths have showcased the impressive strides being made across the industry to maintain ships' hull clean. It is through collaboration and shared knowledge, like those we witnessed here, that we can continue to create lasting solutions to protect our oceans.

And to all participants, thank you for your active engagement and valuable input throughout these past few days. Your enthusiasm and commitment to the protection of marine ecosystems are the true driving force behind the GloFouling Partnerships project. Your energy has enriched this Forum and reaffirmed the global commitment to this important cause.

Lastly, I would like to extend my heartfelt thanks to the GloFouling team. Your tireless work, dedication, and countless hours of preparation have made this event possible. From logistics to program development, every detail was thoughtfully executed. I am immensely proud of what we have achieved together this week, and your hard work has been the foundation upon which this success was built.
As we conclude this Forum, let us carry forward the momentum we have built here. The discussions, connections, and insights gained over the past few days will continue to fuel our efforts to tackle the complex challenges of biofouling and aquatic invasive species. Together, we are building a more sustainable, resilient future for our oceans.

Finally, I invite all countries represented and interested stakeholders to actively contribute to the policy discussion being held at the IMO on biofouling management and in-water cleaning.

Thank you once again to everyone who has contributed to making this event a success. Safe travels, and we look forward to our continued collaboration on this vital journey.
Thank you!

LILIA KHODJET EL KHIL

Project Technical Manager
GEF-UNDP-IMO GloFouling Partnerships

JON STEWART

Moderator

GloFouling R&D Forum

Ladies and gentlemen,

I cannot put into adequate terms how valuable this session has been, and I think I am speaking for all 250+ people involved. We have been educated on new developments, and we have gotten a timely update on others across all sectors and both have paved the way for our future work.

We have heard repeatedly the absolute necessity for stakeholder engagement. Coming away from these four days we have some new signposts to guide us. Identify the desired outcome, develop awareness of the various activities being undertaken globally, reach out, interact and truly collaborate across disciplines and work toward that common goal.

My takeaway is simple - biofouling is not a standalone issue. It is integral to protection of the global marine environment, the biodiversity of the planet and the benefit of humanity. If we recognize this, we can minimize challenges, put aside agendas and find real solutions.

I want to reiterate my admiration for GloFouling as a program, but especially for the team and vision and hard work that led to the success of this Forum. And of course, to our host from Republic of Korea, the Ministry of Oceans and Fisheries and KRISO, but mostly to all of you.

As I said in my opening remarks, this was your Forum. Having such a diverse group here offering your time, your interest and your expertise is truly what made these four days productive and a resounding success. It has been a privilege for me to be involved as your moderator. I have learned and been inspired by you. I leave here a better person for it. So, I offer my thanks to you all.

JON STEWART
GloFouling R&D Forum Moderator

POSTERS

Methodological Aspects of the Economic Impacts of Fouling in Peru: Gaps and Perspectives

Eric Rendón Schneir

Environmental School, Universidad Nacional Mayor de San Marcos, Lima-Perú

ABSTRACT

Peru´s economic growth has been accompanied by an increasing shipping activity generating also fouling impacts. This research has estimated mainly four types of impacts: a) cost overrun due to oil overuse; b) environmental impacts of hydro-washing and solid-waste management; c) impacts on fishing and aquaculture activity; d) Carbon emissions by oil overuse. Taking an average value between 2020-2022, it was calculated that the first economic cost of fouling was oil overuse (72%), fishing and aquaculture reduction (19%), hydro-washing cost and solid-waste management cost (5%) and carbon emissions by oil overuse (4%). Environmental economic valuations are just a tool for contributing to reduce fouling impacts, implementing some specific policies and private initiatives. There are also some additional potential impacts that could be included in the future, like biodiversity loss by ecosystem reduction, impacts of fouling on Ocean energy use and offshore wind energy, among others. This research could serve as a baseline study that could be improved progressively, insofar more specific information could be included, with the purpose of calculating fouling cost and sources of financing for implementing sustainable policies for reducing fouling impacts in Peru.

Keywords: Economic valuation- calculating fouling cost- environmental impacts

METHODOLOGICAL ASPECTS OF THE ECONOMIC IMPACTS OF FOULING IN PERU: GAPS AND PERSPECTIVES

Eric Rendón Schneir [1]: erendons@unmsm.edu.pe

[1]: *Environmental School, Universidad Nacional Mayor de San Marcos, Lima-Perú*

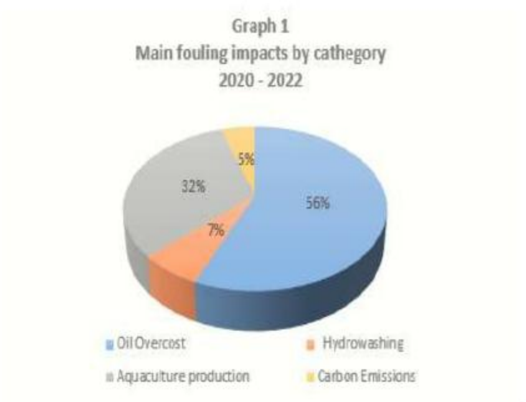
Economic Valuation Methods– Fouling-Peru

Peru´s economic growth has been accompanied by an increasing shipping activity generating also fouling impacts. This research has estimated mainly four types of impacts: a) cost overrun due to oil overuse; b) environmental impacts of hydro-washing and solid-waste management; c) impacts on fishing and aquaculture activity; d) Carbon emissions by oil overuse. Taking an average value between 2020-2022, it was calculated that the first economic cost of fouling was oil overuse (72%), fishing and aquaculture reduction (19%), hydro-washing cost and solid-waste management cost (5%) and carbón emissions by oil overuse (4%). Environmental economic valuations are just a tool for contributing to reduce fouling impacts, implementing some specific policies and private initiatives. There are also some additional potential impacts that could be included in the future, like biodiversity loss by ecosystem reduction, impacts of fouling on Ocean energy use and offshore wind energy, among others. This research could serve as a baseline study that could be improved progressively, insofar more specific information could be included, with the purpose of calculating fouling cost and sources of financing for implementing sustainable policies for reducing fouling impacts in Peru.

MAIN PURPOSES OF THE RESEARCH

The peruvian economic glofouling evaluation was developed taking into account many information gaps, and that´s the reason why, was used mainly secondary data. One of the most important finding of the research is that there are several differences between the national anti-fouling policies and the real impacts of fouling in Peru.

MAIN FOULING IMPACTS BY CATHEGORY



ANTIFOULING POLICIES BUDGET

Between 2021 and 2025 the Peruvian Government has destined a budget for fighting agains invasive species of US$ 402,597; according to the results of our research this represents less than 1% of the damages produce by biofouling.

CHALLENGES AND PERSPECTIVES

1.Taking into account that the main economic impact is the oil overcost because of fouling, the investment in sustainable shipping could lead to save oil.

2.The avoided cost methodology is the most convenient for comparing the investments with the benefits in the main economic activities affected by glofouling.

3.It is necessary to develop detailed research about glofouling in Peru, taking into account other economic activities like mining and tourism, and also considering that chancay port will soon, and maybe biofouling impacts in the Peruvian economics impacts will increase during the next years.

Innovative ROV-Based Propeller Cleaner with Full Collection System for Effective Biofouling Management

Morten Pilnov[1], Christian Hammerich Ackermann[2]

[1] CEO, C-leanship, Køge, Denmark
[2] Chief Technological Officer, C-leanship, Køge, Denmark

ABSTRACT

Biofouling management is a critical aspect of maintaining the efficiency and longevity of marine vessels and structures. Traditional cleaning methods often face operational constraints, particularly in environments where diver intervention is restricted. We introduce our new ROV-based propeller cleaner, designed to address these challenges with innovative technology and enhanced operational flexibility.

Our ROV-based cleaner offers several key benefits:

1. Operational Flexibility: Capable of operating in terminals where diver access is prohibited, ensuring compliance with stringent safety regulations.

2. Concurrent Operations: Allows for cleaning to be conducted simultaneously with loading operations, reducing downtime and enhancing operational efficiency.

3. Detailed Reporting: Provides comprehensive cleaning reports, enabling precise monitoring and management of biofouling levels.

This technology not only minimizes biofouling but also contributes to the overall sustainability, efficiency of marine operations and fleet performance. The system's full collection capability ensures environmentally responsible operations by preventing debris release into the marine environment. Our presentation will detail the technical specifications, operational benefits, and field performance of this innovative solution as well as touch on the importance of propeller cleaning in order to improve vessel efficiency.

Steering the Course: AI-powered Decision Support for Biofouling Management

Captain Amin Al Qawasmeh

Marine Department, PHOENICIA MARITIME SHIPPING, Aqaba, Jordan

ABSTRACT

Biofouling, the accumulation of aquatic organisms on submerged surfaces, poses a major threat to marine ecosystems and the maritime industry. Develop DSS incorporating real-time environmental data (water temperature, salinity), vessel speed and location, and biofouling growth models to predict fouling severity and optimize cleaning schedules.
Investigate AI-powered image recognition for automated biofouling identification and tailoring cleaning strategies based on specific organisms.

Objectives:

Develop a robust DSS that integrates real-time environmental data (water temperature, salinity), vessel speed and location, and biofouling growth models.
Leverage AI-powered image recognition for automated biofouling identification and tailoring cleaning strategies for specific organisms.

Expected Results:

Improved prediction of biofouling severity for optimized cleaning schedules, reducing fuel consumption and environmental impact.
Automated identification of fouling organisms, enabling targeted cleaning strategies and minimizing resource use.

Keywords: Biofouling, Decision Support Systems (DSS), Artificial Intelligence (AI), Image Recognition, Marine Fouling Management

AI-POWERED DECISION SUPPORT FOR BIOFOULING MANAGEMENT

Biofouling, the accumulation of aquatic organisms on submerged surfaces, poses a major threat to marine ecosystems and the maritime industry. Develop DSS incorporating real-time environmental data (water temperature, salinity), vessel speed and location, and biofouling growth models to predict fouling severity and optimize cleaning schedules.
Investigate AI-powered image recognition for automated biofouling identification and tailoring cleaning strategies based on specific organisms.

Authors
Captain Amin Al Qawasmeh: dpa@phoenicia-group.com
1: Marine Department, PHOENICIA MARITIME SHIPPING, Aqaba, Jordan

INTRODUCTION

Biofouling, the accumulation of aquatic organisms on submerged surfaces, presents a significant challenge to marine ecosystems and the maritime industry. This research aims to develop a robust Decision Support System (DSS) that utilizes real-time environmental data, vessel dynamics, and biofouling growth models to accurately predict fouling severity and optimize cleaning schedules. By incorporating AI-powered image recognition, the system will enable automated identification of fouling organisms, facilitating tailored cleaning strategies and minimizing resource consumption. Ultimately, this research seeks to mitigate the detrimental effects of biofouling and promote sustainable maritime practices.

OBJECTIVE

- Create a predictive tool: Develop DSS that accurately forecasts biofouling severity based on real-time environmental data, vessel dynamics, and advanced growth models.
- Revolutionize biofouling management: Utilize AI-powered image recognition to automatically identify specific fouling organisms, enabling targeted cleaning strategies and minimizing resource waste.
- Maximize efficiency and sustainability: Optimize cleaning schedules to reduce fuel consumption, improve vessel performance, and protect marine ecosystems.

RESULTS

- Enhanced operational efficiency: Achieve significant reductions in fuel consumption and emissions through optimized cleaning schedules based on accurate biofouling predictions.
- Environmental stewardship: Protect marine ecosystems by minimizing the impact of biofouling and reducing the need for harmful cleaning chemicals.
- Cost savings: Optimize resource allocation by targeting cleaning efforts to specific fouling organisms, leading to reduced maintenance costs and improved vessel performance.
- Technological advancement: Advance the field of marine biofouling management through the development and application of innovative AI-powered solutions.

ANALYSIS

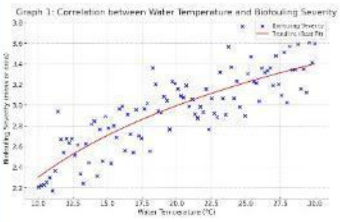
Accurate Biofouling Prediction:
- Enhanced data analysis: AI can process vast amounts of real-time environmental data (temperature, salinity, vessel speed, etc.) to identify patterns and correlations that humans might miss.
- Predictive modeling: AI algorithms can develop sophisticated models that accurately predict biofouling severity based on historical data and current conditions. This enables proactive measures to be taken before fouling becomes severe.

Enabled Efficiency:
- Automated monitoring: AI-powered systems can continuously monitor vessel hulls for signs of biofouling, reducing the need for manual inspections and maintenance.
- Optimized cleaning schedules: By accurately predicting fouling severity, AI can help optimize cleaning schedules, ensuring that cleaning is performed only when necessary, minimizing downtime and costs.

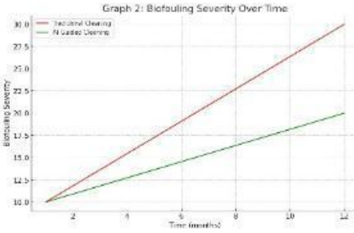
Environmental Benefits:
- Reduced chemical use: Accurate predictions and targeted cleaning strategies can minimize the use of harmful chemicals, protecting marine ecosystems.
- Lower carbon footprint: Reduced fuel consumption due to optimized cleaning can contribute to a lower carbon footprint for the maritime industry.

Reducing Costs:
- Preventive maintenance: AI-driven predictions can enable preventive maintenance, reducing the need for costly emergency repairs.
- Optimized resource allocation: By accurately identifying areas of high biofouling risk, AI can help allocate resources more efficiently.

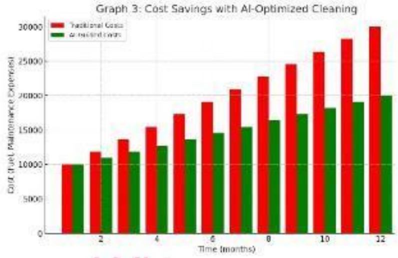
Protecting the Ecosystem:
- Minimizing invasive species: AI can help identify and remove invasive species that attach to vessel hulls, preventing their spread and protecting marine biodiversity.



Shows the correlation between water temperature and biofouling severity, with a trendline indicating the relationship.



Compares biofouling severity over time under traditional and AI-guided cleaning schedules.



CONCLUSION

AI has the potential to revolutionize biofouling management by providing accurate predictions, enabling efficient operations, and promoting environmental sustainability. By leveraging AI-powered solutions, the maritime industry can mitigate the negative impacts of biofouling and contribute to a healthier and more sustainable marine environment.

In-water cleaning with blue diode laser technology and automated handling system

Tim Heusinger von Waldegge[1], Dorothea Stübing[1], Stanislav Zimbelmann[2], Benjamin Emde[2], Markus Baumann[3], Thomas Brune[4]

[1] Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Bremen, Germany
[2] Laser Zentrum Hannover e.V. (LZH), Hannover, Germany
[3] Laserline GmbH, Mülheim-Kärlich, Germany
[4]OFTEC Handelsgesellschaft für Oberflächentechnik mbH, Dorsten, Germany

ABSTRACT
Biofouling presents significant challenges, especially in maritime industries. It increases frictional resistance, resulting in higher fuel consumption and greenhouse gas emissions, and threatens biodiversity by spreading non-indigenous species, along with complex economic implications.
Traditional mechanical removal methods are common but have several drawbacks, such as the risk of bio-invasion, the need for filtration mechanisms to prevent harmful substance release, legal hurdles, and reduced coating lifespan due to abrasion.
In response to these challenges, blue laser radiation is emerging as a promising biofouling removal technology. It can inflict lethal damage on organisms without harming coatings, thereby avoiding the release of biocides and microplastics. Additionally, blue laser radiation’s high transmission capabilities in water allow for extended working distances, enhancing operational flexibility and efficacy.
The method has progressed from controlled laboratory environments to practical use on ship hulls, a key goal of the ongoing "FoulLas²" project. This transition involves developing a laser architecture for underwater applications and implementing stringent safety measures to mitigate potential hazards. A magnet crawler system has also been integrated, enabling semi-autonomous functionality and improving efficiency in fouling removal.
Besides technological advancements, efforts are focused on streamlining workflow processes, developing coatings with reflective properties to enhance the irradiation effect, and navigating regulatory landscapes to ensure compliance with relevant standards. Offshore underwater simulation testbeds have been established to validate novel methodologies, promoting confidence in laser-based fouling removal strategies in real-world maritime applications.
The contribution will provide a technological overview and outline the steps needed for the full implementation of this technology.
Keywords: Underwater, cleaning, biofouling, blue laser, radiation, ship, hull, magnetic, crawler, non-indigenous species, automated, process, testing, maritime, sustainability.

In-water cleaning with blue diode laser technology and automated handling system

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1. Negative consequences of biofouling:

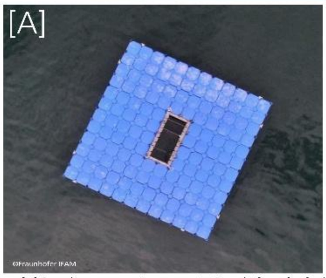
- Increased drag leads to higher fuel consumption resulting in more GHG emissions
- Causes the introduction of alien species - endangers biodiversity and has economic consequences that are difficult to assess.
- Harms coatings and diminishes functionality

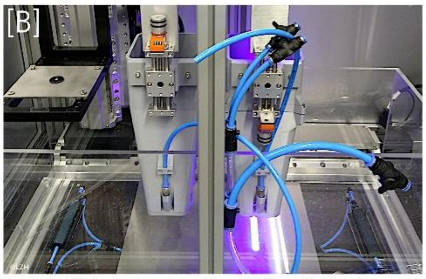
2. Effects of mechanical fouling removal:

- Risk of bioinvasion by organisms/larvae
- Requirement for intricate filtration systems
- Accumulation of substantial amounts of process water
- Coating abrasion
- Release of toxic coating substances

3. Fouling cleaning with blue laser radiation:

- Lethal damage to organisms for the prevention of non-indigenous species invasion
- No abrasion of the coating by mechanical processes
- No biocide release through laser cleaning in SPC systems
- High transmission of the blue laser, allows greater working distance



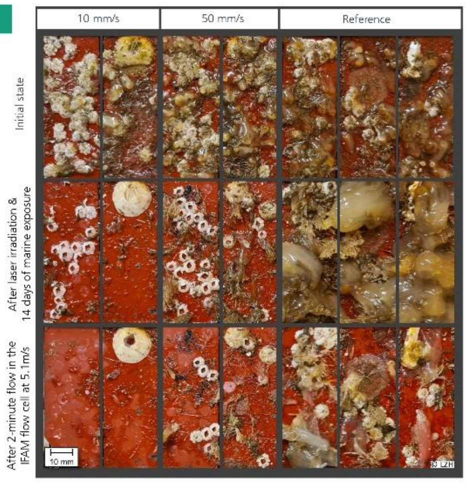


[A] Sample exposure at sea on a testing platform for fouling tests at Heligoland under real conditions, [B] followed by laboratory-scale laser irradiation.

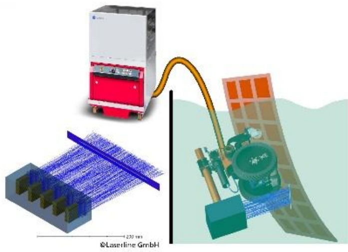
4. Results in previous FoulLas project:

- Effective lethal damage to soft and hard fouling, surface performance up to 18m²/h at 1.5kW and up to 50m²/h at 4kW

Fouling on a still unirradiated sample. Glass slides to which different commercial and experimental anti-fouling coatings have been applied serve as substrates.



5. Advancing the FoulLas method: From the laboratory to the ship



- Innovative laser concept for underwater applications
- Laser safety
- Magnet crawler for semi-autonomous underwater operation
- Workflow
- Development of an easy-to-clean coating with enhanced reflective properties
- Compliance with regulations and documentation
- Establishment of an underwater simulation testbed
- Laser process control for the integration of laser and crawler

Acknowledgements

This work was funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK) as part of the research project "FoulLas" (funding code 03SX489) and the follow-up project "FoulLas² (funding code: 03SX597) and by the project management organization Forschungszentrum Jülich GmbH. The authors would like to express their sincere thanks to the funding agencies, research partners and companies involved for their committed and productive cooperation and support.

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Optical Approaches to Quantify biofouling

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ABSTRACT

Biofouling burdens ships by increasing frictional drag and fuel costs, but also poses a risk of introducing invasive species to new environments attached and transported on ships' wetted surfaces.

Knowledge of the biomass, structure and profile, accumulation rate, and extent of the fouling is critical to understand the risk and, potentially, guide management actions

To address this need, three optical approaches to quantify biofouling were evaluated:

1. a 3-D white light, scanning system for analysis of panels and structures removed from water;

2. an inexpensive, underwater digital camera paired with a custom routine for classifying fouling in 2D images; and

3. 3-D underwater laser scanner for in situ analysis.

Ex situ, 3-D imaging was performed immediately after removing submerged test items. If a pre-treatment (fouling-free) scan was not available, the item was rescanned following cleaning to reveal its base structure, allowing precise measurements of biovolume, surface roughness, and fouling extent. This approach was well-suited to irregular objects (propellors) upon removal from the water. The scanning-cleaning-rescanning approach was used to differentiate between hard and soft fouling.

Under ideal conditions, an inexpensive camera produced digital images with the color range and contrast that allowed estimates of areal coverage and classification into general fouling groups. These two approaches are compared to an underwater laser scanner— ideal for in situ evaluations of submerged surfaces—tested in natural seawater in Key West, FL. Capabilities and limitations of each approach will influence its use as an analytical tool and its value in guiding management decisions.

Keywords: 3-D Imaging, Biovolume, Surface profile

Color Effects On Biofouling Growth

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ABSTRACT

Biofouling is the process whereby microorganisms, plants, algae or animals adhere to and accumulate on wet surfaces (Strietman & Leemans, 2019), or as defined by IMO, "biofouling is the accumulation of aquatic organisms such as micro-organisms , plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling includes microfouling and macrofouling" (IMO, 2011) .

Vessel biofouling is the oldest extant human-mediated maritime vector (transfer mechanism) in the world. It has operated for as long as humans have traveled by boat across coasts, seas, and oceans and its potency is a consequence of that longevity and global reach. The role of biofouling as a leading vector of marine introduced species is well established at global, continental, and regional scales (Ruiz et al., 2000; Eldredge & Carlton, 2002; Hewitt et al., 2004; Hewitt & Campbell 2010;Ruiz et al., 2011).

The set of bio-organisms that grows on submerged structures is composed of hundreds of species such as bacteria, protozoa, algae, mollusks, and hydrozoans, among others. These organisms, which often add up to more than 150 kilograms per square meter (Alonso, 2011), adhere firmly to the surface of the hull, growing rapidly and with great potential for reproduction. the most notorious and harmful effect on marine ecosystems has been the unwanted transport of species attached to the hulls of ships. This problem is even more severe in transoceanic vessels, which sail long distances, from and to very different ecosystems. Due to this transport of unwanted organisms in the hulls of ships, native 9 species of certain seas can become a plague thousands of kilometers from their habitat of origin when they are detached either for natural reasons or for cleanliness. An example of the gravity of invasive species is the case of zebra mussels (Dreissena polymorpha) in the Great Lakes of North America. The zebra mussel is native to the seas of northern Europe; however, and as a result of its transport on merchant ships to America, it became a serious plague that is destroying much of the biodiversity in lakes and rivers (McAvoy, 2013).

As a result of species introductions in marine systems throughout the world, maritime vector management has emerged as a priority for global environmental policy in the last two decades. The role of biofouling as a leading vector of marine introduced species is well established at global, continental, and regional scales. In recent months and years, the vessel biofouling vector has become a focus of management with policies and guidelines developed at the International Maritime Organization (IMO) as well as at national and regional levels. (Evaluating ship biofouling and emerging management tools for reducing biofouling-mediated species incursions)

More recently, the vessel biofouling vector has come under greater scrutiny.The International Maritime Organization (IMO) developed voluntary guidelines (best practices) to promote biofouling management across the global fleet (IMO, 2011)

Biofouling and Its Effects on Ships' Performance

The movement of ships and other floating structures provides pathways for the introduction of Invasive Aquatic Species (AIS)to new marine areas. Introduction may be intentional, such as for fisheries or aquaculture, or unintentional, through discharge of ships' ballast water and biofouling on ship hulls, submerged structures and equipment. Biofouling is a significant maritime problem because the growth of fouling organisms on the hulls of ships leads to very high economic losses every year.

On ships, biofouling can also significantly impact the fuel consumption and total GHG emissions produced. Biofouling increases surface roughness; so, the more fouling, the greater the impact on fuel consumption. The International Maritime Organization is focused on improving ship energy efficiency and adopted an initial strategy for the reduction of GHG emissions from ships under MARPOL6 Annex VI (Regulations for the Prevention of Air Pollution from Ships) in 2018. Management of biofouling to reduce fuel consumption, improve efficiency and reduce GHG emissions is recognised as a practical measure that is a 'win-win' for the environment and the shipping industry.

Figure 3 The effect of frictional resistance

Source: Ship Health Monitoring Solutions “MACEA Ltd.”

Figure 4 The effect of frictional resistance
Source: Ship Health Monitoring Solutions "MACEA Ltd"

MODERN ANTIFOULING PAINTS

In modern times, antifouling paints are formulated with cuprous oxide (or other copper compounds) and/or other biocides—special chemicals which impede growth of barnacles, algae, and marine organisms .
‘Soft", or ablative bottom paints slowly slough off in the water, releasing a copper or zinc based biocide into the water column. The movement of water increases the rate of this action. Ablative paints are widely used on the hulls of recreational vessels which typically reapplied every 1-3 years.

"Hard" bottom paints, or "nonsloughing" bottom paints, are made in several types. "Contact leaching" paints "create a porous film on the surface. Biocides are held in the pores, and released slowly."[9] Another type of hard bottom paint includes Teflon and silicone coatings which are too slippery for growth to stick. SealCoat systems, which must be professionally applied, dry with small fibers sticking out from the coating surface.

These small fibers move in the water, preventing bottom growth from adhering.

BIOFOULING ADHESIVITY ON SURFACES

Marine and coastal species have been able to establish new populations outside their native limits and potentially threaten native species or cause significant ecological and environmental damage, becoming a threat to humans and in many cases having a severe
effect on the economy. Other factors that influence this increase in the transfer of species are global warming, the higher number of ships that currently exist and the greater number of commercial sea routes as can be seen in Figure 1. Global Warming weakens specific natural barriers such as the melting of ice in polar areas while opening new trade routes where ships can travel.

Figure 1 Differences between shipping routes in old times and modern times .

Retrieved from http://www.geographypods.com/2-changing-space---the-shrinking-world.html#

The movement of invasive aquatic species has shown a dramatic increase in frequency, extent, and damage over the last 50 years, and this is mainly due to their transfer via the shipping industry.

According to a study in which information was collected from more than 350 databases, samples and other sources, the results showed that of the 329 marine invasive species considered in the study, shipping was the most common introduction route with 69% of the total, while aquaculture represents 41%, channels 17%, aquarium trade 6%, and finally live seafood trade)%2((Molnar, Gamboa, Revenga, & Spalding, 2008). In the same study, 11 of the 205 species introduced via shipping, 39% were introduced by hull-fouling, 31% via ballast water, and the remainder by both (Jackson, 2008).

All marine biofoulers use sticky materials with permanent or temporary adhesive capabilities, but adhesion mechanisms and detailed molecular characteristics of the glues are largely unknown.

The two exceptions to this are the glues produced by adult marine invertebrates. The protein glues of the blue mussel have been extensively characterised and are members of a dihydroxyphenylalanine (DOPA)-rich family of polypeptides, which cross-link through an oxidative phenolic tanning type process. The second example, the cement produced by mature adult barnacles, appears to consist of a complex of hydrophobic proteins that are unrelated to blue mussel proteins, crosslinked via cysteine residues. Mussels produce threads to attach themselves to solid surfaces in the inter-tidal zone. These ‘byssus’ threads, secreted by the mussel foot are effectively biocomposites of collagen fibres embedded in a proteinaceous matrix. Mefp1 is the best characterised of the polyphenolic foot adhesive proteins.(Marine biofouling: a sticky problem, Maureen E Callow and James A Callow ,University of Birmingham, UK)

Light characteristics (spectra, intensity and time) have a profound influence on microalgal growth, metabolism, and biochemical constituent, however with artificial, cheap, and long lasting LED lights on microalgae are deficient and latest. Hence, in this proposal wefocused on impact of various color filtered LED lights on biomass, pigments and lipid production in microalgae. (Oscillatoria sp. (SRA)

The growth and propagation of microalgae are affected by several environmental factors, such as temperature, salinity, light, and pH. Light, the main source of energy for algae growth, is one important key factor in regulating its growth and development (Takada, J.; Growth and Photosynthesis of Ulva prolifera under Different Light Quality from Light Emitting Diodes. Aquac. Sci. 2011, 59, 101–107)

Adhesion of marine fouling organisms on artificial surfaces such as ship hulls causes many problems, including extra energy consumption, high maintenance costs, and increased corrosion. Therefore, marine antifouling is an important issue. In this review ,
physical and biochemical developments in the field of marine biofouling, which involves biofilm formation and macro-organism settlement .The major antifouling technologies based on traditional chemical methods, biological methods, and physical methods are presented.

Marine fouling is an accumulation of micro organisms, plants, algae, and/or animals on wetted surfaces. These organisms form a fouling community, which can be divided into :
•Micro-fouling: Biofilm formation bacterial adhesion. Appears as layers of bacterial slimes .
•Macro-fouling: Attachment of larger organisms (barnacles, mussels, seaweed, etc.).
Micro-fouling species forms of biofilm that adheres to the surface, then Macrofouling refers to the attachment of organisms such as barnacles, soft corals, and seaweed to produce a fouling community.

Temperature plays a significant role in the settlement of microorganisms, as temperature plays a role in the growth rate and breeding periods of marine animals. Geographical location also plays a role; so does species diversity and the amount of solar radiation, which directly affects photosynthesis. Pollution can reduce solar radiation, thereby reducing the number of plants, nutrients, and species in the environment. Or, pollution can increase the number of non-native species in marine hard-substrate communities, speeding up biofouling .

There are four key phases to biofouling that are determined by these factors. First, the structure or surface gets submerged. In the process, organic carbon is absorbed onto the wetted, submerged surface .
Next, the primary colonizers arrive: diatoms and bacteria that settle onto this organic carbon-enriched surface. This increases the roughness of the surface facilitating the adsorption of larger organisms and particles .
These primary colonizers are followed by protozoa and macroalgae spore: secondary colonizers who bring on the process of microfouling formation.
The increase of the roughness of the surface facilitating the adsorption of larger organisms and particles. This step increases the roughness of the surface, creating the perfect condition for macrofouling: when tertiary colonizers and particles adhere to the surface.
This entire process can take as little as three weeks. It seems innocuous — just some organisms making their home on a new structure — but it can actually cause big problems for emerging marine technologies.

This also called Biofilm
Step 3 [1 week]
After approximately a week spores of macro algae and protozoa constitute the secondary colonizers in the pores of ‘microfouling formation ’

HYPOTHESIS
The primary focus of this research is on the impacts of anti-fouling systems, issues such as ballast water and bio fouling will be analyzed and the effects of hull paint color on the biofouling species; which are directly related to bio fouling and antifouling pollution.
Marine fouling and its prevention-prepared for Bureau of Ships, Navy Dept. Woods Hole Oceanographic Institution, United States. Navy Dept. Bureau of Ships, "Marine fouling and its prevention ; prepared for Bureau of Ships, Navy Dept.", 1952, DOI:10.1575/1912/191, https://hdl.handle.net/1912/191)
the light and illumination factor led for thinking about what if the color has a great contribution on the biofouling growth, according to studies most the biofouling species tends to accumulate on darker surfaces.
The micro algae spores is the first component for the formation of biofilm that will later help other colonizer to be attached to it to create a fouling surface, so what if we could mitigate the colonizing of the algae ?

Light is one of the most important environmental factors affecting the growth and repro
Duction of algae. In this study, the effect of various LED colors on the productivity, chlorophyll (Chl-a Chl-b, and total Chl), protein, and carbohydrate content of Isochrysis zhanjiangensis in indoor culture was investigated. Microalgae monocultures were cultivated under five different colors (red, green,blue, yellow, and white) for twenty-one days. The microalgae cultured under red light exhibited),higher specific growth rate (0.4431) and under white light a higher productivity, The poorest performance was observed under yellow and green lights Interestingly, green light exhibited the highest levels of chlorophylls (Chl-a, 1.473) Interestingly, green light exhibited the highest levels of chlorophylls (Chl-a, 1.473 mg) . The highest protein content was observed under the white light (6.5846 mg L) of the selection of light at the appropriate color (wavelength) to increase the content of organic compounds desired to be obtained indoors with the potential for commercially produced cultures. (Effect of Different Colored LED Lighting on the Growth and Pigment Content of Isochrysis zhanjiangensis under Laboratory Conditions, Bu Lv& others)

WHY STUDYING THE COLOR EFFECTS ?
The effect of substratum color on the formation of micro- and macro fouling communities was investigated. Acrylic tiles, painted either black or white were covered with transparent sheets in order to ensure similar surface properties. All substrata were exposed to biofouling at 1 m depth for 40 d in the Marina Bandar al Rowdha (Muscat, Sea of Oman). Studies were conducted in 2010 over a time course of 5, 10 and 20 d, and in 2012 samples were collected at 7, 14 and 21 d. The densities of bacteria on the black and white substrata were similar with the exception of day 10, when the black substrata had a higher abundance than white ones. Pyrosequencing via 454 of 16S rRNA genes of bacteria from white and black substrata revealed that Alphaproteobacteria and Firmicutes were the dominant groups. SIMPER analysis demonstrated that bacterial phylotypes (uncultured Gammaproteobacteria, Actibacter, Gaetbulicola, Thalassobius and Silicibacter) and the diatoms (Navicula directa,Navicula sp. and Nitzschia sp.) contributed to the dissimilarities between communities developed on white and black substrata. At day 20, the highest amount of chlorophyll a was recorded in biofilms developed on black substrata. SIMPER analysis showed that Folliculina sp., Ulva sp. and Balanus amphitrite were the major macro fouling species that contributed to the dissimilarities between the communities formed on white and black substrata. Higher densities of these species were observed on black tiles. The results emphasise the effect of substratum color on the formation of micro and macro fouling communities; substratum color should to be taken into account in future studies. (Sergey Dobretsov et al , Pages 617-627 | Received 11 Sep 2012, Accepted 02 Mar 2013, Published online: 22 May 2013)
Data from short-term biofouling assays are frequently used to evaluate the performance of antifouling (AF) coatings. There are a large number of factors, however, that may influence community development. One such factor is colour. The hypothesis was that differences in color may impact the short-term development of a biofouling community and therefore bias the results. An experiment was designed to investigate the effect of black and white substrata on settlement of fouling organisms in the field. Both Ulva sp. and Spirorbis sp. had significantly higher settlement on black surfaces. This result emphasises the importance of considering color and other factors when undertaking short-term testing of AF coatings. (Geoffrey Swain et all Pages 425-429 | Received 14 Aug 2006, Accepted 19 Sep 2006, Published online: 11 Jan 2007)
Each color of our visible spectrum has a specific wavelength; as wavelength decreases from red to blue light, so does the ability of light to penetrate water. Blue light penetrates best, green light is second, yellow light is third, followed by orange light and red light. Red light is quickly filtered from water as depth increases and red light effectively never reaches the deep ocean, meaning animals that live in deep water and are red are essentially invisible .
PROCEDURE :
The settlement of marine fouling organisms is influenced by several factors including salinity,pH, temperature, nutrient levels, flow rates and the intensity of solar radiation. These factors vary seasonally, spatially and with depth.
Three phase antifouling proposal :
The aim of this proposal is to reduce anti fouling effect through three phases.
Phase one :
Submerge in sea water iron plates sized 30*30 cm at 10m depth (the average draft value for the ships) painted with different colors (black red white yellow green and blue), continuous monitoring to log the growth of the fouling through one year time (to expose the experiment to affecting factors such as different seawater temperature, current salinity as a result it is assumed that one plate of certain color would show less growth of the fouling species.
Phase two:
To repeat the experiment of phase one on a single color which showed less fouling growth, but with different color contrast.

Phase Three :

Mex the paint surface of the selected color with essential oils to prevent the growth of biofouling .

Plants have evolved an arsenal of chemical defenses to limit attack from insect pests. These include airborne chemicals which help deter insects from landing, followed up with compounds produced to stop insects feeding, including toxic substances like nicotine which can kill would-be attackers.

In addition to having the right defenses to resist an attack, an effective defense response against the attacking insect requires the plant to be able to correctly identify the attacker through molecular IDs/signatures, and then to deploy the appropriate defenses against that particular pest. These sophisticated defenses ensure plants are protected against most insects. (PLANTS VS INSECT PESTS; A NEVER-ENDING BATTLE by the Gatsby Charitable Foundation.)

We have started the experiments to study the color effect on the biofouling organisms growth, it stopped during Covid 19 pandemic

Enhancing the Quality of Marine Environment

Problem

Biofouling on ships and submerged structures can cause the introduction and spread of invasives aquatic species(IAS) through organisms that attach to the structure, survive a voyage and are released in a new aquatic environment. If conditions are suitable, invasives aquatic species can thrive in the new environment. If there are no natural predators, IAS can become dominant and disrupt the biodiversity in the new habitat.

This can have a variety of impacts, including disrupt fisheries, cause significant maintenance and operational problems for coastal industry ,infrastructure, marine vessels and interfere with human amenity.

Hypothesis

The primary focus of this proposal is to add a new tool to the existing anti-fouling systems such as(Marine Growth Preventive System (MGPS) in order to reduce the impacts issues of bio fouling by utilizing the effects of vessel hull paint color on the biofouling species growth.

The settlement of marine fouling organisms is influenced by several factors including salinity, pH, temperature, nutrient levels, flow rates and the intensity of solar radiation. These factors vary seasonally, spatially and with depth.

The Core Of Our Proposal

On ships, biofouling can also significantly impact the fuel consumption and total green house gases (GHG) emissions produced. Biofouling increases surface roughness; so, the more fouling, the greater the impact on fuel consumption.

The International Maritime Organization is focused on improving ship energy efficiency and adopted an initial strategy for the reduction of GHG emissions from ships under MARPOL Annex VI (Regulations for the Prevention of Air Pollution from Ships) in 2018.

Management of biofouling to reduce fuel consumption, improve efficiency and reduce GHG emissions is recognized as a practical measure that is a 'win-win' for the environment and the shipping industry.

Procedure

Our proposal to reduce bio fouling effect consist of three phases.

Phase One :

Where phase one is to merge in sea water iron plates sized 30*30 cm at 15 m depth (the average draft value for the ships) painted with different colors (black red white yellow green and blue), to monitor and to log the growth of the biofouling through one year time (to expose the experiment to affecting factors such as different seawater temp., current salinity as a result bio fouling shall react accordingly. That one plate of certain color would show les growth of the fouling.

Phase two:

To repeat the experiment of phase one on a single color which showed less fouling growth, but with different color contrast. The experiment conducted by Kenneth Dougal McDougall aimed to study the relationship between light intensity and the settlement, growth, and seasonal fluctuations of sessile marine invertebrates.

TABLE 1 Numbers of Organisms Attaching in Chambers of a Light Box in Which the Illumination Progressively Decreased from Chamber No. 1 to No. 6. Exposed May 10 to August 29, 1941. After McDougall (29).

Chamber	Balanus eburneus	Bugula nerilina	Schizo-porella unicornis	Hydroides hexagonus	Sabellaria vulgaris	Pelecypoda	Reniera zubifera
1	173	426	11	958	64	461	11
2	154	339	4	1,016	48	216	17
3	248	541	13	892	68	260	18
4	46	570	19	1,146	64	211	23
5	219	837	30	1,436	64	248	15
6	318	696	23	2,072	144	374	20

Sessile Marine Invertebrates of Beaufort, North Carolina: A Study of Settlement, Growth, and Seasonal Fluctuations among Pile-Dwelling Organisms, Kenneth Dougal McDougall , 01 July 1943

The results of this experiment can provide valuable insights into the effects of light on biofouling, which is the accumulation of unwanted marine organisms on submerged surfaces. While the experiment did not directly study color effects, it can be inferred that different colors of light may have varying effects on biofouling growth. Some organisms may be more attracted to certain colors of light, while others may be less affected.

Phase Three :

Mex the paint surface of the selected color with essential oils to prevent the growth of biofouling .

Plants have evolved an arsenal of chemical defenses to limit attack from insect pests. These include airborne chemicals which help deter insects from landing, followed up with compounds produced to stop insects feeding, including toxic substances like nicotine which can kill would-be attackers.

Experiment

We have started the experiments to study the color effect on the biofouling organisms growth, it stopped during Covid 19 pandemic.

Eng. Nedhal Abu Zeid

Eng. Suhan Nedhal

Biofouling Detection and Classification in Tidal Stream Turbines through Soft Voting Ensemble Transfer Learning of Video Images

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ABSTRACT

This study addresses the biofouling challenges of tidal stream turbines to ensure their reliable and optimal operation. In response to this necessity, we present an effective methodology employing a soft voting ensemble transfer learning-based approach for the detection and extent classification of biofouling. The proposed framework incorporates essential components such as data augmentation, data pre-processing, including image resizing, and data segmentation, forming a comprehensive image-based approach. To overcome the constraint of limited datasets, experimental investigations were conducted, resulting in the acquisition of two datasets: one from the tidal stream turbine platform at Shanghai Maritime University (SMU) and the other from the Tidal Turbulence Test facility at Lehigh University (LU) in Pennsylvania, USA. The three prominent convolutional neural network models, namely VGG, ResNet, and MobileNet, trained on these datasets, demonstrate precise detection and classification of turbine conditions, achieving an accuracy of 0.83 for the SMU dataset and 0.90 for the LU dataset. The noted disparity in accuracy for the SMU dataset is attributed to its smaller size, highlighting the significant impact of dataset scale on classification performance. This research contributes valuable insights to the advancement of biofouling detection and classification strategies tailored for tidal stream turbine systems.

Detection and Classification of Biofouling in Tidal Stream Turbines through Soft Voting Ensemble Transfer Learning of Video Images

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ABSTRACT

This study employs a transfer learning-based soft voting ensemble of CNNs (VGG, ResNet, MobileNet) to tackle biofouling in tidal stream turbines (TSTs). Experiments at the TST platform of Shanghai Maritime University achieved 97% accuracy, enhancing detection and classification for improved turbine performance.

INTRODUCTION

Biofouling affects tidal stream turbine performance by increasing drag and causing recirculation loops and vertices, even with partial colonization [1]. It can also damage the rotor and accelerate corrosion of the protective layer on the blade. Full direct-drive turbines, with large generators and static components, are more prone to biofouling due to their low-speed operation as show in Figure 1.

Figure 1: Clear Current Company tidal stream turbine: retrieved after 5 years due to loss of performance [2].

BIOFOULING DETECTION

Detecting biofouling is challenging due to its unpredictable nature and associated uncertainties, which makes it difficult to accurately predict its effects on the monitored structure. The most effective way to reduce biofouling is through early detection, while it can still be removed using eco-friendly techniques that do not damage the paint or coating. Figure 2 illustrates the substantial impact of biofouling that can be prevented by implementing an efficient detection process.

Figure 2: Illustration of highly impacting biofouling.© Courtesy of Prof. Yusaku Kyozuka [1]

BIOFOULING DETECTION AND CLASSIFICATION FRAMEWORK

Monitoring the performance of a tidal stream turbine can provide an indirect estimate of the level of biofouling:

- A decrease in power output over time may suggest developing biofouling.
- Variations in power output can indicate the extent and severity of biofouling, mainly on turbine blades.

Figure. 3 provides a general framework on how biofouling detection and classification of TSTs can be performed.

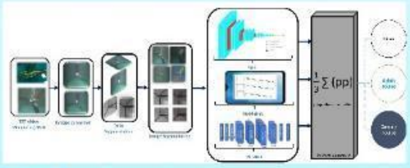

Figure 3: Tidal stream turbine biofouling detection and classification through soft voting ensemble transfer learning approach

RESULTS

Figure 4 shows the classification accuracy of clean, lightly fouled, and densely fouled occurrences is 96.66%.

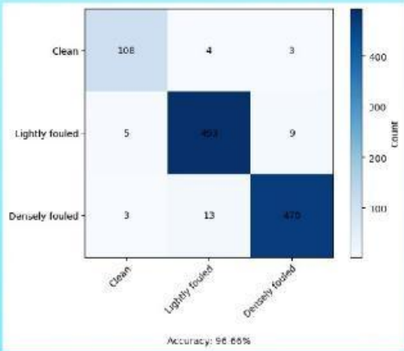

Figure 4: Confusion matrix for biofouling classification [3].

RESEARCH GAPS AND CHALLENGES

Detection and Classification Challenges

- Limited visibility and difficult access in harsh underwater environments.
- Variability in biofouling [4].
- Complex data processing and high implementation costs.
- Operating environment
  - Turbulence.
  - Presence of marine life.

Research Gaps

- Sensor usage
  - Advanced sensors can be used to address the issue of poor visibility and blurry images.
- Data processing
  - Video format can improve biofouling classification by incorporating data from previous and subsequent images.

POTENTIAL PATHWAYS

Use of the digital twin technology to improve both the maintenance and reliability of tidal stream turbines.Figure 5 illustrates a conceptual framework.

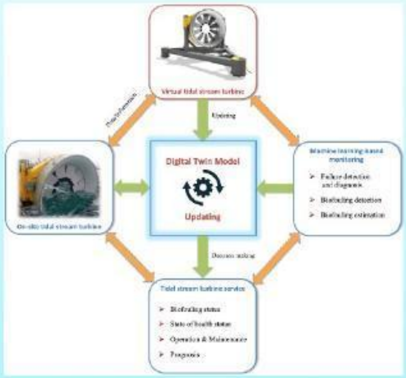

Figure 5: Digital twin conceptual framework for tidal stream turbines monitoring.

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Further Readings

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MEASUREMENTS OF THE HULL ROUGHNESS-INDUCED DRAG PENALTY OF AN OPERATIONAL SHIP

Nicholas Hutchins[1], Jelle B. Will[1], Isnain 'Aliman[1], Bagus Nugroho[1], Hendriyadi[2], Trisnadi Mulia[2], I Ketut Suastika[3], I Ketut A. P. Utama[3], Michael P. Schultz[4], Jason P. Monty[1].

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ABSTRACT

With the global upsurge in shipping over the last decades, the environmental and economic impact of ship hull roughness is more relevant than ever. However, due to a lack of effective predictive correlations linking hull-state to fuel increase, ship operators struggle to see the benefit in expensive and time-consuming dry-docking or in-water cleaning.

This work aims to address these issues by closely monitoring the skin friction drag and the hull state of an operating vessel as the hull state degrades during the intra drydocking period. The hull state is monitored using a novel diver operated in-water surface scanner, and the friction drag is monitored by making laser doppler velocimetry measurements of the flows formed over the hull of the operating vessel.

The ship, a 95 m long chemical tanker, was sand-blasted and fully re-coated in March 2022 at which point the baseline roughness level was documented using surface imprints. For the subsequent two years of this study, hull inspections and boundary layer measurements indicate that the anti-fouling coating is functioning, with little change in friction drag or hull state (as compared to baseline levels observed after recoating). However, flow measurements demonstrate that even straight from dry-dock, the ship incurs a 25% skin friction drag penalty (compared to a perfectly smooth hull) due to underlying paint roughness, weld seems and docking blocks. The most recent hull inspections indicate a depleted anti-fouling coating, and we expect to be able to report results from the bio-fouled hull during this meeting.

Keywords:
Skin, friction, drag
Turbulent boundary layer
Hull roughness
Hull monitoring

A recently cleaned and re-coated ship suffers from a surprisingly large (≈20%) hull roughness drag penalty

Measurements of the Hull Roughness-Induced Drag Penalty of an Operational Ship

Nicholas Hutchins[1], Jelle B. Will[1], Isnain 'Aliman[1], Bagus Nugroho[1], Hendriyadi[2], Trisnadi Mulia[2], I Ketut Suastika[3], I Ketut A. P. Utama[3], Michael P. Schultz[4], Jason P. Monty[1]

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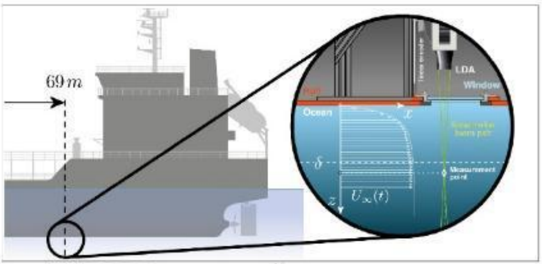
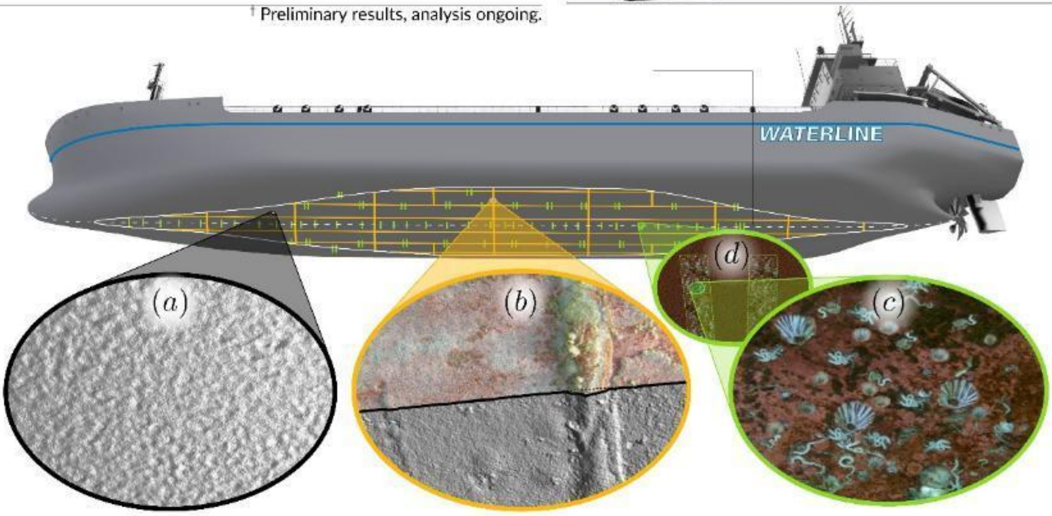
An operating chemical tanker ship has been modified to allow laser doppler anemometer (LDA) measurements in the turbulent boundary layer formed on the underside of the ship. From this we can determine the skin friction drag penalty due to the hull roughness.

- LDA measurements show an approximate 20%[†] skin friction drag penalty.
- Laboratory measurements confirm that the underlying paint roughness causes an approximate 13%[†] skin friction drag penalty.
- The discrepancy presumably arises from docking blocks, weld seams and experimental uncertainty.

[†] Preliminary results, analysis ongoing.





Paint roughness

Weld seams

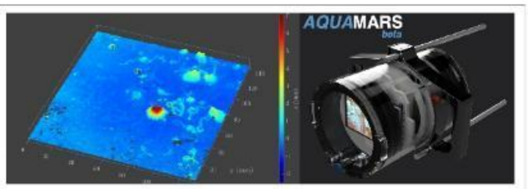
Docking blocks

Underlying paint roughness

The drag of the painted surface topography (captured from imprints during dry-dock) has been measured in laboratory experiments, confirming approximately **13% skin friction drag penalty** due to the underlying orange-peel paint roughness.

AQUAMARS

The weld-seams and docking block roughness are captured using an in-house developed diver-operated in-water hull surface scanner (see QR-code below).



Scan QR code for more details on AQUAMARS

SAMUDERA

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THE UNIVERSITY OF MELBOURNE

National Rapid Economic Assessment on Biofouling Management and Invasive Aquatic Species of Indonesia

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ABSTRACT

Biofouling refers to the accumulation of marine organisms on submerged materials in seawater. This buildup occurs quickly on various artificial structures, leading to significant economic and operational challenges, particularly in marine transportation and offshore structures. The study aimed to assess the impact of biofouling and invasive aquatic species (IAS) on Indonesia's maritime industry and its biofouling management practices. The affected marine sectors include shipping, ports and marinas, aquaculture, capture fisheries, offshore mining, recreational vessels, and aquatic tourism. According to the Guide for the Development of Rapid Economic Assessments on Biofouling Management and IAS, the estimated economic impact of biofouling and IAS was approximately 2% of 51,442 million USD and 6% of 43,127 million USD over ten years across all industrial sectors without biofouling and IAS management policies. Effective management can significantly reduce these impacts. With biofouling management policies, the cost estimation for biofouling and IAS control was 2% of 26,021 million USD and 6% of 21,791 million USD. Implementing these policies can result in a 50% reduction in expenses compared to having no relevant policies. Implementing the biofouling policy in Indonesia will yield gross benefits of 25,421 million USD at a 2% rate over ten years and 21,336 million USD at a 6% rate over the same period. The cumulative cost of implementing the biofouling policy was approximately 286.88 million USD at a 2% interest rate and approximately 276.06 million USD at a 6% interest rate. This difference emphasizes the advantages of implementing biofouling and IAS management policies in Indonesia.

Keywords: Biofouling, cost benefit analysis, invasive species, maritime industry

A Study on the Korea's Response on the AFS Convention in terms of Recent Amendments on Cybutrine

Young Hun Min

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ABSTRACT

As of 1 January 2023, the amendments to the International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001(the AFS Convention) entered into force. The amendments is to introduce controls on cybutryne as biocides in anti-fouling system into the Convention.

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted the amendments at its 76 sessions through Resolution MEPC.331(76). These amendments require member states to ban the use of cybutryne in future installations of anti-fouling system due to its toxic impacts on marine organism. In this regard, the Korean government amended the AFS Convention certificate to incorporate the cybutryne regulation into domestic legislation, focusing on the control of cybutryne in ships engaged in international voyages. Considered its toxicity, regulations for the domestic shipping should also control cybutryne installation to the domestic vessels.

Cybutryne is a booster biocide used as an additive in anti-fouling paints for protection against 'soft fouling'(e.d. due to algae). It inhibits the photosynthesis of marine algae, preventing fouling to the ship's hull. However, scientific research shows that cybutryne has the potential to have adverse effects on non-target organisms, e.g. corals and other non-target organisms on which other species feed. It also persists in the environment (sea- and freshwater sediments) once released from painted surfaces. Therefore, in order to address the harmful effects of cybutryne comprehensively, controling its use should also apply to domestic vessels.

From this point of view, the study explores the legislation of other countries that have banned cybutryne application to the domestic vessels by designating it as a toxic substance. Also it draws implications on the basis of comparison between policies of other countries and Korea with respect to regulating cybutryne in relation to domestic shipping.

A Study on Korea's Response to the AFS Convention in terms of Recent Amendment on Cybutryne

Young Hun Min (Korea Maritime Institute) : yhmin@kmi.re.kr

Introduction

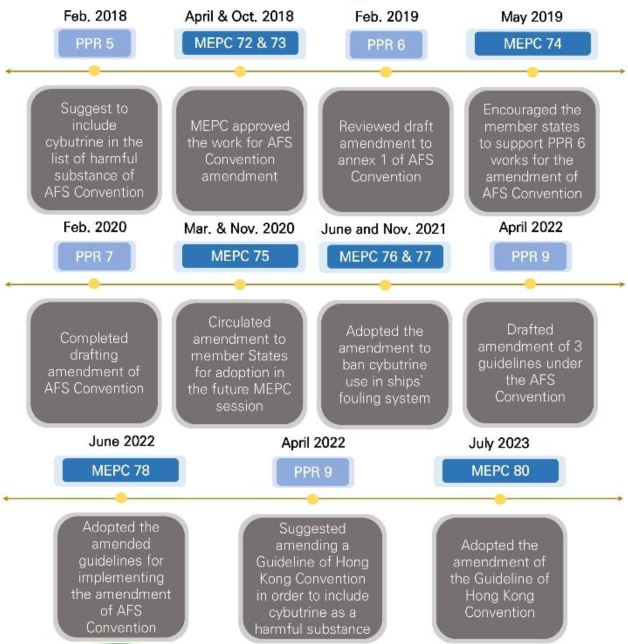
- As of 1 January 2023, the amendments to the International Convention on the Control of Harmful Anti-Fouling System on Ships, 2001 (AFS Convention), entered into force. These amendments introduce controls on cybutryne as a biocide in anti-fouling systems under the Convention.
- The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted these amendments at its 76th session through Resolution MEPC.331(76).
- They require member states to ban the use of cybutryne in future installations of anti-fouling systems due to its toxic impacts on marine organism. In response, the Korean government amended the AFS Convention certificate to incorporate cybutryne regulation into domestic legislation, focusing on controlling cybutryne use on ships engaged in international voyages.
- Given its toxicity, regulations on domestic shipping should also address cybutryne installations on domestic vessels.

Cybutrine as a Biocide

The Impacts of Cybutrine Use in Ships' anti-fouling system

- Cybutrine is a booster biocide used as an additive in anti-fouling paints to protect against 'soft fouling'(e.g. algae growth on ship's hull).
- It inhibits photosynthesis in marine algae, thereby preventing fouling on ships' hulls.
- However, scientific research indicates that cybutryne may adversely affect non-target organisms, such as corals and other species that form part of the food chain.
- Consequently, it inhibits nitrate reductase activity, thereby altering nitrogen metabolism in algae and disrupting the balance of nitrogen metabolism, which may impact the nitrogen metabolism, which may impact the nitrogen cycle within the ecosytem.(Mona Kaamaoush, Nagwa El-Agawany, Mohamed Y. Omar(2023), Environmental toxicological evaluation (in vitro) of copper, zinc and cybutryne on the growth and amino acids content of the marine alga Dunaliella salina, Egyptian Journal of Aquatic Research, 49(1), pp.23-32)
- Additionally, cybutryne persists in the environment (in both sea and freshwater sediments) once released from painted surfaces.
- In other words, Cybutryne can be highly toxic to primary producers such as marine algae and is harmful to mud snails. Additionally, it inhibits the photosynthetic activity of seaweed, ultimately hindering its growth.

Discussion in IMO on Cybutrine control



Amendment to the AFS Convention

Annex 1 of AFS Convention

Anti-fouling system	Control measures	Application	Effective date
Cybutryne CAS No. 28159-98-0	Ships shall not apply or re-apply anti-fouling systems containing this substance	All ships	1 January 2023
Cybutryne CAS No. 28159-98-0	Ships bearing an anti-fouling system that contains this substance in the external coating layer of their hulls or external parts or surfaces on 1 January 2023 shall either: (1) remove the anti-fouling system; or (2) apply a coating that forms a barrier to this substance leaching from the underlying non-compliant anti-fouling system	All ships except: (1) fixed and floating platforms, FSUs, and FPSOs that have been constructed prior to 1 January 2023 and that have not been in dry-dock on or after 1 January 2023; (2) ships not engaged in international voyages; and (3) ships of less than 400 gross tonnage engaged in international voyages, if accepted by the coastal State(s)	At the next scheduled renewal of the anti-fouling system after 1 January 2023, but no later than 60 months following the last application to the ship of an anti-fouling system containing cybutryne

Guidelines

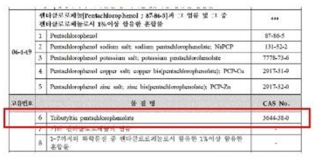
- **(Article 11(1))** 2022 Guidelines for survey and certification of anti-fouling systems on ships (Resolution MEPC 358(78))
- **(Article 11(2))** 2022 Guidelines for brief sampling of anti-fouling systems on ships (Resolution MEPC 356(78))
- **(Article 11(1))** 2022 Guidelines for inspection of anti-fouling systems on ships (Resolution MEPC 357(78))
- **(Annex 4 Regulation 1)** 2022 Guidelines for inspection of anti-fouling systems on ships (Resolution MEPC 357(78))
- **(Hong Kong Convention)** 2023 Guidelines for the development of the Inventory of Hazardous Materials(Resolution MEPC 379(80))

Discussion

Possible amendment to *Marine Environment Management Act*

- **(Article 2(Definition))** The term "harmful anti-fouling paint" means a paint used to restrict or prevent the attachment of organisms to ships, marine facilities, etc. (hereinafter referred to as "anti-fouling paints"), which are prescribed by Ordinance of the Ministry of Oceans and Fisheries as containing ingredients destroying organisms, such as organotin.
- **(Ordinance of the MOF s 5(anti-fouling paints))**
  1. Paints including chemicals designated and publicly announced by the Minister of Environment as restricted substances for antifouling purposes pursuant to Article 27 of the *Act on Registration and Evaluation of Chemical Substances*
  2. Paints containing chemicals designated and publicly announced by the Minister of Environment as prohibited substances for all purposes pursuant to Article 27 of the *Act on Registration and Evaluation of Chemical Substances*, etc
  3. paint containing diuron
  4. paints determined by the IMO as hazardous antifouling paints

(Prohibited substances)



(Restricted substances)

Conclusion

- Based on Article 5 of the Ordinance of the MOF, cybutryne could not be listed as a prohibited or restricted substance under *the Act on Registration and Evaluation of Chemical Substances* to implement the recent amendments to the AFS Convention.
- Given that organotin, as prescribed in Annex 1 of the AFS Convention, is explicitly stipulated in the *Act on Registration and Evaluation of Chemical Substances*, cybutryne should also be listed to ensure legal certainty and support the implementation of international control measures domestically.
- Additional procedures to incorporate cybutryne into municipal law as a harmful substance as outlined in *the Enforcement Decree of the Act on Registration and Evaluation of Chemical Substances* require an assessment of social and economic impact, consultation with stakeholders, and other necessary steps.

3rd Glofouling R&D Forum

KMI 한국해양수산개발원 KOREA MARITIME INSTITUTE

This research was supported by Korea Institute of Marine Science & Technology Promotion(KIMST) funded by the Ministry of Oceans and Fisheries (20210500)

Biofouling and Corrosion Challenges in Marine Renewable Energy Systems: Insights from the Madura Strait, Indonesia

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ABSTRACT

This study aims to address the knowledge gaps in biofouling and corrosion for marine renewable energy (MRE) systems in Indonesia, focussing on biofouling monitoring and mitigation.

Panel settlement experiments at Suramadu bridge, Madura Strait, Indonesia revealed dynamic biofouling communities dominated by the barnacle Amphibalanus reticulatus, A. amphitrite, and Hydroides sp., significantly influenced by submersion duration, material, and depth.

Key impacts on MRE infrastructures include movement obstruction, surface abrasion, corrosion initiation, and reduced power production. The corrosion behaviour of low-carbon steel showed uniform corrosion with localised damage, influenced by submersion duration, with corrosion rates ranging from 0.827 to 3.255 mm/year. A moderate negative correlation was found between biofouling assemblage and corrosion rate, warranting further investigation beyond six months. Environmental data indicated biofouling abundance was lowest at minimum temperatures, with the Amphibalanus genus thriving under varying salinity levels. Antifouling paints like AF Max Guard were effective against biofouling compared to anticorrosion paints, suggesting that combining material selection and coating technologies could enhance mitigation strategies in Indonesia's emerging MRE sector.

Keywords: Biofouling, Marine Renewable Energy (MRE), Madura Strait, Corrosion, Amphibalanus, Antifouling paint

Temperature-Driven Growth Dynamics and Cohort Patterns of Ciona robusta in Coastal Waters

Seongjun Bae, Philjae Kim, Chang-Ho Yi,

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ABSTRACT

Managing marine ecosystems requires a thorough understanding of how invasive species affect them. This study examined the cohort dynamics and environmental dependencies of Ciona robusta, a widespread invasive ascidian, in Mokpo, South Korea. Extensive field observations from June to October 2022 unveiled five distinct cohorts, challenging previous assumptions about lifespan and cohort patterns of C. robusta. Separation index values consistently exceeded 2, indicating clear cohort differentiation throughout the study period. Notably, cohort lifespans ranged from 4 to 10 weeks, substantially shorter than the previously reported maximum of 2 years. This discrepancy highlights the significant influence of local climatic conditions on life history parameters. Growth rates demonstrated a strong positive correlation with environmental factors, particularly temperature. This finding underscores C. robusta's sensitivity to thermal variations, despite its known salinity tolerance. Our results suggest that rising water temperatures due to climate change could potentially accelerate growth and reproductive cycles of C. robusta, thereby enhancing its invasive potential. This study contributes valuable insights into the dynamics of invasive marine species, especially in the context of changing environmental conditions. Our findings can inform the development of targeted management strategies to mitigate the ecological impacts of C. robusta in the face of climate change. Future research should focus on long-term monitoring and predictive modeling to better understand and manage the spread of this invasive species under various climate scenarios.
Keywords : ascidian, invasive species, cohort dynamics, marine biofouling

Temperature-Driven Growth Dynamics and Cohort Patterns of *Ciona robusta* in Coastal Waters

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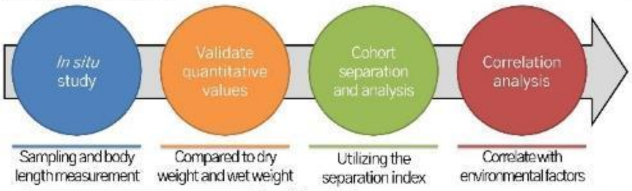
Abstract

Managing marine ecosystems requires understanding impact of marine biofouling organism. This study examined cohort dynamics and environmental dependencies of the biofouling ascidian *Ciona robusta* in Mokpo, South Korea. Field observations from June to October 2022 revealed five distinct cohorts, challenging previous assumptions about lifespan and cohort patterns of *C. robusta*. Separation index values consistently exceeded 2, indicating clear cohort differentiation. Cohort lifespans ranged from 4 to 10 weeks, substantially shorter than the previously reported maximum of 2 years, highlighting local climatic influences on life history parameters. Growth rates showed strong positive correlation with environmental factors, particularly temperature, underscoring thermal sensitivity of *C. robusta* despite known salinity tolerance. Rising water temperatures due to climate change could accelerate growth and reproductive cycles, intensifying the biofouling impact of *C. robusta*. This study provides insights into marine biofouling dynamics under changing environmental conditions, informing targeted antifouling strategies. Future research should focus on long-term monitoring to better understand the fouling behavior of *C. robusta* to improve our ability to develop effective biofouling prevention measures under different climate scenarios.

Materials and methods



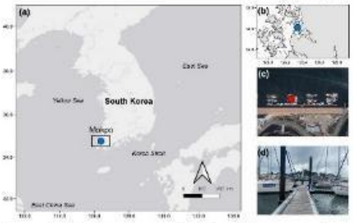


Figure 1. Map showing the location of the survey sites (blue dot) in South Korea (a). Zoomed-in study site (b). Satellite imagery indicating points (red dot) where artificial substrates were installed (c) and foreground photo (b).

- Formula
  - Separation index

$$SI = \Delta L_k / \Delta \delta_k$$

  - Growth rate (Odum, 1971)

$$r = (\ln N_{ti+1} - \ln N_{ti})/(t_{i+1} - t_i)$$

- Statistical analysis
  - Separation index (SI)
  - Two-way analysis of variance (**ANOVA**)
  - Student's **t-test**

Results

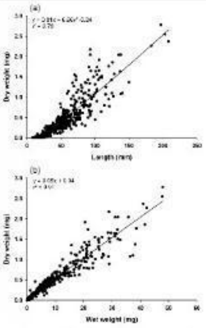


Figure 2. Correlation analysis between body length and dry weight (a), and between wet weight and dry weight (b).

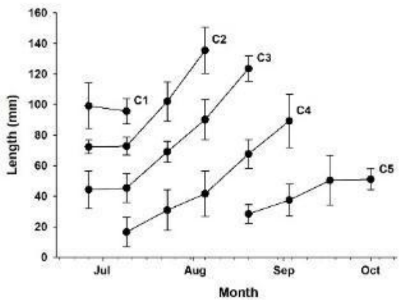


Figure 3. Time series of mean body length (with standard deviation) for each cohort (1-5) observed over the study period.

- Five distinct *Ciona robusta* cohorts identified in subtropical Mokpo, South Korea, revealing dynamic population structure (Figures 3 and 4)
- Cohort lifespan shorter than previously assumed: 4-10 weeks, indicating rapid turnover (Figure 3)
- Temperature: critical factor influencing growth rates, significant correlations observed (Table 1)
- Weak negative correlation between salinity and *C. robusta* (r^2 = 0.18), not statistically significant (Table 1)
- Findings highlight *C. robusta*'s adaptability to subtropical climates, emphasizing its potential as a significant marine biofouling organism

Table 1. Analysis of variance (ANOVA) results for the effect of water temperature and salinity on growth rate for each cohort. Bold indicates significant values (p < 0.05).

Source of variation	df	F	p
Water temperature	1	13.269	**0.002**
Salinity	1	2.616	0.125
Water temperature × salinity	1	0.049	0.828
Residuals	16		

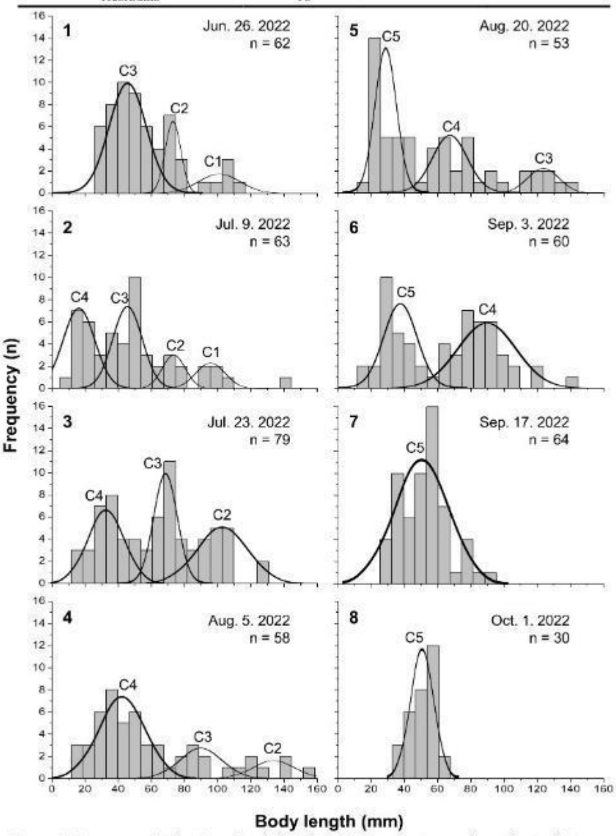


Figure 4. Frequency distribution of body length in *Ciona robusta* samples collected between June 26, 2022, and October 1, 2022, numbered by 2-week interval (1-8). Individual cohorts were defined as the normally distributed components of the sample distribution.

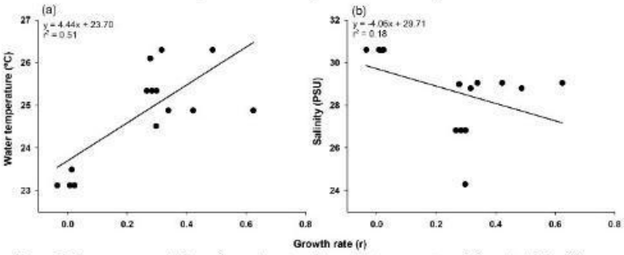


Figure 5. Pearson correlation of growth rate with water temperature (a) and salinity (b), where the black line represents the regression line.

Discussion and conclusion

- This study underscores the importance of in situ observations for understanding the complex interactions between environmental factors and the biofouling dynamics of invasive species such as *Ciona robusta*.
- The results challenge existing assumptions about the longevity and fouling community stability of *C. robusta* in subtropical climates, emphasizing the need for region-specific antifouling strategies.
- Finally, our research highlights the critical role of temperature and, to a lesser extent, salinity in shaping the colonization and growth patterns of *C. robusta*, providing a basis for future studies and mitigation efforts in marine ecosystems affected by biofouling organisms.

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This work was supported by grant from the National Marine Biodiversity Institute of Korea (2024M00300).

HullWiper

HULL CLEANING CASE STUDY
: for Fuel Savings in Korea

Source : HullWiper Co.

HullWiper ROV : Made in Norway

- Hull Cleaning Case Study : Korea Institute of Maritime and Fisheries Training Vessel
- No Fuel Savings with One-Side Cleaning :
  39% Savings with Both Sides Cleaned on Heavy-fouled vessel during COVID-19 period

HullWiper Korea Ltd.

For Details **Email.** sales@hullwiperkorea.com

Add. Korea Maritime & Ocean Univ. #619, Industry-Academic Hall 727,
Taejong-ro, Yeongdo-gu, Busan, Korea (Postal Code: 49112)

10~ 39%

Fuel Savings after ROV's Hull Cleaning

Fuel-Saving Case Study on Korea Institute of Maritime and Fisheries Technology's Training Vessel

	Voyage (Hr)	Fuel Consum-ption (M^3)	SFOC (Ltr/h)	Weather Conditions				
				Wind		Weather	Sea	
				dir.	state		dir.	state
Before Hull Cleaning	3.6	1.6	444.44	NW	3.5	BC	SW	3.5
Only One Side Cleaning	6.2	2.6	419.35	NE	4	C	NE	4
Both Side Cleaning	6.3	1.7	269.84 (39% Fuel Savings)	NE	4	C	NE	3

" Special thanks to Prof. D. W. Shin of the Korea Institute of Maritime and Fisheries Technology for analyzing main engine fuel consumption before and after hull cleaning by HullWiper ROVs "

PROJECT BACKGROUND

- MV. Hanbando (it means the Korean Peninsula) is the latest training ship built by Hanjin Heavy Industries & Construction in November 2017, with a total tonnage of 5,255 tons and L.O.A. of 103 meters, beam of 16 meters, and on-board capacity of 162 passengers
- (Biofouling issue) Training ships are usually on 80-90 voyage days per year, and the rest of period are stand-by at the port. In year 2020, training ship was voyaged only 44 days under the covid-19 pandemic situation and the biofouling contamination of the hull is inclined to accelerate once it started.


Source : Internet, Hyundai Haeyang

METHODOLOGY

A. The First Cleaning Attempt

- Date and Place : March 29, 2021 at Uam Pier 7, Busan Port, Korea
- Obstacles : Due to lack of space between the port side and pier in addition to the tight departing schedule, ROV cleaning performed only for starboard side of the vessel

B. The 2nd Cleaning Attempt

- Date and Place : April 15, 2021 at anchoring site of Jinhae bay
- Note : HullWiper Korea Ltd. provided the ROV cleaning for the port side of the vessel during anchoring at Jinhae bay.

C. Fuel Savings Monitoring

- For the training purpose of anchoring practice under the COVID-19 situation, the training vessel (vessel name : Hanbando) was operated without entering into the port and maneuvering full (avg. 138.0 RPM) for the efficiency of the oil consumption rate and the type of fuel, M.G.O. was used.
- During the anchoring practice (abt. 30min), it was not included in the SFOC as the M/E operation time was very ignorable, so calculated the In/Out-bound average based on S/by-Eng to F.W.Eng.

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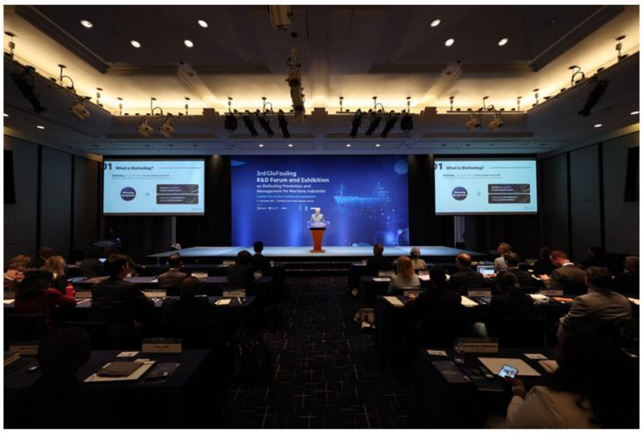
2. CleanSubsea
3. Fleet Robotics
4. HEMPEL
5. i-tech
6. KRISO
7. Nippon Paint Holdings Co., Ltd.
8. SLM Global
9. TAS Global

PHOTOS

OPENING SESSION

OPENING SESSION



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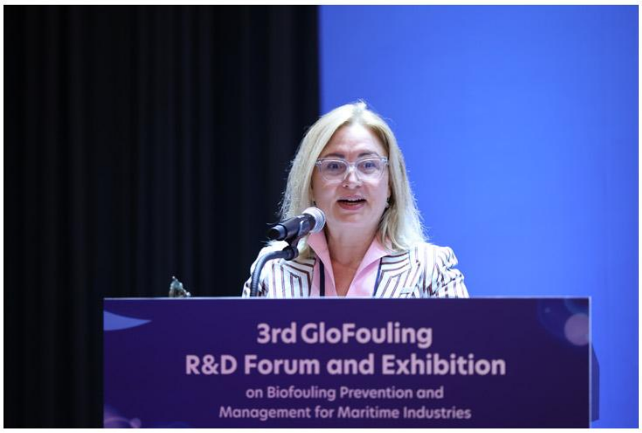
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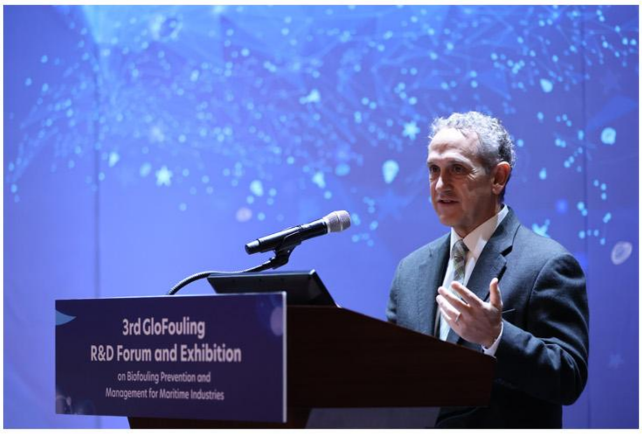
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EXHIBITION


NIPPON PAINT MARINE
FASTAR
fleet


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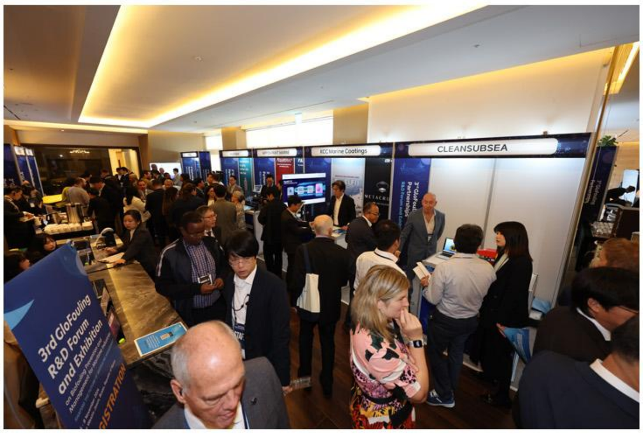
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KRISO
activities on the control and management of
performance analysis for biofouling
deep learning, autonomous niche area cleaning
robotic arm


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GROUP PHOTOS

All photos available at: GloFouling Partnerships | Flickr

More information?

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