

International Conference on
Biofouling and Ballast Water Management

February 05 to 07, 2008

Goa, INDIA



Organized by
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Acknowledgements

Many organisms with a sessile or sedentary mode of life have the dual distinction of being important in hard substratum ecology and a biofouling problem in the marine environment. Their colonization on man-made structures aids in their dispersion into alien environments often with devastating consequences; ship hulls' are a major vector in such dispersion. Likewise introduction of harmful aquatic organisms to new environments via ballast water in ships has been identified as one of the four greatest threats to the health of the world oceans. Yet, rarely do specialists on the topic of biofouling and ballast water transport participate in the same fora. The International Conference on Biofouling and Ballast Water Management aims to address these urgent issues synergistically with the goal of recognizing common problems and the development of new solutions. This conference organized in association with Directorate General of Shipping and Global Ballast Water Management Programme became a reality because of the overwhelming sponsorship and support from the maritime industry.

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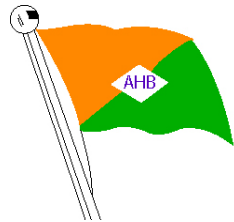


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- **Vadinar Oil Terminal** provides storage and distribution services in India. It owns port and terminal facilities to handle receipt, storage and dispatch of crude oil and petroleum products at Vadinar in Jamnagar, Gujarat, which is an all-weather, deep-draft port. This business serves major oil refineries and independent cargo traders in the region. The terminal has crude receiving capacity of 32 MTPA and product dispatch capacity of 14 MTPA.
- **Essar Logistics** integrates and provides efficient logistics services to Group companies and their customers. It also undertakes stevedoring and lighterage operations. The company owns material handling, lighterage and mobile equipment for efficient Jetty operations and a fleet of dedicated trailers and tankers to cater to the movement of steel and petroleum products.
- **Essar Bulk Terminals** is building a shipping channel at Hazira to enable the port to berth larger vessels. This will enhance the cargo handling capacity at the port. It will also seek opportunities to construct berths and jetties in other ports in India and overseas for captive and commercial use.
- **Essar Oilfields Services** offers onshore and offshore contract drilling, and offshore construction services. It has invested USD 400 million in purchasing drilling equipment and owns 13 onshore rigs and a semi-submersible rig.

Essar Global Limited (EGL) is a diversified business corporation with a balanced portfolio of assets straddling the manufacturing and services sectors: Steel, Energy, Power, Communications, Shipping & Logistics, and Construction. EGL, through its six sectoral holding companies, has an asset base of over USD 10 billion (INR 40,000 crores) and employs 30,000 people worldwide.

*Invited Talks
and
Oral Presentations*

Introductory Talk

Ship mediated marine bioinvasion: Need for a comprehensive global action plan

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Introduction of alien organism into an ecosystem and its successful establishment is referred to as bioinvasion. In its native environment the population of the organism is controlled by ecosystem interactions, however, the absence of such a control mechanism can trigger a population explosion. Hence in an alien environment introduced organisms can turn out to be a threat, bringing about untold, often undesirable consequences in the ecosystem. Bioinvasions can be natural, intentional or unintentional, and at times the impact not easily delineated due to multi-dimensional effects. A review of invertebrate invasions across the world indicates inter-linkages between responsible vectors. In this presentation an effort is made to illustrate the geographical spread of invasive invertebrate organisms from different bioregions and the possible causes for their success. Examining the bioinvasion potential of different organisms needs consideration of reproductive pathways, development and habitat requirements. A synthesis of this information for different taxa indicates that in those cases where larval duration is long and food and environmental requirements are not in a narrow band, the possibility of larval dispersal through ships ballast is a distinct possibility. Survival of organisms inside ballast tanks is dependent on several factors. Conditions in ballast tanks could be inhospitable to some, when compared to those existing in the wild. In the case of organisms attached to the hull of the ship or sea chests, potential inoculation of high numbers of larvae to the environment increases the strength of the fouling vector in the bioinvasion scenario. In view of this while addressing the marine bioinvasion threat through shipping, equal attention to hull fouling and ballast mediations is required.

Keywords: Marine bioinvasion, Ballast water management, Biofouling, Shipping, Invertebrate larval ecology

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Recruitment of larvae of *Lyrodus pedicellatus* (Quatrefages) (Teredinidae, Bivalvia, Mollusca) - influence of primary film

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Recognition of wooden substratum is the critical event in the life history of teredinid larvae for easy settlement and growth. All materials including wood introduced in marine environment develop a primary film consisting of organic molecules, bacteria, diatoms, algae, fungi and organic/inorganic detritus. The role of this primary film in aiding larvae to recognize a suitable substratum was well studied in many fouling organisms whereas in the case of wood borers, especially teredinids, this aspect did not receive necessary attention. Therefore, the significance of primary film in facilitating the recruitment of larvae of a teredinid wood borer, *Lyrodus pedicellatus* (Quatrefages) was studied and the results are presented in this paper.

Keywords: *Lyrodus pedicellatus*, Biofilms, Bacteria

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Industrial Electron Accelerators for Ballast Water Management

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Industrial electron accelerators which produce beams in the energy range of 100 keV to 10 MeV with average power from 1 kW to 500 kW are finding important radiation processing applications in the fields of a) plastic modifications, b) food preservation, c) medical product sterilizations and d) water and air pollution control. The main advantage of electron beam over gamma rays is the availability of very high power, energy and nuclear radiation free processing. Electron accelerators can handle large throughputs as compared to gamma ray sources. High power electron accelerators are being employed for pollution control in the exhaust of thermal power stations (DeSOx/ Denox) as well as for treatment of sludge for safe disposal. It has been found that a dose of 0.2 to 1 kGy is sufficient for treatment of ballast water. Therefore, it is suggested that electron accelerators can be installed at ports for treating ballast water from the ships. BARC had long back realized the enormous potential of these electron beams for non-thermal applications and chalked out an elaborate program to develop these accelerators. Depending on the product and the type of radiation processing, the requirements of energy and power vary vastly. A single accelerator or one type of accelerator cannot meet such diverse requirements. To cover most of the areas of applications, the following three accelerators have been under development at BARC namely: i) 500 keV 10 kW Cock Croft Walton type multiplier DC accelerator (operational), ii) 3 MeV, 30 kW parallel coupled self capacitance type multiplier DC accelerator (under commissioning) and iii) 10 MeV, 10 kW RF Electron Linac (operational). These accelerators have been indigenously developed in India with an objective to demonstrate radiation processing applications in industry. Some of the design features and operational experience of the three accelerators will be discussed in the paper. Experiments to study radiation effects on ballast water can be conducted in collaboration with the interested laboratories.

Keywords: Industrial electron accelerators, Radiation processing applications, High power electron accelerators

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Invited Talk

Biofouling research: Lessons learned and potentials for the future

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Starting in the 1950's the US Office of Naval Research, together with many other organizations, supported basic research on the biology and chemistry of marine fouling organisms. As a result of those many years of effort, we now have a much greater appreciation of the complexity of biofouling and the many processes involved when organisms attach to a solid surface in the sea. There are literally hundreds of species involved, ranging from bacteria, fungi and algae to the young forms of macrofoulers such as barnacles and oysters.

Originally, the solution to the biofouling problem, that is, the prevention of biofouling, was by the use of toxic materials, especially toxins incorporating heavy metals such as copper and, more recently, organotins. In other words, killing everything was seen as the desirable approach, until it became clear that due to the persistence of these toxic heavy metals, there are undesirable environmental side effects. This necessitated the banning of the worst offending toxins. Such bans will undoubtedly become more widespread in the future.

Efforts are underway to find truly effective antifouling approaches that are environmentally benign. These include the search for naturally occurring repellents, toxins or other anti-foulants that break down and do not persist in the environment the way heavy metals do. Perhaps the most promising approaches will involve the use of new materials that employ nanotechnology -- approaches that didn't even exist as options until recently. A prime example of this is the AMBIOS project (web site: <http://www.ambio.bham.ac.uk/>), a 5 year project being supported by the European Commission. A consortium of 31 organizations, it is attempting to use nanotechnology of surfaces to produce non-toxic materials that do not foul in the sea.

Keywords: Biofouling, Toxic heavy metals, Nanotechnology

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Inter-specific variation in adhesion strength of barnacles on foul-release coatings

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As a result of the environment impact of toxic coatings, much effort is being directed to the development of low surface energy silicone and fluoropolymers. Many organisms do attach to these surfaces but the bioadhesive bond is weak and most organisms easily fall off. Thus, the efficacy of these coatings depends on enhancing the fouling release capabilities of these coatings, and better understanding of the adhesion of organisms is needed to further improve the technology. It has been observed that when barnacles attach to siloxane elastomeric coatings, a thick adhesive plaque forms on its base plate. Studies by Holm et al. (2005) have demonstrated that the adhesion strength of barnacle glues within genetic families of barnacles may vary significantly. In this paper, we report the variation in adhesion strength of three different barnacle species to non-stick foul release coatings. *Amphibalanus cirratus*, *A. reticulatus* and *A. amphitrite* occur together at our site, and adhesion measurements were recorded for the three species from the same panels. As barnacles exhibit plasticity in their form under different environmental conditions, we also measured the height and diameter of the barnacles. It was observed that the variation in adhesion strength was also related to the aspect ratio of the barnacles.

Keywords: Barnacle adhesion, Antifouling, Fouling release coatings

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Invasion history and habitat of the alien amphipod *Gammarus tigrinus* Sexton: Modelling of its further range expansion in the northern Baltic Sea

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The northern Baltic Sea is species poor and each ecosystem function is often represented by a single or a few species. Thus, the loss or addition of a species may correspond to the loss or addition of ecosystem function. Over 100 different alien species have been recorded in the Baltic Sea. North-American *Gammarus tigrinus* Sexton was introduced to Europe in ballast water and was first recorded in England in 1931. In the Baltic Sea *G. tigrinus* was found already in 1975, but the significant range expansion started in the 1990s. In the northern Baltic Sea *G. tigrinus* was found for the first time in 2003. The invasion of *G. tigrinus* was extremely rapid and during two years the species became established and even dominant gammarid in many locations throughout the northern Gulf of Riga, northern Baltic Sea. Following the establishment, *G. tigrinus* and native gammarid species seldom existed at the same site indicating spatial separation between native and invasive species. The invasive species was more successful in shallow and sheltered soft bottom areas than in deeper and exposed stony areas. The abundance structure of *G. tigrinus* was mostly related to the biomass of green algae, charophytes and higher plants. The densities of native gammarids were best explained by the biomass of brown and red algae. Concurrent with the invasion of *G. tigrinus* both the density and diversity of native gammarids have declined indicating competitive superiority of *G. tigrinus* over native gammarids. GIS-based generalized regression analysis and spatial prediction (GRASP) were used as methods for predicting the further range expansion of the alien amphipod. Model validation showed good accuracy in predicting the occurrence of *G. tigrinus* indicating that GRASP approach may be helpful for predicting the distribution of invasive species.

Keywords: Alien, Amphipod, Baltic Sea, *Gammarus tigrinus*, GIS, Modelling

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Invited Talk

Non-regulatory technical and operational criteria for ballast water management systems

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G8 provides technical and operational requirements for Ballast Water Management System (BWMS) type approval. Other criteria which would make a design suitable for onboard ship applications and consequently would provide marketability for the final design are not in the remit of IMO or any other regulatory bodies.

Compliance with G8 and approval of IMO may not necessarily be the final verdict on suitability of a management system for onboard ship implementations as well as satisfying ship-owner, operator and builder's perspectives.

This presentation intends to provide a comprehensive set of criteria for assessment of a BWMS and open a wider discussion on technical and operational aspects of implementing IMO guidelines.

Keywords: G8, IMO, Criteria, Ballast water management system, Guidelines

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Methodology for sustainability assessment of ballast water management systems

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The search for sustainable technologies has become an emerging subject worldwide and shipping is not an exception. Researches on ballast water treatment are increasing, and following current trends in other disciplines, they will soon be subjected to a sustainable assessment in order to optimise the design and meet current societal needs.

In parallel to the problems behind the introduction of alien species, ballast water management can also generate additional costs and negative impacts to environment and crew. Although an assumed technology complies with the IMO requirements, it might not present an acceptable sustainable footprint. The nature of materials used for building the equipment, the energy requirement for running the treatment, health hazards crew may face due to contact with the equipment, cost of treating a volume of ballast water and other parameters could make one treatment more preferable than other.

This paper highlights the need for developing sustainable ballast water management systems and it proposes a structured assessment methodology for achieving this. The methodology analyses each sustainability stream separately and it joins them together for obtaining an overall sustainability index. There is also a review of common pollution agents, cost drivers and parameters affecting the wellbeing of crew that ballast water management system could present.

A sustainable ballast water management could be one of the steps for helping maritime transport get on the right direction towards sustainable shipping. Examples for obtaining a sustainable treatment could go from choosing a sustainable treatment to modifying, for example, materials and consumables that are being used on a specific technology.

Keywords: Ballast water treatment, Sustainability assessment, Methodology, Environmental impact, Cost, Social impact

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Modelling, simulation and optimisation of an onboard ballast water treatment system

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Design, development and optimisation of ship board ballast water treatment systems, when compared to land-based water treatment systems, due to their different technical and operational requirements, demand a different approach. In this paper modelling and simulation of an onboard electro-chemical system which is capable of producing a combination of chemicals with proven record of success in treating freshwater is addressed. Data-driven models, using intelligent algorithms have been introduced and their application in simulation and prediction of system's behaviour in unknown operational conditions has been discussed. Development of system's performance maps under varying operational conditions and design settings have been developed and presented. Finally, an attempt has been made to mathematically model the biological performance of proposed ballast water treatment system.

Keywords: Ballast water treatment system, Intelligent algorithms, Modelling, Simulation, Optimisation, Biological effectiveness

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Ballast Water Management (BWM) program in the United States

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The Department of Homeland Security, through the US Coast Guard (CG) is the Federal agency authorized to develop a national regulatory program to prevent ANIS into U.S. waters. Through the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 and National Invasive Species Act (NISA) of 1996, the CG has developed and continues to develop numerous regulations.

Currently the CG is engaged in a rulemaking process that would set a performance standard for the BW discharge. The ANPRM was published on March 4, 2002 to start the rulemaking process. The CG also has taken action to establish a quantitative ballast water treatment performance standard, protocols for testing, verifying, and reporting on treatment technologies; and a program for experimental shipboard installation and operation of promising technologies. NANPCA authorized the CG to develop regulations for a mandatory BWM program for the Great Lakes and Hudson River and were enacted in 1993 and 1994 respectively. On July 28, 2004, the CG published regulations establishing a mandatory BW management program for all vessels with BW tanks. The CG may now impose a civil penalty of up to \$27,500 per day or Class C felony charge for non-submittal of BW reporting forms. On January 2, 2004 the U.S. Coast Guard announced a program to facilitate the installation of experimental shipboard ballast water treatment systems on both foreign and domestic vessels. This Shipboard Technology Evaluation Program (STEP) aims to promote research and development of shipboard BW treatment systems through regulatory incentives, creating more options for vessel owners seeking alternatives to ballast water exchange. Some vessels calling on the Great Lakes declare No Ballast Onboard (NOBOB), but may contain residuals or sediments that have the potential to carry NIS. In 2005 the CG established a policy of best management practices for NOBOB which strongly encouraged saltwater flushing.

Keywords: US Coast Guard, BWM program, Shipboard Technology Evaluation Program

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Self validating, electronic Ballast Water Reporting Form (BWRF)

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Ballast water Management Program, India has developed a self correcting, easy-to-use-and-download electronic Ballast Water Reporting Form for use on ships. The form follows the IMO (International Maritime Organisation) format. Since such a form must be loaded and used by one of the ships officers, who may not necessarily be an experienced computer user, the overriding concern in this exercise has been software that can be easily downloaded and used. After interaction with the intended users, due to expensive internet charges on ships, the size of the software and of the output data became an important concern, with a good amount of effort expended on minimizing file sizes.

The form may be filled up using the commonly available browser Internet Explorer (versions 5.5 and above). The form itself is less than 250 KB in size and may easily be mailed to the ship as an attachment. Since the form runs on a browser, there is no installation procedure that the computer user need follow.

The form is self validating, with over 20 validations in use. These are documented on the supporting website, <http://www.bwmindia.com>. The primary functions of the website are: to make available the Ballast Water Reporting Form for downloading by the ship users and to serve as a data depository for the validated forms.

The validated output is stored to an XML file. The output file may be e-mailed to the port authority in question. During trials, a raw data format was also developed as Indian shipping companies were not comfortable with the extra cost of e-mailing the relatively larger XML data file.

A later version of the form offers more functionality, has an install program and is also much larger in size (2.6 MB after compression). The application can be mailed on a CD or can be downloaded from the website. Features of this version are: printing out the form in the IMO format and loading previously filled forms for viewing, automatic emailing of the filled up form, saving a partially filled up form. The two versions have different intended users and both versions are concurrently in use.

Keywords: Self validating BWRF, IMO format

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Invited Talk

Ballast water treatment options in light of pending and proposed treatment standards

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The past five years have marked a significant increase in global reactions to invasive species transport via ships' ballasting operations. While scientific and engineering interest has not been obvious over this period, political and governmental activity has generated many proposed and pending regulations governing ships' discharge of ballast water. This activity was initiated in February of 2004, when the *International Convention for the Control and Management of Ships' Ballast Water & Sediments* was adopted by consensus at a diplomatic conference at IMO in London. As originally drafted, the convention will enter into force 12 months after ratification by 30 states, representing 35% of world merchant shipping tonnage. These proposed global standards regulated ballast water discharge in terms of concentration of viable organisms segregated by size, e.g. < 10 viable organisms of a size greater than or equal to 50 microns per cubic meter of water. This type of discharge standard mandated that a re-thinking of ballast water treatment technology design was required. Since this time in the USA, individual States, as well as the Federal government have all been working on ballast water discharge standards. The States of California, and Michigan have been especially active in creating and adopting ballast water management requirements for ships visiting ports in these States. Overlaying these initiatives, is the caveat that the US EPA has recently been ordered by a U.S. District Court to regulate ballast water under the Clean Water Act. While this directive is being appealed, the US EPA has issued a notice of intent to develop a permit program for the discharge of ballast water in USA waters. Finally, Federal standards (Coast Guard Authorization Act) are also being generated. From a ballast water treatment point of view, these various proposed standards generate significant challenges to the development of effective and reliable shipboard systems. For example, the proposed Federal standards require that ballast water discharged in the USA meets far more stringent standards than those proposed by IMO. Specifically, the proposed Federal standard regulates the number of viable organisms of size greater than or equal to 50 microns per cubic meter of water to less than 0.1 viable organisms.

The creation of these significantly different ballast water discharge standards through-out the world has the potential to set back work on ballast water treatment technology development. Development of effective treatment systems to address the requirements of these different standards will not be easily achieved. In addition, as the adoption of the IMO standards has shown; a critical component of the process is the certification of treatment systems to achieve the individual treatment goals. While technology developers have already struggled with the poorly defined "certification process" creation of new ballast water treatment standards will further exacerbate the situation.

This paper will discuss the status of global ballast water discharge requirements, and its effect on development of ballast water treatment technologies. Various treatment types will be evaluated, and the potential for effective treatment in terms of meeting the proposed standards will be compared amongst treatment types.

Keywords: Global ballast water discharge requirements, Treatment technologies

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FlowCAM[®] technology – the integrated system for ballast water analysis and regulatory compliance

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The FlowCAM[®] is a continuous imaging flow cytometer now being used for monitoring of microorganisms and particles in water. It combines microscopy, flow cytometry, imaging and fluorescence technologies. A laser interacts with a high resolution digital camera to capture images and data of passing cells or particles. It offers cell counts, size data, pattern recognition, organism classification and image management. It has been used in numerous ballast water treatment projects worldwide. FlowCAM applications include pre-treatment, post-treatment, IMO D-2 standards validation and sampling protocols. It can detect bacteria-size microorganisms; image and count phytoplankton and zooplankton. The fluorescence capability can be used to differentiate live versus dead organisms. An overview of the technology will be presented along with various case studies.

Keywords: FlowCAM[®]; Ballast water; Viability; Imaging; IMO, Microorganisms

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Practical challenges to ballast water management and treatment

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This presentation will cover the general “theory” underlying the designs of ballast water systems and the range of specific scenarios that occur when ballast is managed on different types of commercial vessels. For specific types of vessels and routes, it will include consideration of how ballast water is taken on, handled, and discharged; volumes and rates of ballast water management; the degree to which water from different tanks is combined during discharge or released directly without passage through the internal piping and pumps; and how these variables impact the efficacy of aquatic invasive species removal and/or treatment. It will describe and provide solutions to the logistics that affect the practicality of ballast water management treatment technologies, as well as approaches to determining compliance with discharge standards.

Keywords: Ballast water management, Ballast water treatment technology, Aquatic invasive species

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Pioneering Biofouling Management in the LNG Industry: Plant Cooling Seawater System and Carrier Hulls

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Qatargas have developed two pioneering technologies within the Liquefied Natural Gas (LNG) industry to control fouling. Qatargas currently operates a three-train LNG plant at Ras Laffan Industrial City with a fleet of 11 Moss-type LNG carriers. Fouling is an issue within the plants cooling seawater system and on the hulls of the carriers. Both cases demonstrate win-win scenarios: operational improvements that lead to enhanced environmental performance.

Fouling of the cooling seawater system (e.g., at strainers and heat exchangers) at Qatargas has only ever constituted a minor inconvenience. Fouling control has been adequately achieved within Qatargas using industry standard techniques, however, electrochlorinator (ECP) maintenance issues in combination with tough new environmental regulations provided the incentive to look for alternative anti-fouling strategies. Since 2004 Qatargas has investigated the use of a new chlorination technique, termed pulse-chlorination. The adoption of pulse-chlorination has allowed part of the ECP to be mothballed, reducing operational / maintenance requirements and reduced the amount of sodium hypochlorite added to the cooling seawater by 56%. Further system optimizations are on-going and shall be discussed.

Qatargas took the proactive steps towards compliance with the non-TBT antifouling paint international legislation recently introduced with the use of a silicon-based paint on the hulls of the LNG carrier fleet with sea trials being conducted in 2001. Fouling significantly increases the drag of a normally smooth hull and thus increases fuel consumption. This leads to increased transportation emissions and reduced profitability. The use of such technology has also allowed the extension of dry-dock periods for antifouling paint reapplication reducing waste production.

Continual improvement is a key factor of Qatargas' vision of being an industry leader with high environmental standards. Preparation of the Qatargas LNG fleet for certification by the "green" award and the current / future implications of ballast water management shall be discussed.

Keywords: Qatargas, Electrochlorinator maintenance issues, Pulse-chlorination, Silicon-based paint

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Modelling the dispersion of ballast water discharge off Visakhapatnam port, east coast of India

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Dispersion of suspended particles or organisms reaching the marine environment through ballast water depends on the hydrodynamic conditions prevailing in the region. Most of the planktonic larvae living in marine habitats are sessile or sedentary and can disperse over a large distance depending on the currents. The particles/organisms will advect along with the current and their net movement can be simulated using hydrodynamic model. Dispersion of ballast water discharge off Visakhapatnam has been studied using numerical simulation of hydrodynamics of the region. MIKE21 2-dimensional model with hydrodynamics (HD) and particle analysis (PA) modules has been applied to study the dispersion around the discharge location. HD simulates flow pattern prevailing in the region, and PA simulates the dispersion of dissolved and suspended particles present in the ballast water. The ballast water released at the spoil ground off Visakhapatnam is considered to be having different temperature-salinity characteristics as compared to the ambient water. The concentration and spreading of the dissolved and suspended particles around the discharge point are simulated to analyse the fate of the ballast water.

The model was forced by applying water level variations along the open boundaries and winds on the sea surface. A large model domain covering Kakinada in the south and Visakhapatnam in the north was selected for the simulation. Tides along the open boundaries were predicted at the coastal tidal stations using four major constituents M2, S2, K1 and O1. The tidal elevations required at the offshore boundaries were interpolated and applied to drive the model. The model results were validated with current measurement carried out during May 2006. The maximum water level obtained during spring tide was 1.72m, and the maximum observed current speed was 0.38 m/s (with a mean of 0.11 m/s). In general, both the u and v current components were negative, indicating the presence of southwestward current under the northeasterly winds prevailing during May 2006.

The model results as well as the measurements indicate that under the influence of the southwestward current, the discharged water and the particles flow southwestward, parallel to the coast and it does not advect towards the coast. The plume is seen at the source during the discharge period of 10h, and thereafter disappears from the source.

Keywords: Dispersion, Ballast water discharge, Hydrodynamic conditions, MIKE21 2-dimensional model

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Invited Talk

Hydrodynamic cavitation for water treatment

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Water as a resource is getting scarcer by day due to many environmental factors and also as a result of the pollution of the water bodies caused by the discharge of effluents as a result of industrial and anthropological activity. The recycle and rescue of water as well as the treatment of effluents to prevent pollution of water bodies is an area of active research for the past several decades.

A unique solution which is universally valid and carries out on-line treatment in variety of damaging situations has now emerged as a front runner. Hydrodynamic cavitation where the kinetic energy of water is used to create cavitating condition has shown a real promise. Cavitation, which can be described as generation growth and subsequent violent collapse of microscopic vapor or gas-vapor bubbles have shown to create following situations, which can be effectively used to treat water/effluent.

- a) Generation of local conditions (the point of cavity collapse) which have temperature of several thousand degrees centigrade and pressure shock waves of several hundreds of atmosphere.
- b) Creation of extreme microscopic turbulence on a near molecular scale and local fluid velocities of several hundreds of meters/second.
- c) Creation of highly reactive free radicals capable of mineralizing (oxidizing) organic and inorganic matter in water bodies.

As can be seen from the conditions generated by the phenomena of cavitation, there exists a possibility of using these conditions for the following applications related to water treatment.

- a) Local high temperature and pressure (shockwave) generated can effectively disrupt/sterilize a variety of microbes rendering them unviable. These shockwaves can also break large complex organic molecules making it possible to treat them by conventional biological treatment processes.
- b) Microscopic turbulence can be effectively used to de-agglomerate microbial colonies exposing them to the disinfecting chemicals more effectively.
- c) The reactive free radicals can oxidize many bio-refractory pollutants rendering them innocuous.

We will present various cases explaining the above applications where hydrodynamic cavitation has been successfully used for potable water disinfection, control of bio-fouling and oxidation of bio-refractory pollutants and demonstrate the efficacy of this emerging technology.

Keywords: Hydrodynamic cavitation, Potable water disinfection, Biofouling, Oxidation of bio-refractory pollutants, Emerging technology

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Invited Talk

Recruitment on rocks, reefs and rafts in the sea: why invertebrate larvae settle when and where they do?

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Benthic communities in the sea, whether growing on rocks, living biological coral reefs or floating objects such as ships, become established and remain so principally by recruitment of larvae of each of their component species from the water column. Whether released from their parent animals as sperm and eggs or as well developed stages, larvae of marine invertebrates must achieve the developmental capacity to recognize suitable recruitment sites, attach to them and undergo metamorphosis, a state referred to as “competence,” before recruitment can occur. The minimal pelagic period varies greatly across invertebrate larvae, correlating especially with pelagic-vs.-benthic early development, and whether or not the larvae feed in the plankton. This talk will explore the recruitment biology of larvae from coral reefs and fouling communities, including both feeding and non-feeding types, and the nature of cues that they utilize to indicate appropriate settlement sites (adsorbed vs. soluble cues). It will also explore the biological and physical nature of the communities into which larvae must recruit, and discuss how the minute larvae manage to recruit into good sites in the swirling, shearing flow that characterizes most marine habitats. Larvae types to be discussed include those of a polychaete worm, a bryozoan, a barnacle, an ascidian and a reef-building coral. Research approaches include both field studies and laboratory experiments.

Keywords: Larva, Recruitment, Metamorphosis, Settlement cues, Invertebrate

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COI gene variability in established East Asian populations of the Caribbean bivalve *Mytilopsis sallei* (Dreissenidae)

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Mytilopsis sallei is one of a small number of tropical estuarine bivalves known to have successfully established themselves outside their native range in the Caribbean. Their occurrence in major ports of call in East Asia strongly suggests transport of larvae and/or adults by vessels. However, transfer pathways remain speculative, and direct evidence is difficult to obtain. Analysis of genetic variability between established populations may provide a means of tracing their movements. In this study, sequence variation in the 376-base-pair fragment of the mitochondrial cytochrome oxidase I (COI) gene of *M. sallei* was examined for the first time in 254 individuals from 11 discrete populations outside its native range from Singapore, India, Hong Kong and Taiwan. Some 15 haplotypes with variation over 24 nucleotide positions were identified, indicating high genetic diversity with no evidence of sex-specific sequences. Haplotype diversity ranged between 0.6 and 0.8 in eight Singapore populations, and an analysis of molecular variance showed that there was no significant genetic segregation in these eight Singapore populations examined. Haplotype diversity was equally high in a population from Visakhapatnam, India, but was slightly lower (0.5) in samples from Kaohsiung, Taiwan and those from Tolo Harbour, Hong Kong. Cladistic analyses showed that haplotypes were not segregated based on geographical location in East Asia. However, pair-wise analyses of the pooled Singapore population against those elsewhere indicated that there were significant differences between populations in Singapore and Hong Kong, and between Singapore and India. These differences can be attributed to two dominant haplotypes which characterise populations in Singapore and Taiwan on one hand, and those in Hong Kong and India in the other. Nevertheless, the two haplotypes were consistently present in all populations examined. The results suggest recent and possibly on-going, transfer of genetic material between *Mytilopsis* populations established in Asia in spite of their separation in physical distance and salinity.

Keywords: Alien invasive species, Dreissenidae, *Mytilopsis*, Bivalvia

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Larval metamorphosis in barnacles: linking the internal and external ecologies

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The ability of an organism to acquire information from the surrounding environment is an essential determinant of ecological function. The organism must sense and respond to the environmental and biological cues to behave in an ecologically appropriate manner. In the life cycle of a benthic organism the competitive larval stage is the transitory stage between the pelagic and the sessile life and its role in finding a suitable juvenile habitat is predominant. Microbes bridge the pelagic and benthic ecosystems by actively interacting with the metazoans in the water column. Surfaces submerged in the aquatic environment are rapidly covered by biofilms comprising of various microorganisms among which bacteria are major sources of chemical cues inhibiting or inducing larval settlement of marine invertebrates.

Barnacles (Cirripedia; Thoracica) are dominant components of the hard bottom inter-tidal zone of the marine habitat and form a major group of fouling organisms. They are also the organisms of major focus in marine antifouling research. There have been numerous empirical studies to elucidate the influence of different components of biofilm on barnacle settlement. These studies indicate that larvae can perceive the presence of suitable substratum while being in the water column and also have the capability to accept or reject a surface when in contact. Hence, both olfaction and contact chemoreception are equally important. Experiments carried out point out to the possibility that when the receptor sites for contact chemoreception are blocked the exploration of the surface is furthered through olfaction. In other words, it is possible to say that surface associated cues play a major role in mediating settlement and metamorphosis, whereas the water borne ones can act like signposts for the swimming larva.

Keywords: Barnacles, Biofilm, Settlement, Olfaction, Contact chemoreception

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Invited Talk

Community stability in the face of environmental change: things that matter

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Currently, natural benthic (i.e. stationary) communities experience environmental change of an unprecedented speed and amplitude. This may be caused by directly climate change related shifts of abiotic variables in a given habitat, changes in marine current patterns bathing a given site in new water bodies, the introduction of new biotic interactors, or the translocation of communities attached to motile substrata (e.g. ship hulls, floating litter). The stability of a given benthic community faced with the shift in biotic and abiotic environmental factors will determine how fast and how profoundly ecosystems change.

In a globally replicated experiment, environmental change was simulated by translocating hard bottom communities of 2 different successional stages between structurally similar habitats 100s of m to 10s of km away. This treatment simulated ship hull transport or change in current patterns.

Community stability was assessed as its inverse: the rate of structural convergence towards local hard bottom communities of identical age. This convergence was driven by 2 processes: mortality of introduced alien species and colonization of available space within the introduced community by local propagules.

Younger communities converged faster (i.e. were less stable) than older communities. Age is a sum parameter of other community properties such as free substratum, dominance, taxonomic and functional diversity all of which tend to change during succession.

Partial correlation allowed identifying the contribution of these parameters to community stability. Open substratum space and dominance reduced stability whereas taxonomic and functional diversity strengthen stability. The degree of dominance had the strongest negative impact on stability, functional richness the strongest positive effect. Despite substantial variability among biogeographic regions, together, these 4 community properties explain about 50% of the 'global' community stability.

Keywords: Benthic communities, Stability, Dominance, Functional richness, Biogeographic regions

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Expression of biosynthetic gene cluster in sponge associated bacterium during co-cultivation experiment: Chemical warfare between bacterial neighbors

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The role of sponge surface-associated bacteria in host epibacterial chemical defense is well known. The production of antibacterial metabolites by sponge-associated bacteria confers a selective advantage to the producer for competition with other bacteria, populating the same ecological niche. In this investigation, a sponge associated bacterium SB2 (alpha-proteobacterium MBIC 3368) showed antibacterial activity against its bacterial neighbors. In SB2 bacterium a KS3 gene from polyketide synthases (PKSs) gene clusters was detected and it was predicted that this particular genetic machinery is responsible for the production of antibacterial metabolites. The regulation of PKS gene cluster was investigated in this microbe, upon challenging it with its competitor microbial strain SB6 (gamma-proteobacterium), isolated from the same sponge surface. In this co-cultivation experiment, the up-regulation was observed in PKS gene cluster (at RNA level) expression. Simultaneously, PKS cluster expression was investigated in comparison with the growth curve of SB2 bacterium. This experiment showed up-regulation of PKS cluster during late exponential phase and early stationary phase, which is reported to be a peak period of secondary metabolite production in bacteria. This investigation highlights the role of biosynthetic gene cluster in the defense strategy of bacteria against their competitors in the microfilm.

Keywords: Marine sponge, Bacteria, Antibacterial activity, Gene cluster, Up-regulation

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Invited Talk

Shipping as a vector for bioinvasions in the United States: past, present, and future

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Biological invasions in coastal ecosystems result from a variety of human activities, and the relative importance of different transfer mechanisms (vectors) varies in space and time. For the continental United States, commercial ships have been a dominant vector over the past several hundred years. Approximately 350 non-native marine species of invertebrates and algae are considered established in U.S. waters. Most of these invasions are attributed to shipping as a vector, and the relative contribution of shipping (to documented invasions) has increased greatly over time. These organisms were transferred primarily in ballast tanks and on the underwater surfaces (hulls) of ships. However, because many species have life-stages that can occur in either location, it is difficult to estimate the relative importance of ballast versus hull fouling. At present, the U.S. receives annually ~100,000 commercial ship visits to various ports around the country. Based on current ship-specific information, we estimated annually that (a) the underwater wetted surface area (WSA) associated with these arrivals is roughly 800 million m² and (b) the discharge of ballast water is approximately 100 million m³. While numerous studies document the density and diversity of organisms transferred in ballast tanks, and also the effects of ballast water exchange as a management strategy to reduce such transfers, relatively few data exist to document biota on ships' hulls. Several studies are underway to characterize biota associated with hulls and to begin exploring effects of various coatings on hull communities. Although management efforts are focusing intensively on reducing the quantity of organisms transferred on ships, and especially on ballast water discharge, the reduction in invasion risk is not well established and will depend upon (a) the shape of dose-response relationships between propagule supply and invasion establishment and (b) the relative importance of ballast versus hull fouling as a source of invasions. Advancing our understanding in these critical areas requires repeated, field-based measures to estimate temporal changes of invasion patterns in response to management as well as quantitative experiments to estimate establishment probability under diverse field conditions.

Keywords: Ships, Ballast water, Hull fouling, Invasions, United States

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Larval development in *Balanus amphitrite* (Cirripedia:Thoracica): implications in biofouling and bioinvasion

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Most of the marine benthic/sessile organisms spend some part of their life in the water column (planktonic) as larva before they settle and recruit. Events during planktonic larval development have strong impact on settlement and recruitment success. Factors such as food concentration/starvation, temperature, salinity etc. influence the duration of larval development and also the ability of the larvae to metamorphose. The impact of these factors on larval development of an acorn barnacle *Balanus amphitrite* collected from a tropical estuarine environment was assessed.

Generally the larvae of *B. amphitrite* are raised in the laboratory through mono-species diatom culture e.g. *Skeletonema costatum*, *Chaetoceros calcitrans*, etc. The specific food availability in the nature and the concentration provided in the laboratory is far from reality. A comparison of the larvae raised in the microcosm in the field and that in the laboratory using mono-algal food indicated that the nutritional condition of the field reared larvae though inferior, was not comparable to the quantum of food assessed through chlorophyll a in the natural environment. This indicates the larvae are in a position to feed on other sources and complete development. Experiments on the starvation tolerance of these larvae showed that the ability to survive and undergo successful metamorphosis to be temperature dependent, i.e. 216h (5°C) to 48-60h (25°C). These results point out that these larvae are robust and capable of surviving under diverse stress conditions. In light of these observations it is possible for these organisms to endure the conditions inside the ballast tank. The presentation provides a basis for incorporating these factors of cirripede larval development into marine bioinvasion risk assessment.

Keywords: larval development, *Balanus amphitrite*, Food availability, Temperature, Marine bioinvasion Risk assessment

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Susceptibility of phytoplankton to bioinvasion in a tropical, monsoon-influenced environment

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The phytoplankton community in a tropical port environment along the west coast of India was assessed for its susceptibility to bioinvasion. Since the South West (SW) monsoon is the main source of climatic variation in the study area, sampling was conducted during two consecutive post-monsoon periods (2001 and 2002) and the intervening pre-monsoon period (2002). Distinct seasonal trends in both – diatom and dinoflagellate communities were observed, with maximum values of species richness and diversity recorded during the pre-monsoon period. These observations indicate the potential for intra-seasonal variations in bioinvasion susceptibility. This presentation deals with the pre-monsoon and post-monsoon scenarios with respect to susceptibility of diatoms and dinoflagellates to bioinvasion and focuses on the strategies employed by these organisms to survive and compete under the circumstances. The effects of decadal changes in nutrient enrichment and variations in SW monsoon pattern on the phytoplankton community and its implications on ecosystem functioning are also elucidated.

Keywords: Diatoms, Dinoflagellates, Susceptibility, Bioinvasion, Pre-monsoon, Anthropogenic enrichment, South West monsoon

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Invited Talk

Determination of benthic marine populations: from larval transport to survival to reproduction

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The population dynamics of coastal species such as barnacles, oysters and mussels are governed by many processes, including larval production, pelagic larval survival, larval transport, settlement and recruitment. These processes are complex, sequential, and some carryover to the next set of processes. For example, pelagic larval experience carries over to recruitment, and larval production determines how many larvae settle. Moreover, timing of each process may be critical to understand the “coupling” among processes and ultimately distribution and population dynamics of a species e.g. previous work has suggested that a mismatch in pelagic larval occurrence and phytoplankton algal blooms can result in recruitment failure.

In this talk I discuss (1) issues of timing, and (2) some of the complex phenomenology of the larval transport process. First, I discuss issues of timing at local scales (m's) in the barnacle *Semibalanus balanoides*, a common barnacle in boreal rocky shores. In particular, I describe the recruitment window, the date vs. frequency function of the settlers that survive to reproduction. Our results suggest that the fine temporal scales of settlement rate (the rate at which free-living larvae attach to the bottom) can determine survival to reproduction. Second, I discuss some of the challenges and scales involved in investigating larval transport processes such as larval transport by internal tidal bores. Finally, I briefly discuss how focusing on the individuals that survive to reproduce (i.e. the recruitment window) may guide larval transport and dispersal studies, and reduce the number of variables and processes to a more manageable set.

Keywords: Benthic marine Populations, Larval transport, *Semibalanus balanoides*, Recruitment window, Survival, Reproduction

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Invited Talk

Granular biofilms: their generation and application in environmental biotechnology

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In natural environments, microorganisms predominantly exist as members of complex communities, often as surface-associated consortia. Living in a community facilitates enhanced metabolic cooperation and genetic exchange among the bacteria. This mode of biofilm growth empowers the bacteria with enhanced tolerance to abrupt environmental changes, stressors and toxicants. Biofilms are at the core of the emerging interdisciplinary research area collectively known as “environmental biotechnology”. Environmental biotechnology has been defined as “managing microbial communities to provide services to society” (Rittmann 2006). Biofilms involved in such useful applications are broadly classified into 1) communities that detoxify contaminated water, soil and sediment and 2) communities capable of generating usable energy in the form of methane, hydrogen or electricity. It has been established that the beneficial functions in all these processes are performed by bacterial communities existing in the form of biofilms. Formation of biofilms under natural and/or engineered conditions involves self-immobilization of microbes with the help of an attachment substratum. Using engineered systems, microorganisms can also be self-immobilized into dense macro-scale granules (granular biofilms), without providing any carrier material or attachment substratum. Such microbial granules, consisting of mixed culture microorganisms, find application in liquid waste treatment because of their ability to quickly sink, facilitating easy liquid-biomass separation. Moreover, granular biofilm reactor technology allows designing of compact and high rate bioreactors. It is expected that future wastewater treatment plants will increasingly use granular biofilm based systems in place of the existing activated sludge process. This presentation will cover generation of granular biofilms using sequencing batch reactors, highlighting advantages of granular biofilms and possible mechanisms involved in their development. Specific examples of possible applications of granular biofilms in environmental biotechnology (biodegradation and biosorption) are illustrated.

Keywords: biofilms, bacteria, environmental biotechnology, granular biofilms

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Biofouling on marine sensors and its prevention by ultraviolet radiation (UVR-C)

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Biofouling of sensors is one of the most serious problems hindering their long-term operations, especially in coastal environments. To facilitate the long-term monitoring of oceanic processes using remotely operated system, it is necessary that the sensors remain foul free during deployments. In order to develop an efficient monitoring system, it is not only important to keep the sensors clean but also to understand the nature of effect on the operation of marine sensors. An overview of these issues will be addressed in the presentation. The results obtained from the practical application of ultraviolet radiation (UV-C; 254 nm) in preventing biofouling from the optical windows of fast repetition rate fluorometer (FRRF) will be presented. The presentation further highlights the importance of design of the optical windows for fluorometers such as FRRF in minimizing interference from the biofilm algal fluorescence during measurements.

Keywords: Biofouling, Sensors, Ultraviolet radiation

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Spatio-temporal variations in demersal fish community structure along the fishing grounds of Goa, Central West coast of India

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Coastal, estuarine and bay waters of Goa, along the Central West coast of India, in the near vicinity of the Mormugao Port Trust, support diverse demersal fish fauna as evidenced from the observations made in the present study. The present study updates the baseline information of the demersal fish community structure in the light of the anthropogenic input in the port region. Data collected in the present study from 41 trawl hauls have been analysed to elucidate aspects such as taxa composition and seasonal variability among the total community. In the present study, a total of 137 taxa comprised of finfish, crustaceans, molluscs and other miscellaneous groups were observed, of which 91 were regularly occurring, whereas, 46 were rarely occurring. Observations made in the present study reveal that the number of taxa among teleosts (99) was higher than crustaceans (20) however percentage contribution to the total catch displayed an inverse trend among these two groups. In addition to these taxa, other miscellaneous taxa (18) contributed in meagre quantities to the total catch. Among the species reported in the present study, *Caesio cuning* is being reported for the first time from the West Coast of India, and 13 species are being reported for the first time from Goa coast. The results obtained on the seasonal variations among major demersal, minor demersal and pelagic faunal groups are presented and discussed with respect to habitat variability.

Keywords: Demersal fish, Seasonal variations, Species diversity, Community structure, Goa, Central west coast of India

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Competitive strategies within a fouling diatom community

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Natural diatom biofilms were studied under controlled conditions to understand the roles of nutrients, initial cell inoculum and seasonal variation in species composition in structuring the fouling diatom community. Seasonal variations were observed in the diatom species interactions during the monsoon, post-monsoon and pre-monsoon periods depending on the species composition. In the monsoon community, high densities achieved by the opportunistic species, *Nitzschia longissima* in nutrient enriched (NE) condition probably denied access to key nutrients to its competitors, thereby resulting in competitive exclusion. However, in unenriched (UE) condition the same species could not prosper, even though its initial field inoculum was high, probably because of its higher half-saturation constant for nutrients thereby resulting in co-existence of many species. In the post-monsoon community, NE favored the species with comparatively higher growth rate, *Amphora coffeaeformis* thereby suppressing the growth of other co-existing species whereas UE resulted in similar growth rates of the initial dominant species. This competitive trait was found to be effective at an appropriate cell density ratio of the competitive and target species. In the pre-monsoon community, nutrients did not play an important role for *Navicula transitans* var. *derasa* f. *delicatula* and *Amphora turgida* in contrast to *A. coffeaeformis* and *Amphora hyalina* because of their lower initial inoculum. In these experiments, as the community was developing, certain species were dislodged from the substrata and hence removed from the environment. In another experiment, where all the species stayed in the community throughout, it was observed that the larger sized species which are known to be the 'storage specialists' that can store the nutrients for use during the low nutrient conditions, dominated the community ultimately. This shows that, not only the strategies employed by the species but also the environmental conditions play a role in deciding the fate of the community. Understanding such pathways within the biofouling community will be useful for modeling the interactions between diatom species in various habitats under different resource conditions.

Keywords: Fouling diatom community, Initial cell inoculum, Species composition, Competitive exclusion, Co-existence, Storage specialists

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Distribution and effects of the key invasive species in the northern Baltic Sea

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In recent years at least one successful invasion has been recorded annually at the coastal range of the northern Baltic Sea. Providing very low biological and functional diversity of these coastal ecosystems such high invasion rate undoubtedly destabilizes the integrity of our ecosystems. The polychaete *Marenzelleria neglecta*, the bivalve *Dreissena polymorpha* and the amphipod *Gammarus tigrinus* are ranked among the most influential exotics in the Baltic Sea. The species are potentially able to affect biodiversity and modify organic matter and energy transfer pathways compared to the pre-invasion time. In this paper distribution and ecological impacts of these three keystone species are described in the northern Baltic Sea. *M. neglecta* prevails in eutrophicated soft bottom habitats where the species may reduce the growth and survival of native polychaetes and amphipods. *D. polymorpha* is able to colonize both fresh and brackish water bodies as well as soft or hard sediments. Prior to this invasion there was no benthic suspension feeding mode in the northern Baltic Sea where salinity is below 5 psu. Thus, *D. polymorpha* potentially increased the energy flow from pelagic system to benthos and caused a shift from pelagic production to benthic production. This was also supported by experimental observations about the fertilizing effect of the bivalve on macrophyte and associated invertebrate communities. The effects of *D. polymorpha* were more pronounced in fresh than in brackish water environments. *G. tigrinus* is currently the most aggressive nonindigenous species in the region. Since the late 1990s and 2000s *G. tigrinus* significantly expanded its distribution in the Baltic Sea and currently threatens the integrity of mesoherbivore assemblages in the area. The studied abiotic environmental variables did not explain the spatial variability of *M. neglecta*, *D. polymorpha* and *G. tigrinus* indicating that the species are still at their initial phase of invasion.

Keywords: Baltic Sea, *Dreissena polymorpha*, *Gammarus tigrinus*, *Marenzelleria neglecta*, Diversity

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Invited Talk

Using CFD for Enhancing Ballast Water and Biofouling Management

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Bio-fouling and ballast water exchanges introduce harmful aquatic organisms into alien environments. This may cause irreversible changes affecting human health and industries as well as the ecological balance of the seas. Several institutes including the International Maritime Organization (IMO) and researchers have been working on developing effective ways to manage dangers posed by bio-fouling and ballast water. At present, IMO recommends ballast water exchange at sea as a measure to manage threats posed by ballast water. Many of the proposed approaches rely on use of biocides, UV or heat to kill harmful organisms. In recent years, there is also significant work on harnessing hydrodynamic cavitation for this purpose (for example, see Pandit et al, 2006 and Ranade et al, 2007). Almost all of these approaches require effective and efficient handling of large amount of water (of the order of 3500 m³/hr) and associated mixing or cavitation issues. Computational Fluid Dynamics (CFD), which allows 'a priori' predictions of flow, mixing and heat transfer in complex equipment, provides unprecedented opportunities to optimize ways of managing bio-fouling and ballast water. State of the art CFD capabilities make it possible to account for complex shapes of ballast water tanks, network of pipes, valves and pumps and complex ways of ballast water exchange protocols. In this presentation, an attempt is made to illustrate the potential and power of CFD for enhancing effectiveness and efficiency of bio-fouling and ballast water management technologies. Basic methodology is described with the help of several examples. The developed methodology and the presented results will be useful to facilitate such enhancements in practice.

Keywords: Ballast water, Biofouling management, Hydrodynamic cavitation, Computational fluid dynamics

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Investigations on the probability of biomineralisation of manganese on titanium surfaces exposed to coastal waters of Kalpakkam

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Titanium is widely used in seawater-cooled power plants as heat exchanger material owing to its superior corrosion resistance. However, being an inert material, titanium is prone to attachment of micro- and macroorganisms. Formation of biofilm on titanium surfaces reduces the efficiency of heat exchangers that employ this material. Besides, some of the marine bacteria in the biofilm can also oxidize soluble Mn(II) in seawater to insoluble oxides; this phenomenon is called biomineralization. A two-year long study was carried out to isolate and characterize various bacterial species present in the biofilm formed on titanium surfaces exposed to coastal waters of Kalpakkam and to assess the manganese oxidizing potential of the marine isolates. The amount of manganese present in the biofilm was also measured using atomic absorption spectrometry (AAS). The results of this study showed that titanium was susceptible to biofouling and more than 50% of marine bacterial isolates were capable of bringing about oxidation of Mn(II). All these manganese-oxidizing bacteria were heterotrophic. The AAS results confirmed that the manganese content in the biofilms increased with increasing exposure time. Hence, the study indicates that the titanium surfaces when exposed to seawater were colonized by a large number of heterotrophic bacteria, which have the ability of bringing about biomineralisation of manganese. Thus the probability of biomineralisation of titanium surfaces in Kalpakkam coastal waters cannot be ruled out.

Keywords: Titanium, Seawater, Biomineralisation, Biofilm, Heterotrophic bacteria

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Signatures of amyloid-like nanofibrils discovered in barnacle adhesive

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Nanoscale properties of barnacle adhesive, a natural bioadhesive (*Balanus amphitrite*) has been studied using fourier transform infrared (FTIR) spectroscopy, chemical staining and Atomic Force Microscopy (AFM). FTIR data of the bulk glue shows predominantly beta-sheet conformations while chemical staining with congo red and thioflavin-T dyes confirmed the presence of the amyloid-like structures. The self assembly of the proteinaceous multimer has been imaged under artificial sea water conditions exhibiting amyloid-like fibrils ranging in lengths from a few hundred nanometers to a few microns. The force spectra reveal a “sacrificial” bond mechanism involving the unzipping of a proteinaceous multimer giving rise to a saw-tooth profile. The reversible nature of the force spectra predicts the “self-healing” property of the material. Nanoindentation measurements on the amyloid-like fibril structures yielded an elastic modulus value of 20-70 MPa. Results of this study indicate that the strength of the barnacle adhesive is significantly derived from the modular nature of the proteins and the intrinsic strength of the amyloid-like fibrils.

Keywords: *Balanus amphitrite*, Atomic force microscopy, Amyloid-like nanofibrils

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Invited Talk

Environment friendly BAT technology for antifouling: Optimization of biocide dosing through Pulse-Chlorination®

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Seawater as a coolant implies the necessity of an antifouling strategy to ensure undisturbed plant production. Sodium hypochlorite produced by electro-chlorination is the industry standard biocide for controlling biofouling. However, for decades the use of sodium hypochlorite has been associated with negative environmental issues by the residual oxidants and the formation of halogenated by-products in the receiving marine environment.

A new chlorination strategy for fresh- and seawater cooling water, called Pulse-Chlorination® was developed by KEMA. Pulse-Chlorination is based upon the principle that biofouling species like mussels and oysters, in general have a recovery period before fully opening their valves and start filtering water after exposure to a short chlorination period. The new chlorination regime takes advantage of this recovery time by using short successive pulses of chlorine dosing, alternating with periods without chlorine. This chlorine regime methodology is nowadays the Best Available Technique (BAT) under the European Union terms of Integrated Pollution Prevention and Control (IPPC) for macro fouling mitigation in once-through seawater systems. Pulse-Chlorination is investigated and successfully implemented through field tests carried out on-site worldwide on four continents. The method has proven to be universally applicable, but needs to be attuned to local conditions. The overall aim is to ensure optimal performance of cooling seawater system and condenser/ heat exchangers with minimal environmental repercussions.

The backgrounds and main results of the chlorination method at different locations are discussed in the light of (a) how to improve the protection of the seawater distribution system from biofouling organisms and biofilms, (b) how to reduce the amount and concentration of oxidants discharged to the recipient water body in line with the new regulatory requirements and (c) how to lower the operational costs of related equipment, e.g., electro-chlorinators.

Keywords: Pulse-chlorination, Antifouling, Chlorine dosing, Best available technique

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Role of β , 1-4 linked polymers in biofilm structure of marine *Pseudomonas* sp. CE-2

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EPS play role in the biofilm formation, stabilization and persistence of the biofilm on surfaces. Several studies had proved the role of polymers in biofilm formation and stabilization. However, little is published with respect to marine bacterial biofilm. The present study describes the type and role of specific polymers in biofilm formation and stabilization of marine *Pseudomonas* sp. CE-2. This culture shows attachment to stainless steel, glass and polycarbonate coupons and form thick biofilm. When the cells were grown in the presence of Calcofluor (200 μ g/ml), a fluorescent dye specific for β , 1-4 linked polymers, adhesion and biofilm formation was reduced. Conversely, when the cells were grown in the presence of Concavalin A (Con A) and *Triticum vulgare* (WGA) lectin there was no effect on adhesion and biofilm formation. Epifluorescence microscope observation of calcofluor, Con A and *Pisum sativum* (PS) lectin treated cells attached to SS showed the binding of these stains by the attached cells. These results suggest the presence of β 1-4 linkage, α -D- glucose, and α - D- mannose in the biofilm matrix. Moreover, protease and lipase treatment did not remove the cells from biofilm. While, cellulase (120U/ml) treatment that degrades β 1-4 linkages in the biofilm matrix resulted in significant cell detachment, creating a central hollow in the microcolonies. These results strongly indicate the role of β 1-4 linked polymers in maintaining biofilm of CE-2 on this surface.

Keywords: Biofilm, β 1-4 linked polymers, Calcofluor, EPS, Con A

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Natural product antifoulants – present Scenario and future prospects

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The commonly employed most effective and economic antifouling agent, Tri-n-Butyl Tin (TBT), is currently facing a total global ban imposed by the International Maritime Organisation (IMO) realizing its hazardous impacts on non-targeted marine biota. The antifouling paint industry, therefore, is presently in a very precarious situation and there is an urgent need for finding an immediate alternative for TBT. Natural Product Antifoulants (NPAs) have emerged as one of the best alternatives in this context and hence, the research on NPAs has gathered considerable momentum during the last two decades. Although, commendable effort has been expended by the international scientific community, research on NPAs from the Indian subcontinent is rather limited. Natural Product Antifouling Laboratory (NPAL) at the regional centre of the National Institute of Oceanography, Kochi, has recently acquired the necessary expertise in screening, isolation, characterization and structure elucidation of NPAs and have successfully identified a few NPAs. However, much challenges remains ahead before dreaming its applications at an industrial scale.

Keywords: Natural Product Antifoulants, Marine Biofouling, Tri-n-butyl tin

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Invited Talk

Molecular genetic probes for detection and management of marine pests

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Many marine invasive species are transported through the world's oceans at sizes that render them invisible to the naked eye and at developmental stages, indistinguishable from their native counterparts even under the microscope. To circumvent these limitations, over the last 5 years CSIRO Marine and Atmospheric Research (CMAR) has developed and deployed genetic probes for detection of five key marine pests of concern to Australia. Initially a standard nested PCR approach was adopted to differentiate target species from mixed biological samples (biofouling and ballast water) with the results feeding back to refine the Ballast Water Decision Support System used by Victoria to manage domestic ballast water. More recently we have developed quantitative PCR detection assays for 4 of the species and are currently applying these tools to acquire more accurate data on encounter rates, variability and uncertainties associated with sampling techniques as well as to obtain more accurate data on natural histories (spawning season, spatial and temporal heterogeneity, etc). When more gene probes become available it would be advantageous to amalgamate them on to a single platform incorporating the advantages of both signal amplification (PCR) and amenability for high throughput screening (e.g microarray) afforded by the modern molecular techniques. However, the major bottleneck at the current time is the lack of species specific probes for many invasive species of concern and for marine species in general where the probes are being used to investigate recruitment dynamics and dispersal in the plankton. In light of this we conclude by looking at further development of these genetic technologies (including developing more probes) and recommend that a collaborative international approach be initiated, if scientists and managers are to reap the rewards of these genetic technologies. Globally such collaborations will help the maritime states (both flag and port) to comply, monitor, enforce and test the specific efficacy of ballast water management required by the IMO, Globallast convention (2004). The probes will also have application to testing management measures to restrict the spread of marine invasives by the many other vectors and thus conserve the identity of bioregions.

Keywords: Molecular genetic probes, Marine pests

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Studies on settlement, distribution and abundance of fouling organisms at Mumbai harbour

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The present work has been carried out for a period of 16 months at two sites viz. Near-shore waters (St. 1) and Tidal basin (St. 2) in Mumbai harbour (lat.18° 55'N; long.72° 50'E). The biofouling at two sites was examined with regard to species abundance (density) and its composition. Sixty species were recorded during the investigation period (2000 – 2001). These species mainly belong to phylum annelida (11 species), bryozoa (22 species), cirripedes (4 species), mollusca (5 species.), coelenterata (6 species), tunicata (10 species) and porifera (2 species). Of the sixty species, 35 species have been recorded from Tidal basin, a site which is influenced by organic pollutants released through sewage water. Of the 60 recorded species, 16 species were new records from the region.

The study revealed that the density recorded at Tidal basin was significantly ($P < 0.00005$) higher than that of Near-shore waters. The influence of sewage water pollution was obvious showing considerable impact on species diversity.

With increasing use of seawater as an industrial fluid by shore based industries several problems of material durability as well as marine biofouling are presently encountered. It is, therefore, necessary to generate scientific data that may help in understanding the ecological aspects of fouling species and their distribution. This work will provide information regarding community and predominance of organisms. The work involved in the study were i) quantitative and qualitative assessment of biofouling and ii) seasonal influence on its occurrence. This information will be further useful for developing eco-friendly antifouling compounds.

Keywords: Biofouling, Seasonal variation, Species composition, Pollution, Biodiversity

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Invited Talk

Vessel-mediated dissemination of fouling mussels in world waters

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Mussels rank among the most troublesome organisms among the large number of invasive species so far recorded in literature. Species such as *Dreissena polymorpha* and *Perna viridis* have been reportedly causing considerable economic damage due to their large-scale occurrence beyond their normal range of geographical distribution. Invasive alien species can take a heavy financial toll on ecology, governments, industries, and private citizens. A recent study estimates that invasive alien species cost the United States of America more than \$100 billion a year and at least this much in six other countries combined. Ship hull fouling has been identified as a major vector for anthropogenic dissemination of mussels beyond their native location. Mussels, by virtue of their ability to attach to surfaces using their byssus apparatus, are particularly suited to long-range transport via ship hulls and ballast water tanks. It is expected that the proposed complete ban of tributyltin-based antifouling paints on ships might lead to a significant increase in the number of introductions of invasive species via hull fouling in future. In this context, we have carried out comprehensive analysis of historic data on alien species invasion through literature with particular reference to species such as *Dreissena polymorpha*. However, there is scarcity of data in the context of relative recent introductions such as *Perna viridis*. *P. viridis* is a remarkable species in terms of its ability to reach very large biomass levels, to withstand environmental fluctuations, to colonise artificial marine habitats and to invade new geographic territories. It is argued that the remarkable success of *P. viridis* as an invasive species basically stems from its long larval duration, fast growth rate, high fecundity, early maturity, high productivity and ability to withstand fluctuating environmental conditions. In this review we attempt to summarise information available on the invasive mussel species from both tropical and temperate waters.

Keywords: Mussels, invasive species, *Dreissena polymorpha*, *Perna viridis*, Ship hull fouling, Tropical, Temperate waters

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Ballast water management in Malaysia: issues and concerns

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Ballast water is necessary to maintain safety and stability at sea. However, it is also one of the major transporters of non-indigenous organisms, leading to serious ecological, economical and human health repercussions. The development of faster and larger ships, as well as rapidly increasing world trade, has reduced the natural barriers to the dispersal of species around the world. The shipping sector however is also the lifeline for Malaysia's international and national trade. Malaysia's dependence on maritime trade which carries 95 per cent of its goods means that the country is particularly susceptible to the impact of alien species introduction through ballast water. For example, more than 60,000 ships pass through the Strait of Malacca annually carrying large amounts of ballast water which could contaminate the marine environment if not managed or regulated properly. Thus, this paper examines the issues and concerns involved in ships' ballast water management in Malaysia. This is done by examining the threats and implications of marine invasive species; observing the shipping trends; describing the current international instruments and domestic policies being applied to the problem; studying the status and issues for Malaysia; reviewing the present national legal and procedural arrangements to control or abate this problem; addressing the relevant stakeholders' concerns on its implementation; and finally recommending what actions could be taken to address the issue.

Keywords: Ballast water, Introduced species, Trade, Shipping, Management

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Ceyhan marine terminal ballast water risk assessment

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The main aim of this study was to undertake a Ballast Water Risk Assessment (BWRA) study, according to the IMO – GloBallast BWRA methodology, for tanker movements between ports of tanker origin (source ports) and Ceyhan Marine Terminal (CMT) port to determine the risk of biological contamination between the ports.

The Ceyhan Marine Terminal export facility is located on the north-northwest coast of the upper Gulf of Iskenderun, Eastern Mediterranean Sea in Turkey. Iskenderun Gulf has many industries and approximately 2200 ships berth in the Gulf every year. After official inauguration of BTC Marine Terminal in July 2006, tanker traffic has increased in the Gulf. Loaded of the first tanker at the port of Ceyhan with oil from the Baku-Tbilisi-Ceyhan (BTC) pipeline took place on 4 June 2006. Marine facilities of the terminal include a fiscal metering station, a jetty capable of berthing two 300,000 Dead Weight Tonnage (DWT) tankers simultaneously, and facilities for loading oil onto tankers. The planned oil transport activity from the BTC Marine Terminal represents some 56.4 million DWT per year.

In the BWRA carried out for the CMT, it has been assessed and described as far as possible from available data the risk profile of invasive aquatic species being introduced to in ships' BW and identified the source ports posing the highest risk for such introductions. Risk has been determined on a 5 point scale of highest, high, medium, low and lowest. The shipping data used in the study is between June 2006–May 2007.

Keywords: Ballast Water, Risk Assessment, Invasive Species

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Invited Talk

Forging Global Alliances for Marine Biosafety through GEF-UNDP-IMO GloBallast Partnerships Programme

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Capacity building and policy, legal and institutional reforms remain to be key hurdles in managing marine bioinvasions in several developing regions. The second phase of the GEF-UNDP-IMO GloBallast Programme, titled *GloBallast Partnerships*, will aim to remove these barriers by forging strategic alliances at global, regional and national levels and working very closely with IMO Member States and various other stakeholders from public and private sectors. GloBallast Partnerships will assist especially vulnerable developing countries to reduce the risk of aquatic bio-invasions mediated by ships' ballast water and sediments and will expand and build on a successfully completed GEF-UNDP-IMO pilot project (GloBallast Project) during 2000-2004. With the help of tools and expertise developed and lessons learned from the pilot project, the new project will expand government and port management capacities, instigate legal, policy and institutional reforms at the country level, develop mechanisms for sustainability, and drive global/regional coordination and cooperation. The project will also spur global efforts to design and test technology solutions, and will enhance global knowledge management and marine electronic communications to better manage the issue. The partnership effort is three-tiered, involving global, regional and country-specific partners, representing government, industry and non-governmental organisations. Private sector participation will be achieved through establishing a Globallast Industry Alliance for Marine Biosafety (GIA) with partners from major maritime companies. All told, more than 70 countries in 14 regions across the globe will participate in the project, including the six pilot countries whose expertise and capacities will be drawn on for this global partnership effort. The presentation will cover the salient features of the project and highlight the key role the project will play in accelerating the implementation of the Ballast Water Management Convention.

Keywords: Ballast water, Marine Biosafety, GloBallast Partnerships, Global Industry Alliance, IMO, Ballast Water Management Convention

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Denmark and the BWM Convention

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The problem in DKExtend: Danish waters have recently experienced a wide spread introduction of the *Mnemiopsis leidyi*. Within 2007 the *Mnemiopsis* have spread throughout Danish inner waters and is regarded a potential hazard. Apart from the *Mnemiopsis*, Danish waters have seen the introduction of many species including *Ensis americanus*, which is distributed widely along the Danish west coast (towards the North Sea).

Measures: What requirements does the DK government have prior to recognition?

The Danish government require a full investigation into the questions:

Is there a problem?

Can the problem, if any, be solved by measures stated in the international convention?

Cost/benefit? What are the resources to establish facts?

According to government officials two to three persons are working part time with this matter and they do not have sufficient resources nor knowledge to answer the questions stated above. Therefore sufficient knowledge is not readily available to the environmental department to recommend ratification of the convention.

Future: What can be done in the future?

First of all this problem suffers from complete lack of interest and attention in Danish government and public.

Future progress therefore depends on two things:

1. Increased focus by government and NGO's
2. More resourced dedicated research into this area.
3. Work progressively for a joint ratification by all EU member states.

The shipping industry needs to focus more on this matter. Most ship owners await governmental initiatives – or have just never heard of the convention and relevant technologies at all.

Keywords: Bioinvasion in Denmark, Government approach, Future steps toward ratification

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Ballast water risk scenario for Mormugao Port, India

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The introduction of harmful aquatic organisms and pathogens to new environments via ships' ballast water (BW) and other vectors has been identified as one of the four greatest threats to the world's oceans. The issue can be addressed by implementing various management options. One of the management options is to conduct port specific ballast water risk assessment, which is a semi-quantitative approach. The method deals with collation of data from Ballast Water Reporting Forms (BWRFs) to identify the source ports from which BW is imported. A multivariate procedure is then used to determine the relative environmental similarity between the receiving port and each of its BW source and destination ports. Comparing port-to-port environmental similarities provides a relative measure of the risk of organism survival, establishment and potential spread. The various BW discharges, environmental matching and risk species data are then processed with other risk factors, including voyage duration and tank size, to provide a preliminary relative overall risk posed by each BW source port.

Information from 1173 BWRFs, collected from February, 2001 to October, 2006 by the Mormugao port (MPT) authority, was utilized for the exercise. Out of these, 766 BWRF were considered valid and taken up for risk analyses. The split-up of ship types visiting MPT suggested maximum visits by Bulk Carriers (79%). There were 245 trading ports, out of which, 143 were source ports and 102 destination ports. The maximum ballast discharged by any ship was 64,350 tonnes. A country wise ballast water discharge indicates highest by Japan (25%). The other major contributors were China, Korea, Pakistan and Persian Gulf (together >35%). The presentation provides an overview of the risk analyses at MPT, taking into consideration the proportion of all discharges (BW discharge frequency), proportion of total discharged volume and environmental similarity coefficient.

Keywords: Ballast water, Ballast water reporting forms, Risk assessment, Environmental similarities, Mormugao Port, Ballast water discharge

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Invited Talk

Implication of ship bio-fouling and ballast water management on shipping operations and economics

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Marine bio-invasions have been identified as a major global environmental and economic problem with several thousand species estimated to be in the ballast tanks of the world's shipping at any one time. The 'Atlantic box jelly', believed to have been released in a ship's ballast water, helped wipe out life in the Black Sea. In San Francisco Bay, a new foreign species takes hold every 14 weeks, scientists warn.

A significant milestone for the protection of the marine environment was reached by IMO in adopting the Ships' Ballast Water Management Convention in February 2004. One of the major environmental concerns linked with shipping is the control of ballast water to prevent the transfer of harmful marine organisms around the world. Ballast water is an essential feature of safe ship operation for many vessels. In developing guidelines for the environmentally sound control of ballast water discharges, the International Maritime Organisation (IMO) recognises the need to maintain safety of vessels and on-board practices.

Hull fouling may also be a vector for introduction of exotic species. Ships traditionally used TBT paints as a means of controlling the growth of exotic organisms on hulls, both to improve fuel efficiency and control the introduction of exotic species. Scientific studies showed that certain antifouling systems, specifically the Tributyltin (TBT) based anti-fouling paints, pose a substantial risk of toxicity and may have significant chronic impacts at the species habitat and ecosystem levels. The IMO responded to this serious marine environmental issue by ratifying the Anti-fouling Convention (AFS) which is aimed at protecting the marine environment and human health from adverse affects of antifouling systems on ships by phasing out the use of harmful organotin compounds as biocides in antifouling paints and by establishing a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. Since the AFS Convention will now enter into force on 17 September 2008, the international shipping industry is examining alternative anti-fouling treatments or systems that will be as effective and economically viable.

In the twin aspirations to improve the 'green' profile of ship operations and limit the consequential growth of fuel and maintenance costs, it is necessary to examine the economic viability of controlling translocation of invasive aquatic species by ships ballast water and by fouling of ships' hull in view of unavailability of suitable shipboard ballast water treatment systems. Similarly, consequent to the ban of TBT paints, we need to consider the economic impact of ship operations due to spiralling costs of aluminium and zinc based anticorrosive primers, epoxy based hull coatings and biocidal antifoulings containing copper to prevent fouling growth.

Keywords: Marine bioinvasion, IMO, Ballast water, Hull fouling, TBT, Anti-fouling Convention, Economic impact

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Next Generation of Ballast Water Management Plants

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Maritime transport will continue to be the most important transport mode in developing trade for the foreseeable future. Transfer of species in ballast water started as early as shipping trade. The movement of some 3 to 12 billion tonnes of ballast water in ships internationally each year has been responsible for the settlement of about 100 million tons of sediment. Its cleaning and the disposal of the ballast sludge produced involve enormous costs, (approximately 30.000 € for a small bulk carrier). Besides these economic aspects, Ballast Water has been recognised as a major vector for the translocation of aquatic species across bio-geographical boundaries. It is estimated that 10,000 alien species of plants and animals are transported per day in ships around the world. As ships travel faster and world trade grows, organisms are better able to survive the journey. The focus of this paper is the presentation of the BaWaPla (Ballast Water Management Plant) project results. BaWaPla (Ballast Water Management Plant) is one of the important European ballast water management projects. 12 partners from eight countries are cooperating to develop a new solution for ballast water management. Aim of the project is the development of a new hybrid BW treatment technology (UV, filters and electrolysis) into a self-controlled BW treatment system. The main objective of the proposed project is the invention of an effective treatment technology incorporating non permanent, seawater-generated active substances as a necessary measure to UV and Filter treatment technology. By producing active substances through electrolysis of sea water, there will be no need to carry or store hazardous and corrosive chemicals onboard ships. It also represents a more economical alternative to using chemicals for treating large volume of ballast water onboard ships. Results and experiences of the BaWaPla test implementation will be presented on the conference.

Keywords: Ballast tanks, Ballast, Water management, Aquatic organisms

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Poster Presentations

Confocal laser scanning microscopic investigation of biofilm formation

Nancharaiah YV¹, P Sreehari², VP Venugopalan¹

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Characterization of microbial growth at liquid-liquid interface between oil and water portends considerable ecological and economical significance in oil-bioremediation, microbially enhanced oil recovery and in oil souring in storage tanks and pipelines. Dual fluorescent staining and subsequent imaging by confocal laser scanning microscopy (CLSM) was used to investigate the microbial growth pattern occurring at liquid-liquid interface between diesel oil (as well as hexadecane) and aqueous medium in shake flask marine sediment microcosms. Nucleic acid binding stain SYTO 9 and lipid binding stain Nile Red were used for *in situ* visualization of bacteria and droplets of the hydrophobic substrate. Initial bacterial colonization and subsequent biofilm formation on the diesel or n-hexadecane droplets resulted in the development of floating macroscopic bioaggregates. In the laboratory marine sediment microcosms, biofilm development on diesel oil/n-hexadecane involved colonization, complex biofilm formation and break-up of biofilm aggregates. The results clearly suggest that establishment of direct contact between the substrate and bacteria through biofilm formation has a functional role in the effective utilization of hydrophobic substrates, especially n-alkanes. The method described here would enable direct visualisation and monitoring of the colonization and utilization of highly hydrophobic substrates. In addition, the bacterial diversity of mixed consortium exhibiting efficient utilization of diesel oil was studied using culture based approach to decipher the importance of consortia development. This paper highlights the significance of interfacial growth in hydrocarbon-utilization and *in situ* characterization using CLSM and fluorophores.

Keywords: Biofilm, Bioadhesion

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Impact of Irgarol 1051 on biofilm diatom and barnacle nauplii

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Structures submerged in the aquatic environment are subject to biofouling which causes extensive damage. Biofouling is one of the most serious problems currently faced worldwide by maritime industries. In nature, biofilms, consisting predominantly of bacteria and diatoms, begin to develop almost immediately after a surface is immersed. In order to solve this problem, marine coatings industries are developing antifouling products, which slowly leach out from the coatings into the marine environment. Prior to the early 1990s, organotin biocides [e.g. tributyltin (TBT) and triphenyltin] were commonly used in antifouling paints. However, research during the last 25 years has demonstrated the toxic effect of TBT on both target and non-target organisms, even at very low concentrations, thus imposing a ban on the use of this compound. This resulted in the development of copper-based paints supplemented with so-called 'booster biocides', including herbicides.

Effect of one such algicide, Irgarol 1051 on the biofilm diatom, *Amphora coffeaeformis* was assessed. Reduction in the number of *A. coffeaeformis* cells in the biofilm was observed when treated with Irgarol 1051, indicating its role as an inhibitor of photosynthetic activity. The impact of this compound on naupliar development of *Balanus amphitrite*, an acorn barnacle was evaluated through its impact on *Chaetoceros calcitrans* provided as food for larvae. Reduction in the number of cells of *C. calcitrans* was observed when treated with Irgarol 1051. When larvae of *B. amphitrite* were reared using *C. calcitrans* in presence of Irgarol 1051, their mortality increased with an increase in the concentration of Irgarol (13% at 1000ng L⁻¹ to 47% at 1000µg L⁻¹) when compared to control (6%). Nauplii reared in the presence of Irgarol showed longer development duration (8-9 days) compared to control (4-5days).

Keywords: Irgarol 1051, Biofilm, *Amphora coffeaeformis*, *Balanus amphitrite*, *Chaetoceros calcitrans*

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Application of confocal laser scanning microscopy in marine microalgal ecotoxicology studies

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Chlorination is a widely accepted method for biofouling control in cooling systems employing seawater and freshwater. Though largely effective, chlorine has undesirable environmental implications because of its effects on non-target organisms in the recipient water body. In order to realistically assess ecotoxicity of discharged biocides, rapid, sensitive, multi-species and multi-parametric techniques are desirable. Techniques that permit toxicity analysis at environmentally realistic concentration of biocides and organisms, at the same time allowing measurement at single cell level, may prove to be more sensitive and precise for ecological monitoring. Confocal Laser Scanning Microscopy (CLSM) allows *in situ* quantitative assessment of fluorescence properties of algal cells, with the added advantage that visualization and quantification are possible at single cell level. Using this technique, the effect of in-use concentrations of chlorine on marine microalgae (*Cocconeis scutellum* and *Chlorella vulgaris*) was determined. Chlorophyll autofluorescence and esterase activity determined through fluorescein diacetate (FDA) hydrolysis were used as toxicity end points. Determination of Mean Fluorescence Intensity (MFI) per cell by collecting chlorophyll autofluorescence from single cells in x, y and z- dimensions permitted reproducible toxicity evaluation at single cell level. Chlorine-induced inhibition of autofluorescence in laboratory cultures was dose-dependent. FDA staining allowed the determination of intracellular esterase activity and thereby cell viability following exposure to chlorine. Results clearly demonstrate that chlorine causes significant reduction in chlorophyll autofluorescence and esterase activity in individual microalgal cells in short-term exposure experiments. Esterase activity determined through FDA hydrolysis in single cells appears to be the more sensitive end point as compared to the chlorophyll autofluorescence. Combined autofluorescence-FDA technique described here is rapid and has clear advantages in terms of using environmentally realistic toxicant and cell concentrations.

Keywords: Chlorination, Confocal Laser Scanning Microscopy

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Biofilm diatom community structure from copper and cupro-nickel substrates: influence of exposure period and season

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Copper (Cu) and Cupronickel (70:30%; Cu-Ni) materials or coatings are widely used as components in marine structures to prevent biofouling. Hence understanding of variations in the dominant diatoms on toxic substrates would serve as a basis for selecting model species for studies related to pollution, marine biofouling and corrosion. Though biofilm formation on these materials has been reported the information on biofilm diatom community structure is limited. To address this issue a study using Cu and Cu-Ni coupons was carried out in a monsoon influenced tropical bay (Dona Paula Bay, Goa). In this study both the coupons were exposed in the bay, for short-term (1 to 4 days) as well as long-term (1 to 4 weeks) once in a season (monsoon, post-monsoon and pre-monsoon) and the diatom population was enumerated at daily and weekly intervals during short- and long term exposures respectively. In both short- and long-term exposures, the biofilm diatom community showed insignificant variation among the materials. In short-term exposure, biofilm diatom abundance and diversity increased or remained constant with exposure period whereas in the long-term exposure diatom abundance increased and diversity decreased with the exposure period. The dominance of pennate diatoms such as *Navicula*, *Amphora*, *Nitzschia* and *Thalassionema* throughout the study period indicated their potential to tolerate the toxicity of the substrata.

Keywords: Biofilm, Copper, Cupro-nickel, Diatoms, Exposure period

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Influence of non-replenished and pulsed state nutrient conditions on the fouling diatom community

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Diatoms are the dominant autotrophic forms encountered in biofilms. The fouling diatom community is made up of a consortium of various species, and cell-cell interactions play an important role in structuring diatom communities through various competitive strategies. In view of this, experiments were carried out with a two-species and a multispecies community in non-replenished and pulsed state nutrient conditions in artificial sea water. In an earlier experiment with *Navicula transitans* var. *derasa* f. *delicatula* and *Amphora coffeaeformis* (small sized pennate diatoms), the latter dominated the former irrespective of the initial inoculum only in the pulsed condition. However, in this multispecies experiment, which also included the above two species, although the initial trend was similar to the earlier experiment wherein the smaller species dominated the community, with time, the larger sized species i.e., *Odontella aurita* (centric diatom) was seen to override the other members of the community, in both the non-replenished and pulsed state nutrient conditions in terms of biomass. This shows that the structure of the community in either non-replenished/pulsed condition depends on species-specific competitive strategies. Usually, the smaller species are the “velocity adapted” species with a high maximum uptake velocity for nutrients and a high maximum growth rate. In the case of pulsed condition due to space limitation these species get dislodged from the substrata and are replaced by the larger sized species, which attach to substrata with the help of stalks. In case of the non-replenished state, the smaller cells exhibit lowered growth rates with time as the surrounding nutrient concentrations decline. Whereas the larger cells which are the “storage specialists” utilize the initial nutrient pulse for luxury consumption which enables them to survive the following period of reduced nutrient availability thereby gaining competitive superiority with increasing nutrient depletion. This information sheds light on the species succession in biofouling communities under variable nutrient conditions and will help in selecting model species for antifouling assays.

Keywords: Non-replenished, Pulsed state, Nutrient, Fouling diatom community, Velocity adapted, Storage specialists, Species succession

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Settlement Inducing Protein Complex (SIPC) of *Balanus amphitrite* – an analysis of non-canonical weak interactions in their structural stability

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Settlement Inducing Protein Complex (SIPC) from cyprid stage of barnacle, *Balanus amphitrite* plays an important role in their settlement property. Recently the protein sequence of this complex has been elucidated, however the three dimensional structure of this protein complex has not been reported yet. In this study, the three dimensional structure of a SIPC domain was studied using bioinformatics tools. The importance of non-canonical and canonical interactions in the structural stability of this modeled protein has also been studied. This study reveals that the number of non-conventional hydrogen bonding is higher than conventional hydrogen bonding to the structural stability of the proteins. Among all the interactions (CH...OC, NH...OC and OH...O interactions) between the amino acids, the % contribution is higher in main chain - main chain interactions only. In the cation- π interactions of SIPC, Lys-Phe pair shows the highest cation- π interaction energy of -5.56 kcal/mol, however more cation- π interactions are formed between Arg-Phe pairs only. Overall this study may help to understand the importance of weak interactions to the structural stability of modeled SIPC domain complex.

Keywords: Biofouling, Barnacle, Settlement Inducing Protein Complex, Non-canonical

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Recruitment responses of teredinid larvae to monospecies marine bacterial films

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Recruitment cues originating from microbial biofilms have long been understood as a potential source in triggering the metamorphosis of marine benthic invertebrates. As Turner (1971) pointed out “Approach to control, either biological or by treatment of the wood, should be centered around the behaviour and sensitivities of the larvae particularly at the time of settlement”. In general, studies on recruitment responses of marine wood boring teredinids to bacterial films are lacking. Therefore, investigations on recruitment responses of the larvae of the marine wood borer, *Teredo parksi* Bartsch against individual biofilms of four bacterial species were carried out. Experimental biofilms were developed on pine wood wafers (20 x 15 x 5 mm) using previously isolated and purified cultures obtained from wooden panels exposed in natural sea water. It was observed that recruitment response of the borer larvae differed from bacterial biofilm of one species to the other. Thus, this study elucidates the importance of cues emanating from bacterial films in the recruitment of teredinids on marine wood substrata.

Keywords: Recruitment response, Bacterial films, Teredinids, Larvae, *Teredo parksi*

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Gut microflora of *Mytilopsis sallei* (Recluz) occurring along pollution gradient at Visakhapatnam port, east coast of India

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Mytilopsis sallei (Recluz) is a marine invasive species spreading to many harbours around the world. In Visakhapatnam harbour, it was first noticed during late 1960s. Subsequently, it has spread in the entire inner harbour area of the port. The mussel typically prefers polluted waters and has been recorded from such zones in Visakhapatnam and Mumbai. In an attempt to investigate the mechanisms that impart an ability to successfully inhabit the polluted waters to this bivalve, gut flora of the animals occurring in three sites along pollution gradient in Visakhapatnam port were analyzed. The analyses revealed most of the bacteria to be Gram -ve. The microflora identified were common to all animals collected from the three sites but for *Xanthobacter* sp. and *Serratia* sp. additionally occurring in *M. sallei* from the Shipyard jetty, where extensive heavy metal inputs prevail due to shipping activities. The results are discussed in the light of the nature of these bacteria and their possible role in bioaccumulation of pollutants.

Keywords: *Mytilopsis sallei*, *Xanthobacter*, *Serratia*

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Macro-fouling communities of Kudankulam coastal waters, east coast of India

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Information on the organisms, forming the fouling complex is necessary in view of the damages they cause to various marine structures and for a better understanding of the protective measures. The accumulation of organisms on an exposed surface depends obviously on the species which are naturally present at a given site as well as their ability to attach and grow on that surface. Although, biofouling studies from the south east coast of India have been extensive, there is a lack of information on the fouling potential of Kudankulam coastal waters, where a new Mega Power Project is now under construction. In the present study, an attempt has been made to investigate the macro-fouling community of Kudankulam coastal waters. Wooden test panels (10x10x2cm) were exposed in the coastal waters for a period of two years, from May 2003 to April 2005. The test panels exposed in the first week of every season were retrieved at the end of that season. Barnacles, mussels, ascidians, polychaetes, amphipods and seaweeds were the common fouling groups settled on the test panels. Temporal variation in species composition was observed with respect to seasons. While barnacles and mussels were abundantly seen on panels exposed during pre-monsoon and monsoon seasons, ascidians were dominant during post-monsoon season. The hydrological parameters of the coastal waters were also monitored throughout the study period to analyze the possible influence of environmental conditions on the fouling activity.

Keywords: Biofouling, Fouling community, Kudankulam; Gulf of Mannar

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Epibiosis in Mangroves

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Mangroves interlink land and sea and are a unique habitat that supports diverse organisms due to high productivity levels. The mangrove ecosystem harbours variety of micro and macro flora and fauna. Attachment of epibiotic communities, particularly, barnacles to mangrove seedling and roots, has been suggested to be an important factor affecting their survival. In order to elucidate the implications of epibiosis in mangrove environment, sampling was carried out in the Mandovi estuary (Goa, West Coast of India). The mangrove epibiotic community at this locality is dominated by barnacle (*Balanus amphitrite*) followed by oysters (*Crassostrea cucullata*). Simultaneous observations were also made on the recruitment of barnacles on inert material and saplings planted in the area. Observations on the recruitment pattern of epibionts indicated low recruitment of barnacles during pre-monsoon (23 ind dm⁻²; February-May) and monsoon (10 ind dm⁻²; June-September) as compared to high settlement during the post-monsoon (60 ind dm⁻²; October-January) season. In addition, observations on epibionts on mangroves from selected localities in the estuarine system of Goa are also presented in this poster.

Keywords: Epibiosis, Mangrove, Barnacle

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Biofouling community in cooling circuits of a coastal power plant

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Cooling water circuits of power stations operating on a once through mode serve as excellent places for settlement and growth of biofouling organisms. Cooling circuits are characterised by flowing water that brings in fresh nutrients and oxygen. Different sections of the cooling circuit have unique geometries, structural materials, flow paths and environmental conditions (high velocities, elevated temperatures, presence of biocides). In the present study, the fouling community in the process water-cooling circuit of a nuclear power plant was assessed. The process water removes heat primarily from the moderator (heavy water) system; in addition it also cools a number of heat exchangers of the auxiliary system. Seawater is used for cooling the process water. Seawater is drawn from an offshore intake point at a design rate of $35\text{m}^3\cdot\text{s}^{-1}$. Seawater at this point is treated by continuous low-level chlorination ($0.2\text{-}0.3\text{ mg L}^{-1}$ as total residual oxidants) with twice-a-week booster dosing ($0.4\text{-}0.6\text{ mg L}^{-1}$ TRO). The fouling community at the intake was dominated by the green mussel *Perna viridis* with a load of 5.2 kg m^{-2} . Subsequently, the water reaches the pump house (fouling load 2.4 kg m^{-2}), which experiences continuous low level chlorination ($0.2\text{-}0.3\text{ mg L}^{-1}$ TRO), where the community was dominated by pearl oysters (*Pinctada fucata*), gorgonians and to some extent by green mussels. The water then passes through a circular concrete tunnel (6.3 kg m^{-2} , dominated by green mussels and barnacles) before it reaches the valve pit comprising of mild steel pipelines. Fouling load was the highest in these sections ($6.6\text{ - }9.36\text{ kg m}^{-2}$ dominated by barnacles and green mussels). Active bromide is dosed ($0.15\text{ - }0.2\text{ mg L}^{-1}$ TRO at outfall) at this point, which resulted in a reduced load of 3.99 kg m^{-2} (dominated by barnacles) in these sections. The water then enters a rectangular concrete tunnel (6.4 kg m^{-2} , dominated by green mussels and barnacles) before it enters the heat exchangers (4.1 kg m^{-2} dominated by barnacles). After passage through the heat exchangers, the warm water ($30\text{-}33^\circ\text{C}$) is discharged at an onshore discharge (6.33 kg m^{-2}), which was colonized by barnacles and the brown mussel *Brachidontes striatulus*. Fouling load was comparatively low (0.58 kg m^{-2}) in the main condenser discharge section, where water temperatures were around $38\text{-}40^\circ\text{C}$. The paper presents data on the colonization pattern and correlates it with the environmental conditions, emphasizing the species-specific tolerance in specialized environmental conditions within the cooling circuit.

Keywords: Macrofouling, Barnacles, Oysters, Biofouling Load, Chlorination, Bromination

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Vertical and temporal stratification of foulants in Chennai harbour

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Epibenthic assemblages settling on hard substratum in the marine environment have been used to study interaction among larvae, local hydrodynamic conditions, physical, chemical nature of substratum (type, topography, orientation depth of immersion), antifouling property and bioinvasions. Spatial variations reflect on the dynamics of benthic communities whereas temporal variations reflect more on the structure of adult populations. Biofouling load and community structure on different metallic surfaces (mild steel, cupronickel 90:10, stainless steel, and titanium) and coatings (galvanized iron and copper based paints) was studied at the surface and 6 m depth over an eight month period. The test substrates were exposed using a moored raft near the entrance to the harbour breakwater zone. Long term and monthly panels were used in the study. Substratum specific accumulation of organisms showed maximum load on mild steel surfaces (12 kg cm^{-2}) followed by stainless steel (10.7 kg cm^{-2}), galvanized iron (7.2 kg cm^{-2}), titanium (6.3 kg cm^{-2}), copper based antifouling coating (2.8 kg cm^{-2}) and cupro-nickel 90:10 (1.0 kg cm^{-2}). In comparison at 6 m depth maximum loading was observed on stainless steel surfaces (5.2 kg cm^{-2}), followed by mild steel (4.6 kg cm^{-2}), titanium (4.0 kg cm^{-2}), galvanized iron (0.9 kg cm^{-2}), cupronickel (0.3 kg cm^{-2}) and copper based antifouling coating (0.1 kg cm^{-2}). Barnacles (*Balanus amphitrite amphitrite*) and hydroids were the initial colonizers on substrates. Peak settlement was observed in the month of March after ninety days of exposure where the fouling community was dominated by the serpulid polychaete *Hydroides norvegicus* and the seaweed *Gracillaria edulis*. Subsequently the fouling community was dominated by barnacles, colonial and solitary ascidians with increase in exposure period. Even though fresh settlement of green mussels was observed on harbour piers their settlement was not observed on test substrates. In comparison short term panels introduced and retrieved monthly revealed a loading of $0.4 - 4.7 \text{ kg cm}^{-2}$ on titanium, $0.1 - 4.1 \text{ kg cm}^{-2}$ on mild steel $0.9 - 4.1 \text{ kg cm}^{-2}$ on stainless steel, $0.02 - 1.2 \text{ kg cm}^{-2}$ on galvanized steel, $0.03 - 0.1 \text{ kg cm}^{-2}$ on cupronickel and $0.05-0.5 \text{ kg cm}^{-2}$ on copper based antifouling coating. Results showed that settlement densities on fresh surfaces were higher compared to already colonized surfaces (long term panels). Similarly reduced settlement was observed at 6 m for all the surfaces tested. Results are discussed in view of species-specific colonization of foulants on material surfaces.

Keywords: Macrofouling, Biofouling load, Barnacles

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Response of green mussel *Perna viridis* to antifouling measures

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The green mussel *Perna viridis* is a major macrofouling species in the cooling water circuits of Madras Atomic Power Station (MAPS), located at Kalpakkam. Low-level continuous chlorination ($0.2\text{-}0.3\text{ mg L}^{-1}$ as total residual oxidants) is practiced with twice a week booster dosing ($0.4\text{-}0.6\text{ mg L}^{-1}$ TRO) for fouling control in the cooling water circuits. This biocidal dose and regime were found to be inadequate as fresh settlement was observed in the conduits, in spite of the treatment regime in practise. The reduced biocidal activity of chlorine may be attributed to two reasons, viz.: 1) chlorine reacts with seawater to form hypochlorous acid (HOCl), which is highly unstable at higher pH values similar to those observed in seawater (8.2) and disassociates to H^+ and OCl^- ions, the latter being a weak biocide. Compounded to this, mussels can detect chlorine levels as low as 0.1 mg L^{-1} in water and are able to tide over continuous low-level /intermittent chlorination by closing their shells. 2) There is large-scale release of ammonia from the fouling community in the intake tunnel of MAPS, which reacts with hypochlorous acid converting it into mono and dichloramines. The present study was initiated to understand to what extent the above attributes had a measurable effect on the physiological response of the green mussel *Perna viridis* to chlorination. Green mussels were collected and acclimatised in the laboratory for 48 h. The mussels were segregated according to their size and individual mussels were introduced into airtight polypropylene containers with filter-sterilized aged seawater and an initial chlorine residual of 0.7 mg L^{-1} . After different time intervals (1, 3, 5, 7, 9, 11, upto 38 hours) the animals were removed and flesh weight determined. Dissolved oxygen, pH, free and combined residual oxidants, ammonia, nitrite, nitrate and phosphate in the water were measured. Parallel controls (seawater with chlorine and seawater with mussels but without chlorine) were run alongside. Oxygen consumption by mussels decreased following chlorination. About 50% reduction in free available chlorine was recorded within one hour of incubation with mussels. The ammonia excreted by the mussels reacted with the free available chlorine, resulting in an increase in monochloramine levels with time. Differences in release of inorganic nutrients like phosphate, nitrite and nitrate with respect to treated and untreated mussels were not significant. Results indicate that the reduction in biocidal efficiency of chlorine in the cooling water circuit of MAPS may be attributed to the organic loading by the tunnel community.

Keywords: Green Mussel, Chlorination, Monochloramine, Ammonia, Nutrient release

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Seasonal succession of biofouling communities in coastal waters of Kalpakkam in the vicinity of a nuclear power plant, east coast of India

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The coastal water of Kalpakkam is used for dissipating heat, extracted from the nuclear reactors of Madras Atomic Power Station (MAPS), where biofouling is an operational problem in its cooling water system. Studies on biofouling in the coastal waters of Kalpakkam were started in 1984 and continued upto 1991. On the basis of the findings, a suitable biofouling controlling measure (low dose continuous chlorination) was implemented for smooth operation of the cooling water system of MAPS. A Prototype Fast Breeder Reactor (PFBR) of 500 MW (e) capacity is under construction, which is going to use about 30 m³/s of seawater for cooling and would be operational by 2010. In view of the fact that an update of data on biofoulers is not available, it was essential to study the biofouling potential of Kalpakkam coastal water with the following objectives in mind. To find out

- a) any change in the settlement pattern of biofoulers after a gap of 15 years
- b) seasonal succession of macrofoulers
- c) the present dominant species and their breeding pattern
- d) the impact of tsunami on biofouling assemblage
- e) any invasion by foreign species

Seasonal distribution and community succession of macrofoulers were studied using teak wood panels (12 x 9 x 0.3 cm) in the coastal waters of Kalpakkam for a period of one year (May, 06- Apr. 07). The panels were suspended at 1 m depth from the lowest low water mark and categorized into three series of observation (weekly, monthly and cumulative at 30 d intervals). The major fouling organisms observed were barnacles, mussels, hydroids, polychaete worms, flat worms, sea anemones, oysters. Considerable faunistic and biomass variations were noticed with respect to different time periods. On the weekly panels, the maximum fouling biomass was 11 g/100 sq cm, whereas on the monthly and cumulative panels, it was 116 g/100 sq cm and 685 g/100 sq cm (in 150 d panel) respectively. A comparison with the biomass values reported from elsewhere shows that biomass build-up in Kalpakkam coastal waters is relatively high. Weekly and monthly panels were dominated by barnacles (99 %- weekly, 85%- monthly) and other crustaceans (62%- weekly, 64.1%- monthly). However, in the cumulative observation, mussels (especially, green mussel, *Perna viridis*) were found to be the dominant community from the month of July and gradually succeeded the barnacle population. With the increase of mussel population, it was found that the 150d old panel was totally covered with mussels (95%), without any barnacles. The two unique features of this study are a) for the first time photographs of each series is taken and available in digital form and b) also for the first time fouling study at an interval of 7 d (weekly) is available. The other striking feature observed was that the fouling pattern was significantly different between successive weeks. Moreover, it was also observed that the fouling concentration of Kalpakkam coastal water has elevated during post-tsunami period as compared to the pre-tsunami findings. Other parameters like fouling intensity, % of area coverage, diversity indices and the influence of coastal water hydrography on the pattern of settlement and succession of biofoulers are discussed in the paper. It is presumed that the result of this study can be used to establish a more effective control regime than the present one.

Keywords: Biofouling communities, Kalpakkam, Nuclear power plant, East coast of India

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Organotins in fishes, clams and crabs collected from Mumbai fish market

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Attachment and growth of organisms on a surface is generally known as biofouling. The best example of biofouling is growth of organisms on the hull of a ship. Biofouling on any industrially useful surface can cause considerable economic losses. This is because biofouling can increase frictional drag on the ship, thereby increasing fuel consumption, induce metal corrosion, impair heat transfer, etc. In order to reduce economic losses, paints containing antifouling compounds are applied on the surface to be protected. One of the most commonly used antifouling compounds is Tributyltin (TBT). This compound is highly toxic to many organisms and thus very effective in controlling fouling over a period of 3 to 4 years. However, when released into marine waters it is highly toxic to non-target organisms. TBT can cause high larval mortality, shell deformation, retardation of cell growth, imposex etc. Because of these concerns, use of TBT has been banned in several countries. In India, TBT is used in antifouling compound, and there is no ban on its use. Moreover, not much is known about the organotin levels in economically important fishes, clams and crabs. In view of this, it is essential to monitor the distribution of TBT, and other organotins in edible fishes, crabs and clams.

In this paper, we present data on the distribution of organotins in edible fishes, clams and crabs. In fishes TBT, dibutyltin (DBT), monobutyltin (MBT), triphenyltin (TPT), diphenyltin (DPT) and monophenyltin (MPT) were present at various levels. Total butyltins and phenyltins varied from 10 to 145 ng/g dw, and from undetected to 38.6 ng/g dw, respectively. Most of the fishes contain low levels of TBT and high DBT/TBT ratio indicating that the inputs were not fresh. In contrast, higher amounts of TBT were present in clams (114 to 128 ng/g) and crabs (15 to 85 ng/g), suggesting that these organisms have more potential for TBT bioaccumulation. Interestingly, both showed very low DBT/TBT ratio suggesting fresh inputs. Phenyltins were present at very low levels or were absent in most of the organisms.

Our data suggest that organotin contamination was moderate in fishes and relatively high in clams and crabs. Nevertheless, the levels are good enough to cause harmful effects in these organisms which may be of concern to human health.

Keywords: Organotins, Fishes, Clams, Crabs, DBT/TBT ratio

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Effects of TBT on the phospholipid fatty acid composition of the marine bacterium, *Pseudomonas* sp. CE-2

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TBT (tributyltins) are organic compounds, containing three alkyl groups attached to the tin atom exhibiting biocidal activity against a wide range of organisms, hence are used as antifouling agents in paints applied for marine vessels. Its increased use as an antifouling agent has resulted in high concentrations of TBT in the water column, sediments and tissues of marine organisms, thereby causing contamination of aquatic and marine environments. TBT being a hydrophobic molecule, interacts with the membrane leading to toxicity, thus membrane adaptation capability could determine the survival of the cell. Phospholipids are the most important group of lipids, as they form the main framework of the cell membrane in microorganisms. However little is known about the effect of TBT on PLFA concentration and composition in bacteria. In view of this, a study was attempted to assess the effect of TBT on the PLFA composition of the marine bacterium, *Pseudomonas* sp. CE-2.

CE-2 culture was grown for 6 days using BSS (Basal Salt Solution) medium containing 0.1 % glucose and the medium was supplemented with different concentrations of TBT (0 µg/l, 1.21 µg/l, 6.05 µg/l, 12.10 µg/l). Cell biomass measured as cell dry weight decreased while total PLFA increased with the increase in TBT concentration. A total of 27 PLFAs were identified from the CE-2 cells using GC and GC-MS. Branched PLFAs (a- anteiso and i- iso), which includes a-C_{15:0}, i-C_{16:0}, i-C_{15:0}, i-C_{17:0} and i-C_{14:0}, and other PLFAs C_{16:1}, C_{16:0} and C_{12:0} were most abundant accounting for 95 % of the total PLFAs. The a-C_{15:0} PLFA was the most abundant fatty acid in the CE-2 culture and its abundance decreased in the presence of TBT. Similarly, i-C₁₆ and i-C₁₇ concentrations generally decreased whereas C_{16:1} and some other fatty acids increased in the TBT treated cells. It was interesting to note that C_{22:2} PLFA was exclusively produced by CE-2 in response to TBT contamination. In conclusion, the presence of TBT influences the PLFA profile of the CE-2 culture by changing the relative concentrations of the PLFAs and/or by synthesizing new or removing some PLFAs from the lipid. Moreover, there is an overall decrease in the growth of the CE-2 cells when grown in the presence of TBT. Therefore, the change in the PLFA composition can be used as an indicator to evaluate TBT contamination in the marine environment.

Keywords: TBT, PLFA, GC-MS, CE-2

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Effect of TBT on the carbohydrates production by *Pseudomonas* sp. CE-2, a marine fouling bacteria

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Organotins are toxic to microorganisms. Trisubstituted organotins (TBT) are considered more toxic than disubstituted (DBT) or monosubstituted (MBT) compounds. TBT (tributyltins) are organic compounds, containing three alkyl groups attached to the tin atom exhibiting biocidal activity against a wide range of organisms to reduce economic losses due to fouling, hence TBT are used as antifouling agents in paints applied for marine vessels. Use of TBT in antifouling paints and other several economic benefits has resulted in high concentrations of TBT in the water column, sediments and tissues of marine organisms, thereby causing contamination of aquatic and marine environments. Carbohydrate is an important compound in the biofilm formation in marine environment. TBT has physiologic and metabolic effects on the bacterial growth and cell activity. Currently, very little information is available about effect of TBT on the extra-cellular and cellular carbohydrate production by bacteria.

CE-2 culture was grown for 6 days using BSS (Basal Salt Solution) medium containing 0.1 % glucose and the medium supplemented with different concentrations of TBT (0 µg/l, 1.21 µg/l, 6.05 µg/l, 12.10 µg/l). Extracellular polysaccharides (PCHO) (except 12.1 µg/l) increased with increasing TBT concentration. General metabolic activity and URA/PCHO ratio effectively increased with increase in the TBT concentration. More interestingly, both extracellular as well as cellular acidic sugars such as, uronic acids (URA) showed linear positive relation whereas neutral sugars showed inverse relation with TBT concentration. The abundance (wt%) of rhamnose (Rham) decreased (58.7 to 38.2) with an increase in TBT concentration. In contrast, glucose (Glu) (wt%) abundance increased (15.7 to 34.1). The URA composition by HPLC analysis showed that the presence of TBT inhibited glucuronic acid production as well as decrease in galactouronic acid production, thus suggesting that other uronic acids can be induced by concentration of TBT.

Overall, TBT influenced cellular and extracellular carbohydrate production, monosaccharide composition and cell growth of CE-2 culture. Data suggests that, acidic carbohydrates may serve as an indicator of TBT contamination.

Keywords: TBT, Extracellular, Carbohydrate, Uronic acids, Monosaccharides

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Effect of TBT on the L -and D- amino acid composition of a marine bacterium *Pseudomonas* sp. CE-2

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Tributyltin (TBT) is a highly toxic chemical to both eukaryotic and prokaryotic organisms. TBT is been used commercially in variety of applications such as in agriculture biocides, wood preservative, plastic stabilizers and as a component of antifouling paints, which eventually reaches the aquatic environment. In aquatic environments, microorganisms play an important role in the degradation of organic compounds. TBT being a hydrophobic organic pollutant, its toxicity depends on its interactions with biological membranes. In microorganisms, amino acids are the major building blocks of protein and makeup a large fraction of organic biomolecules. In order to survive in the presence of this toxic compound, bacteria could adapt by enhancing production of some amino acids. However, no information is available on the effects of TBT, on the amino acid concentration and composition in bacteria. Therefore, the aim of the present study was to assess the effect of TBT on the amino acids in a marine bacterium, *Pseudomonas* sp. CE-2.

CE-2 bacterial cells were grown in the BSS (Basal Salt Solution) medium containing 0.1% glucose and various TBT concentrations (0, 1.21, 6.05, 12.10 $\mu\text{g/l}$) over a period of 6 days. The cells were analyzed for L- and D- amino acids by HPLC. It was observed that the L- and D- amino acid concentration and yield decreased with the increase in the TBT concentrations. In order to assess the effect of various TBT concentrations on the individual amino acids, a molecular level analysis of the cells was done. We observed 14 individual L- amino acids and 4 D-amino acids in the CE-2 cells. The mole % of cellular amino acids such as aspartic acid, glutamic acid, alanine and valine increased while the cell wall amino acids such as glycine plus threonine decreased with TBT concentrations. Further increase in the TBT concentration, resulted in a relative increase in the mole % of serine, glycine plus threonine and ornithine. The analysis of bacterial cell wall peptidoglycan, showed the presence of D-aspartic acid, D-glutamic acid, D-alanine and D-serine. However, relative distribution of these D-amino acids was not influenced by TBT levels. The above results prove that TBT affected the L- amino acid composition of the CE-2 culture.

Keywords: TBT, Bacteria, L- and D- amino acids, HPLC

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Epibiotic chemical defense of the marine sponge *Ircinia fusca* (Carter): Elucidation of temporal variations through laboratory and field assays

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Sponge needs to protect itself from a wide gamut of epibiotic organisms and this threat is temporally variable. Tropical marine sponge *Ircinia fusca* was evaluated for its epibiotic chemical defense through laboratory assays with bacteria, diatoms (*Amphora coffeaeformis* and *Navicula delicatula*), barnacle (*Balanus amphitrite*) larvae and field assays. Temporal variation was not observed in the antibacterial activity of crude extract. However the efficacy of different polarity fractions was temporally influenced. The mid-polar and polar partitions of the crude extract were effective during all the collection periods and the non-polar petroleum ether fraction displayed strong antibacterial activity during increased bacterial threat in the environment (warm months). In the control of diatom epibiosis, the non-polar and mid-polar partitions of the sponge extract were effective round the year. The field evaluation of sponge extracts for antifouling activity at their natural concentrations showed temporal variability. Antifouling activity at times did not correspond to the intensity of antibacterial activity. Laboratory assay with *Balanus amphitrite* larvae and field antifouling evaluation revealed that the sponge extracts exhibit stronger activity during peak larval recruitment period. It appears that the sponge modulates its epibiotic chemical defense according to the nature and intensity of the threat.

Keywords: Sponge, Epibiosis, Chemical defense, Antifouling, Temporal variation

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Potential antifouling metabolites from benthic marine invertebrates

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Competition among benthic marine invertebrates for living space on hard substrata is intense, particularly in the photic zone. As a result, complex communities of so-called fouling organisms often densely populate marine surfaces. Biological surfaces contribute to spatial niches in such environments; however, hosting a fouling community may have significant detrimental effects on the basibiont. In clear contrast to inanimate marine substrata, the surfaces of many algal and soft-bodied invertebrate species such as seaweeds, sponges and soft corals are virtually free of epibiotic macroorganisms. Soft-bodied marine sessile organisms, e.g. corals and sponges, have been widely investigated and demonstrated to defend themselves against epibiosis. They produce biologically active secondary metabolites having anti-bacterial, anti-algal, antifouling and anti-fungal properties and are promising potential sources of non-toxic or less-toxic environment friendly antifouling compounds. The isolated compounds belong to the group of terpenoids, steroids, phenolics, brominated hydrocarbons, brominated tyrosine derivatives and saponins. In this presentation, knowledge about these antifouling compounds identified so far will be highlighted.

Keywords: Fouling, Secondary metabolites, Anti-bacterial, Anti-fungal, Anti-fouling

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Seasonal variations in organotins in the waters of the Dona Paula bay, west coast of India

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Organotins have been used since the 1970s as active agents in wide range of applications including stabilizers in the PVC industry, plastic additives, industrial catalysts, insecticides, fungicides, bactericides, wood preservatives and antifouling paints. TBT- based antifouling paints prevent the attachment of algae, barnacles, bacteria, tubeworms, mussels and invertebrates on ship hulls. These paints are highly effective in controlling fouling on industrially useful surfaces. These antifouling paints are the main source of organotins in coastal waters. When released into water, organotins, especially tributyltins (TBT) are highly toxic even at $<2 \text{ ng l}^{-1}$ to non-target organisms. TBT compounds cause many harmful effects including shell thickening, shell deformation, retardation of growth and imposex. In view of this, there is a need to monitor the levels of TBT in coastal waters. As we do not have much information on the distribution and seasonal variations of TBT in our coastal water, this investigation was planned to assess the seasonal variations of organotins in the waters of the Dona Paula Bay, west coast of India.

Surface sea water samples from Dona Paula Bay, were collected at weekly intervals during March 2007 to August 2007, and these samples were analysed for organotin compounds such as TBT, dibutyltin (DBT) monobutyltin (MBT), triphenyltin (TPT), diphenyltin (DPT), monophenyltin (MPT) using GC-MS system. The concentrations of TBT, DBT and MBT varied between 14 - 37, 8 - 20 and 11- 28 ng l^{-1} respectively. TPT, DPT and MPT were not detectable. It was observed that the highest levels of TBT, DBT and MBT were recorded during May followed by April and March 2007. This could be due the reason that shipping and tourism activities are very high during these months. The observed levels are high enough to cause harmful effects in marine organisms. Moreover, it is essential to continue the monitoring of organotins distribution in the areas affected by shipping activities.

Keywords: TBT, DBT, MBT, MPT, DPT, TPT, Water sample, Dona Paula Bay, West coast of India

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Nemic bioinvasion

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Bioinvasion is the category of environmental degradation and commonly termed as biopollution. The exotic species of biota invading local ecosystem may induce long-term effects on host population. The nematode genus *Dichelyne* is an excellent example of invasive species in fish host (Catfishes) in India. This genus *Dichelyne (Cucullanullus) minutus* was reported in 1819 from marine fish host (Family: *Mugilidae*) in Black Sea. Later the fresh water species of this genus *D. (C.) cotylophora* was reported in 1917 from North America. In India the genus *D. (Neocucullanullus) longispiculum diacanthus* and *D. (N.) wallagonia* were reported in 1961 and 1977 from the marine habitat on the east coast (Bay of Bengal) while the first report of fresh water species of *D. (N.) thapari* was reported in 1986 from riverine ecosystem at district Kanpur. The distribution pattern of the genus *Dichelyne (Neocucullanullus) marinus.n.sp.* and *Dichelyne (Capoorina) allahabadensis subgen.et.n.sp.* from marine habitat of Goa as well as fresh water habitat of Allahabad confirms its dispersion along the east coast (Bay of Bengal) to west coast (Arabian sea). Zooplankton are an intermediate host of cyst forms of this nematode species; such intermediate hosts could be carried during ballasting and deballasting shipping activity.

Keywords: Bioinvasion, Biopollution, *Dichelyne (Capoorina) allahabadensis subgen.et.n.sp.*, *Dichelyne (Neocucullanullus) marinus.n.sp.*, Nematodes, Catfish

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Hard substrate community at Mormugao Port, West Coast of India: A bioinvasion perspective

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Bioinvasion through shipping has been recognized as a growing environmental threat. Detection of bioinvasion demands careful and sustained monitoring to achieve detailed information on biodiversity and ecosystem functioning. Under the Ballast Water Management Program, such an initiative is underway at some of the major ports in India. Observations carried out to study biodiversity of hard substrate community in the vicinity of Mormugao Port, Goa, indicated the presence of 120 different types of organisms. Among these, 77 were previously recorded whereas 20 species are new reports from the region. For remaining 23 types, the taxonomy needs to be detailed out. An overview of biodiversity of hard substrate community is presented which will serve as a basis for further bioinvasion studies.

Keywords: Bioinvasion, Shipping Biodiversity, Hard substrate community, Mormugao port

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Demersal marine fish community from Goa, central west India- A search for rare species

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The estuarine and shelf waters of Goa, Central West India (up to 20 m depth) are potential fishing grounds. The region harbors substantially rich diversity of demersal fish, crustaceans and miscellaneous groups. In view of the above, intensive sampling involving 40 offshore and 1 inshore trawl operations were carried out during the tenure of study. Altogether, 123 species of major faunal groups have been identified. 14 species of finfish are reported for the first time from the study area. A reef fish, *Caesio cuning* was observed for the first time from the West Coast of India. The present poster attempts to focus on the bio-geography and endangered status of 4 newly reported species listed in the IUCN Red List of Endangered Species, viz. *Aetobatus flagellum*, *Glaucostegus granulatus*, *Rhinobatos obtusus* and *Epinephelus coioides*.

Keywords: Rare species, Demersal fish, Goa, Fishing grounds, Endangered species

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Mumbai harbour: A gateway for introduction of marine organisms?

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In recent times bioinvasion has achieved great impetus due to environmental implications and posing human health hazard and loss of economy. In view of this, the status of Mumbai harbour marine environment from the perspective of bioinvasion was reviewed. The harbour environment was surveyed on three different occasions during 2001 to 2002. The samples representing macrobenthic fauna, zooplankton and hard substrate community exhibited changes in their community structure. Verification of earlier records from the area suggests that some species are new to the locality. The paper presents an account of all the newly reported species in Mumbai harbour and the vectors facilitating such an introduction is discussed.

Keywords: Bioinvasion, Mumbai harbour, Zooplankton, Hard substrate community, Macrobenthic fauna

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A status on the census of hard substrate community from Mumbai harbour, India

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Hard substrate community structure provides a basis for biodiversity and biofouling potential in the environment. A census on hard substrate community on a regular basis would also provide a base for detecting introduction of alien species in the locality. In view of this intensive sampling was carried out in Mumbai and Jawaharlal Nehru port area as a part of Global Ballast Water Management programme, an initiative of International Maritime Organization/UNDP/Global Environmental Facility, on three different occasions during 2001 to 2002. The study recorded 29 species of hard substrate community and 14 associated fauna. Acorn barnacle *Balanus amphitrite* and tube dwelling polychaete *Protula tubularia* were the dominant hard substrate communities recorded from the area. *Protula tubularia*, with no previous records from Indian waters, appears to be an introduction in the locality. The bivalve *Mytilopsis sallei*, which has been reported earlier as an invasive species in Indian waters, was mostly found restricted to enclosed habitat within the ports. A comparative account of the hard substrate community, based on the literature available, indicates the presence of 15 species which are reported for the first time from this environment. From this observation it is possible to envisage that the hard substrate community structure in Mumbai harbour environment is changing, probably due to the ever increasing human perturbation.

Keywords: Hard substrate community, *Balanus amphitrite*, *Protula tubularia*, *Mytilopsis sallei*, Mumbai harbour

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What do barnacle larvae feed on? Implication in biofouling ecology and marine bioinvasion risk assessments

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Barnacles can travel either as adults, growing on ship hulls or through their planktrophic larval forms in ballast water tanks thus making the organism capable of using both ballast water and hull fouling vectors to invade new environments. The success of introduction through ballast water depends upon the capability of the larvae to survive the dark and hostile conditions within the ballast tanks whereas in the case of fouling vector the capability of the larvae to survive in the alien environment and compete for space is of paramount importance. Generally larval development in barnacles (eg. *Balanus amphitrite*) includes planktrophic larval stages followed by pre-settling cyprid instar. Earlier studies have shown that availability of food during naupliar development is of critical importance to successful metamorphosis of the cypris larva. Traditionally barnacle larvae are raised in the laboratory providing mono-algal cultures of diatoms as food organisms. Such a luxury may not be the case in the natural environment or inside the dark ballast water tanks of the ships.

Observations were made to quantify the food available for the nauplii in a tropical estuarine environment influenced by monsoon and characteristic temporal variations in the phytoplankton abundance and diversity (Zuari estuary, West Coast of India). Results indicate that the percentage of defecating larvae (an indicator of food consumed) was comparatively higher during the pre-monsoon season. However, the average number of fecal pellets defecated by a larva remained constant throughout the period of observation. The maximal number of larval defecation observed during the pre-monsoon period coincided with the reduction in chlorophyll *a* concentration in the water column. These observations indicate a possible shift in the food available for the larvae. As the fecal pellets did not always have remnants of diatom frustules, it is possible to say that the larvae survived on food material other than diatoms. The results of settlement and recruitment study of the barnacle *Balanus amphitrite* in the vicinity pointed out that such shifts in the food of the larvae can have far reaching implications on its recruitment. In view of this it is important to consider the consequences of such changes to the availability of food for the larvae within the ballast tanks when one postulates the risk of translocation of organisms with such planktrophic larval developmental pathways.

Key words: Barnacle larvae, *Balanus amphitrite*, Ballast water, Hull fouling, Bioinvasion, Fecal pellets

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Changes in copepod population along the coast of Goa, India

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Copepods are the dominant zooplankton groups found all over the world. They play a vital role in structuring of the food web. Copepod population in a particular area largely depends upon the primary production of the area thus plays a key component in shaping the pelagic ecosystem. The area under study is a tropical mesotrophic environment influenced by south west monsoon. In order to evaluate changes in the population of copepods, the data collated from literature (since 1970's) is compared with observations carried out through Ballast Water Management Programme India (2005-2006). Efforts are made to delineate the changes in copepod population and the results indicate a decrease in the abundance of copepods over the year.

Keywords: Zooplankton, Copepods, Food web, Primary production, Goa

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Is there a new species of Paracalanidae along the west coast of India?

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Transport of biota through ballast water from one bioregion to other is now well recognized. The catastrophic damages caused by marine bioinvasion have also been documented. Bioinvasion scenario of a given region depends upon how best we know the biodiversity. In order to augment such information along the west coast of India, intensive sampling in major ports, is under way through ballast water management programme. The efforts include quantification of zooplankton biodiversity. The observations show that a calanoid copepod species belonging to the family Paracalanidae is abundant. Morphological characteristics of this species indicate that it is probably a species of *Paracalanus* and is different from its congeners available in literature. Scanning electron microscopy of its 5th pair of swimming legs indicates the presence of 6 teeth-like structures along its inner terminal spine and 2 small, stiff spines at the end of the second segment. Such characters have not been reported in any other species of *Paracalanus*. As the genus *Paracalanus* has conflicting/overlapping taxonomic status with the genus *Parvocalanus*, a comparison of the species being reported is made with species belonging to both genera. From the information available at this point of time, it appears to be a new species of *Paracalanus* and further efforts are underway to elucidate its taxonomic status.

Key words: Copepod, Paracalanidae, *Paracalanus*, *Parvocalanus*, West coast of India, Ballast water, Bioinvasion

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Does *Limnoria* (Isopoda: Crustacea) pose potential threat as invasive species in Indian waters?

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Commonly called as “gribbles”, limnorids are a group of tiny (<4mm) marine isopods under the Class Crustacea. These forms along with three other main groups, namely, pill bugs (sphaeromatids), piddocks (pholadids) and shipworms (teredinids) constitute an important assemblage of animals collectively termed as ‘wood borers’. These organisms invade timber of all kinds including bamboo, dead wood, decaying live mangrove trunks and roots, etc. for food and shelter. These isopods also bore into algae and sea-grasses besides attacking certain man-made materials. These borers infest timber facilities erected along water and harbour fronts and cause substantial material, manpower and monetary losses. Annual damages arising from the destructive activity of these organisms around the world are estimated to run into several million dollars.

The presence of limnorids in Indian waters was first reported by Stebbing in 1905 from Minicoy Islands. Three decades later, Barnard (1936) recorded their occurrence from Andaman Islands. Again after two decades, Palekar and Bal (1957) noticed their incidence in Mumbai. Subsequently, they were also observed from Andamans, Chennai, Ramnad, Mandapam, Karwar, Mumbai and Lakshadweep Archipelago by different researchers. This scenario indicates a gradual increase in species diversity as well as spread of limnorids along the tropical coasts of India. Further, the works of Santhakumaran (1969), Karande (1978), Karande et al. (1993) and Swami and Udhayakumar (1997) also reveal increasing destructive activity of these marine borers at various Indian ports.

At this alarming juncture, it is shocking to realize that these animals have invaded into Visakhapatnam waters on the north east coast of India also. Until recently, the harbour and its surroundings were infested with sphaeromatids, pholadids and teredinids, but not with limnorids. This unwelcome development followed by the looming threat is briefly discussed in this paper.

Keywords: Isopoda, *Limnoria*, Visakhapatnam harbour, Invasion

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Sewage-pollution indicator and human pathogenic bacteria from Mormugao Bay

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Seasonal variations, occurrence and distribution of pollution indicator and certain human pathogenic bacteria were surveyed from different locations in Mormugao Bay. The sampling covered the estuarine and upstream regions of rivers Mandovi and Zuari during pre-monsoon (May 2005), monsoon (September 2006) and post-monsoon (November 2005) months. The overall ranges (and their mean abundance; no.ml⁻¹) of the monitored groups of bacteria were: total coliforms: 0 to 29046.67 ml⁻¹ (3134.14 ml⁻¹); total streptococci: 2.92 to 14596.67 ml⁻¹ (798.28 ml⁻¹); total vibrios: 12.5 to 42274.58 ml⁻¹ (2529.75 ml⁻¹); *Escherichia coli*: 0 to 1333.18 ml⁻¹ (123.11 ml⁻¹); *Vibrio cholerae*: 0 to 3012.18 ml⁻¹ (206.72 ml⁻¹); *Salmonella* spp: 0 to 1646.32 ml⁻¹ (89.54 ml⁻¹); *Streptococcus faecalis*: 0 to 612.67 ml⁻¹ (88.26 ml⁻¹) and *Aeromonas* spp: 0 to 2759.58 ml⁻¹ (204.98 ml⁻¹). The recent sampling during the 2007 monsoon (September), the abundance of all the above groups was higher at most locations. Studies on the distribution and types of various pollution indicator bacterial populations are rare from this typically tropical estuarine bay. Using the seasonal data collected from this region, it is suggested that abundance of sewage pollution indicator bacteria such as total coliforms and total streptococci in general was lower than that reported from many other locations worldwide.

Keywords: Seasonal variations, Pollution indicator, Human pathogenic bacteria, Tropical estuarine bay

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Changes of distribution of non-native charophytes species *C. connivens* in the Baltic Sea

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The Baltic Sea, one of the largest brackish water area in the world, is a relatively young sea and known by large number of non-indigenous species. Charophyte *C. connivens* are known as the only invasive macroalagae in the northern Baltic Sea. So far distribution of *C. connivens* has been scarce in the Baltic Sea. All former localities from the southern part of the Baltic Sea, like Öregrund archipelago, Greifswald/Rügen area, Gdansk bay, Gulf of Riga, are connected with ballast sites. *C. connivens* has disappeared from all mentioned areas except Öregrund archipelago. However, according to our recent investigations, the species is quite common in NE Baltic Sea. Species was found from many localities in West Estonian Archipelago Sea, coastal waters of Saaremaa Island, from Haapsalu and Matsalu Bays as well as some locations on the northern Gulf of Riga. First findings of species in the northern Åland archipelago were reported in July 2004. The manipulative experiments designed to study the effect of grazing on charophyte communities showed that selected invertebrates, *Gammarus oceanicus* and *Idotea baltica*, preferred the coarse *Chara tomentosa* over the fine *C. connivens*. Low consumption of *C. connivens* may reflect its non-native origin. Consequently, the establishment of *C. connivens* in the Baltic Sea was likely favored by an effective vegetative reproduction of the species and the absence of grazing during the productive season. Numerous recent findings of the species refer that *C. connivens* is expanding distribution area in the Baltic Sea.

Keywords: Charophytes, Invasive species, Distribution, Grazing, Baltic Sea

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Composition of soft bottom polychaetes (Macrobenthos) along the Indian coast

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The composition of soft bottom community with reference to polychaetes was investigated from the region Mormugao (south central west coast of India) to Kakinada (central east coast of India). The samples for this study were collected during December 2006 to January 2007 at 12 different sites between two above mentioned sites. The samples were collected from a depth of 26-28m. Altogether 65 different forms of polychaetes were identified. *Prionospio pinnata*, *Capitella capitata* and *Diopatra neopolitana* are the most widely distributed species along the coast. A polychaete was obtained from a sample collected in the east coast (Machalipatnam), which was not having some segments of the posterior end and was having 90 segments. After carefully looking into the identification characteristics it was found that this form belongs to genus *Ninoe*. This was further compared with all the other species of *Ninoe* found along the Indian coast and found to be a possible new report from the Indian coast. The identification keys (prostomium conical, eyes not seen, anterior setae are slender winged capillaries, simple hooded hooks appear on setiger 37 and become more numerous further back) indicate that this species bears close resemblance to *Ninoe lagosiana* (Polychaeta; Lumbrineridae). This species was reported in Lagos and Nigeria along the western African coast (Augener, 1918).

Keywords: Soft bottom polychaetes, *Prionospio pinnata*, *Capitella capitata*, *Diopatra neopolitana* *Ninoe lagosiana*

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Tracking history of dinoflagellate distribution in Goa, west coast of India through ^{210}Pb dating

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India being one of the major maritime countries is susceptible to ship mediated bioinvasion. The introduction of harmful dinoflagellates to a new environment via ships ballast water can have direct impact on fisheries and human health. Dinoflagellates form dormant cysts that can survive for years in sediments. To study long term changes of dinoflagellate cysts, sediment cores were collected from coastal locations of Goa. Based on ^{210}Pb dating, the cores were dated upto the year 1879. Heterotrophic dinoflagellate cysts dominated the cyst assemblages. In terms of presence of toxic dinoflagellates cysts in sediment, *Gonyaulax spinifera* had the longest history whereas *Cochlodinium polykrikoides* and *Pyrodinium cf. bahamense* were recently recorded.

Keywords: Dinoflagellate cysts, Heterotrophic, Sediment, Toxic, Dating

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Dinoflagellate cysts from surface sediments along west coast of India

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Increase in Harmful Algal Bloom (HAB) occurrences in recent years suggests that global factors such as climatic changes and increased international shipping traffic are the driving forces. Dinoflagellates are one of the main groups causing HABs, and there is increased awareness of possible role of cysts as seed banks. In order to understand the distribution of dinoflagellate cysts in Indian waters, surface sediments were collected from port (Ballast water management programme, India) and coastal locations. A total of 43 different cyst types were recorded. *Protoperidinium* cysts were the most diversified group, predominating at most of the locations sampled. Decreasing trend in cyst abundance was observed along the continental shelf from Mumbai to Trivandrum. This can be related to sediment texture where sandy locations exhibited lower abundance and diversity of cysts. Cysts of dinoflagellates capable of producing Paralytic Shellfish Poisoning (PSP) and yessotoxin producers were detected in some locations.

Keywords: West coast, Dinoflagellate cysts, Harmful Algal Bloom, Heterotrophic, *Protoperidinium*

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Detection of *Karlodinium veneficum* from Goa, India: cause for concern

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Ballast water exchange processes have been linked with blooms of harmful organisms, including certain potentially toxic dinoflagellates. Intensive phytoplankton sampling during different seasons was carried out in the vicinity of Mormugao Port, located along the central west coast of India. This study was carried out as a part of biological baseline survey under the Ballast Water Management Program (India). Dinoflagellates were isolated from water for identification and development of cultures. Through this effort, we could identify the presence of *Karlodinium veneficum* (Ballantine) J. Larsen. To the best of our knowledge, this is the first report of *K. veneficum* from the waters around India. Its ability to produce toxins and its potential to survive in ballast water for several days is a cause of concern. The poster presents the taxonomy and life cycle strategies of this species.

Keywords: Dinoflagellate, Ballast water, Phytoplankton, Mormugao, Harmful

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Temporal variations in the distribution of dinoflagellates from a monsoon influenced tropical estuary

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In recent years, concerned with global increase in invasion by harmful dinoflagellates, studies related to their dynamics, both cysts and vegetative cells, and the environmental factors influencing them have gained importance. The temporal variation (September 1999 to January 2001) in the distribution of dinoflagellates, vegetative cells from water column and cysts from surface sediments, in the Zuari estuary (Goa) located along central west coast of India was evaluated. A basis for the understanding of the benthic-pelagic coupling in dinoflagellate population in monsoon influenced estuarine environment is discussed through this first time series study from the region. Among the phytoplankton, dinoflagellates formed the second most dominant group in the water column. From the water column vegetative cells of 34 dinoflagellate species whereas from the sediments, cysts of 43 dinoflagellate species were recorded. In the water column dominance of dinoflagellates was maximum during pre-monsoon followed by monsoon and post-monsoon. During monsoon, dinoflagellates were dominant only during the break period (July 2000) and the community was mostly represented by blooms of *Gymnodinium catenatum* and *Cochlodinium polykrikoides*. The highest cyst abundance was observed during the restart of monsoon (August 2000) after an intermittent break period (July 2000). In general cyst abundance increased from late post-monsoon to peak during early pre-monsoon (March 2000). Univariate measures such as species count, richness and diversity also showed a similar trend. The distribution of dinoflagellates was mainly influenced by environmental factors such as salinity, nutrients and turbidity.

Key words: Dinoflagellates, Vegetative cells, Cysts, Monsoon

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Composition and distribution of meiobenthos of Visakhapatnam harbour sediments, east coast of India

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A comprehensive study on the taxonomy and community structure of meiobenthic fauna at 21 locations in the Visakhapatnam harbour (17°41' 594"- 17°44'013"N; 83°16'363" - 83°18'205" E) was undertaken through a single cruise in January 2007. For the sake of convenience, the study area has been divided into 5 broad regions as Northern arm (7 stations), Western arm (3 stations), Turning circle (3 stations), Entrance channel (4 stations) and Ore berth (4 stations). At each location replicate samples were collected using a van Veen grab (0.1m²) and data on sediment texture, organic content, ambient salinity and dissolved oxygen obtained synchronously according to standard protocols. During this investigation, 8 diverse taxa of meiobenthos represented by nematodes (75.8%), polychaetes (8.3%), formaminiferans (5%), copepods (1.2%) and others (9.8%) including ostracods, nauplii and turbellarians were encountered. Overall, meiofaunal (mean) abundance ranged from a mere 8 numbers (st. VZPTB) to a high 710 nos.10cm⁻² (st.VZPTRCL). Biomass was least (0.03mg.10cm⁻²) at VZPFJT and highest (2.43 mg.10cm⁻²) in the sediments of VZPTRCL. On the whole, nematodes constituted an overwhelming 76% of the total meiofauna in terms of numerical abundance and biomass. Altogether 48 nematode species belonging to 31 genera and 14 families were reported. Univariate indices (e.g. Margalef d & Shannon-Wiener H') revealed high nematode diversity (d: 3.746; H': 2.154) at VZPOLB and d: 0.7578; H': 0.869 at VZPWQB -1. Based on Bray-Curtis similarity and multidimensional scaling (implemented in PRIMER) it was possible to demonstrate two distinct assemblages among nematodes. The sediments (Northern arm) seemed to support an assemblage of nematodes characterised by *Desmolaimus zeelandicus*. Sediments at Western arm, Turning circle, Entrance channel, Ore berth supported different species namely *Paracomesoma dubium*, *Metalinhomoeus longiseta* and *Setosabatieria sp.*

Keywords: Nematodes, Visakhapatnam harbour, Similarity, Diversity

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You can lead horses to ballast water information, but you can't make them remember it: Evaluating the WCBOP's aquatic invasive species and ballast water outreach

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A primary goal of the West Coast Ballast Outreach Project (WCBOP) is outreach about ballast water management and treatment technologies, vessel fouling and aquatic invasive species (AIS) along the West Coast of North America. Outreach materials include our "Stop Ballast Water Invasions" poster, companion brochure, biannual newsletter Ballast Exchange, and a website. While these materials have reached thousands of individuals, this alone does not indicate assimilation and use of the information. To determine the effectiveness of the WCBOP's outreach materials, feedback on the materials and resulting changes in AIS knowledge/awareness will be obtained using online and emailed surveys, personal interviews, and presence/absence surveys, depending on the audience. Our audience includes the maritime industry, research sector, port/harbor staff, instructors, regulators, and legislators. Evaluation is an essential aspect of any outreach project. Our poster will present lessons learned from our evaluation process that will help guide future outreach efforts for a wide variety of AIS projects, leading to enhanced AIS spread, prevention and improved management of new invasions.

Keywords: Aquatic invasive species, Ballast water management, Evaluation

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Role of bacteria-invertebrate interactions in ballast water management

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Although the coexistence of bacteria with many marine invertebrates is well known, little is known about their ecological relationship. It has been reported earlier that many invertebrates harbor species-specific bacteria on their surface as well as within their body, which are diverse from those found in the surrounding water. Such studies can be crucial in elucidating the symbiotic interactions between microbes and invertebrates and whether these can be tapped for any biotechnological applications. Since plankton represents bacterial hotspots in the oceans, these microhabitats can play a more crucial role in trophic dynamics. The identification of closely associated bacteria with these, which might be new to science, is highly significant as recovery and sustenance of these bacteria after de-linking its association with the specific host is an extremely difficult task. Also some of these bacteria which are eventually released by the plankton can be potential pathogens.

In view of this experiments were carried out to isolate and identify the surface-associated bacterial communities (epibiotic) as well as the internal bacteria (endobiotic) of dominant invertebrate forms (barnacle, copepod and bivalve). Copepod harbored the maximum number of epibiotic and endobiotic bacteria followed by bivalve and barnacle larvae. The predominant bacteria in barnacle were represented by *Aeromonas salmonicida* and *Photobacterium angustum*. In case of bivalve, *P. angustum* and *Vibrio fischeri* were dominant, while in case of copepod it was *Aeromonas schubertii*. Certain degree of form specificity was observed in case of endobiotic bacteria of each of the tested forms. This has implications in ballast water treatment technology as these invertebrates have extensive surfaces for bacterial attachment, the decomposition of which would not only lead to nutrient recycling but also would result in increased bacterial production in the marine environment.

Keywords: Bacteria, Invertebrates, Epibiotic, Endobiotic, Ballast water treatment technology

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Ballast water management studies in Turkey

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Turkish Republic started a two years national project which is going to be finalized on 01.08.2008 in order to handle with the threat of invasive aquatic organisms for Turkish shore lines. This project is executing between the Undersecretariat for Maritime Affairs of Turkey (UMA) and The Scientific and Technological Research Council of Turkey (TUBITAK). It is aimed to produce a synergy between these two public bodies and achieve an operative ballast water management system in Turkey.

In the framework of the project the inventory of the shipping activities of Turkish coasts is produced. Ten years approximation is made for the maritime traffic and ballast water transportation by trend analysis method. All the ports of Turkey are categorized with Globallast Risk Assessment Method. It is planned to establish a geographical information system and draft legal instruments before the end of the project.

Turkey supports “The International Convention for the Control and Management of Ships Ballast Water and Sediments”. This project would be a baseline study to ratify this convention. This study summarizes the parts of the project and the results achieved.

Keywords: Invasive aquatic organisms, TUBITAK, Ballast water management system, Turkey
Globallast Risk Assessment Method

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A profile of ballast water discharge in some major ports of India

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Shipping is the backbone of global economy and facilitates transportation of around 90% of commodities. A single bulk cargo ship of 200,000 tonnes can carry up to 60,000 tonnes of ballast water. It is estimated that nearly 2-3 billion tonnes of ballast water is carried around the world every year. Translocation of organisms through ships' ballast water is considered an important vector. Considering the importance of ships' ballast water, we collated the data available from randomly collected Ballast Water Reporting Forms (BWRFs) from 5 important ports of India namely Kandla, Visakhapatnam, Kakinada, Kolkata and Mormugao Port Trust (MPT) to evaluate the amount of ballast discharged at these ports.

The data from the BWRFs indicated the importance of both domestic and international ports in ballast water discharge. The poster presents an overview of the ballast discharged for each of these ports. MPT received maximum ballast from the ports of Japan followed by China. Visakhapatnam received maximum ballast water from Indian ports, which include Haldia, Tuticorin, Hazira, Ennore and Paradeep. Among the international ports, the maximum ballast water discharged at Visakhapatnam port was from Japan. Kakinada received 60% of ballast water throughout the year from Haldia and 30% contributed by other ports of India. The remaining 10% of ballast water was received from the ports of Malaysia, Sri Lanka, Bangladesh and Japan. Similar results were obtained for Kandla port, which also received maximum ballast water from Indian ports followed by ports from Arabian Gulf, South East Asia and Japan.

Keywords: Ballast water, Ballast water reporting forms, Ports of India, Domestic and international ports

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Ballast Water Reporting Forms: Common errors

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Ballast water reporting in most of the countries is done manually which involves a series of handling procedures before the information gets logged into the database. In the current scenario to track the ships' ballast history is difficult, as the manually entered Ballast Water Reporting Forms have several drawbacks. In an effort to identify the errors that can creep in during manual submission of the reporting forms, data was collated from 1,666 ballast water reporting forms submitted by ships to a port in India from October 2001 to April 2006. Among these, approximately 15% of the forms had different types of errors. The error types include incorrect vessel information, voyage information, ballast water usage and capacity, ballast water history, illegible entries and forms in different format. Such limitations can be overcome by adopting the electronic Ballast Water Reporting Form developed by India.

Keywords: Bioinvasion, Ballast water, Treatment technology

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Bacterial communities associated with plankton: implications to ballast water management

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Transport of ballast water through ships to different regions has created long distance inoculation and distribution of various microorganisms. Microorganisms are introduced into alien environments in large numbers than any other organisms owing to its abundance, capability to form resting stages, potential pathogenicity and capability to withstand wide range of environmental conditions. It has been reported that concentrations of bacteria and viruses in ballast water exceed other taxa by 6 to 8 orders of magnitude.

Microorganisms are either found in ships ballast water, residual sediment, biofilms formed on interior tank surface or those originating from disintegration of associated macro organisms or metazoans. Little is known about the contribution of associated bacteria with plankton towards the pool of micro-organisms. An investigation was taken up to quantify bacteria associated with plankton and their release into the free form once plankton is destroyed.

Results indicated that potential pathogenic forms such as *Streptococcus faecalis* and *Vibrio cholerae* increased subsequent to destruction of plankton. This indicates their release from associated plankton as on disruption the plankton would release the bacteria harbored within different parts of their complex body structures. The accounting of such bacterial inputs in ballast water requires attention.

Keywords: microorganisms associated bacteria, plankton, pathogenic, *Streptococcus faecalis*, *Vibrio cholerae*, disruption

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Analysis of physical and biological data of the Mormugao port region using GIS

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An Information System is designed to represent, query and to analyze the physical and biological data including marine species collected from the Mormugao Port region under Ballast Water Risk Management project. This system provides the end users with query-based interface to help them to analyze the data effectively.

Two customized tools are provided along with predefined tools in Arc View 3.2a in order to query the data. The species data collected in the study region are stored in MS Access. Arc View 3.2 is basically used to display the port map and the stations in the study region from where data were collected. Of the two, one tool is used to query on map, using which, user can select any one station, and query data for that station. The other tool allows the user to query data and view region using the above tool. It also allows the user to view the images of the species found in that particular region.

The data on marine species were collected in the Mormugao Port region during May 2005. These data were compiled and stored in Access database. Scripts were written in Arc Avenue to connect the database with GIS and to prepare user-friendly interface to query data. The contours were generated for physical and biological parameters of the study region. This enables the scientists in our institute to view and query the base map of Mormugao Port with different layers and attributes when the maps are posted in the website using Arc IMS.

Keywords: GIS, ARC View, Mormugao Port, Physical, Biological

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An evaluation of ballast water treatment technologies

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The growing concern over bioinvasion due to ballast water has made it mandatory to search for possible solutions to this problem. The foremost requirement is a technology that can treat ballast. There are many technologies available today but only the best would board the vessels. An attempt has been made in this paper to evaluate these technologies on the basis of efficiency, design characteristics, safety, and time of operation, cost and maintenance. The objective has been to present a striking yet simple comparison of these technologies. Finally, the best technologies are rated for four different types of vessels based on their ballast water capacity using weighted-mean technique.

Keywords: Bioinvasion, Ballast water, Treatment technology

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Utility of altered ballast water distribution system in treatment technology

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The growing concern over bioinvasion due to ballast water has made it mandatory to search for possible solutions to this problem. Some of the limitations posed for the technologies that are under development, can be overcome by having a suitably altered ballast water distribution system. Here, we present the design of a parallel filtration system as an option to overcome the barriers. The design takes into consideration flow rate, footprint, cost effectiveness, vessel stability and elucidates the utility of the system under different ballasting conditions.

Keywords: Bioinvasion, Ballast water, Parallel filtration system

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Dinoflagellate cyst distribution in recent sediments from the south-east coast of India

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Dinoflagellates are one amongst the ten most unwanted forms listed as bioinvaders of marine ecosystems. A baseline data on prevalent dinoflagellate population in a bioregion is a prerequisite for bioinvasion studies. In view of this, dinoflagellate cyst distribution was evaluated from the sediments of 8 stations stretching from the coast of Visakhapatnam to Nagapatnam along south-east (SE) coast of India. To the best of our knowledge this study is the first report on dinoflagellate cyst community from this region. Cysts of 36 species belonging to heterotrophic (*Protoperidinium*, *Zygabikodinium*) and autotrophic (*Gonyaulax*, *Lingulodinium* and *Gyrodinium*) dinoflagellates were recorded. Amongst them, cysts of heterotrophic dinoflagellates (>52%) dominated the community whereas rest of the community comprised of autotrophic dinoflagellates (<48%). Autotrophic dinoflagellates were mostly represented by *Gonyaulax spinifera* and *Lingulodinium polyedrum* which are known to be toxic. The number of cysts as well as their abundance decreased southwards (Visakhapatnam to Nagapatnam). Maximum cysts were found in clayey and silty sediments. Comparison of this data with that of published data on west-coast of India showed that *Protoperidinium* cysts were dominant and also the total cysts densities were in similar range. However, the number of cysts of toxic dinoflagellates is comparatively lesser in SE coast of India (2 species) as compared to west-coast of India (11 species).

Keywords: Dinoflagellates, Cyst distribution, South-east, Heterotrophic, *Gonyaulax spinifera*, *Lingulodinium polyedrum*, Toxic

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Distribution of *Trichodesmium* in the Bay of Bengal as a marker for dispersion of planktonic organisms

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The most commonly employed ballast water management (BWM) practice is mid-ocean exchange. Subcontinent of India is in close proximity to the hub of oil tanker routes. Mid-ocean exchanges of ballast water in the region are likely to seed population to the coastal habitats. Such facilitations are of great relevance in identifying ballast-mediated introductions.

In this study through the detection of *Trichodesmium*, an important nitrogen-fixing cyanobacterium, the possibility of dispersion-mediated introductions is elucidated. The interesting and intriguing feature of *Trichodesmium* blooms is the suddenness with which the blooms appear and disappear. Advancement in remote sensing techniques provides an alternative solution for mapping *Trichodesmium* on a global scale. However its usefulness is totally dependent on the sea/ground truth data. The distribution of *Trichodesmium* in Bay of Bengal was tracked through regular analysis of surface water samples collected from passenger vessels plying between Chennai – Port Blair – Kolkata (October 2006 to August 2007). Observations revealed the prevalence of *Trichodesmium* for most part of the year with a peak during winter months (November – January) in the Andaman Sea (i.e. waters around Port Blair). During inter-monsoon period (April – May), maximum *Trichodesmium* abundance was observed in the northern region (i.e. towards Kolkata). Earlier studies have indicated the prevalence of *Trichodesmium* in the south-eastern part of the Bay during the winter months (November – January) and in the west (west Bay of Bengal and east Arabian Sea) during summer (February – May). This raises the possible role of physical forcing in the dispersal and seeding of *Trichodesmium*. This case study can provide a basis for understanding the dispersal of free floating planktonic organisms through ocean circulation.

Key Words: *Trichodesmium*, Bay of Bengal, Dispersal, Ocean circulation

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Fouling diatom community structure in enriched and non-enriched nutrient conditions

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Diatoms, *Coscinodiscus* sp., *Odontella* sp., *Amphiprora* sp., *Achnanthes* sp., *Thalassionema nitzschioides*, *Amphora coffeaeformis*, *Cylindrotheca closterium*, *Navicula subinflata* and *Navicula transitans* var. *derasa* f. *delicatula* were grown in mixed culture for a period of 30 days in seawater enriched with f/2 nutrient medium and in un-enriched seawater. Two sets were maintained: in one set the media was replenished every alternate day and the other set was kept stagnant. Initial observations showed that *Amphiprora* sp. dominated the community in both the sets. But eventually, in the stagnant set, *Odontella* sp. survived competition from other species under low nutrient conditions by the formation of spores. In the enriched condition, as the community aged, *Amphiprora* sp. was removed from the community because of the tendency of cells to float and disperse when space became a limiting factor. Ultimately *Achnanthes* sp., that otherwise were present in moderate numbers throughout the experiment, dominated the community. Unlike the above set, the un-enriched sea water, showed the growth of all the species in the stagnant set, except *Coscinodiscus* sp. and *Cylindrotheca closterium*, in moderate numbers that reached stationary and death phase within 24 days. On the contrary, the other set with the sea water being replenished every alternate day showed opportunistic growth patterns of the species, and was finally dominated by *Odontella* sp. When this experiment was conducted in artificial sea water, the resulting community was dominated by *Odontella* sp., in both the stagnant as well as the pulsed nutrient conditions. These observations show that species behaviour within a community differs with respect to the varying nutrient conditions.

Keywords: Fouling diatom community, Enriched, Non-enriched, *Amphiprora*, *Odontella*

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Different environmental setting in tropics: bioinvasion implications

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Abiotic and biotic interactions are critical components of bioinvasion ecology. Capability of any given organism to establish successfully in an alien environment is also habitat dependent. Tropics are generally rich in biodiversity. Such environments when influenced by anthropogenic activity or seasonal forces such as monsoon, the community oscillates. Keeping this in view, study is under way at three major ports of India, viz. Mumbai, Mormugao and Visakhapatnam, to understand bioinvasion ecology. Mumbai and Mormugao, situated along the central west coast of India, are mainly influenced by the south west monsoon and the port environments are influenced by estuaries. Mumbai port is characterized as mesotrophic owing to anthropogenic pressure whereas, Mormugao port is comparatively less pressurized. On the other hand Visakhapatnam port, situated on the east coast, is a semi-enclosed water body with restricted water circulation. This poster provides an overview of the environmental settings in these 3 ports and their significance in terms of bioinvasion ecology.

Keywords: Bioinvasion, Mormugao, Mumbai, Visakhapatnam, Mesotrophic, Eutrophic

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Prohibition of organotin compounds in antifouling paints: The AFS-Convention

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Organotin based antifouling paints are highly effective against most fouling organisms and their application results in enormous savings to the shipping industry. On the other hand, TBT is also described as the most toxic substance ever introduced in marine environment. Consequential environmental impacts of the TBT led to the regulations on TBT in many countries. However, serious concerns are raised concerning complete prohibition of organotin-based compounds in antifouling paints. Therefore, though toxic impacts of TBT are widely agreed, there was a debate on banning organotins. After long deliberations, Convention to Control the use of Harmful Antifouling Systems on Ships (AFS Convention) was adopted on 5 October 2001. The convention will prohibit the use of harmful organotins in anti-fouling paints used on ships. It will enter into force on 17 September 2008. The poster describes activities carried out under a project titled 'Assessing impacts of tri-butyltin (TBT) on multiple coastal uses' funded by the European Commission under the Sixth Framework Programme (FP6). These activities are expected to help in effective implementation of the AFS-Convention. The poster is aimed at creating awareness about the prohibition of organotin compounds and the AFS Convention among various stakeholders. Details of the project can be found at <http://www.teriin.org/teri-wr/projects/tbtimpacts.htm>

Keywords: Organotin, Antifouling, TBT, AFS Convention

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Ships Ballast Water Reporting, India

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About Ballast Water Reporting

Manually filled Ballast Water Reporting Forms (BWRF) are found to have numerous errors

- The e-BWRF allows you to fill up and save the form on your ships computer, automatically validating the form as you fill up.
- The form is easy to install and use, and saves repeated effort
- The filled up form can be e-mailed to the port authority, or printed and faxed/ manually conveyed, the printed form is in the approved IMO format
- Text file to be emailed to port authority is a minimal 50KB in size.
- Download the software from our website, <http://www.bwmindia.com>
- You can also fill up the form on-line from the website.

The screenshot displays the 'Ballast Water Reporting e-Form' interface. It is divided into several sections:

- 1. Ship Information:** Includes fields for Ship Name, Type, IMO Number, Gross Tonnage, Call Sign, Flag, Agent, Last Port & Country, Next Port & Country, and Actual Port.
- 2. Ballast Water:** Contains 'Ballast water on board?' and 'Management plan implemented?' sections with radio button options.
- 3. Ballast Water Tanks:** Features a table for 'Ballast Water Reporting e-Form' with columns for Tank/hold, Date, Port, Volume, and Temperature. A table below shows data for tanks No.1 to No.8.
- 4. Ballast Water History:** Includes a 'Ballast Water Discharge' table with columns for Tank/hold, Date, Port, Volume, and Temperature.

Navigation tabs at the top include: 1. Ballast Water Reporting e-Form, 2. Ballast Water, 3. Ballast Water Tanks, 4. Ballast Water History, and 5. Ballast Water Guidelines. A search bar is located at the top right.



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