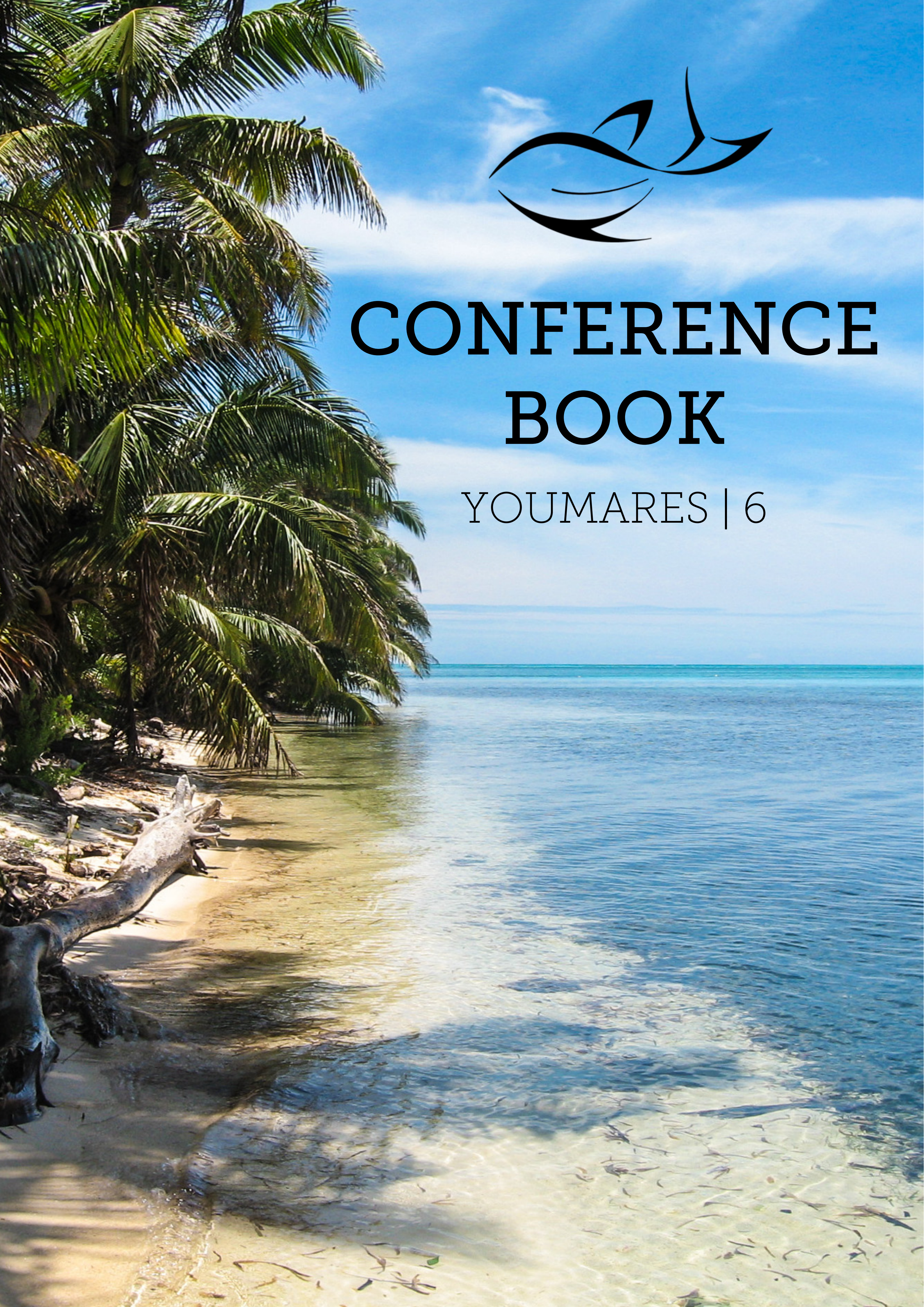
CONFERENCE BOOK

YOUMARES | 6



Conference Book

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Index

Welcome

Dear participants, dear visitors, and dear Youmares team,

A warm welcome from our side to the 6th Youmares conference in Bremen. We cannot believe that another year has passed since out last meeting and that we have another great event in front of us.

The last weeks and months were becoming again quite busy and the rapidly approaching conference pushed us to give our best to provide you (and us) with an awesome conference. It was again wonderful how so many committed people in the team sacrificed their time to make this event possible. With the right amount of seriousness, fun, and chaos we had a nice time preparing the event.

But without the contributions from the participants, Youmares would be a little bit sad. We were amazed by the plethora of highly professional applications, both at the session and the presentation level. The choice was often not easy and we had to reject contributions and comfort motivated people for next year's Youmares. At the same time, we are very happy to accomplish again Youmares primary mission and provide a platform for so many young scientists to present, exchange, and discuss ideas of many fields of marine research.

Now it is your turn to fill this sparkling room with your engagement and passion. Enjoy your curiosity, ask questions, get inspired, build your networks, and come aboard the Youmares organization team! It is you, who Youmares depends on and for who it has been created. Take your chance.

Sabrina Kalita, Vera Golz, Christian Jessen
(YOUMARES coordination team)

September 2015

2 | Genetics for Sustainability

Population genetics as a powerful tool for the management and sustainability of natural resources

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ABSTRACT

The efficiency at developing molecular markers is increasing, so that genetic analyses of natural resources, that involve both, the currently exploited resources and the potential resources to be exploited become more powerful every time. The aim of this session is to discuss how this amount of data generated by the new sequencing technologies could be used to improve the management and sustainability of marine and aquaculture resources. For the global discussion of these issues, population genetic studies as well as sustainable management actions derived from genetic data will be welcomed to this session.

ORAL PRESENTATIONS

2.1)	**Ramona Brunner**	Vertical connectivity of two scleractinian coral species in Bermuda
2.2)	**Patricia Kaiser**	MALDI-TOF Mass Spectrometry – a novel method for the identification of pelagic copepods
2.3)	**Alfonso Pita**	Genetic assessment of mussel recruitment in Ría de Vigo (NW Spain)
2.4)	**Peggy Weist**	Stay with me! Kin aggregations in coral reef fish larvae

POSTER PRESENTATIONS

2.5)	**Henrik Christiansen**	Monitoring the genetic status of marine populations – AGENDEX
2.6)	**Ashfaque Ahmed**	Molecular diversity analysis of *Sonneratia apetala* Buch. Ham. and its application to the coastal zone management of Bangladesh

Vertical connectivity of two scleractinian coral species in Bermuda

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ABSTRACT

In a world with declining coral reefs, the 'deep reef refugia' hypothesis is a gleam of hope for future oceans. This hypothesis postulates that the relatively unexplored mesophotic reefs may be less vulnerable to certain stressors (e.g. storms, thermal bleaching) compared to shallow reefs and could provide propagules to their shallow counterparts. Therefore, this study investigates (1) the extent of vertical connectivity between shallow and deep populations and assesses whether (2) *Symbiodinium* association and (3) skeletal features differ between 10 m and 40 m. The gene flow of the brooding species *Agaricia fragilis* (n=112) and the broadcast spawner *Stephanocoenia intersepta* (n=111), collected from water depths between 13 m and 40 m around Bermuda (Sargasso Sea; Atlantic Ocean), was investigated using the population genetic approach of Restriction site–associated DNA (RAD) sequencing. Vertical connectivity of corals can be also limited by symbiont depth zonation and therefore the *Symbiodinium* diversity and distribution was assessed using ITS2 genotyping after Denaturing Gradient Gel Electrophoresis (DGGE). Finally, skeletal characteristics (e.g. corallite dimensions, inter-corallite distances, corallite density) of *A. fragilis* and *S. intersepta* were measured and compared between shallow and mesophotic populations, in order to discover morphological adaptations to their local environments. The outcomes of this study will extent current knowledge about vertical connectivity between depth-generalistic coral species so that the question whether mesophotic corals can replenish shallow populations can be assessed for reefs around Bermuda.

MALDI-TOF Mass Spectrometry – a novel method for the identification of pelagic copepods

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ABSTRACT

Accurate species identification is a crucial step in plankton studies and essential to fully understand ecosystem functioning. Beside morphological analyses, molecular methods such as DNA barcoding gained great attention during the last decades. However, these methods are still time consuming and cost intensive. A novel alternative is the identification of species by proteomic fingerprinting. Matrix assisted laser desorption/ionization time of flight mass spectrometry (MALDI-TOF MS) is an already well-established technique to identify bacteria and viruses. Recent studies also show promising results in identifying metazoans such as fish, insects and zooplankton. MALDI-TOF MS requires only one simple extraction step, thus being much more rapid and cost effective than DNA based approaches. The aim of this study is to demonstrate that MALDI-TOF MS is a suitable and efficient method for the identification and quantification of pelagic copepods. Therefor specimen of the copepod family Spinocalanidae of two tropical stations in the eastern Atlantic Ocean were investigated. Spinocalanid copepods were divided into four groups, depending on their copepodite stage: CI-III, CIV, CV and CVI. For the measurements single specimen were placed into 5 µl of matrix and then incubated for 10 min. 1 µl of extract was applied in three replicates on the target plate. Each target-spot was measured three times, resulting in nine replicate measurements per specimen. Around 1.500 individuals have been measured. Preliminary results indicate the applicability of this method for adult- as well as copepodite-identification.

Genetic assessment of mussel recruitment in Ría de Vigo (NW Spain)

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ABSTRACT

The existence of propitious environmental conditions for mussel growth in the Galician Rías allow mussel farmers to obtain enough seed from intertidal rocky shores or from collectors after the spawning season.

Such free swimming spat abundance may be a drawback to cultivate mussel seed selected in hatchery for a given trait (e.g. size, weight, growth rate) in order to improve productivity. Actually, little is known on both, the rate of larvae replacement once recruited to ropes and along the fattening period.

Our study aims to assess the genetic identity of a selected strain of mussel juveniles at harvest time which had been cultivated in suspension ropes for 13 months. For such purpose, a selected mussel progeny from one family was suspended in ropes from the jetty facilities of ECIMAT - Marine Station (University of Vigo, Spain) and allowed to grow for 13 months. Around 500 mussels sampled sequentially during the fattening period were genotyped with six multiplexed microsatellites and assigned to their original source, i.e. either to the selected progeny or to the wild mussel population from Ría de Vigo. Only a 1.7% external spat fixation was recorded during the first three samplings (April – June, 2008). Such recruitment was null in the last sampling (November, 2008) except at those free niches provided by previous samplings. In those free niches, external recruitment raised to 95.8% of the sample. We conclude that by controlling various factors such as latitude, the out-from-hatchery time of the year, the availability of free niches (storms) or the predator's impact on cultures, it is feasible to grow up a selected strain of mussels with warranty of its final authenticity.

Stay with me! Kin aggregations in coral reef fish larvae

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ABSTRACT

A pelagic larval phase is very common in demersal coral reef fishes. The dispersal phase has been suggested to promote high levels of gene flow among populations. Yet, recent studies found that late-stage larvae are not only passive planktonic particles, but instead, possess sophisticated sensory and behavioural abilities that allow active navigation and directed orientation. During this phase close kin may school and disperse together until settlement, which would explain distinct spatial population structure observed for various reef fishes. To determine the degree of genetic differentiation and relatedness of larval aggregations, we collected presettlement larvae of a common coral reef fish, *Pomacentrus coelestis* (Jordan & Starks, 1901), who have a pelagic larval phase of 21 days. From 2007 to 2012, larvae were sampled using light traps off four reefs of the Capricorn Bunker Group in the Great Barrier Reef, Australia. Seven highly polymorphic microsatellite markers were used for genotyping each individual (n=257). We found strong genetic differentiation between light trap samples collected at different reef sites and years, indicating multiple origin sites of larvae. Furthermore, over 40% of all light trap samples contained a significant proportion of sibling pairs, a surprisingly high amount given the length of this species' pelagic larval duration. These results suggest, that early-stage pomacentrid larvae possess sensory and behavioural mechanisms for the detection of kin and obtain high levels of kinship within schools, which may explain the complex genetic structure observed for these and other coral reef fish populations.

Monitoring the genetic status of marine populations - AGenDex

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ABSTRACT

Genetic variation is an integral part of biodiversity, next to species and ecosystem diversity. Yet, it is under-represented in monitoring and conservation efforts. Harvesting can have adverse effects on genetic diversity, exploitative selection alters phenotypes, and genetic changes may occur even before other effects are discernible. The Southern Ocean features one of the most pristine marine ecosystems worldwide, thus providing baseline data close to the natural state. On the other hand, some fish populations have been heavily fished and the Western Antarctic Peninsula is among the fastest warming regions on Earth. Loss of genetic variation can hinder evolutionary change that is crucial for adaptation to such a changing ecosystem. Here, we therefore describe a framework using Antarctic fish to develop a genetic index – AGenDex. Notothenioid species with variable life strategy and subject to varying amounts of fishing pressure are compared. Next generation sequencing, more specifically a modified double digest restriction site associated DNA (ddRAD) sequencing approach, is used to efficiently identify and genotype markers. Bioinformatic processing allows calling of single nucleotide polymorphisms (SNPs), which are subsequently used to carefully assess population genetic parameters, such as genetic differentiation, heterozygosity, and effective population size. Comparative analyses and defining guidelines accompany final index construction. The derived results strengthen the management of marine living resources and can furthermore be used for the designation of biologically sound marine protected areas (MPAs). Finally, insights provided by AGenDex may be applied to European cases, where the assessment of good environmental status is now obligatory.

Molecular diversity analysis of Sonneratia apetala Buch. Ham. and its application to the coastal zone management of Bangladesh

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ABSTRACT

The *Sonneratia apetala* Buch. Ham. is the most successful plant in the coastal afforestation program in Bangladesh but the regeneration is almost nil in these planted mangrove forests. The present study intended to know whether any homozygocity existed in the planted forest that might have caused the cease in natural regeneration. For this leaf samples were collected from 3 different areas of Nijhum dwip and Char Tomuruddin of Hatia, Noakhali and Sonadia Island of Cox's Bazar District from planted forest. DNA isolated from 15 samples of 3 distinct area were subjected to RAPD and SSR analysis using 10 primer sets. SSR primers PCR product for the genetic diversity indices were calculated using the software GeneALEX 6.5. A total of 13 alleles were detected with high genetic diversity (Ho = 0.480) in the Tomuruddin populations and the least or no genetic diversity (Ho = 0.000) found in the Nijhum Dwip populations. Fixation Index value (F) also showed a high value for Nijhum Dwip populations (F = 1.00) indicating absence of random mating within populations. The opposite was observed in the Sonadia and Tomuruddin populations. A low but significant genetic differentiation was observed among populations in three areas with $F_{ST} = 0.021$, $p<0.05$. Low number of migrant per generation (Nm = 1) also bolstered the findings of low level of gene flow within and between populations. From Dendrogram drawn by POPTREE 2.0 software and Principal Coordinate Analysis (PCoA), it was clearly revealed that Nijhum Dwip population showed almost similar genetic settings within population and high genetic distance with the distant populations from Sonadia and Tomurrudin. Low or absence of heterozygosity for Nijhum dwip population might excel the level of homozygosity that might result in inbreeding depression and reduce the level of survival ability to establish them in a stressful environmental condition. On contrast, Tomurrudin population showed high genetic diversity with random mating populations compared to the other areas. Therefore, it could be suggested that for further plantation program in the coastal islands, seeds collection should be avoided from Nijhum Dwip as inbreeding depression may further enhance regeneration problems of this species.

3 Cephalopods and Society

Cephalopods and society: Scientific applications using cephalopods as models

Sílvia Lourenço[1] **, Rita Franco-Santos[2] *, Felipe Briceño[3], Augusto Crespi[4], Stefanie Keller[5], Rigoberto Rosas[6]**

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ABSTRACT

Cephalopods were first represented 4000 years ago in pottery artifacts from the Minoan, an ancient civilization that flourished in the Mediterranean. From the mythological Kraken, who brought fear to the hearts of seal hunters of the Nordic seas, to the early dreams of Jules Verne to explore the deep ocean, cephalopods (octopus, squid, cuttlefish and nautilus) have been inspiration to many artists, philosophers and scientists throughout human history. In modern times, the onset of neurobiology and behavior science during the first half of the 20th century set the pace for the increasing importance of cephalopods in science and in society. We present an overview of the applications of cephalopods as models to research (physiology, behavior and robotics) or society activities (cultural representation, fisheries and aquaculture).

ORAL PRESENTATIONS

3.1)	**Giovanna Ponte**	Cephalopods as Laboratory Animals: Back to the future
3.2)	**José Seco**	Short-finned squid distribution inferred from diets of Southern Ocean albatrosses
3.3)	**Carla Bertapelle**	*Octopus vulgaris* brain as a model to study adult neurogenesis
3.4)	**Pascal Carlier & Andrew Packard**	Why do cephalopods change colour? A "tensity" model of cognition

Cephalopods as Laboratory Animals: Back to the future

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[4] *Presentation on behalf of 43 Members of the Management Committee of CephsInAction*

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ABSTRACT

Cephalopod molluscs are listed in Article 1 of the Directive 2010/63/EU making them the first and sole invertebrates considered in the European legislation regulating the use of animals for scientific purposes. Research on cephalopods can be dated back to the XIX century. Scientific interest on these animals emerged from the extraordinary richness of their behavioral repertoire, the advanced forms of behavioral and neural plasticity they reveal, and many physiological adaptations that led these species to compete as predators with teleosts in the marine realm. The relationship between humans and cephalopods is long-standing, placing them in an important 'social' dimension spanning from food 'items' to characters in arts, literature and advertising. The diversity of living forms, physiological adaptations, and extraordinary genome complexity – among other features - make cephalopods a challenge for the scientific community. Among the about 700 living cephalopod species, only about twenty are currently utilized as "Laboratory Animals", and a few others are currently exploited for their potential in aquaculture. Compliance with the Directive 2010/63/EU and the increased concern for animals' welfare issues face scientists and regulators with an added challenge. Cephalopod 'community' is relatively small, represented by a diverse set of expertise working on a diversified number of "Laboratory" species. This provides an unprecedented advantage that prompts interesting questions for science, education, bioethics and social dimension. Cephs*In*Action has this ambitious aim. As COST Action, it takes the advantage of fostering an interdisciplinary network of experts aimed to promote sharing of tools, training, and to increase scientific knowledge to improve approaches required for the care of cephalopods in different contexts. Cephs*In*Action operates to foster multi-disciplinary and inter-species scientific exchanges to integrate knowledge on welfare practices, and to promote cephalopod research, conservation and public awareness. The COST Action FA1301 – Cephs*In*Action is also strongly committed to provide to early career investigators a framework of excellence and inclusiveness aimed to foster a modern view for cephalopods and increasing their interest to ask key questions in research and innovation with these animals.

Bringing new generations, we believe, facing with 'different models' where new ideas can be tested will support international cooperation and the exploration of new research frontiers in the European Research Area, an open space for knowledge and growth. Training and education, fostering research avenues and facilitating early career are our mission and represent the tools for making this challenging task possible. Currently, Cephs*In*Action (www.cephsinaction.org) includes 19 countries, and involves more than 180 researchers.

Short-finned squid distribution inferred from diets of Southern Ocean albatrosses

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ABSTRACT

Climate change can affect species distribution, leading to poleward range shifts and invasion of new habitats. The diets of marine predators are a potential source of information about range shifts in their prey. For example, the short-finned squid *Illex argentinus*, a species which is commercially fished in the Patagonian Shelf in the South Atlantic, has been reported in the diet of grey-headed (*Thalassarche chrysostoma*), black-browed (*T. melanophrys*), and wandering (*Diomedea exulans*) albatrosses breeding at Bird Island, South Georgia (54°S 28°W), in the Southern Ocean. Tracking data suggests that these birds may feed on *I. argentinus* while foraging in Southern Ocean waters during their breeding season. This led to the hypothesis that *I. argentinus* may occur south of the Antarctic Polar Front. To test this hypothesis, we used stable isotope analysis to assess the origin of *I. argentinus*. We compared *I. argentinus* beaks from the diets of the three albatross species with beaks of cephalopod species endemic to the Patagonian Shelf and others from the Southern Ocean. Our results show that *I. argentinus* beaks from the diet of albatrosses at Bird Island have $\delta^{13}C$ values in the range of -18.77 to -15.28 ‰. This is consistent with $\delta^{13}C$ values for *Octopus tehuelchus*, a typical species from the Patagonian Shelf. In contrast, *Alluroteuthis antarcticus*, a Southern Ocean squid, has typically Antarctic $\delta^{13}C$ values in the range -25.46 to -18.61. This suggests that *I. argentinus* originated in the warmer waters of the Patagonian Shelf region. It is more likely that the albatross species obtained *I. argentinus* by foraging in the Patagonian Shelf region rather than *I. argentinus* naturally occurring south of the Antarctic Polar Front.

Octopus vulgaris brain as a model to study adult neurogenesis

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ABSTRACT

Adult neurogenesis occurs in organisms that have complex and centralized nervous system, as teleosts, amphibians, reptiles, birds and mammals, and among invertebrates, decapods and insects. Adult neurogenesis takes place in neural districts characterized by structural plasticity, involved in learning, memory and sensory stimuli integration. It suggests that the process plays a crucial role to support high cognitive capabilities. *Octopus vulgaris* has a complex and centralized nervous system, located around the esophagus, with a hierarchical organization. It is considered the most "intelligent" invertebrate due to its advanced cognitive capability, as learning and memory, and its sophisticated behaviors. Cell proliferation, neural plasticity, and synaptic remodeling, the base of adult neurogenesis, underlie these capabilities and behaviors. In our work we found cell proliferation in areas of the brain that are involved in learning, memory and sensory stimuli integration. Performing behavioral experiments, we showed that intellectual, physical and sensory stimuli increase neural plasticity and synaptic remodeling, conditioning adult neurogenesis. At last, we isolated and cloned a gene of Elav family from *O. vulgaris* nervous system, which we used as a marker of this process.

Why do cephalopods change colour? A "tensity" model of cognition

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ABSTRACT

Variations of colour and pattern amongst cephalopods are usually interpreted in terms of their adaptive function: hiding from predators, being an "invisible" hunter. While such functional explanation is valid for understanding how they ensure survival of the species, it tells us nothing about the animal *subject* operating [expressing] the various patterns. The more or less rapid changes of colour and form can also be explained in terms of intra- and inter-specific *communication* between subjects: identification, threat, attraction, warning. Such explanations are heavily charged with postulates [assumptions] about the cognitive capacities of cephalopods irrespective of any parsimony principle.

To explain the [overall] phenomenon of cephalopod colour change we here propose a *cognitive dynamic tension* model covering three biopsychosocial contexts: (i) biological: matching the environment (rest, predation, ...); (ii) psychological: emotional expression (fear, anger, …); (iii) social: intraspecific relations (communication of intentions, etc.). The *cognitive tensity* model allows us to fit the various manifestations observed in each context within a single framework that serves not only to define the "way of life" of cephalopods, but also as a particular example of a general cognitive ethology strictly obedient to the phenomena. Once the emphasis on *meaning* of this "tensity" model comes to be understood, it will be seen to fit with ideas that are revolutionising biology: whether at the level of the cell and its relations with the physical environment (direct signalling between substrate and nucleus, biotensegrity) or at the level of participant/observer relationships (intersubjectivity, Goethe's *Zarte Empirie*) governing attitudes to research.

Cephalopods and Society: Scientific applications using cephalopods as models

Sílvia Lourenço[1], Rita Melo Franco-Santos[2], Felipe Briceño[3], Augusto Crespi[4], Stefanie Keller[5], Rigoberto Rosas[6]

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Cephalopods were first represented 4000 years ago in pottery artifacts from the Minoan, an ancient civilization that flourished in the Mediterranean. From the mythological Kraken, who brought fear to the hearts of seal hunters of the Nordic seas, to the early dreams of Jules Verne to explore the deep ocean, cephalopods (octopus, squid, cuttlefish, and nautilus) have been inspiration to many artists, philosophers, and scientists throughout human history. In modern times, the onset of neurobiology and behavior science during the first half of the 20th century set the pace for the increasing importance of cephalopods in science and in society. We present an overview of the applications of cephalopods as models to research (physiology, behavior and robotics) or society activities (cultural representation, fisheries and aquaculture).

1. Cultural representations of cephalopods

Inhabiting all marine ecosystems, from shallow waters to canyons in the deep sea, cephalopods always caught the attention of human societies. They were first represented in pottery artifacts from the Minoan, an ancient civilization that flourished in the Mediterranean island of Crete during the Bronze Age, from ca. 2000 BCE until ca. 1500 BCE (Cartwright, 2009). Its pottery is particularly famous for the marine motifs, which show detailed, naturalistic drawings of several marine animals, including octopuses (Cartwright, 2009). Moreover, Minoans took advantage of the octopus fluid body to fill and surround the curved surfaces of their pottery in a unique artistic style

(Cartwright, 2009). Likewise, cephalopods were also artistic inspiration for ancient American civilizations such as the Moche (northern Peru, 200BC - 700DC), who venerated octopuses as gods and represented them in ornamental jewelry made of gold for the emperor (Bondil & Pimentel, 2013). Greek philosophers also took an interest in cephalopods - Aristotle wrote about inking cuttlefish 2500 years ago. As a matter of fact, Aristotle himself has been described by his contemporaries and modern scholars as cephalopodan, with the simile that "he is like the cuttlefish who obscures himself in his own ink when he feels himself about to be grasped" (Derby, 2014).

During the middle ages, the mythological Kraken, represented as either a giant squid or a monstrous octopus, inspired fear in the hearts of fisherman and sailors in the coast around Norway and Greenland. More recently, the Kraken became a fiction character in famous novels by Herman Melville (*Moby Dick*, 1851) and Jules Verne (*Twenty Thousand Leagues Under the Sea*, 1870). Later on, the horror fiction writer H.P Lovecraft was inspired by an octopus to create the 'Cthulhu', a gigantic entity described as part octopus, part man and part dragon published in *Weird tales* (1928). Cephalopods have even made their way into the movie business with the deadly poisonous blue-ringed octopus (genus *Hapalochlaena*) playing a part in the James Bond Series *Dr. No* in 1962. Despite being frequently portrayed as creatures of nightmares in films and literature, the truth is that people are fascinated by cephalopods (Fiorito et al., 2014).

Nowadays, some cephalopods are considered as charismatic species. Among them are the living fossil *Nautilus*, the only recent cephalopod possessing a coiled, pearly, external shell (Jereb & Roper, 2005); the giant squid *Architeuthis dux*, which has currently been suggested as the emblematic invertebrate species to be used for raising awareness about biodiversity and issues related with conservation of marine species and habitats (Guerra et al., 2011); and the 'Dumbo octopuses' (*Grimpoteuthis* sp.) which, despite their rarity as deep octopods, have received special attention as 'ridiculously adorable and ultimately fascinating' animals by the public. Public aquariums all over the world exhibit cuttlefish and octopus in their collections (e.g. Monterey Bay Aquarium in California, USA), and the public seems to perceive cephalopods as masters of camouflage, intelligent animals who are capable of learning.

2. Cephalopods as fisheries resources

Historical fishing records lack information about cephalopods fisheries. Nevertheless, humans have most likely been taking advantage of the octopus and cuttlefish that can be readily found in shallow water since coastal settlements established in prehistoric times. Recent studies on worldwide squid fisheries have reported information on cephalopod fisheries by ancient Greek, Roman (e.g. 177 and 180 AD), and Japanese civilizations, illustrating the long history between cephalopods and human coastal communities worldwide (Arkhipkin et al., 2015). The consumption of cephalopod products throughout history has been highest in South East Asian countries such as Japan, Korea, Thailand, Taiwan, and China. To date, these are still the most important countries in cephalopod commercial fisheries, which consist mainly of short and long-finned squids (Boyle & Rodhouse, 2005).

During the 20th century, the impact of fisheries on marine resources increased substantially, mainly due to the technological advances brought about since the Second World War. The increasing fishing effort applied on finfish stocks resulted in 75% of them being fully exploited or overfished (FAO, 2000; Hilborn et al., 2003). The combination of over exploited finfish stocks and practices which can be described as fishing down the food web (Pauly et al., 1998) resulted in an increasing interest and effort applied to cephalopod resources. Since the 1970's, cephalopod catches have increased from approximately 1 million tonnes in 1970 to over 4.3 million tonnes in 2007 with a small decrease in the following years (Arkhipkin et al., 2015). The world cephalopod captures rely mostly in the landings of loliginids and ommastrephids, mostly dominated by *Todarodes pacificus*, *Nototodarus sloanii*, *Illex argentinus*, and *Illex illecebrosus* (Arkhipkin et al., 2015).

3. Cephalopods as potential candidates for aquaculture

The origin of cephalopod aquaculture coincides with the first studies using cephalopods as experimental models in neurobiology, at the beginning of the past century (Sykes et al., 2014). A specific 'momentum' in cephalopod research occurred in 1963 when A.L. Hodgkin and A.F. Huxley won the Nobel prize in Physiology and Medicine for their work on nerve impulses using the giant axon of the Atlantic squid *Doryteuthis pealeii*. Thereafter, cephalopods were recognized as one of the most relevant model organisms for neuro-biological studies. That being said, the need for cephalopod cultures led to a rapid increase in demand for knowledge of specie biology and for the development of suitable technologies. From this incipient period until the present, the applicability of cephalopod aquaculture ranges from mechatronics to high-quality food source for human consumption (Sykes et al., 2014). Furthermore, cephalopod aquaculture has been ecologically important as a source for re-stocking and enhancement of natural populations (e.g., South East Asia, Nabhitabhata & Segawa, 2014).

The development of cephalopod aquaculture can be divided into four main periods (further descriptions in Sykes et al., 2014): (1) the first studies on experimental cephalopod culture (1960s), mostly conducted by Japanese researchers; (2) studies on cephalopod biology (1970s), with major advances in Europe (e.g., Spain and France) and USA; (3) studies for large-scale (or mass) culture (1980s), mostly developed in the USA; and (4) studies on the optimization of culture protocols (1990-2000). The latter was motivated by the increasing demand for cephalopods as food source for human consumption, given their high-quality nutritional profile (e.g., high protein content, 70-90% body weight) (Hanlon, 1990; Villanueva et al., 2014). Moreover, substantial attention was placed on cephalopods as potential candidates for aquaculture due to their fast growth, short life cycle (6 months to 3 years), elevated fecundity, high food conversion rates, and high adaptability to captivity conditions (Hanlon, 1990; Uriarte et al., 2011; Vidal et al., 2014).

Throughout the history of cephalopod aquaculture more than 16 species have been used for acquiring scientific knowledge and technological development in experimental and pilot cultures. Despite the large effort invested on such development, culture protocols have been developed only for four species (Villanueva et al., 2014): *Sepia officinalis* (Portugal), *Sepioteuthis lessoniana* (Thailand and Japan), *Octopus maya* (Mexico), and *Octopus vulgaris* (Spain). These species represent cephalopod culture models which have helped the development of protocols for other species, demonstrating the active collaboration among research groups for developing a world-wide cephalopod aquaculture (e.g., Uriarte et al., 2011).

A scaling production at industrial levels is the main aim for most of these culture models, although at the present only small-culture is possible, given the high mortalities (bottleneck) during the paralarval stage (Vidal et al., 2014). Major challenges are associated with a better understanding of nutritional requirements during early stages, as well as, the need of a better control in reproduction (Vidal et al., 2014; Villanueva et al., 2014).

4. Cephalopods as models for physiologic studies

The effects of climate change and global warming, which include (but are not restricted to) a reduction in the oxygen minimum layer and in the seawater pH, will likely require some level of physiological adaptation by marine organisms. Cephalopod species have much in common among one another, and where differences can be pointed out in their general biology, these can usually be interpreted in terms of differences (or different requirements) in the habitat that they occupy (Boyle & Rodhouse, 2005). Despite being organisms fairly adaptable to environmental shifts, given their short life cycle and life history plasticity (Xavier et al., 2015), certain species or stages of the cephalopod life cycle may be more susceptible to the impacts of environmental changes.

Species that inhabit the pelagic zone are generally metabolic active, adapted to low CO_2 values, and have higher oxygen demands (Pörtner et al., 2004; Seibel, 2007); while the opposite can be said for those inhabiting the deep sea (Seibel et al., 1997; Boyle & Rodhouse, 2005). In addition, cephalopods possess statoliths, structures whose calcification process is negatively affected by a reduction in pH in most marine invertebrates. Recent research has, however, shown contrary outcomes (Gutowska et al., 2008), but more studies regarding calcification of statoliths in cephalopods are required before predictions can be made about the effects of acidification on these invertebrates. That being said, it is clear that cephalopods represent a range of responses to changes in seawater pH and to vertical habitat compression. Some species will be tolerant of such phenomena, such as *Sepia officinalis* (Gutowska et al., 2008) and *Vampyroteuthis infernalis*, while others, such as most ommastrephids and loliginids, will be highly intolerant (Pörtner et al., 2004; Seibel, 2007).

In the case of life stages, recent research has indicated that ocean warming may result in faster embryonic stages, higher chances of premature hatching (Rosa et al., 2012, 2014), and in hypercapnic and hypoxic conditions inside egg capsules (Rosa et al., 2013), all of which would likely impact individual survival and fitness (Xavier et al., 2015). Higher temperatures (due to El Niño conditions) were also related to shifts in distribution and life history strategies in juvenile jumbo squid, *Dosidicus gigas* (Hoving et al., 2013).

Although cephalopods are generally not top predators, some species do play an important role in food webs, being prey for several top predator species, and support major commercial fisheries. That being said, any changes in their habitat that could possibly impact population dynamics would, thus, have severe ecologic and economic consequences (Andre et al., 2010).

5. Cephalopods as models in behavior studies

Cephalopods show complex behavior patterns which include matting strategies and parental care in some species. They also display signals of “high intelligence”, that are the result of sophisticated motor, sensory, and cognitive capabilities, such as highly efficient flexible arms, rapid signal transmission between nerves, the ability to learn, and high-resolution polarized vision (Hochner et al., 2006; Borreli & Fiorito, 2008). Squid and cuttlefish often gather to mate and their sexual behavior is fairly known, nevertheless a description of the common behavior of a species, an ectogram, has only been defined for *Octopus vulgaris* (Mather & Scheel, 2014). As a matter of fact, *O. vulgaris* has been widely used in behavior studies, with an impressive contribution by Dr. JZ Young and his students. This research group produced, between the 40’s and 70’s, important pieces of knowledge about the anatomy and physiology of the octopus’ nervous system, behavior and learning capabilities (Borreli & Fiorito, 2008). There are several practical reasons for using *O. vulgaris* as a research model to study the neural bases of complex behavior: it takes only a few days for an octopus to adapt to captivity (rapid acclimatization); they show highly stereotypic predatory behavior which is easy to activate and to quantify; and they are resilient to invasive surgery and recover rapidly following lesions in their central nervous system under deep anesthesia (Hochner et al., 2006).

Nowadays, most of the behavioral studies focus on the neurophysiological aspects of the behavior of cephalopods. Their anatomical features provide unique research opportunities, and some of the themes that have been investigated include: squid giant axon and giant synapse; behavioral studies and search for neural correlates; neurotransmitters; nociception; regeneration; neuromotor control; physiology of sensory systems; communication through color change in jumbo squid *Dosidicus gigas*; and development and functional organization of the brain and muscles (Fiorito et al., 2014). Most recently, the reviews conducted by Fiorito et al. (2014) and Brown & Piscopo (2013) revised many of the aspects related with the most advanced research and challenges related with neurophysiological studies using cephalopods as model organisms, including issues related with the adoption by the European Union countries of the Directive 2010/63/EU on the “Protection of Animals used for Scientific Purposes”. In fact, the adoption of the directive has created more research lines, which are related with adverse effects - “pain, suffering, distress or lasting harm” - in experimental animals (Smith et al., 2013).

6. Cephalopods as models for robotic studies

A growing number of engineers have been turning to biological systems as an alternative inspiration for new technologies in robotics. A sub-category within the bio-robotics field is that of soft robotics (for more information and references, please refer to Laschi & Cianchetti, 2014 and Rus & Tolley, 2015), which employs soft, deformable components (in contrast to the hard components of typical robotics) to obtain robots which can change shape according to the task to be performed or environment in which it is used. And when searching for malleability examples in nature, one cannot help but to think of cephalopods. They are extraordinary animals, and some aspects of their biology make them ideal model organisms for new robotics technology development. Many studies have focused on the octopus for identifying traits desirable and useful for robots (for example, Cianchetti et al., 2015), of which four are described below.

Their malleability (due to their soft bodies) has inspired, for example, the development of a new medical apparatus that can switch from being stiff to being completely soft, which is destined for use in surgeries and procedures (laparoscopies and endoscopies) such that the approach is minimally invasive (Jiang et al., 2013).

Cephalopods are also masters of camouflage and can change not only their color, but also their shape and texture in order to disguise themselves. Researchers have used the principle of chromatophore expansion and contraction (responsible for controlling the color changes in cephalopods) to formulate an electro-mechano-chemically responsive elastomer (Wang et al., 2014). The applications of this new material are vast and include, besides the obvious use for dynamic camouflage coatings, optoelectronics, biomedical luminescent devices, flexible displays, and so on (Wang et al., 2014). Another group of researchers went even further into the biology of color change and worked with devices analogue not only to chromatophores, but also leucophores, muscles, and distributed opsins, to create adaptive optoelectronic camouflage sheets with applications for domestic users, industries and the military (Yu et al., 2014). Camouflage principles have also been applied to robots themselves, with the intent of improving their display, which can come in handy in situations where the robots must be easily noticed, as is the case in search and rescue operations (Morin et al., 2012). The same team that built the latter also developed a similar robot that has the ability to withstand flames, water, and the weight of a car (Tolley et al., 2014).

The US Army Research Lab and collaborators have also been looking at cephalopods for new ideas, and developed a 3D-printable suction cup based on the sensory suckers present in the arms and tentacles of cephalopods. These are meant for improving the grasping abilities of robots and can be used, for example, in disaster relief environments where imminent dangers would keep humans from entering (US Army ECBC, 2013). The suckers and skin have also inspired the development of a sensorized arm skin for a (octopus inspired) robot which, besides conferring the soft and stiff requirements for the utilization of the machine, enables it to develop substantial suction forces underwater (Hou et al., 2012).

Locomotion in cephalopods is extremely effective and efficient, despite being a discontinuous system (when it comes to power), in contrast to most underwater propulsion systems, which are continuous (propellers, boats, etc.). During their "swimming", the animals thrust themselves in the water column by means of jet propulsion. This is a mechanism that has previously inspired the production of pulsed-jet propelled underwater vehicles, and more recently, the creation of a model that mimics the octopus, i.e., that matches its shape and is made of flexible material in order to display an efficient propulsion mechanism (Serchi et al., 2012). Another prototype has been developed for providing a silent propulsion system for boats and water sport devices - it doesn't copy the shape of cephalopods, but has the advantage of being 3D-printable, thus low cost and readily produced (Fraunhofer, 2013).

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4 Coastal Pollution & Restoration

Challenges and innovative solutions for monitoring pollution and restoration of coastal areas

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ABSTRACT

Coastal systems are under continuous and increasing pressure by different pollutants (e.g. metals, hydrocarbons, pesticides, POPs, etc.). Consequently, contamination assessment and remediation are amongst the most complex and concerning issues in the current global environmental scenario. Thus, a representative monitoring must address broadly chemical contamination, biological impacts, and oceanographic variables. However, contaminant analytical procedures and difficulty in interpreting biological endpoints limit holistic monitoring. This session will discuss the assessment of contaminant distribution, impacts and the development of mitigation tools. Studies addressing new related challenges, contaminant mixtures in diverse environmental compartments, or techniques to ameliorate environmental pollution are welcome.

ORAL PRESENTATIONS

4.1)	**Deni Ribičić**	Use of Chemical Dispersants to Promote Microbial Remediation of Oil Spills
4.2)	**Esther Thomsen**	Effects of sewage discharge on seagrass communities at Roatán, Honduras
4.3)	**Rafael Gonçalves-Araujo**	Zinc toxicity to the diatom *Conticriba weissflogii:* possible implications for ecosystem dynamics
4.4)	**Milad Adel**	Trace elements in blood of Caspian pond turtle (*Mauremys caspica*) from the Southern basin of Caspian Sea
4.5)	**Stefan Partelow**	Pollution impacts on marine protected areas: A global assessment

POSTER PRESENTATIONS

4.6)	**Milad Adel**	Survey of heavy metals contamination in muscle tissue of Caspian kutum (*Rutilus frisii kutum*)
4.7)	**Tanja Hilbig**	Emission Detectives: Stable isotopes trace the nutrient flow in mariculture
4.8)	**Ruth Lewo Mwarau**	Magnitude and fate of riverine inputs into Spermonde Archipelago, Sulawesi, Indonesia
4.9)	**Z. S. Woldeyohannes**	Spatio-temporal distribution of amino acids on the surface sediment of the Segara Anakan Lagoon
4.10)	**Imke Podbielski**	How to Assess the Impact of Submarine Groundwater Discharge in the Lab

PROCEEDINGS

Assessment of pollution and environmental restoration in coastal areas: challenges and solutions

Use of Chemical Dispersants to Promote Microbial Remediation of Oil Spills

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ABSTRACT

Oil exploration and production represent risk to the marine environment. The Deepwater Horizon oil spill reminded us of the fatality of such events. More than 4.5 million barrels of crude oil were discharged to the Gulf of Mexico causing affected part of the gulf ecosystem to be off equilibrium for months later. However, the marine environment has an extraordinary potential for self-recovery. A number of processes occur after the oil has been released, like physical and chemical weathering, and biodegradation. A wide variety of microorganisms are able to use petroleum compounds as carbon and energy sources. Depending on the weather conditions (incl. wind and wave actions), oil-in-water dispersion may be created, that may jump-start biodegradation of hydrocarbon compounds. Biodegradation can also be promoted artificially by applying chemical dispersants. When dispersants interact with oil in seawater larger oil bodies are broken into small droplets. This results in increased water-oil surface area, to which number of microorganisms can attach. Although, there are indications that chemical dispersants may cause additional toxicity throughout the food-web when used, the application of dispersants is environmentally favorable in certain conditions. In our mesocosm experiments, we show that size of oil droplets created by chemical dispersants, as well as seawater temperature matters when it comes to biodegradation. Quick shifts of distinct microbial communities can be observed over the incubation time, with oil-degrading microbes becoming abundant before hydrocarbons are depleted. The most abundant degraders can be found within the phylum of Firmicutes and the class of Gammaproteobacteria. These specialized hydrocarbon degraders are able to deplete petroleum within days and weeks, depending on the oil chemical structure and concentration. There is a need to further investigate how chemical dispersants interact with microbes and genes in order to optimally exploit their bioremediation properties.

Effects of sewage discharge on seagrass communities at Roatán, Honduras

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ABSTRACT

Increasing coastal urbanization and associated sewage outfall present a thread to land-sea interface ecosystems. Globally seagrass loss has been reported, but the response of seagrass to increasing nutrient levels in particular is still not well understood and widely debated. This study evaluates the effect of elevated nutrient concentrations and river runoff on seagrass communities by comparing between a bay impacted by a close sewage plant and a relatively pristine neighboring (1 km distance) bay at Roatan, Honduras. We measured nutrient concentrations of the water column, biological oxygen demand (BOD), sedimentary oxygen demand (SOD), turbidity and water color as environmental parameters that potentially effect the seagrass, algae and epiphyte community and seagrass morphology. Effects on *Thalassia testudinum* physiology were determined using bottle incubations to assess gross oxygen production. Findings revealed that inorganic nutrient concentrations were strongly (NH3 x 2556, NO2 x 115, NO3 x 3.7, PO4 x 182 compared to control site) increased in front of the sewage plant and decreased with increasing distance. BOD and SOD were significantly higher throughout the affected bay, while the visibility was significantly lower. Water color indicated increased nutrient and dissolved organic matter concentrations. While in the control bay, a dense (ca. 90 % coverage) seagrass community was observed, the impacted bay was dominated by bare sediments showing a spare seagrass (ca. 10 % cover) and algae community. Even though *Thalassia testudinum* plants had a significantly larger leaf surface in the impacted bay, gross photosynthetic rates were reduced. The epiphyte community was dominated (ca. 36 % coverage) by crustose coralline algae in the pristine bay, while in the impacted bay seagrass was inhabited increasingly by filter feeders and epiphytic red algae. Overall, the pronounced differences in water quality obviously also controlled seagrass composition, physiology, and epiphyte communities.

Zinc toxicity in the diatom Conticriba weissflogii: possible implications for ecosystem dynamics

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ABSTRACT

Diatoms are vital primary producers in marine ecosystems, and their growth may be affected by harmful concentrations of zinc in the environment. However, limited information exists on the response of some important physiological parameters to zinc as contaminant. In the present study, we evaluated the effect of zinc exposure on growth, chlorophyll a and in vivo fluorescence of the diatom *Conticribra weissflogii* under laboratory conditions. Furthermore, assumptions regarding the implications of toxicity damage on that primary producer to environmental dynamics were accounted. Cell numbers were significantly reduced after 48 h exposure to 450 and 900 µg Zn L^{-1}. Growth rates estimated after 96 h exposure (in div day^{-1}) were 0.81, 0.85, 0.69 and 0.59 for cells exposed to control, 90, 450 and 900 µg Zn L^{-1}, respectively, and it was significantly reduced at 900 µg Zn L^{-1}. There was a tendency of increase in chlorophyll *a* per cell after 3 h exposure to zinc. However, the ratio of in vivo fluorescence to chlorophyll a strongly decreased after 3 h exposure to zinc, suggesting that the mechanism of toxicity would involve a zinc-induced damage to the photosystem II. Possible metabolic routes for this damage and its environmental implications are discussed.

*Trace elements in blood of Caspian pond turtle (*Mauremys caspica*) from the Southern basin of Caspian Sea*

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ABSTRACT

The pollution of the Caspian Sea represents a problem of great impact to the health of wildlife, humans and ecosystems. Heavy metals have a great relevance in ecotoxicology because they are highly persistent and their potential toxicity to all organisms. The Mauremys caspica (Gmelin 1774) belongs to the Geoemydidae is a medium-sized freshwater turtle that is widespread throughout the Middle East. The Caspian pond turtle (Mauremys caspica) is one of the most important species in the Southern basin of Caspian Sea. This study determined the concentrations of trace elements in blood samples collected from both sex of Caspian Pond Turtle (n=60) inhabiting the Southern basin of the Caspian Sea in Sept. till Oct. 2014. Based on the results, the concentrations of metals detected were present as follows: Zn>Mn>As>Ni>Cu>Pb>Cd>Hg. The highest and lowest reported metal concentration in blood of M. caspica was Zn and Hg, respectively. Results also showed that accumulation of these elements was not significantly different between both sex of turtle ($p>0.05$). Cd and Pb concentrations recorded in the present study were higher than some species of sea turtles. Concerning to our knowledge, this is the first report into heavy metal accumulation in blood of Caspian Pond Turtle from the Southern basin of Caspian Sea. Further studies are needed to measure different heavy metals and trace metals in this valuable species and determine the role of these heavy metals in the physiology and Immunology of this species. In conclusion, our results confirmed the blood is an excellent tissue for the monitoring of the levels of contaminating trace elements, monitoring pollution and is easily accessible and nonlethal for Caspian Pond Turtle. The actual heavy metals concentrations present in Caspian Pond Turtle most be considered like a vital risk not only for this specie, but also for the organizations that develop in the region, including human populations.

Pollution impacts on marine protected areas: A global assessment

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ABSTRACT

Marine protected areas (MPAs) face many challenges in their aim to effectively conserve marine ecosystems. Considerable attention has been drawn to the need for better institutions, design and enforcement to improve MPA success. However, additional factors contribute to the success of MPAs including their inherent biophysical characteristics and pollution impacts. In this study we analyze the extent of pollution impacts on the global set of MPAs. We analyze the spatial extent of current and future pollution impacts and the affects they are having on regionally clustered groups of MPAs with similar biophysical characteristics. To cluster the MPAs into characteristic signature groups, their bathymetry, baseline biodiversity, distance from shore, mean sea surface temperature and mean sea surface salinity were used. We assess the extent at which each signature group is impacted by certain pollution types. Clustered biophysical groupings of MPAs display similar impacts on a regional scale. Our discussion highlights how the challenges MPAs face today can be addressed through design and implementation considerations for more integrated terrestrial and marine management approaches within regional scale networks. Furthermore, we present diagnostic social-ecological indicators for addressing the challenges facing unsuccessful MPAs.

Survey of heavy metals contamination in muscle tissue of Caspian kutum (Rutilus frisii kutum)

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ABSTRACT

The pollution of aquatic ecosystems with heavy metals, have always been a major concern for aquatic organisms and human health. Contaminants such as heavy metals are accumulated along the food chain and then transmitted to human body. Levels of contaminants in fish are of particular interest because of the potential risk to human health. The Caspian white fish or Caspian kutum (*Rutilus frisii kutum*) is a commercially valuable species in the Caspian Sea. This species is now considered as a threatened species because of overfishing and destruction of spawning grounds. This study examined the levels of more important heavy metals pollutants such as Cadmium (Cd), Lead (Pb), Cobalt (Co), Manganese (Mn), Zinc (Zn) and Copper (Cu) in muscle tissue of *Rutilus frisii kutum* from the Caspian Sea and then compared with the standards established for human health. This research was done on 40 samples of *R. frisii kutum* obtained from Southern parts of Caspian Sea by Multi mesh gillnets in fishing season in Feb. 2015. The samples were digested by concentrated Nitric acid (HNO_3), and then were analyzed by Atomic Absorption Spectrophotometers. The concentrations of metals detected were present as follows: Zn> Cu>Cd> Co> Mn>Pb. Mean concentration of Cd, Pb, Co, Mn, Cu and Zn was 0.78 ± 0.08, 0.16 ± 0.01, 0.28 ± 0.04, 0.19 ± 0.02, 5.84 ± 0.42, 56.12 ± 1.06 (µg/g dry weight), respectively. Based on the results no significant correlation was observed between heavy metals concentrations with fish body weight and length. The levels of surveyed heavy metals were lower than the standard levels established by WHO, FAO, NHMRC, INSO and EPA. Measured elevated levels of metals concentrations in muscle tissue of *Rutilus frisii kutum* indicated that no health risks for the fish and consumers of these fish, especially human consumption.

Emission Detectives – Stable isotopes trace the nutrient flow in mariculture

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ABSTRACT

In the challenge for feeding the world, sustainable marine aquaculture will gain importance in near future. As the EU Marine Strategy Framework Directive explicitly demands to avoid potentially negative impacts of mariculture on the environment, the development of reliable methods to trace and moreover avoid pollution is essential. This study investigated the retraceability of nutrient emission from fish aquaculture into the benthic environment using stable isotopic signatures.

Sea bass (Dicentrachus labrax) were fed three experimental diets containing fish meal (FM), soy protein concentrate (SPC) and wheat gluten (WG) as main protein sources. The fish tank effluents were passed through a separate shrimp (Litopenaeus vannamei) tank. Shrimps as benthic model organisms were supposed to use the respective effluents and the thereby developing biofilm as food. Whereas all fish δ13C values increased during the experiment, fish δ15N values increased only in plant protein feeding groups. If fed with fish meal diet, fish δ15N values decreased slightly. Shrimp δ13C and δ15N values increased to higher values than those of the respective fish in the FM and WG feeding groups. δ13C and δ15N values decreased from fish to shrimp in the SPC feeding group. Shrimp reared in the effluents of fish on fishmeal based diet showed highest values of δ13C and δ15N, higher than those of the respective fish and similar to those determined in benthic organisms from the North Sea. Although the experimental diets were metabolised differently in fish, it was possible to show that feed-derived isotopic signatures are reflected in organisms living on the effluents (uneaten feed and/or faeces) of fish culture. Therefore the analysis of stable isotopes is a suitable tool to trace aquaculture emissions into the associated environment.

Magnitude and fate of riverine inputs into Spermonde Archipelago, Sulawesi, Indonesia

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ABSTRACT

The coastal zone is a dynamic region where the rivers, estuaries, ocean and land meet allowing for studies on the connectivity between the systems. It receives varied riverine inputs from terrestrial systems, mangroves and seagrass ecosystems. The Spermonde archipelago is separated from open marine settings by a discontinuous barrier reef. Mangroves and Seagrass meadows are found along the mainland coast with the latter growing on intertidal reef flats on many of the other islands in the lagoon. The research aimed at identifying the forms and magnitude of organic inputs from various sources and its ultimate fate in the archipelago. The inputs were analyzed in the form of organic carbon. Water samples were collected during the dry season (November 2014) and the wet monsoon season (February 2015) along transects originating from the three main rivers discharging into the archipelago. These were analyzed for Chl-*a* and TSM concentrations. Bare sediments samples were collected for sediment characteristic analysis and stable isotope analysis. Additional samples of leaf and sediment were also obtained from various mangrove and seagrass sites, which were used for stable isotope analysis. Preliminary findings indicate a seasonal variation in Chl-*a* and TSM values with high Chl-*a* concentrations during the wet season while TSM had lower concentrations for the same period. The concentrations also varied spatially with the coastal area having upto 60±5mg/m3 of TSM that gradually reduced towards the edge of the shelf. The sediment showed clear variability with mud and clay particles at the coastal areas while the open archipelago area composed of sandy particles. The organic carbon on LOI at the river mouths had 10±2% decreasing to about 3±1.2% in the open archipelago area about 40km from the river mouths. This suggests high riverine inputs at the coastal area while the open coastal archipelago derive their inputs from phytoplankton.

Spatio-temporal distribution of amino acids on the surface sediment of the Segara Anakan Lagoon

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ABSTRACT

The purpose of the study was to determine the spatial-temporal abundance and composition of total hydrolysable amino acids on mangrove-fringed coastal lagoon sediments in Segara Anakan Lagoon, Java, Indonesia. Total organic carbon (C_{org}), total nitrogen (TN), carbon/nitrogen ratio (C:N), stable isotopic compositions of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), total hydrolysable amino acids (THAA) and hexosamines (THHA) were measured from surface sediments. The surface sediment samples were collected from 11 stations during two sampling campaigns in February and September, 2008 (representing the rainy and dry seasons, respectively). The sediment C_{org} and TN value of the stations were as high as 3.4% and 0.2% for the rainy, and 4.5% and 0.2% for the dry seasons, respectively. While the δ13C_{org} values showed a range between -24.83‰ and -27.9‰, the $\delta^{15}N$ (‰) values range between 2.4‰(SA 3-02) and 5.6‰(SA 2-19) in the dry and rainy seasons. Correlation of the AA-C% and AA-N % contribution across the stations in the rainy and dry seasons were comparable (r^2= 0.6). However, AA-C% display a slight decrease from western to eastern area of SAL. A C:N ratio of rainy and dry seasons showed a range between 23.8-7.9 and 36.4-7.3, respectively. which clearly marked that the stations are getting mixtures of OM from autochthonous and allochthonous OM sources. Results from the RI and production of non-protein amino acid reveal strong positive correlation of the dry and rainy seasons. The β-alanine and γ-aminobutyric acids range (1.9-3.6 mol%) fits well within the coastal sediment ranges. The most abundant amino acid was glycine both in the dry and rainy seasons.

How to Assess the Impact of Submarine Groundwater Discharge in the Lab

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ABSTRACT

Submarine groundwater discharge (SGD) is a major pathway delivering nutrients into coastal waters. Nutrients enter groundwater when it is recharged and can undergo chemical reactions during the sometimes long (>50a) transport to the oceans. However, not only nutrients are transported through the aquifers. In some areas groundwater can be heavily loaded with other pollutants, organic and inorganic substances from natural as well as anthropogenic sources. In certain regions, the nutrient load through SGD may rival river input. In contaminated aquifers, N/P ratios may exceed those in river water and are higher than the Redfield ratio. Due to its substantial mass flux and its biochemical components, SGD can strongly impact marine ecosystems.

Despite an increasing understanding of the potential importance of SGD for marine ecosystems in the scientific community, few published works have studied SGD from a biological perspective. One reason for this, especially in tropical regions, is the difficulty to locate SGD in the field. To find a suitable study site is even more challenging. Simulation of SGD in aquarium tanks could relieve researchers from these problems and facilitate the assessment of individual stress response. We aim to assess the impact of environmental stress associated with SGD, such as eutrophication or pollution, on marine ecosystems around tropical islands. We plan to measure the individual stress response of key species using this novel experimental technique. In combination with ecological field survey these experiments can shed light on the impact of SGD on coastal benthic ecosystems.

Keywords: Submarine groundwater discharge, aquarium experiment, nutrient enrichment, coastal ecosystem, physiological stress response

Assessment of pollution and environmental restoration in coastal areas: challenges and solutions

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Coastal areas are under continuous and increasing pressure from different human activities. A cocktail of contaminants (e.g. metals, hydrocarbons, pesticides, persistent organic pollutants (POPs), and others) threatens water, sediment and biota. Additionally, coastal systems are highly dynamic, integrating the physicochemical dynamics of freshwater bodies, estuaries and lagoons with the oceanographic characteristics of adjacent seas. Thus, contamination assessments and remediation of coastal ecosystems are among the most complex and current issues in ecotoxicology and environmental management. Lack of not expensive and sensitive multi-contaminant analytical procedures, difficulties in interpreting biomarkers as bioanalytical tools, and the lack of multidisciplinary approaches limit holistic environmental health assessments. Concomitantly, a controlled coastal retreat strategy known as managed realignment is becoming common mitigation tool for anthropogenic impacts. In turn, managed realignment might impact coastal biogeochemistry. This article discusses some of the current challenges and opportunities in the assessment of contaminant distribution, and its interaction with managed realignment. In conclusion, it is highlighted that representative monitoring must address the chemical contamination, biological impacts, and their interaction with the environmental features. Similarly, managed realignment might provide positive outcomes if uncertainties and impacts on contaminant remobilization are observed.

1. Introduction

About 70% of the global population lives in coastal areas (Bortone, 2005), where the rapid growth of cities and human activities leads to escalating anthropogenic pressure. Activities such as tourism, agriculture, fisheries, aquaculture, naval traffic and industrialism generate a broad diversity of pollutants in amounts that are potentially harmful to the environment (Zagatto, 2006). This is especially concerning because coastal systems have been used as deposits of urban and industrial wastes during the last centuries, which turned coastal and transitional waters into the final receptacle of a complex cocktail of contaminants (Kennish, 1991).

Metals, hydrocarbons, pesticides, and several POPs are among the main chemical contaminants affecting coastal ecosystems (Seeliger et al., 1988; Kennish, 1991; Neto et al., 2008). Pharmaceuticals and personal care products (PPCPs), flame retardants and new generation anti-fouling compounds have more recently joined into the list of chemicals of emerging concern. Concomitantly, researchers are increasing awareness about certain environmental stressors that were previously considered unproblematic. For example, changes in pH (due to climate change), increased water temperature (due to climate change and usage by power plants), and increased sediment load (due to watershed uses and coastal engineering) have been demonstrated to threaten aquatic systems on the long run.

Consequently, contamination assessment and remediation are among the most complex and concerning issues in terms of environmental health and ecosystem services. A representative monitoring program must address chemical contamination, biological impacts, and oceanographic variables. Therefore, the present study discusses various challenges and solutions for monitoring pollution and the mitigation of impacts on coastal areas.

2. Environmental health assessment

Numerous approaches can be used to measure environmental impacts of pollutants, and the selection of the most appropriate methodology will depend on several factors, e.g. the objectives of the study, the environmental matrix, and the analysed compounds. Monitoring tools, such as measurements of chemical concentrations, are traditionally employed to verify the level of contaminants in a given environmental compartment (air, water, soil, sediment, biota) (Borgå and Di Guardo, 2005). Different compartments will provide particular responses to contamination depending on a wide range of factors and the interactions between them. These influencing factors include the physical characteristics of each compartment and each study area, the physical-chemical properties of the analysed compounds, biological aspects, and proximity to the pollution source (Binelli et al., 2009; Parolini et al., 2010).

Contamination sources are mainly located in populated, industrialized and agricultural areas, where anthropogenic contaminants can reach the environment by urban and industrial sewage discharge, leaching from agriculture, direct spillages into soils, urban runoff and volatilization (Breivik et al., 2002; Litskas et al., 2012). Atmospheric deposition and water transport are the most important mechanism by which contaminants are transferred from the source to residential and background areas (Ruiz-Fernández et al., 2012; Argiriadis et al., 2014).

Atmospheric transport is the main way of long-range transport of contaminants and global distillation effects (Vallack et al., 1998). Since concentrations and composition of pollutants in the air are highly influenced by primary emission sources, the assessment of air contamination represents a useful tool to assess recent emissions of contaminants, distance from sources and pathways of transport of pollutants (Nriagu and Pacyna, 1988; Pozo et al., 2006).

Water represents another major mean of transportation for contaminants on local and global scales. Water bodies can temporarily store chemicals. Their contamination sources are usually leaching from soils and discharge of effluents and industrial wastewaters into river-linked tributaries, including small streams, rivers, lakes, and drinking water supplies (Sodré et al., 2010; Mahmood et al., 2014). Water quality, in terms of physical and chemical contaminant levels, is an important issue in terms of human health and environmental conditions, and could constitute a direct measure of the degree of marine pollution (Montuori et al., 2014).

After transport, contaminants' final reservoirs are coastal areas and estuaries, where sediments act as a sink for most pollutants, which accumulate and remain in the sedimentary matrix for long periods of time, from several years to decades (Sahu et al., 2009; Ruiz-Fernández et al., 2012). Consequently, sediments can represent a record of pollution levels and environmental quality of aquatic ecosystems. Surface sediments, for example, can be used to determine horizontal distribution of chemicals, relating to the distance of sources, while sediment core data represent an important tool for describing the historical input of contaminants and understanding pollution trends over time (Hong et al., 2003; Martins et al., 2010; Combi et al., 2013).

Contaminants present in air, water and sediments can influence the surrounding biota, directly or indirectly. Compounds such as POPs, metals and PPCPs have the potential to accumulate through the food web, affecting marine biota, aquatic-dependent wildlife, and human health (Borgå et al., 2001; Hong et al., 2003). Therefore, the assessment of biota contamination is essential to understand the extension and possible risks of pollution levels as well as the transference processes between compartments (Borgå and Di Guardo, 2005).

Compared to other types of assessment, bioanalytical tools or biological assessment tools convey more information about health and functioning of the ecosystem. Additionally, biological assessment provides relevant information in terms of bioavailability and potential toxicity (Neto et al., 2008). A multitude of biological parameters are currently being used in ecotoxicological research to infer environmental health and contamination (Box 1). Examples are various biomarkers (Monserrat et al., 2007; Machado et al., 2013), toxicity tests (Zagatto, 2006), levels of compounds in specific tissues of biota present in the environment (i.e. usage of biomonitors) (Seeliger et al., 1988), and the presence or absence of certain species or feature (i.e. usage of bioindicators).

Box 1. Biological Assessment Tools

- Biomarkers (quantitative): Measurable biological responses on body fluids, cells, tissues, or organism (including behaviour) that indicate the presence of contaminants.
  - Exposure biomarkers: Report exposure to some level of contamination
  - Effect biomarkers: Denote that contamination reached level high enough to disrupt biological functions.
- Biomonitor the level of contaminants on organisms (quantitative): Type of exposure biomarker from which bioaccumulation and bioavailability of a chemical to diverse organs and organisms can be inferred.
- Toxicity tests (quantitative): Include laboratory exposure to environmental samples (water and sediment) or environmentally relevant conditions to infer toxicity to the local fauna.
- Bioindicators (qualitative): Include interpret the presence or absence of certain species according to the normal of certain environment.

3. Challenges and solutions for environmental management

3.1 Contamination assessment and analysis

The quantification of chemicals in environmental samples is performed through several steps, such as sampling, extraction, purification, and instrumental analysis. A range of issues can affect the efficiency of environmental chemistry analysis, such as the usage of large volumes of solvents and reagents, which in some cases are toxic (e.g. toluene and hydrochloric acid for the extraction of organic compounds and metals, respectively), low sensitivity and selectivity, long extraction times, and high costs (Zhang et al., 2011).

Despite the efficiency of traditional extraction methods, there are limitations regarding detectable levels of contaminants (Qiu and Cai, 2010). For example, while there are numerous studies regarding contaminants in sediments and biota, especially in highly impacted areas (e.g. Koh et al., 2006; de Souza et al., 2008; Kanzari et al., 2014), a limited number of papers presents data from water samples with extremely low concentrations (Qiu and Cai, 2010).

Another issue regarding contaminant analysis is the amount of chemicals currently or historically used. Estimates suggest that more than 100 000 chemicals are currently in use for different purposes around the world (Robles-Molina et al., 2014). The existence of such a high number of compounds in the environment leads to interferences during chemical analysis. Interferences can significantly reduce or preclude the analysis of target compounds (Liu et al., 2006). Additionally, co-contaminated matrixes (matrixes contaminated with two or more groups of pollutants, e.g. metals and organics) can be complex in terms of understanding the interaction mechanisms between different compounds and environmental conditions (Sandrin and Maier, 2003).

The development and optimizations of analytical methods that are environmental friendly and capable of detecting multiple classes of compounds at very low levels (e.g. parts per trillion – ppt) is currently one of the biggest challenges in environmental chemistry (Sterzenbach et al., 1997; Lara-Martín et al., 2011; Pintado-Herrera et al., 2013). In recent decades, many advances have occurred in this sense, with the advent of new analytical techniques and the improvement of instrumental analyses. For example, new techniques have been developed for the extraction of metals and organic compounds, such as PAHs (polycyclic aromatic hydrocarbons) and PCBs (polychlorinated biphenyls).

Accelerated solvent extraction (ASE), ultrasonic agitation/sonication (US) and microwaving are alternative techniques with recognized advantages over traditional procedures (e.g. Soxhlet and *aqua regia* extraction for organic compounds and metals, respectively). Advantages of the modern techniques include less use of solvents, elimination of additional clean-up steps and concomitant extraction of numerous classes of compounds, including emerging compounds (Nieuwenhuize et al., 1991; Aguilar et al, 2014).

3.2 Biomarkers: a promising set of biomonitoring tools

Biomarkers are a common tool in current biomonitoring studies (Rose et al., 2006), and their potential as early warning indicators for contamination effects on higher biological levels is widely acknowledged (Monserrat et al., 2007). Distinct biological responses are used as biomarkers. Amongst those commonly used are the quantification of detoxification enzymes and polypeptides, oxidative stress, DNA damage, mutagenic potential and nuclear abnormalities, immunologic responses, neurotransmission, and body composition (Machado et al., 2013, Machado et al., 2014). Several metabolic pathways in various animal organs are known to be disrupted by environmental pollution, and are therefore potential biomarkers of contamination (Monserrat et al., 2007).

However, a major constrain to the usage of biomarkers is the lack or controversial information about control level of responses as well as concerns regarding dose-response curves for both individual contaminants and mixtures. Additionally, because biomarkers are restricted to the organism level, there is considerable uncertainty about how to extrapolate such metrics to higher levels of biological hierarchy (Brown et al., 2004). Thus, linking the biomolecular, biochemical, cellular, tissue, and organism level biomarkers to population and ecosystem stressors constitute a current challenge for broader biomarkers application.

3.3 Coastal restoration, contamination, and climate change

Climate change modifies the oceanographic conditions of coastal areas, and ultimately alters contamination patterns and influences coastal management. For example, climate change can lead to enhanced volatilization of POPs from primary sources and re-emissions from secondary sources, such as meltwater from glaciers (Breivik et al., 2011; Geisz et al., 2008). Sea level rise and related risks of storm surge, flood, and erosion are already increasing the maintenance costs of hard engineered coastal defences. Often, hard defences are no longer economical, and coastal management policy is now redirected towards more natural and sustainable coastal restorations, such as "managed realignment" (MR), "managed retreat" or "coastal setback" (POSTnote 342). MR denotes deliberately breaching engineered defences to allow the coastline to migrate to a new line of defence landward in response to sea level rise (Andrews et al., 2006). This is currently one of the most common solutions to restore coastal systems in industrialized countries and mitigate effects of climate change and contamination.

3.4 A mitigation tool: Managed realignment

Hard defences provide a false sense of security and encourage urban development in high flood risk zones (Andrews et al., 2006). Additionally, sea walls prevent the natural migration landwards of tidal systems in response to sea level rise. This provokes "coastal squeeze" (Pethick, 2002), compromising environmental services of coastal ecosystems. Therefore, current costal management favours managed realignment, which propitiate the creation of new tidal areas, delivering several environmental services such as:

- Reduction of coastal defences (Andrews et al., 2006);
- Intertidal habitat for biodiversity;
- Environmental quality: Recycling water nutrients and functioning as store of green-house pollutants (CO_2 and CH_4);
- Flood defence: Intertidal zones are natural defences, attenuating wave height and energy, and tidal amplitude (Pethic, 2002);

- Compensation for habitat loss related to coastal squeeze as required by the EU Habitats Directive (Council, 1992);
- Landscape diversity.

Risks of managed realignment

MR practices flood soils that were previously used for various activities and might contain contaminants. In turn, the polluted soils can be eroded by water, and undergo chemical and biological changes, thereby increasing contaminant remobilization. Such remobilization of contaminants from soils to water is problematic because metals bound to sediments are considered mainly not bioavailable. However, dissolved in water they are bioavailable and potentially causing toxicity to aquatic organisms and ecosystems.

Coastal restoration and management in Europe

Historic coastal protection favoured hard defences such as sea walls and groynes (Andrews et al., 2006). About half of England's coastline is currently protected by hard defences (POSTnote 342). New management practices are being adopted in UK and Northern Europe towards managed realignment (Box 2). Important initiatives with potential to change coastal biogeochemistry at national and international levels are:

- Shoreline Management Plans cover the entire coast of England and Wales, favouring the work with natural processes, resulting in coastlines no longer being defended (POSTnote 342).
- Thames 2100 is a shoreline plan to London and the Thames estuary, including adaption to future climate conditions by 2100. It combines re-structuring dikes, resilient defences, and warning and emergency systems for flood protection (Thames 2100, 2015).
- The Netherlands- Delta Management Plan: €100 billion for the next 100 years. It creates intertidal beaches in North Coast, preserves and improves tidal flats south-western (Sheldet), and provides more room for Rhine and Meuse, with estuarine protection and a new gates in the Rhine (Delta Committee, 2015).

Box 2. Managed Realignment Techniques

Ordered according to increasing costs and environmental intervention.

- Do not renew existing hard defences when their functional time is over.
- Remove part of or entire existing sea walls to allow flooding.
- Reallocate coastal defences to higher grounds while minimizing their length.
- Engineer re-created intertidal systems, mudflats, saltmarshes, realigned estuaries, and tidal macro and micro channels.

Managed realignment and potential contamination

MR can affect sediments and thus, the fate of metals and other sediment-associated contaminants in several ways:

- Changing redox conditions by flooding air-exposed soils (Du Laing et al., 2009).
- Increment of organic matter in flooded sediment due to non-optimal degradation, which enhances risks of organic mobilization (Du Laing et al., 2009).
- Salinity intrusion in freshwater saturated soils might increase desorption.
- Possibility of previously contaminated sediment to be eroded (Bianchi, 2007).
- Creation of a depositional habitat and sink of contaminants (Bianchi, 2007).

- Allowing new interactions with plants and benthic fauna.

3.5 Uncertainties

Climate Change Uncertainty

Climate change is unequivocal, but the extension of oceanographic changes in coasts, as sea level rise (POSTnote 363), climate variability and storms (POSTnote 400), and climate feedbacks (POSTnote 454) are uncertain. All those coastal and oceanographic shifts affect erosion and biogeochemistry, constituting open challenges for coastal pollution, projection, and management.

Political Uncertainty

- MR is still in an experimental phase, and it is not certain how long and how restored tidal marshes will take to function as natural (Andrews et al. 2006).
- Population scepticism and >£150 billion investments in structures along the UK coast pushes to the maintenance of hard defences (Pethic, 2002).
- Some policies as "Make Space for Water" launched in 2005 for England (Defra, 2005) favouring MR are still not fully implemented (POSTnote 362).
- EU Water Framework Directive (WFD, 2015) and Maritime Strategy Framework Directive (MSFD, 2015) for the "good ecological status" aren't completely implemented.

4. Conclusions

Environmental management and pollution assessment represent complex matters, including analytical chemistry, ecotoxicology, and environmental engineering in a transdisciplinary manner. It involves a wide range of dynamic issues such as global warming, air, water, and sediment pollution, coastal erosion, control of toxic substances and human, biological, and ecological adverse effects. New tools and approaches have been constantly developed and optimised to deal with the constantly emerging challenges of this dynamic theme. Managed realignment might deliver positive outcome if uncertainties and impacts on contaminant remobilization are properly considered. Overall, it is important that new efforts and approaches regarding environmental management and pollution assessment provide multidisciplinary and integrative analyses. This would consequently lead to a better understanding of the extension of anthropogenic impacts on coastal and aquatic systems.

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5 ScienceTainment

How to communicate science entertaining

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ABSTRACT

The Internet and its features offer great opportunities for scientists to present their work to the public. Using new media channels like Youtube, TedTalks or blogs, scientists can offer their research in a creative, entertaining and intelligible way to the public.

ORAL PRESENTATION

MOVIE PRESENTATION

PROCEEDINGS

Bringing back the life of coral reefs

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ABSTRACT

In 1997/98 an extended El Niño event coupled with the Indian Ocean Dipole caused a massive coral bleaching around the world. In Seychelles, Indian Ocean, 97% of shallow water coral reefs died, and they have not recovered. Therefore, a coral reef restoration project began in 2011 to bring back the life to the former coral reefs. The Reef Rescuers Project used the “coral gardening” technique to restore a degraded coral reef at a marine reserve in Cousin Island Special Reserve. In a large scale project (25,000 corals transplanted), using local and recycled materials, fragments of coral survivors from the bleaching event were reared in underwater nurseries before being transplanted to the degraded reef site.

While volunteering for this project I realized how our effort has a significant impact not only on the ecosystem but also on the local community. Today the former degraded reef is thriving again resulting in happy marine life, happy scientist, happy fishermen, happy hotel managers and happy tourists. The large scale coral gardening technique used in Seychelles is a successful low-budget method to give coral reefs a head start on their way back to life.

Keywords: El Niño, coral reef restoration, Seychelles

A Golden State for Sharks?

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ABSTRACT

The Western Australian shark cull is a state government policy of capturing and killing sharks such as great white sharks, bull sharks and tiger sharks larger than 3 meters by use of baited drum lines. The policy was implemented in 2014 to reduce the risk of shark attacks following the deaths of seven people along the Western Australian coast since 2010. National demonstrations opposing the policy have attracted international attention and the policy has been criticized by numerous marine scientists, environmental activists and non-governmental organizations. Media is talking of the biggest shark protection movement in history. Thanks to a lot of effort from national and international scientists and the public, the program was ceased in the end of 2014. But there remain a number of fatal shark attack programs around the world that kill not only sharks but also many other marine animals every year.

“A golden State for sharks?” aims to inform the public about facts and risks related to the Western Australian shark culling policy in order to facilitate the public to form and express an opinion to decision-makers, not only in Australia but wherever shark attacks are of concern. The movie explores pro and contra arguments for the shark cull policy, points out the importance of marine apex predator in the oceans and explains their threats. It furthermore is looking at more sustainable alternatives for a more peaceful co-existence of humans and sharks.

ScienceTainment - How to communicate science entertaining

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1. Introduction

In recent years, communication of science to the public has largely changed from print to new digital media, such as videos, animations, cover songs with scientific lyrics, science slams and many more which are mainly available on the World Wide Web. Scientists are increasingly confronted with demands to popularize, communicate, and disseminate information about their research and findings to a non-scientific audience (Brossard, 2013; Jensen et al., 2008). In the following, we will explain why science communication, using new media, has become increasingly important for scientists, research institutes, and universities.

Traditionally, journalists have delivered science information from researchers to lay audience by being a translating mediator (Peters et al., 2014). Some scientists even considered talking to the public as a waste of time (Chappell, 2003). Yet, researchers can no longer stay as external, detached experimenters providing solutions to society, but have to become active participants in the process of democratic self-governance which is the participation of the members of a democratic society in the making and adapting of the rules within the collective (Barbour et al., 2008; Ostrom, 2005).

Not too long ago, the popularization of science was restricted to magazines, newspapers, public lectures, radio, and television (Bentley and Kyvik, 2011). Technological developments in recent years have made the internet the main source of information for learning about specific science issues in the USA (National Science Board, 2012), whereas it is of less but increasing importance in the EU (Euopean Commission, 2013). The internet has created an instantaneous availability of a heterogeneous amount of science related information to an interested non-scientific audience (Peters et al., 2014), whereby science communication has changed its format and scope (Peters et al., 2014; Sugimoto and Thelwall, 2013). The amount of science related blogs has grown exponentially between 2008 and 2013 (Brossard, 2013). The video platform YouTube is the third most visited webpage online (Alexa Internet Inc., 2015) containing 1.007.249 channels related to science (YouTube, 2015). The TED (Technology, Entertainment, Design) video website (www.ted.com), a popular format of appealing talks by researchers, lists half a million views daily (TED 2012). One third of those videos are science and technology related (Sugimoto and Thelwall, 2013). The potential that lies within these media platforms is huge and provides a novel and interactive platform for the direct popularization of science from researcher to audience without a mediating journalist (Leon, 2008; Sugimoto and Thelwall, 2013).

2. Why do we have to communicate science?

But why is it so important that science communication uses new media? On the one hand citizen support of science is important, as the general public can be seen as a stakeholder in the process of governmental based science funding, and today, funding agencies ask more often for self-representation in the media (Brossard, 2013; Pearson, 2001; Rödder, 2009). The American Academy of Arts and Science (2013), in alignment with the guidelines of the National Science Foundation (2007), even names improved communication to the public as a necessary action to address the funding crisis of research institutes, requesting scholars to make a case for the public value of their work. This is mirrored in the increasing pressure upon universities and institutes to gain public support and ensure legitimization as a public and government funded institution which competes for funding against other public services (Marcinkowski et al., 2014). Going further, Marcinkowski and colleagues (2014) have shown that a higher proportion of third party funding in a research institute's total budget has a positive effect on media efforts. This indicates the rising need to attract the attention of private and public funding partners through media visibility (Dunwoody and Ryan, 1985; Gascoigne and Metcalfe, 1997; Peters et al., 2008).

On the other hand disseminating scientific findings is important, because it helps members of the public, including policy makers and stakeholders, to consider scientific knowledge in decision making processes, enabling them to critically question a topic. Thereby, an informed dialogue can be created, which could ideally prevent misconceptions and poor decision making (Brossard, 2013; Kroger, 1986). We would like to use the state of education on climate change as an example to support our opinion on why the general public needs to learn about and understand research findings. Following Gallup polls, conducted in 127 countries in 2007 and 2008, one third of the world's population has never heard of global warming and although 97 % of US citizens are aware of global warming only 49 % of these 97 % believe that global warming is a result of rising temperatures (Pelham, 2009).

3. New Media

There are positive and negative sides to the described new trends in science communication. In the following paragraph, we will present arguments for both sides allowing a critical view on those trends.

By directly addressing an audience through online communication, the dependency on journalists as translators is reduced, thereby decreasing the bias in science reporting created by editorial choices (Peters et al., 2014) particularly as journalists are considered to specifically look for sensational results (Kroger, 1986). However, in the vast online offerings of scientific texts, videos, talks, etc., it is difficult to gain attention for ones work which in turn, can mislead scientists and press offices of institutions to choose catchy, overrated, and sensational titles for their contributions which beyond being a message are also a marketing tool Mcnutt (McNutt, 2014; Peters et al., 2014). Communicating science to a lay audience is not easy and requires motivation, time, and communication skills (Peters et al., 2014). Unfortunately, talking to the public and providing entertaining media contributions does not necessarily imply that someone is listening. Yet, if someone does listen, science communications can provide a direct resonance from the audience to the communicator through comments, likes, shares and tweets (Peters et al., 2014; Teif, 2013). These new response functions of the web shift the traditional uni-directionality of science communication from a public inability to actively engage and discuss a presented topic (Kidd, 1988) to an exchange between scientists and lay audience (Jasanoff, 2003). This can encourage conversation and discussion about a topic. Sugimoto and Thelwall (2013) found that the highly commented contributions were those of controversial nature and not the ones most liked. Critical however, is the finding of Anderson et al. (2014) showing that "uncivilized" comments, following a neutral article, can influence a readers perception of the article, prompting skewed opinions on the presented topic. Another concern for many scientists is the potential de-professionalization of online contributions, caused by a lack of peer review and no clear separation of opinion and fact in e.g. blogs where science and public communication overlap (Brossard, 2013; Peters et al., 2014; Teif, 2013). Some scientists even fear a loss of reputation amongst peers when engaging in new media (Weigold, 2001) as there is a need to simplify scientific findings, thereby potentially loosing accuracy (Olson, 2009).

4. How to communicate

Before presenting several formats of communication in new media we describe how communication to a lay public should be principally designed. One point is to avoid highly technical language (Weigold, 2001). The task is to translate science into a common language that makes the reader interested and excited, so chose your words well and consider usage of alliterations, ploys, and symbols (Kroger, 1986; Negrete, 2002). Present your topic in a short, mostly humorous, and easy accessible way (Kim, 2012). However, do not overuse interactivity as low levels have been shown to be more effective in generating knowledge than medium and high amounts of interactivity (Xenos et al., 2011). It is best to use the ice-berg technique meaning the tip is sufficient; do not bore or overload your audience with details (Kroger, 1986). One recommendation from us, stick to the five rules on successful science communication from Olson (2009):

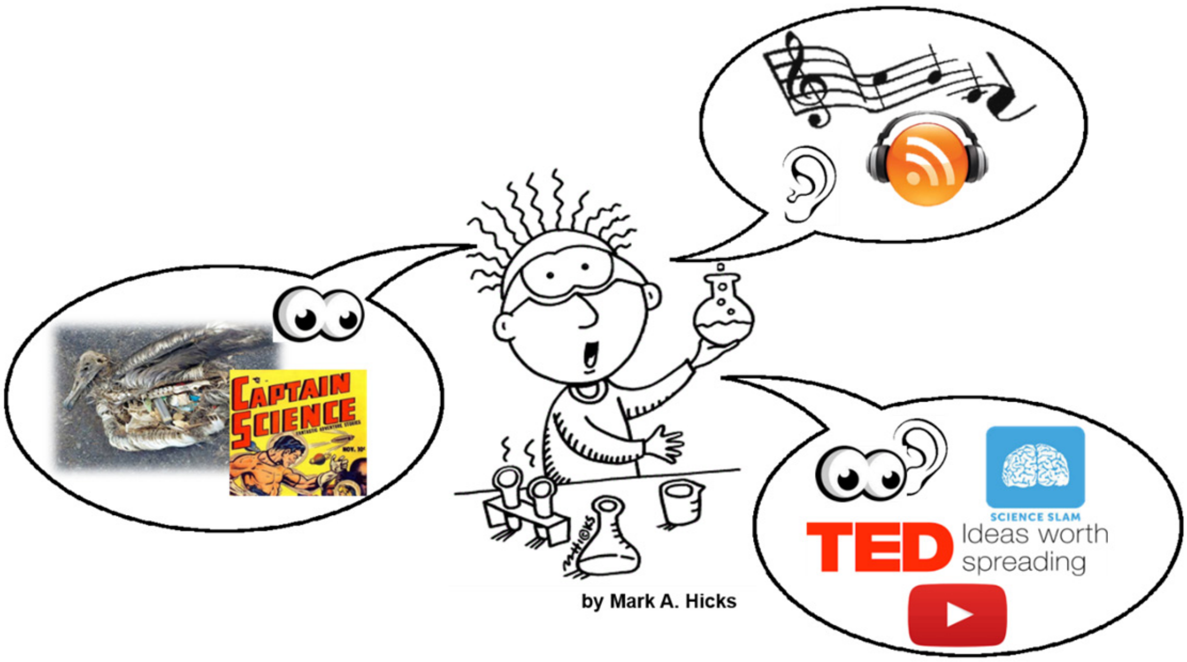
a) "Don't be to cerebral"

b) "Don't be so literal minded"

c) "Don't be such a poor storyteller"

d) "Don't be so unlikeable"

e) "Be the voice of Science"



clipartpanda.com; de.dreamstime.com; ecowatch.com; androidpit.de, school.discoveryeducation.com; musik.fiedler.at; startplatz.de; hausderwissenschaft.org; logok.org; lingholic.com

Fig. 1: Modern ways of scientific communication by sound (ear) and sight (eyes)

5. Communication by sounds

Explaining how to communicate science, we may start with the simplest way of communication: talking. If you are asked what your research is about, you will rather tell than show somebody. But how can you explain your research without just talking. During the last years many songs and poems about scientific topics appeared on the internet. You may know songs about photosynthesis (NinjaStacie09, 2015), as well as cover songs of famous radio hits, like “It’s too late to apoptize (apologize)!” (Science With Tom, 2015) and the BioRad commercial “GTCA”(Bio-Rad Laboratories Inc., 2015). Another way of communicating research topics and knowledge are podcasts, many of which are hosted by science magazines (Macmillan Publishers, 2015; ScienceBlogs, 2015), popular media (BBC, 2015), universities (Cambridge University, 2015) and comedians (Kirshen et al., 2015).

6. Visualisation of a message

But sometimes words are not enough. Pictures can have a great impact, because they are worth a thousand words. One of the hot-topics in marine science is plastic pollution. Pictures of dead birds with stomachs full of plastic (incorporated in Fig. 1) or sea turtles, sharks and dolphins entangled in plastic nets show how severely impacting plastic pollution is, thereby awakening the concern of the public. Other ways to visualize scientific topics are comics and illustrations. Tatalovic (2009) gives an overview of the use of comics and graphic novels in science. Since the 19th century comics have been used to communicate different science related topics to children and the general public (Tatalovic, 2009).

As pictures alone are often not sufficient, we use our language to explain what we see. The most common way of communicating science to the public is almost the same way you use with your colleagues – giving talks and presenting graphs and pictures. Spice up plain talks, like they are given at conferences, and the public will be more susceptible for your science message. Since the 80ies, TED Talks have been a common way for scientists to communicate their research in a brief and enjoyable way (Sugimoto and Thelwall, 2013).

Another popular form of scientific communication are Science Slams, which are primarily European phenomena (ARGE, 2015; Büning, 2015; Marí and Marga, 2015) but also hosted in other countries, like Egypt (DWZ Kairo, 2015) and Russia (VK, 2015). Often these talks are videotaped and uploaded on websites and video platforms like Youtube (YouTube, 2015).

On Youtube you will also come along many short clips about everything in life. Besides all those cat clips, you will find short and long clips showing scientific work (YouTube, 2015). These videos are made to explain methods or to show the outcomes of a project to the public. Videos for competitions like "Dance your Ph.D" (Gonzolabs, 2015) are uploaded to the internet as well, so everybody can vote for his/her favourite video. In his Book "Don't be such a scientist" Randy Olson (2009) recommends to prepare a compilation of your videotaped talks as a reference for you presentation skills.

7. Ways to distribute your message

When you have made up your mind on what, to whom and how you want to communicate your research you will have to choose a channel of media for distribution. You can simply post and upload all types of communication mentioned above, almost everywhere in the internet. You have to choose the channels depending on the audience you want to communicate your research to. Social networks like Facebook and Twitter are suitable mass media distribution tools you can use to publish the research that should reach the general public. Your post can go viral when the right people "like" it, or repost it. In Social media, you can post videos, songs, poems, audio files, pictures etc. – nothing restraints you. Similar but yet different are video platforms like Youtube and Vimeo, where you can upload video and audio files. There people can mark your video as favourite, but it is more difficult to "spread the news" as fast as social media can.

Also related to social media is blogging. During the last years people started to share their private and work-related life trough blogs on the internet. Research institutes have blogs to inform about research cruises and expeditions (AWI, 2015; Helmholtz Association, 2015). The other way is to post your research on blogging sites like *scilogs.com* (Spektrum, 2015) or *scienceblogs.com* (ScienceBlogs, 2015).

Besides the above mentioned channels for science communication, there are many more options to communicate to colleagues and the general public interactively. In webinars people can participate in order to learn about a topic, like "Scientific writing", or newly developed methods like feeding regimes in aquaculture to fish farmers (O'Malley and Thompson, 2015; Tower and Longshaw, 2015).

Computer and internet games (Swarm Interactive, 2015), as wells as apps to register fisheries bycatch (IMEDEA and CSIC, 2015) can be used for education. In order to arouse public interest for science and environment, smartphone apps can be used that turn citizens into scientists (Malykhina and Scientific American, 2015). In "Citizen Science" people communicate their observations of invasive species (NPS and UCLA, 2015), marine debris (NOAA, 2015), to scientists, which increases the amount of data for only little money.

8. So, what is the bottom line?

The way of scientific communication has changed fundamentally in the last two decades with the increasing access to the World Wide Web. It became important for us scientists to use new media in order to reach the public and raise the awareness for our work. The public is in parts responsible for our funding. Therefore, it is crucial for the public to understand the results and impacts of our research. Just doing science is not enough since it has to be understood. Especially in climate change research, it is the politicians and the broad public that have the power to change things in order to mitigate the impacts on our climate. For communication the internet is a great platform, where you can impart your research in blogs, videos on Youtube and social media.

This means that we don't have to patiently wait in our labs for a journalist to come by, so we can tell him/her what we are doing. It is in our hands and we should take over the control (Olson, 2009). To raise the public's awareness for your research topic you need to do some marketing, like it is common in economy, which is a delicate task requiring you overall to stay reasonable. Let's tell and show the world how great and interesting the things we investigate are.

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6 | Marine Invasion Ecology

From invasive species to novel ecosystems

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ABSTRACT

The invasion of non-native species can have profound effects on native populations and communities, ecosystem functioning and even human health and economics. Investigating invasion patterns, mechanisms and their effects receives increasing attention as the number of reported invasions increased almost exponentially over the past 200 years. This session provides a platform for young marine researchers to present their research on species invasions from the whole spectrum of spatio-temporal scales and methods. Case studies of distribution patterns of single species, of overarching invasion mechanisms or of the development of novel ecosystems, e.g. Pacific oyster reefs in the Wadden Sea, are welcome.

ORAL PRESENTATIONS

6.1 Stephan Gollasch	The transfer of organisms and their impacts
6.2 Floriaan Devloo-Delva	The case on an invasive mussel in the Avilés estuary
6.3 Nicole Schwartz	Comparison of antifouling properties of native and invasive *Sargassum* species
6.4 Frederike Peiffer	Effects of lionfish removal on coral reef communities at Roatan
6.5 Tom J. Langbehn	Photoperiodic implications on range expansion in polar marine ecosystems

POSTER PRESENTATIONS

6.6 Martina Marić	Trophic interactions in MPA Pelagie Islands: The role of invasive alien species

PROCEEDINGS

From invasive species to novel ecosystems

The transfer of organisms and their impacts

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ABSTRACT

There is a diverse range of transport vectors and pathways, resulting in species to reach new environments either with deliberate or unintentional releases. Sometimes vectors overlap so that it becomes unclear which exact vector was responsible for a new species finding. However, in a recent summary of alien species along the German coasts it was documented that shipping plays an outstanding role with ballast water as dominating pathway. The annual number of new species records world-wide is increasing and has paralleled shipping. For example, in ICES member countries a new introduction which formed a new population beyond its natural range was found approximately every nine weeks. One of the first possible occurrences of a non-indigenous species introduced in ships' ballast water was likely documented by Ostenfeld (1908) who reported the Asian phytoplankton species *Odontella* (*Biddulphia*) *sinensis* after its mass occurrence in the North Sea in 1903. Although the introduction of species by ships' ballast water is known since more than 100 years, it was not until 1970s that the first biological samples from ballast water were taken to document which species arrive in a port. More than 1,000 species were identified world-wide from ballast tanks and this includes human pathogens. It was estimated that 3,000 to 7,000 different species are moved around the globe by ships on a daily basis and it was concluded that each vessel has the potential to introduce a species. One of the most "exotic" means of a species introduction is with floatplanes, as suggested for a jellyfish introduced from Norway to Germany during the Second World War. Not all species find a suitable situation in the new environment they are introduced to, but it was suggested that >2,000 aquatic non-indigenous species were introduced world-wide, of which in minimum 850 were likely introduced by ships. Not all introduced species are considered harmful. For some species this is quite the reverse as they support important industries (e.g., fishing, aquaculture). However, drastically impacting species are known and some had almost catastrophic and irreversible impacts to the recipient environments. In Europe alone, the costs of the summed impacts amount to more than one billion Euro annually. Consequently, a precautionary approach is recommended, which means, e.g., a pre-border analysis of live species movements (e.g. aquaculture imports) and further to assume that every vessel transporting ballast water should be seen as a potential risk to introduce harmful species. Therefore ballast water and biofouling management measures were agreed. Although it makes sense to manage the prime species introduction vector (i.e. shipping) first, in Europe only voluntary measures are in place to regulate ballast water. Other vectors such as aquaculture imports of living organisms are addressed by EU regulations and directives. However, considering the floatplane example stated, it seems unlikely to regulate all possible species introduction vectors to the same protection level.

The case of an invasive mussel in the Avilés estuary

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ABSTRACT

Ever since globalisation started increasing, the number of biological invasions rose along with it. This has led to negative effects on ecosystems, economy and human health around the world. Estuaries are the major corridors to marine invasions. In 2014 a potential invader (*Xenostrobus securis* Lamarck) was observed for the first time in the Avilés estuary (Asturias, Bay of Biscay). The goal of this study was to assess the stage of invasion, based on ecological and genetic characteristics. Several estuaries in Asturias (Spain) were surveyed and different biotic and abiotic measurements were obtained. Findings suggest a restricted distribution of X. securis in Asturias, since it was found only in Avilés. Morphometric features were examined in 1597 mussels. A total of 130 *X. securis* individuals were genetically analysed for the mitochondrial COI gene in order to determine genetic diversity, population structure, expansion trends and introduction history of this species. Results pointed out that the invader is already established and spreading in Avilés. This population shows high genetic variation levels and includes two genetically distinct clades. These results might suggest multiple introductions from several source populations. A species-specific set of primers for PCR amplification from eDNA was designed. Finally, management measures were proposed for future eradication and prevention.

Keywords: *Xenostrobus securis*, biological invasion, population genetics, Asturias (Spain), COI, species-specific primers, eDNA

Comparison of antifouling properties of native and invasive *Sargassum* species

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ABSTRACT

The invasiveness of algae species can be facilitated by chemo-ecological traits that allow the establishment of invasive species in a highly competitive environment. Antibacterial, anti-quorum sensing, anti-diatom, and anti-larval properties of the invasive brown macroalga *Sargassum muticum* and three native *Sargassum* species from Oman waters were compared both in laboratory and field experiments to assess whether these traits have the potential to facilitate the invasion process. Only extract of invasive *S. muticum* inhibited bacterial growth of four marine bacterial strains and quorum sensing (QS) in the reporter strain *Chromobacterium violaceum* CV017. Settlement, growth and survival of the diatom *Cylindrotheca closterium* and larvae of the bryozoan *Bugula neritina* were significantly inhibited by all *Sargassum* extracts in laboratory experiments. However, crude extract of *S. muticum* had the strongest antifouling effect. Tissue level concentration of *S. muticum* extract reduced diatom density fivefold compared to the controls. Larval mortality increased by 80 to 90% compared to controls with threefold diluted *S. muticum* extract. Significant antidiatom activity of *S. muticum* was confirmed in the field experiments with *Sargassum* extracts embedded in a Phytagel matrix. Comparison of non-polar compounds by gas chromatography mass spectrometry (GC-MS) demonstrated that *S. muticum* extracts had overall fewer secondary metabolites but more species-unique compounds than extracts of native *Sargassum* spp. The higher antifouling defense of invasive *versus* native *Sargassum* species indicates a selective trait that contributes to the invasion success of *S. muticum*.

Keywords: Sargassum, antifouling, invasive alga, chemical defense

Effects of lionfish removal on coral reef communities at Roatan

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ABSTRACT

A pressing concern in the Caribbean is the invasion of the Indo-Pacific lionfish, *Pterois* sp. This invasive species poses a threat to native coral reef communities by competing with other predators and feeding on fish and invertebrates, some of which are commercially or ecologically important. At Roatan, Honduras, a local non-governmental organisation, Roatan Marine Park (RMP), received permission by the governing agency for fisheries (DIGIPESCA) to train people of the community and tourists on targeted spearfishing in order to control the population of lionfish. The aim of this study was to assess the efficiency of local removal efforts in reducing lionfish population and to test a potential influence on coral reef fish communities using a combination of stakeholder interviews and reef surveys. Findings revealed that removal efforts significantly reduced the abundance of lionfish by 80 % and the average size by 15 % at sites that are regularly visited for culling compared to unfished sites. Furthermore, results imply that removal efforts have a positive effect on the functional diversity of prey sized fish (<15cm) since the abundance of herbivorous damselfish and cleaner wrasses and basslets was 30 to 40 % higher at fished sites. Therefore, the study shows that local management efforts can control the impact of lionfish and should be focused on sites of high ecological or economic value.

Keywords: biological invasion, lionfish, control strategies, predator-prey interactions, functional diversity

Photoperiodic implications on range expansion in polar marine ecosystems

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ABSTRACT

Recent global warming is amplified in polar regions and has lead to a substantial reduction in Arctic sea ice. As a consequence, large changes in the species composition are anticipated for the Arctic. A borealization of the Arctic Ocean and adjacent seas coincides with increased abundances in many sub-polar species and a concurrent polewards expansion and shift in home ranges. Besides temperature, light is an important driver structuring marine ecological dynamics. Due to extreme seasonality in photoperiod, high latitude oceans are dark during winter, and sea-ice breakup might not occur before mid-summer. Thus, reduction in sea ice extent and thickness will result in elevated light levels and changes of the seasonal light environment. Light-driven tipping points are likely to occur, which may cause regime shifts, as light governs both bottom-up control through primary productivity and exerts top-down control by determining visual foraging efficiency. Prey encounter of visually searching predators such as seabirds, fish and large zooplankton is tightly bound to the light regime. Consequently, how are visual implications on feeding in an extreme-light environment affecting predator-prey interaction and subsequently community composition and distribution patterns of arctic vs. boreal species and light vs. dark-adapted communities?

Mechanistic modelling of light transmittance and foraging efficiency of visual predation in seasonally ice-covered waters yield new insights into ecological interactions. Here we focus on investigating the performance of visually searching predators over the annual cycle and along gradients of latitude and sea ice condition. This allows for the unique opportunity to study hypothetical photoperiodic implications on species expansion. Hence, we hope to contribute fundamental understanding to invasion mechanisms in a changing ecosystem.

Keywords: mechanistic modelling, seasonality, borealization, sea ice loss, visual ecology

Trophic interactions in MPA Pelagie Islands: The role of invasive alien species

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ABSTRACT

Invasive alien species can have adverse effects on biological diversity, ecosystem functioning, economy and human health in invaded regions. The objective of this study was to evaluate the impact of invasion of green algae *Caulerpa cylindracea*, red algae *Asparagopsis* sp., crab *Percnon gibbesi* and sea hare *Aplysia dactylomela* on zoobenthic taxa inhabiting the upper infralittoral rocky shores in MPA Pelagie Islands. Here, we present the results of the stable carbon and nitrogen isotope analysis of benthic macroinvertebrates and potential food sources in order to characterise trophic interactions between native and alien species. Using comparisons of species' isotopic niche widths and Bayesian mixing models, we investigated whether the diet of alien herbivores *P. gibbesi* and *A. dactylomela* overlapped with those of native herbivorous species and calculated the food source contribution to diets of native and alien herbivores. Isotopic niches of *P. gibbesi* and *A. dactylomela* showed no overlap with native macroinvertebrates and fish. Mixing models showed that contribution of *C. cylindracea* in diets of alien herbivores and native sea urchins *Paracentrotus lividus* and *Arbacia lixula* is between 9% and 22%. Highest contributions are those in diets of *P. gibbesi* and *A. dactylomela* (16% and 22%, respectively). Contribution of *Asparagopsis* sp. was lower, between 1% and 4%. Here we provide the example how multiple species invasion causes synergistic interactions and how spread of alien macroalgae is increasing the diversity of available prey, thus can facilitate spread of another alien species, significantly altering the food web. Furthermore, although *P. gibbesi* and *A. dactylomela* are not in direct competition for food with native sea urchins, their high abundances are likely to be reducing the energy available to higher consumers.

Keywords: invasive alien species, herbivores, trophic interactions, marine protected area, Mediterranean

From invasive species to novel ecosystems

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1. Introduction and Definitions

Biological invasions are widely recognized to have impacts not only on native species but also on communities, ecosystem functioning, economics and human health (Ruiz *et al.* 2000). Due to this wide spectrum of effects and the almost exponential increase in reported species introductions in the past 200 years, a similarly rapidly growing body of knowledge on this topic is becoming available (Ruiz *et al.* 2000, Kennedy *et al.* 2002). This section aims to give a short overview of different phases and mechanisms during the introduction and successful establishment of non-native invasive species in novel habitats. Furthermore, the case of a particular invasion which led to the conversion of an entire ecosystem will be described: The invasion of the Pacific oyster, *Crassostrea gigas* in Europe.

Non-indigenous species are those species occurring in habitats where they did not originate and were transported often by human activities, namely shipping or aquaculture purposes (Prentis et al. 2008). Defining "invasive species" is difficult. Non-indigenous species, when only occurring in huge masses or causing negative impacts do not have to be necessarily considered "invasive species". Mostly, the combination of both, mass-occurrence and remarkable negative impacts, define a species as "invasive" (Sakai et al. 2001 and references therein, Colautti and MacIsaac 2004 and references therein). Accordingly, every invasive species is non-indigenous but not all non-indigenous species are invasive. However, non-indigenous species can become invasive. The major difference between both lies in the species´ invasiveness, i.e. the species ability to numerically dominate a new habitat and to cause negative impacts of any kind (Sakai et al. 2001 and references therein). For instance, at the time of its first finding in Europe in 1999, the Asian shore crab *Hemigrapsus sanguineus* was identified as an alien species (Breton *et al.* 2002). However, in following publications, after becoming more and more dominant in its new habitat, *H. sanguineus* was described as nothing else but invasive (Dauvin 2009a, Dauvin 2009b, Landschoff *et al.* 2013).

A more detailed definition of "invasive" species is possible following the "neutral terminology" of Colautti and MacIsaac (2004) (Fig. 1). Stages of an invasion process were defined how (potential) invaders can be categorized. This framework reaches from propagules still present in the native area of a potential invader (stage 0) over established (stage III, localized and numerically rare) to widespread and dominant populations (stage V). From one to a higher stage, the species has to pass a filter which can be described as a barrier the species has to overcome to shift into the next stage. Colautti and MacIsaac (2004) emphasize the importance of categorizing individual populations and not entire species. Following the neutral terminology, the current European population of *H. sanguineus* can be allocated to stage V as it is now one or even the dominant decapod crab species at the north-western coasts of Europe ranging from the Contenin Peninsula, France to the northern part of the German Wadden Sea (Dauvin and Dufossé 2011, Landschoff *et al.* 2013).

2. Vectors of invasive species

The first step towards the establishment of an invasive species is the arrival of individuals in new habitats (Sakai *et al.* 2001). The transport of non-native species is typically associated with human activities (Hellmann *et al.* 2008). Species have been intentionally introduced into new environments for aquaculture, stocking, or scientific purposes, often resulting in establishment outside their native range. An example is the red king crab (*Paralithodes camtschaticus*), which was intentionally introduced to the Russian Barent Sea as a new commercial source in the 1990s (Jørgensen *et al.* 2005). Due to natural larvae dispersal, the

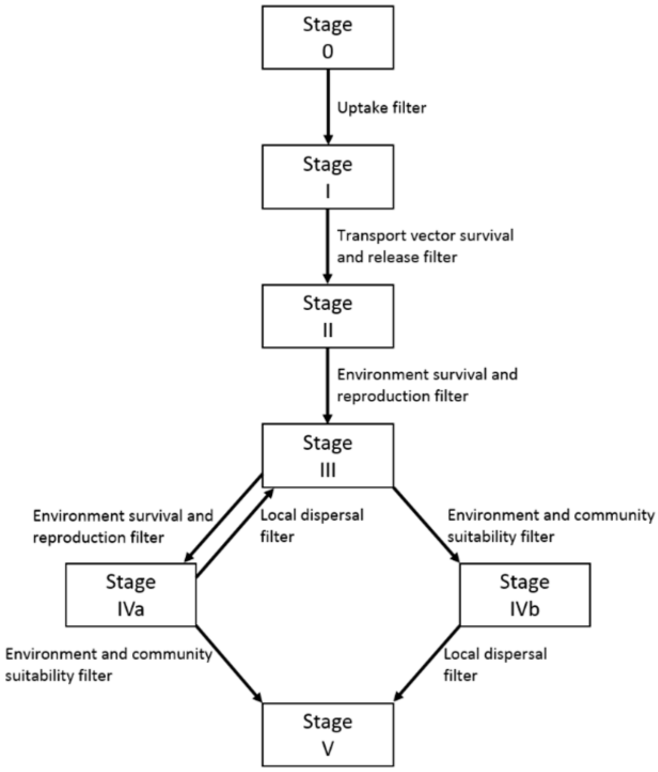

Fig. 2: Suggested framework for defining operationally important terms in invasion studies (redrawn after Colautti and MacIsaac 2004). Potential invaders begin as propagules residing in a donor region (stage 0) and pass through a series of filters that may preclude transition to subsequent stages. Note that stages III through V are divided based on the species abundance and distribution. Under this framework, a non-indigenous species may be localized and numerically rare (stage III), widespread but rare (stage IVa), localized but dominant (stage IVb), or widespread and dominant (stage V). Adjectives are intended only to aid in conceptualizing each stage, but should not be used to refer to the stage of interest (e.g. “stage IVb”, not “dominant”) (Colautti and MacIsaac 2004).

invader spread from the initial site of introduction potentially causing ecological concerns (Falk-Petersen *et al.* 2011). Similarly, the red seaweed *Kappaphycus alvarezii* has been introduced to more than twenty countries world-wide for carrageenan production (Bindu and Levine 2011). Non-target species that are associated with aquaculture species may be unintentionally transported to new habitats (Savini *et al.* 2010). For instance, the importation of oysters is a prominent vector for the introduction of non-native species (Ruesink *et al.* 2005). Species travelling on oysters are not only found on the shell but also occur within the mantle cavity and tissues (Verlaque *et al.* 2007). For macroalgae, the accidental introduction as epibiont of aquaculture species is a main invasion vector (Wallentinus 2002). Another key introduction vector of invasive species is the unintentional transport via international shipping (Gollasch 2006). Species arrive in new environments as fouling organisms on hulls of vessels (Gollasch 2002, Mineur *et al.* 2007), or are carried in water or sediment within ballast water tanks of ships (Williams *et al.* 1988). Due to the (a) increasing number, (b) size and (c) speed of vessels, including (d) greater volumes of ballast water, more non-native species are being transported, enhancing the probability of species invasions (Carlton 1996, Reise *et al.* 1998). The ballast water volume that is discharged without treatment globally is estimated to be about 3500 million tons per year (Endresen *et al.* 2004). A variety of different organisms are being transported within ballast tanks, including bacteria and viruses, diatoms, dinoflagellates, microscopic stages of macroalgae, zooplankton, larvae of benthic species, meiobenthic and vertebrate species (Hallegraeff and Bolch 1992, Chu *et al.* 1997, Ruiz *et al.* 2000, Wonham *et al.* 2000, Pertola *et al.* 2006, Radziejewska *et al.* 2006, Drake *et al.* 2007, Flagella *et al.* 2007, Klein *et al.* 2010). Gollasch *et al.* (2002) detected a 15 cm long fish in a ballast water tank. The presence and abundance of organisms may vary with season (Endresen *et al.* 2004) and some species are even capable of reproducing within ballast water tanks (Gollasch *et al.* 2000). Harbours and marinas are likely to be the point of first entry for invasive species on new coasts (Reise *et al.* 1998, Ashton *et al.* 2006) acting as stepping-stones for the invasion of the natural environment. Secondary transport of invasive species, such as the spread from harbour to harbour, is often achieved by fouling of boat hulls (Gollasch 2002, Frey *et al.* 2009). The world-wide aquarium trade, as well as the escape or release of ornamental aquaria species, i.e. tropical fish, are known to be mechanisms of species introductions (Semmens *et al.* 2004, Calado and Chapman 2006). A prominent example is the introduction of the seaweed *Caulerpa taxifolia* to the Mediterranean Sea from an aquarium culture in the mid-1980s (Jousson *et al.* 1998). Species might also travel on aquaria accessories, such as rock consisting of coral skeletons which is frequently used for salt-water aquaria (Bolton and Graham 2006).

Human activities do not only provide the direct transport of potentially invasive species but might also indirectly create invasion vectors. The opening of the Suez Canal, for example, created a direct connection between the Mediterranean and Indian Ocean and favoured the influx of invasive species (Bianchi & Morri 2000).

3. Establishment in new environments

<u>*Abiotic conditions*</u>

The fundamental niche of an organism is determined by conditions and resources that ensure its survival and reproduction without considering biotic interactions (Hutchinson 1957). Therefore, the geographic distribution of a certain species is partly determined by physiological tolerance to environmental conditions (Somero 2010). Similarly, physical conditions such as temperature and salinity regulate invasion success (Levine 2008). Early experiments demonstrated that the distribution of the invasive blue crab *Callinectes sapidus* in Florida is determined by water chlorinity (Odum 1953). Habitat suitability models that relate environmental factors to the likelihood of a species occurrence (Hirzel and Le Lay 2008) are used to predict species invasions (Gallien *et al.* 2010). Changing abiotic conditions, as observable due to pollution or climate change, also impact the invasion success of certain species (Crooks *et al.* 2011). Compared to taxonomically related natives, invasive species are not inevitably more physiological tolerant (McMahon 2002). However, the invasive blue mussel Mytilus galloprovincialis displayed a higher thermal tolerance than its congener M. trossulus (Lockwood and Somero 2011).

<u>Biotic interactions</u>

After arriving in a new habitat and surviving the new abiotic conditions, an introduced species must be able to cope with biological interactions in order to become established. These interactions are predation pressure by and competition for space and food with native species. The generally accepted diversity resistance hypothesis claims that communities with high diversity of native species are more resistant towards invasions (Kennedy *et al.* 2002). Experimental evidence for this hypothesis focused on plants (Kennedy *et al.* 2002, Stachowicz *et al.* 2002). However, few studies confirm the diversity resistance hypothesis for the marine sessile benthos (Stachowicz *et al.* 1999, Stachowicz *et al.* 2002). Decreasing diversity of native species led to a higher coverage of invaders at the end of the experiments. Interestingly, experimental increases of abundances of single native species had no effect. Instead, increasing diversity of native species led to a lower amount of open space, suggesting space availability to be a direct result of native species diversity (Stachowicz *et al.* 2002).

The concept of biotic resistance can be viewed as part of the diversity resistance hypothesis. It focuses on species interactions that hinder the spread of invasive species in a new habitat due to strong novel biotic interactions. The biotic resistance hypothesis is often applied as an explanation when introduced species fail to invade specific communities (Maron and Vilà 2001, Dethier and Hacker 2005). Contrastingly, the natural enemies (or enemy release) hypothesis is often consulted to explain the rapid spread of an introduced species in a new habitat where they are not restricted by their co-evolved predators, parasites, etc. (Maron and Vilà 2001, Colautti *et al.* 2004). However, both hypotheses are not comprehensive enough to explain all cases of successful or failed introductions (Maron and Vilà 2001, Colautti *et al.* 2004).

4. Management of invasive species

Invasive species in marine habitats pose a threat to biodiversity, and may cause ecological and economical concerns (Molnar *et al.* 2008). Management options include the prevention of introduction, early detection and the eradication of the entire population within a certain area (Pyšek and Richardson 2010). The vector of introduction, however, cannot always be identified (Gollasch 2006). To prevent the arrival of non-native species requires controlling a wide range of human activities (Bax *et al.* 2003). The

International Maritime Organization (IMO) adopted a convention for the control and management of ships' ballast water and sediment, which requires ships to execute management measures and to control discharges. Reballasting at sea, which involves emptying and refilling the tank, is stated to be the best available measure to avoid unintentional transport of organisms. Alternative measures for control and management of ballast water include filtration, ultraviolet radiation, thermal, ultrasound, magnetic or electrical treatments, and chemical methods (Tsolaki and Diamadopoulos 2009). Tamburri *et al.* (2002) proposed deoxygenation of ballast water as a possible method to kill contained organisms.

Monitoring the arrival, distribution and reproductive success of invasive species is limited by funding and personnel constraints (Delaney *et al.* 2008). The value and quality of data collected by volunteers, so-called citizen scientists, is more and more recognized (Silvertown 2009, Crall *et al.* 2010) and has already been used to predict potential distributions of invasive species (Kadoya *et al.* 2009).

Establishment alone does not exclude eradication as a feasible solution but is dependent on the size of the established population (Bax *et al.* 2001). An example of a successful local eradication occurred with the discovery of the invasive brown kelp *Undaria pinnatifida* on a sunken trawler in front of the Chatham Islands, New Zealand, and the actions taken thereafter (Wotton *et al.* 2004). Adult sporophytes of the invader were detected on the hull of the vessel and were removed by divers. A heat treatment was applied to kill microscopic stages of the seaweed that are only detectable after germination and continuous monitoring was performed to confirm the success of the procedure. The overall costs for treatment and inspections were approximately 285.000 € (Wotton *et al.* 2004).

5. The case study of the Pacific oyster *Crassostrea gigas* in Europe

The Pacific oyster *Crassostrea gigas* is an example of an invasive species, which was introduced for human aquaculture activity. The causes and consequences of the invasion success of *C. gigas* were comprehensively reviewed by Troost (2010). In the Netherlands, the oyster aquaculture activities traditionally focused on the European flat oyster *Ostrea edulis*. Already declining in the 1940´s and 50´s, a variety of factors including overfishing, severe winters, and the introduction of a parasite, favoured the eradication of the last populations of *O. edulis* (Drinkwaard 1999). After a successful trial to grow osyters in Dutch waters in 1964, oyster farmers were allowed to introduce *C. gigas* in 1966 (Drinkwaard 1999). In contrast to previous assumptions, *C. gigas* was able to reproduce in mid-European water temperatures. Larvae of *C. gigas* spread successfully along the coast and by 1971, one-year-old wild oysters were found in a Dutch harbour and in 1975 oyster spat was found settled on mussel shells (Drinkwaard 1999, Troost 2010). By now, the Pacific oyster *C. gigas* is found from the Dutch to the Danish Wadden Sea and locally even in Scandinavian waters (Troost 2010). This range however, is not only the result of natural spreading but also by repeated oyster introductions for aquaculture purposes at different locations along the north-west European coast. Accordingly, the initial colonization of *C. gigas* was induced and maintained by oyster farmers. Nevertheless, *C. gigas* shows a variety of characteristics, which are generally attributed to successful invaders (see Table 2 in Troost 2010). One of these characteristics is good dispersability. Oyster larvae can travel up to 5 to 15 km along the coast with residual currents (Wehrmann *et al.* 2000). This mode of spread was identified to be the main cause for the invasion of *C. gigas* in the East Frisian Wadden Sea (Wehrmann *et al.* 2000, Brandt *et al.* 2008). Additionally, the enemy release hypothesis applies to *C. gigas* as the European predators mostly fail to have a significant effect on *C. gigas* populations (Troost 2010). European *C. gigas* is infected by a variety of natural parasites and diseases found in its native range, yet the impacts of these parasites and diseases are diminished in Europe (Troost 2010).

Pacific oysters invading a new habitat start up a self-enhancing establishment mechanism due to their morphology and ecology. Larvae of *C. gigas* settle preferably on shells of conspecifics or in adjacent areas where oyster spat previously settled before (Diederich 2005, Troost 2010). As settling includes cementing the shells of settlers to the underground, *C. gigas* forms dense three-dimensional reef structures, which further optimizes habitat characteristics for settling. The reef structure of a dense oyster population buffers water movements in the reef, prevents heat and desiccation, and provides shelter from benthic and bird predators (see references in Troost 2010). These effects are also beneficial for *C. gigas* itself as the survival of oyster spat is enhanced by a lower predator-prey encounter rate. Additionally, clumping together enables groups of oysters to size-escape from predators which prefer solitary individuals (Troost 2010). It was observed that the structure of oyster reefs increases water turbulences above the reef, which leads to increased water and thus food flux towards the oysters (Jonsson *et al.* 2005). Even the persistence of shells of dead *C. gigas* has a positive effect on oyster recruitment, as they provide hard substrate for the settlement of larvae (Troost 2010). Further, the underlying sediment is remarkably more stable in comparison to mussel beds because of the oysters' ability to stick deep in the underlying sediment (Reise and van Beusekom 2008). Therefore, it has been suggested to view this characteristic of *C. gigas* as protection of the Dutch Oosterschelde estuary from further erosion (Troost 2010).

On a broader scale, oyster reefs are, similar to beds of the native blue mussel *Mytilus edulis*, expected to increase habitat complexity and thus biodiversity (Buschbaum *et al.* 2009, Troost 2010). Two studies from the German Wadden Sea provide evidence for this hypothesis. Both studies, a sampling study conducted near the island of Juist (Markert *et al.* 2010) and an experimental study from the Königshafen bay at the island of Sylt (Kochmann *et al.* 2008), found the communities in oyster and mussel dominated beds both to be largely similar. The sampling study revealed a higher species richness in the oyster reef compared to the mussel beds (Markert *et al.* 2010). The authors explained this with the fact that the oyster reef is permanently sediment-free in its upper part while the mussel beds are frequently buried under sediment. Oysters seem to replace the ecological function of the mussel as a filter feeder and mussel populations have been found to decrease where oyster populations are in abundance (Markert *et al.* 2010). This extrusion mechanism does not only happen indirectly via competition for space but also via direct interference. Often, *C. gigas* appears to have settled on *M. edulis* and to smother them whilst growing (SJ, pers. obs.). Similar to the study of Kochmann *et al.* (2008), slight differences in the infaunal community between oyster reefs and mussel beds were detected. However, generally both bivalves were found enriching the underlying sediment with organic material due to their production of pseudofaeces (Kochmann *et al.* 2008, Markert *et al.* 2010). For the Dutch Wadden Sea, the presence of *C. gigas* was argued to facilitate the establishment of other non-indigenous species from the Asian Pacific coast (Wolff 2005). Contrastingly, an increase of biodiversity due to enhanced habitat complexity and the presence of oysters themselves should decrease the probability of success for new invasions (Stachowicz *et al.* 1999, Stachowicz *et al.* 2002).

To evaluate the impact of *C. gigas* on the invaded habitat, the food intake mechanisms of *C. gigas*, the native blue mussel *Mytilus edulis,* and the native common cockle *Cerastoderma edule* were compared (Troost *et al.* 2009). Although inhalant and exhalant feeding current speeds in these three bivalves only differed slightly, the roughness height of oysters is likely to alter the water turbulences close above the oyster reef. As a result, oysters may ingest a relatively higher proportion of zooplankton compared to native bivalves. The authors explain this with a reduced efficiency of hydrodynamically triggered escape reactions of the zooplankton organisms due to a higher turbulence background (Troost *et al.* 2009). Generally, *C. gigas* and *M. edulis* appear not to compete for exactly the same food as *C. gigas*, which was found to utilize a much broader spectrum of food particles (Troost 2010). Bivalves reject unsuitable food particles as pseudofaeces. Thus, they may indirectly interfere by reducing other species´ food levels via sedimentation of particles. As *C. gigas* generally showed food-limited growth (Smaal et al. 2001) but failed to show this in an experimental trial surrounded by *M. edulis* (Troost 2009 cited in Troost 2010), it was concluded that *C. gigas* does either ingest more food, utilizes an additional food type, or shows an higher digestion efficiency compared to *M. edulis*. In areas with restricted water exchange on a local scale, food competition might play a role in structuring the composition of the Wadden Sea epifauna (Troost 2010).

Despite the top-down effect on phytoplankton communities, *C. gigas* might affect higher trophic levels through indirect cascading effects (Troost 2010). Firstly, due to the effect on phytoplankton, zooplankton and further fish and fish-eating birds and seals might be affected. Secondly, if the expansion of *C. gigas* causes a remarkable reduction of *M. edulis* biomass in the future, shorebirds mostly predating on *M. edulis* might be negatively affected (Troost 2010). Despite the gap in research on the large-scale community effects of Pacific oyster *C. gigas*, it can safely be stated that *C. gigas* is a highly invasive species with the potential to shift invaded habitats both structurally and in regards to prey availability for predators which depend largely on *M. edulis*.

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7 Marine Remote Sensing

From outer space to the deep sea: remote sensing in the 21st century

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ABSTRACT

Direct sampling of marine communities can be very difficult, especially in the deep sea. Thus, marine research intensively relies on indirect observation methods, such as tethered video surveys or the use of remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). Bathymetry and environmental data are often gathered by ship-based sensors. Airborne and satellite systems further allow for continuous sampling over large spatial and temporal scales. In situ observations using drones, camera traps and acoustic sensors provide another indirect sampling method. All these methods help to acquire a vast amount of data, which can be used to further our scientific understanding and make predictions about future changes.

ORAL PRESENTATIONS

7.1)	**Andrew Davies**	Turning observations into impact, species distribution models for vulnerable marine ecosystems
7.2)	**Ingrid Angel-Benavides**	Biophysical interactions in submesoscale eddies observed using airborne remote sensing
7.3)	**Michael Ginzburg**	SOARing π – A new dimension in remote sensing
7.4)	**Stefan Raimund**	From the first idea to the ready-to-use instrument. Development of monitoring systems for the marine environment
7.5)	**Sebastian Menze**	Estimating fin whale distribution from ambient noise spectra using Bayesian inversion
7.6)	**Alfred Schumm**	The TransparentSea Initiative: from vessel tracking to marine conservation

POSTER PRESENTATIONS

7.6)	**Mariyam Ali**	Environmental and biological controls of glass sponges around the Discovery Islands (BC, Canada)
7.7)	**Alfred Schumm**	The TransparentSea Initiative: from vessel tracking to marine conservation

PROCEEDINGS

From outer space to the deep sea: marine remote sensing in the 21st century

Turning observations into impact, species distribution models for vulnerable marine ecosystems

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ABSTRACT

Turning observations into usable societal impact is a challenge scientists are facing worldwide. One tool that has emerged that has conservation and management applications are species distribution models. Over the last decade, models have become increasingly used by conservationists and governmental bodies interested in studying and managing vulnerable marine ecosystems (VMEs). VMEs are challenging to study, as they are often found far from shore and at depth, so datasets are often incomplete and expensive to produce. Models can help fill the gaps, by taking observations and best available data, and use these to produce maps that can guide agencies or researchers. Recent studies have begun to address a key limitation, the quality of data, by using multibeam echosounder surveys and species data from video surveys to acquire high-resolution data. Despite improvements in model algorithms, environmental data and species presences, there are still significant limitations in the reliability of models, especially in the deep sea. In this talk, I will present how models have become widely used in deep-sea research and in particular how a single word in EU legalisation was instrumental in driving research into this area.

Biophysical interactions in submesoscale eddies observed using airborne remote sensing

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ABSTRACT

Submesoscale motions in the ocean are thought to play an important role in biogeochemical processes. Numerical models predict changes in primary production and phytoplankton distribution as a result of strong vertical velocities and horizontal straining associated with increased submesocale turbulence. However, due to their rapid dynamics (hours to days) and small spatial scales (0.1-10 km), these features are difficult to sample and observational evidence of those processes is scarce. Eddies with diameters between 0.2 and 1 km were observed for several hours during the Submesoscale Experiments (SubEx) using an innovative multi-platform sampling scheme. We describe the signatures of submesoscale features in high-resolution airborne visible and infrared imagery collected near Santa Catalina Island (California, USA) during SubEx 1 (April 2011). Two cyclonic eddies were detected due to their sharp cold-core signature in an otherwise homogeneous surface temperature area. Optical data in the visible showed that the eddies are entrained in a north-east oriented front, along which higher chlorophyll concentrations occur. While the eddy cores are characterized by chlorophyll concentration and chlorophyll fluorescence maxima, a distinct patch between them exhibits similar chlorophyll concentrations but no distinct signature in neither fluorescence nor temperature. The cold temperature of the eddy cores suggests that they are most likely dominated by upward vertical advection. Furthermore, the observed high fluorescence per chlorophyll unit in the eddy cores could be caused by a short-time scale response of upwelled phytoplankton cells to increased light intensities. On the other hand, the eddy peripheries seem to be dominated by horizontal advection. As inferred from a series of infrared imagery, water is transported horizontally towards the front due to the eddy rotational velocities. The front acts as an advection barrier inducing a convergence region where accumulation of surface phytoplankton could cause the observed high-chlorophyll/low-fluorescence patch between the eddies.

SOARing π – A new dimension in remote sensing

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ABSTRACT

Remote sensing possibilities under water are sparse. Only shipboard and satellite data are widely accessible. Available airborne data are mainly limited to those recorded by fast moving airplanes or punctual measurements e.g. recorded on weather balloons. This ultimately leads to low spatial coverage and resolution. High-resolution aerial thermography data on different altitudes and scales are being missed.

The SOARing π system not only enables us for the first time to study submesoscale near surface turbulences via IR-imaging on scales that are not even closely resolved in satellite imagery, but provides a highly versatile payload section for numerous remote sensing applications and mission support opportunities for exploration systems like AUVs (Autonomous Underwater Vehicle) and gliders.

Especially designed for at sea missions from board of steaming vessels, SOARing π enables an operation up to an altitude of 1 km and variable flight distances depending on the weight of the payload and the weather conditions. Fully automated take off, landing and way point mission planning as well as live video control and manual control take over gives us the highest possible mission flexibility and efficiency.

From the first idea to the ready-to-use instrument - Development of monitoring systems for the marine environment

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ABSTRACT

Based at the western end of the Baltic Sea at Kiel, the company SubCtech has more than 25 years of experience in scientific and industry-based marine technology. Our core business activity comprises monitoring systems, data logger, sensor development (pCO2), and rechargeable battery systems for any kind of underwater application. Our typical clients are research institutes, universities, and environmental agencies. We also deliver our technology to the offshore and aquaculture industry.

So called flow-through-systems helping to monitor the ocean surface. Scientists operating those instruments on research vessels, ships of opportunity and other platforms in order to investigate sea surface parameters as salinity, temperature, dissolved oxygen, fluorescence, or pCO2. All those parameters are highly relevant to gain a better understanding of ocean circulation, ocean acidification, or climate change. During the talk, the development of two instruments will be presented: a) a compact, robust and reliable instrument for pCO2 analysis and b) a mobile and robust flow-through-system for extreme conditions on the high seas.

Estimating fin whale distribution from ambient noise spectra using Bayesian inversion

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ABSTRACT

Passive acoustic monitoring is increasingly used to study the distribution and migration of marine mammals. Marine mammal vocalizations are transient sounds, but the combined sound energy of a population continuously repeating a vocalization, adds up to a quasi-continuous chorus. Marine mammal choruses can be identified as peaks in ocean ambient noise spectra. In the North Atlantic, the fin whale chorus is commonly observed as a peak at 20 Hz. A method to estimate the distribution of vocalizing fin whales based on a set of fin whale chorus recordings is proposed. This is an extremely under-determined inverse problem. The method is based on Bayesian inverse theory and uses simulated annealing to estimate the most likely distribution of sound sources (vocalizing whales) on a geodesic grid. This includes calculating a transmission loss matrix connecting all grid nodes and recorders, using an arbitrary sound propagation model. Two models were successfully implemented: geometrical spreading and the ray trace model BELLHOP. The inversion method was tested under different scenarios. The results indicated that an imprecise transmission loss matrix is tolerated by the inversion method. The accuracy of the method depended mainly on the number and distribution of recorders. For the Norwegian Sea, simulations showed that fin whale chorus inversion is possible using as few as 12 recorders between Iceland and Svalbard. An inversion based on data from published fin whale chorus observations indicated realistic winter distribution patterns. Existing methods to study marine mammal distribution are often confined to the summer months and a limited area. Future application of the proposed method admits automatic year-round monitoring of marine mammal distribution on a basin-wide scale.

The TransparentSea Initiative: from vessel tracking to marine conservation

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ABSTRACT

Transparency of activities at sea is crucial for safety reasons, fighting illegal fishing, protecting sensitive areas, collecting data about fishing methods, and ensuring the traceability of seafood products. WWF and its partner navama are working to promote the use of a new, effective, and affordable way to use satellite data for monitoring fishing activities, known as the Automatic Identification System (AIS). AIS is widely used in commercial shipping to help ships avoid collisions and provides data on GPS location, speed, direction of travel and ship identity.

With the overall aim to increase transparency at sea and provide affordable AIS technology solutions to the public, WWF and its partner navama have developed four AIS-based tools which will be introduced in the guest talk.

Firstly, the seeOcean explorer is an integrated viewer and analysis tool for marine geographic information and GPS/AIS tracks. It enables access to a big-data AIS satellite database with data layers such as marine protected areas, seamounts, and weather data to monitor fishing operations and visualize routes of fishing vessels including vessels that are suspected of illegal fishing. Secondly, the public website TransparentSea.org offers fisheries the possibility to prove best transparency practices by signing up and committing to transparency at sea. Moreover, smartTrack is a vessel tracking system for artisanal fisheries based on vendor independent hardware solutions. Finally, SEEyourFISH is a European economic interest group working towards value increase of sustainable certification processes and seafood labels in joint effort by WWF, navama and LuxSpace.

All tools aim to improve the collaboration on transparency between fisheries, NGOs, administration, the seafood industry and science.

Environmental and biological controls of glass sponges around the Discovery Islands (BC, Canada)

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ABSTRACT

Glass sponges (Porifera, Hexactinellida) are enigmatic creatures. Widespread during the Jurassic period, this archaic group of sponges is now largely restricted to high-silicate environments: the deep sea and coastal regions of the Antarctic and British Columbia (BC), Canada. With this study we consider the relative roles of environmental and biological parameters controlling the distribution of glass sponges around the Discovery Islands, an understudied region in the northeast of Vancouver Island, BC. The analysis of video footage and corresponding environmental data concurrently collected with a remotely operated vehicle (ROV) shows the occurrence of three main species (*Aphrocallistes vastus*, *Heterochone calyx*, and *Rhabdocalyptus dawsoni*) between 27 m and the maximum depth observed (250 m). Highest sponge densities were found between 50 m and 150 m depth, corresponding to the lower vernal thermocline and winterly deep waters, with temperature, salinity and chlorophyll *a* ranges between 8 and 9 °C, 29-30, and 0.04 to 0.13 mg/m^3, respectively. Vertical oscillations of the thermocline up to 20 m during ROV dives suggest that internal waves may play a role in vertical mixing and pelagic-benthic coupling, improving the feeding condition for the filter-feeding sponges. The predatory sea star *Ceramaster* sp. and the epizooic squat lobster *Munida quadrispina* were found in the vicinity of glass sponges. In this study it will be discussed whether the abundance of glass sponges is governed by top-down or bottom-up control.

The TransparentSea Initiative: from vessel tracking to marine conservation

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From outer space to the deep sea: marine remote sensing in the 21st century

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Direct sampling of marine communities can be very difficult, especially in the deep sea. Marine research intensively relies on indirect observation methods, such as tethered video surveys or the use of remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). Bathymetry and environmental data are often gathered through ship-based sensors or airborne and satellite systems, which allow for continuous sampling over large spatial and temporal scales. In situ observations using unmanned aerial vehicles (UAVs), camera traps and acoustic sensors provide another indirect sampling method. All these methods have been increasingly used and have helped to acquire a vast amount of data, which helps us to further our scientific understanding and make predictions about future changes.

1. Introduction

Global change is a current hot topic that is likely to cause further challenges to the research, management and policy community in the future (Pereira et al. 2010). Being able to predict future scenarios, enables us to prepare for these challenges, however this requires a vast amount of data in order to make reliable predictions. Collecting field data is generally very resource intensive and difficult to implement across large spatial and temporal scales. Remote Sensing (RS) offers a good alternative and thus is an important tool for measuring environmental conditions, as well as the state of biological diversity and ecosystem services across multiple spatial and temporal scales (Pettorelli et al. 2014).

There has been an exponential increase in using RS over the past decade (Pettorelli et al. 2014). Sensors, methodologies and data availability have strongly developed and using RS has become simpler and more widespread (Palmer et al. 2014). This is not only true for the terrestrial environment, but RS has also become increasingly important in studying the marine environment (Brewington et al. 2014). Methodologies commonly applied in the marine realm include camera traps (Bailey et al. 2007, Ahumada et al. 2011), tethered video surveys (Biber et al. 2014), ROVs (Lorance & Trenkel 2006) and AUVs (Eriksen et al. 2001, Yoerger et al. 2007), field spectrometry (Murphy et al. 2008), acoustic sensors (Van Parijs et al. 2009), aerial (Scheritz & Dietrich 2002, Koh & Wich 2012) and satellite monitoring (Baldock et al. 2014), as well as vessel monitoring systems (Bastardie et al. 2010).

2. Application of RS

Rose et al. (2014) recently highlighted the importance of remotely sensed data in order to answer important questions in conservation. However, these questions also highlight the importance of RS for ecological research in general.

Remote sensing has already been applied in a large range of areas of marine research (Brewington et al. 2014). Environmental variables, such as sea surface temperature (Smit et al. 2013, Baldock et al. 2014), chlorophyll α (Dierssen 2010, Raitsos et al. 2013), salinity (Lagerloef et al. 1995, 2008) and suspended particulate matter concentration (Evans et al. 2012, Bowers et al. 2014) can be easily obtained from satellite measurements and are frequently used in marine environmental research. Sea floor features and bathymetry have been widely mapped using ship-based depth soundings and satellite altimetry (Smith 1997, Becker et al. 2009). Remote sensing can also be used in shoreline change detection (Chen & Rau 1998, Li et al. 2001), mapping of marine habitats, such as salt marshes (Ozesmi & Bauer 2002, Belluco et al. 2006), coral reefs (Lirman et al. 2007, Huvenne et al. 2011), as well as seagrass (Pasqualini et al. 2001) and mangrove ecosystems (Giri et al. 2011, Satyanarayana et al. 2011), and for fisheries management (Stuart et al. 2011), species movements (Lander et al. 2013) and risk assessment (Gillespie et al. 2007, Römer et al. 2012). Species distribution and abundance is commonly measured in ecological research. Traditionally, trawling and other extractive methods have been used for determining the abundance and distribution of marine species. Advances in technology have allowed for non-destructive remote alternatives, such as camera traps, ROVs and tethered video surveys. Camera traps can not only be used to record the species composition of fish assemblages and estimate its abundance, but also to observe the behaviour of individuals. They have especially been applied in the deep sea (Bailey et al. 2007), as it is a more cost effective and simple way of obtaining ecological data at great depths. ROVs have increasingly been used to estimate fish density. However, some fish species are thought to be attracted to or avoid the light and noise emissions of ROVs (Trenkel et al. 2004). These methods are particularly useful for studying vulnerable marine ecosystems and protected areas or species (Marouchos et al. 2011, Martinez et al. 2011). Acoustic surveys offer another way of predicting the spatial distribution, species composition and length of fish species by analysing the acoustic backscatter of fish and correlating them to trawl or video data (Juntunen et al. 2012). The spatial distribution of species observations is often limited to individual point observations. Species distribution models (SDMs) provide a mean of interpolating point species abundance and distribution data and thus have a high relevance for marine conservation and management (Degraer et al. 2008). Species distribution modelling can provide an important function for managing invasive species (Bernal et al. 2015) and for stearing evidence-based conservation efforts (Guinotte and Davies 2014). However, the application of SDMs in the marine environment is still sparse, in particular in deep-sea marine ecosystems (Marshall et al. 2014).

Marine protected areas (MPAs) are an important tool for conserving vulnerable marine ecosystems, marine biodiversity and controlling anthropogenic impacts, such as fishing. Aerial imagery can be used to identify habitat categories, and thus being a cost-effective method for the identification of high-priority areas for sustaining marine diversity of coastal ecosystems (Ward et al. 1999). The analysis of animal movement patterns is further an important tool for effective management and conservation of species and habitats. For many migratory marine species, such as cetaceans, sharks and marine turtles, as well as for marine birds, the breeding as well as the foraging grounds need to be protected and both need to be linked (Pendoley et al. 2014). Therefore, the complex interaction of seasonality, life stage and availability of food resources needs to be considered in order to come up with a successful conservation strategy (Lander et al. 2013). Radio telemetry offers a way of gathering species presence data over time, linking temporal and spatial changes in species abundance to changes in environmental conditions, and hereby providing important information for the management of habitats for threatened or endangered species (Jacoby et al. 2012). For bird species, such as the Manx shearwater (*Puffinus puffinus*), breeding colonies are often designated as special protection areas, but they hardly ever extent into the marine environment. Manx shearwaters form rafts and then spent a considerable time at sea. Using radio telemetry the rafting distribution of Manx shearwaters was investigated and the maximum extent of rafting was identified. This could then be used to define protected areas for birds in the marine realm (Wilson et al. 2009).

Unmanned aerial vehicles, such as balloons or helicopters, can be an inexpensive alternative to satellite and airborne sensors and offer a much higher spatial resolution. They are particularly useful for measuring ecosystem processes on a small scale and can be used for producing digital elevation models, the mapping of land cover or to survey large animals (Scheritz & Dietrich 2002, Koh & Wich 2012). Marine ecosystems range from complex heterogeneous habitats, such as rocky shores (Meager et al. 2011) and coral reefs (Wilson et al. 2007), to homogeneous and featureless soft-sediment seafloors (Kraan et al. 2009). Habitat complexity is an important driver of ecosystem structure and functioning. Meager et al. (2011), for example, used high-resolution 3D fractal surface and temperature measurements to analyse the effect of habitat complexity of intertidal rocky shores on species abundance and body size of invertebrates. Data derived from airborne digital cameras further offer a way to count and map individual animals, for example marine birds, in order to estimate population size and animal-habitat interactions. The resulting knowledge can for example be applied to environmental impact assessments of marine installations, such as offshore wind farms (Groom et al. 2013). Marine systems provide the majority of global ecosystem services, with most of it coming from coastal systems (Costanza et al. 1997). Seagrass meadows, for example, provide a great economic and ecological value of goods and services, such as nutrient cycling (McGlathery et al. 2007), enhancement of fish productivity (Watson et al. 1993), as well as habitat and food provisioning (de la Torre-Castro & Rönnbäck 2004). Yet, seagrasses have been disappearing since they were initially recorded in 1879 and rates of decline have even accelerated in the recent past (Waycott et al. 2009). Other important marine ecosystems, such as mangroves (Valiela et al. 2001) and coral reefs (Hoegh-Guldberg et al. 2007), show similar losses. Remote sensing offers a way of examining the state and extent of these ecosystems on a global scale (Giri et al. 2011).

Mangroves have shown resilience to disturbances caused by shoreline changes and are likely to be resilient to anthropogenically amplified sea level rise in the future, while climate change is thought to cause a global loss of 10-15% of mangrove forests. However, anthropogenic disturbances, such as deforestation, give rise to much greater concern, as the annual deforestation rate of mangroves is 12 % (Alongi 2008). Remotely sensed imagery can be used for tracking the deforestation of mangroves (Rahman et al. 2013) and can further be used to assess the mangrove development, within mixed mangrove-aquaculture farming systems, which helps the government to regulate the extent of aquaculture farming areas (Vo et al. 2013) and thereby limits deforestation. Ocean acidification will have a tremendous effect on coral species in the near future (Fabry et al. 2008). In a worst-case scenario, the majority of cold-water coral reefs is expected to be exposed to corrosive waters by 2060 (Jackson et al. 2014). In order to manage coral reefs in an era of changing climate, we need to be able to measure and map coral reef resilience. Coral and algal cover, as well as a range of coral reef stressors, can be estimated using RS (Knudby et al. 2014). Bleached corals further have a strong optical signal, which can also be detected from airborne or satellite sensors (Andréfouët et al. 2002). This can then be used to establish marine protected areas that harbour coral reefs, which are resilient to climate change.

Satellite measurements have enabled us to better assess and predict natural hazards. Earthquakes, floods, tsunamis, storms and fires can be readily analysed over a number of spatial and temporal scales using remote sensing (Gillespie et al. 2007). The effects of tsunamis on the landscape can be assessed using high-resolution satellite imagery (Umitsu et al. 2007) and areas of high risk can be identified for the future. Models suggest that mangrove forests of at least 100 m in width can significantly reduce the wave flow pressure of tsunamis (Alongi 2008). RS of the spatial distribution of mangrove forests could thus also help to identify areas that are particularly vulnerable to tsunamis and could so help to reduce the risk of tsunamis by informed future development decisions and restoration projects.

Sea-ice extent and thickness are important climate variables in the Polar Regions. According to satellite measurements summer Arctic sea-ice extent has decreased over the past three decades. However, it is also subject to large inter-annual and regional variations (Serreze et al. 2007, Stroeve et al. 2012). Satellite measurements further show that the decline in sea-ice extent has been accompanied by a decline in sea-ice volume (Laxon et al. 2013). Using an electromagnetic-induction (EM) system sea-ice thickness can be measured from icebreakers and small helicopters (Haas et al. 2009).

3. Limitations

In recent years, RS has been more widely applied in the marine realm, but generally lies far behind the terrestrial application of RS. Technological difficulties are still hampering the use of RS, in particular in marine systems. SDMs, for example, have been widely used, but are still lacking for the deep sea and on a regional scale. The movement, in particular the foraging behaviour, of marine animals is largely unknown, as tagging of animals is much more difficult than for terrestrial species. The effects of environmental changes due to natural and anthropogenic causes on marine ecosystems have been widely studied, but there is still a huge potential in increasing our knowledge by using RS.

RS has the advantage of providing continuous spatio-temporal data. However, different data products only occur on a certain spatial or temporal scale, especially long-term data products. Furthermore, temporal and spatial resolution are conflicting each other, as a high temporal resolution is usually sacrificed by a lower spatial resolution or a smaller spatial extent, and vice versa. Optical sensors, in particular of satellites, cannot pass through clouds. Thus, areas with persistent cloud cover usually lack data (Turner et al. 2003), limiting the use of RS in areas with high cloud cover, such as the tropics.

Furthermore, remote sensing products are usually based on a large number of complex algorithms, which require baseline in situ data from ecological surveys in order to ground-truth our estimates. These estimates can have huge associated errors, for example Dierssen (2010) argues that chlorophyll α estimates from satellites can have an error by a factor of 5 or more. Estimation uncertainty and error are further likely to increase in the future, with an increasing variation in future climatic conditions.

Despite these drawbacks, RS is a powerful indispensable tool for ecological research and marine research in particular. Future high-resolution satellites and more readily-available remotely sensed data products will help to increase our scientific understanding of marine communities even further and allow for the implementation of these data sources in conservation management and policy-decision making.

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8 Marine Social-Ecological Systems

No living without the ocean: Social-ecological systems in the marine realm

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ABSTRACT

Marine coastal ecosystems play a vital role for the livelihood and wellbeing of more than one billion people all over the world. However, multiple drivers such as overfishing, pollution, coastal development and climate change threaten the functionality of coastal ecosystems and reduce ecosystem services (fishing, aquaculture, tourism, protection against erosion). To protect marine ecosystems and to keep them productive, solutions are needed that are both ecologically and socially sustainable. In this session, young researchers share their work illuminating the social-ecological linkages in coastal areas, the impact and the dependence of humanity on coastal marine resources and ecosystems as well as ideas for a more sustainable use.

ORAL PRESENTATIONS

8.1	**Lotta Kluger, in Sophia Kochalski, Philipp Gorris**	**Towards an holistic analysis of social-ecological systems the marine realm**
8.2	**Ivonne Vivar**	**Epibenthic community changes by effects of Scallop (*Argopecten purpuratus*) cultivation in Sechura Bay, Peru**
8.3	**Stefan Koenigstein**	**Participatory modeling of climate change impacts on marine ecosystem services**
8.4	**Rafael León**	**Experimental analysis of coordination of fishing effort to reduce dissipation of economic rent in stock**
	enhancement	
8.5	**Ricarda Reuter**	Criminalization of fisher folk at Lake Victoria Uganda

POSTER PRESENTATION

8.6	**Sophia Kochalski**	Conflict as an indicator for the sustainability of marine socio-ecological systems

PROCEEDINGS

Towards an holistic analysis of social-ecological systems (SES) in the marine realm

Towards an holistic analysis of social-ecological systems in the marine realm

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ABSTRACT

Coastal and marine ecosystems across the globe are affected by multiple anthropogenic impacts altering ecosystem functioning at increasing speed. The degradation of the marine environment occurs from small to global scales and strongly impacts human populations who depend on coastal and marine ecosystems. The term social-ecological system (SES) has been developed in order to emphasize the integrated position of human in nature. This contribution focuses on network analysis as an analytical tool to disentangle the complex relationships in coastal and marine SESs. A SES comprises the biological and biogeochemical units as well as associated social actors, institutions and their interactions. Due to close complex social-ecological linkages in many coastal settings, changes in marine ecosystem dynamics and functioning can have severe consequences and even result in tipping points of the coastal ecological system. Network analysis is increasingly used in the study of both the ecological and the social parts in the marine realm to advance understanding of coastal and marine SESs. It aims at contributing to the understanding of complex systems through constructing connections and interactions between the elements of the network. It can be applied irrespective of whether the elements of a network are for instance fish stocks and biophysical drivers in ecological networks or fishermen and socio-economic drivers in social networks. Hereby, network analysis holds strong potential for advancing the understanding of coastal and marine SESs by learning about a system's dynamics and behavior, feedback mechanisms and interdependencies within the system.

Epibenthic community changes by effects of Scallop (Argopecten purpuratus) cultivation in Sechura Bay, Peru

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ABSTRACT

Sechura Bay is among the most productive areas in regard of scallops (*Argopecten purpuratus*) cultivation in Peru. Due to the continuous activities of on-bottom cultivation and harvest of scallops, the area of production on the seafloor of the bay increased over the years. These alterations might have an ecological impact accompanied by habitat changes in the future, such as new benthic assemblages caused by an increased availability of hard bottom substrate due to the scallops, compared to soft bottom surface. Our study focused on the determination of the impact of on-bottom scallop cultivation on the epibenthic community. So far those possible changes are not well studied within the bay and are assessed by comparing biodiversity measures between areas including and excluding scallop cultivation. Thus, two different study sites were set up: an intensive hard bottom culture (30 ind/m^2) and non-culture area. The sampling was conducted four times with a bimestrial frequency (September 2013 to May 2014) and every time six replicates were taken from each site and the study was replicated in four different areas along the bay: Parachique, Vichayo, Delicias and Barrancos. This analysis only considers epibenthic fauna which has been taxonomically identified and expressed in units of biomass and abundance. Multivariate tests results (Anosim Second stage) displayed significant differences between areas related to scallop cultivation and also differences on benthic assemblages according to 4 zones. Despite diversity and richness index did not display differences for all samplings, community dissimilarity analyses (Simper) identified the species that discriminate the two areas, being dominating species *Argopecten purpuratus*, *Caulerpa flagelliformis* and also predators as *Solenosteira fusiformis*, *Crossata ventricosa*, *Thaisella chocolata* and *Cicloxanthops sexdecimdentatus* in areas including scallop cultivation.

Participatory modeling of climate change impacts on marine ecosystem services

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ABSTRACT

Ecological models can be used to explore the impacts of climate change on ecosystem dynamics and on the provision of marine ecosystem services to societies. We present a case study from the Barents Sea and Norwegian Sea, where climate-related shifts are already visible and impacts of ocean acidification are expected in the near future. We developed a social-ecological system dynamics model which links climate change scenarios to the response of marine ecosystems and to human uses of ecosystem services, integrating both scientific results and stakeholder concerns in a participatory approach to enable improved management of marine ecosystems.

We engaged stakeholders from Norway and Russia through personal interviews, two local workshops, and online surveys, gathering knowledge and concerns about changes in marine ecosystems. This served to identify the societally most relevant ecosystem services in the region: fisheries, tourism and recreation, carbon uptake, and cultural and educational services. Based on stakeholder interests, a multi-species model structure was developed to incorporate scientific results on climate-sensitive processes and ecosystem elements relevant for providing services to society. The model incorporates ecophysiological effects of warming and acidification on early life stages of fish from laboratory and mesocosm experiments, to explore the resulting consequences for fish population and community dynamics. Other ecosystem elements relevant for ecosystem services, such as phytoplankton and zooplankton groups, marine mammals and seabirds, are dynamically linked through the food web.

The model was used to let stakeholders evaluate potential ecosystem changes under climate change scenarios and identify adaptation options. The model integrates environmental and anthropogenic drivers across different scales, and can serve as a practical tool for developing management strategies that are informed both by knowledge about ecosystem dynamics and by societal uses and values.

Experimental analysis of coordination of fishing effort to reduce dissipation of economic rent in stock enhancement

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ABSTRACT

Individual Transferable Quota (ITQ) systems have been used to control harvests and increase fisheries' economic efficiency; however, they do not eliminate competitive fishing which can result in stock and congestion externalities that are especially apparent when resources are spatially heterogeneous within the controlled region of the ITQ system. These externalities arise because ITQ systems do not control the spatial distribution of effort leaving fishers to concentrate their effort in more profitable patches. We explored the potential for cooperative behavior to reduce this congestion using an experimental economics approach in the context of management of a stock enhancement program (SEP). Four treatments were applied involving different systems which were: compulsory, voluntary and by-use payment for the SEP, with either open or exclusive access to the enhanced zone (EZ). Income is either directly to individuals or split between participants through income-sharing (as occurs in cooperatives). Voluntary payment to fund the SEP enabled individuals to opt out of cooperation, which reduced the enhancement activity and led to a significantly lower cooperation than the optimal level and also lower relative to the compulsory payment system. Treatments that included a by-use payment combined with exclusive access to the EZ were most effective in preventing dissipation of economic rent. The different rule settings were affected by participants' expectations of reciprocity, with greater involvement and thus production from the SEP amongst cooperative participants. Perceptions of vulnerability were also important, as more self-interested participants were more likely to exclude themselves from the SEP. The structure of rules may enable individuals who are more intrinsically cooperative to drive the fishery towards a state with low rent dissipation.

Criminalization of fisher folk at Lake Victoria Uganda

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ABSTRACT

Criminalization of marginalized groups of society is a core issue in the fight for socio-ecological justice. In the case of fisheries at Lake Victoria Uganda, the dominant discourse on fisheries management stigmatizes local fisher folk as criminals. To contribute to the fights for justice of those, whose perspectives are underrepresented in the discourse on fisheries management, this study rethinks non-compliance with legal fishing regulations at Lake Victoria Uganda through the approach of history from below. Following the stories of women from local fishing communities I underline their perspectives on non-compliance and contextualize those stories in larger socio-ecological processes. The material consists of notes and recordings from seven qualitative, semi-structured interviews and six group discussions, primarily with women from fishing communities in Mukono district, collected in February 2014.

This study found a complex historicity in which local and global socio-ecological processes are interrelated. Ineffective national fisheries management along capitalist rationales co-creates the probably most prominent local driver for non-compliance: vicious circles of vulnerability and poverty. Such interrelations are not mirrored in the dominant discourse on fisheries management at Lake Victoria Uganda, which primarily focuses on local and individual characteristics. Here, stigma about fisher folk and other oversimplifications create and justify injustice towards local fisher folk and further increase socio-ecological crises. Needed is a truly socio-ecologically just approach to fisheries management needs to be realistic, complex, and future-oriented. From such a perspective, non-compliance with fishing regulations at Lake Victoria Uganda would, amongst many things, stand out as a successful attempt of local fisher folk to survive, to keep it going – to build resilience.

Conflict as an indicator for the sustainability of marine socio-ecological systems

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ABSTRACT

Reduced global fish stocks, concern about the impacts of fishing on the ecosystem, and an increase in population in coastal areas have turned 'sustainability' into the principle target for the management of marine and coastal socio-ecological systems (SES). Trade-offs between different sustainability goals such as biological conservation, economic viability and social equity are blamed for the difficulties in achieving sustainability in marine SES and for causing conflict between stakeholders.

I propose to change the perspective on this chain of events and treat conflict as a representative indicator of sustainability in SES. Based on the assumptions that opposing sustainability goals of different stakeholders can be equally legitimate and that different values and interests are given the opportunity to be expressed, conflict indicates that one or more sustainability goals are not being achieved satisfactorily. To estimate conflict, I used event data analysis, a formal assessment method from policy analysis, which characterises the discrete interactions between the stakeholders. These are scored as being either positive or negative in quality. The net quality of the interactions between key stakeholders represents the level of conflict within a fishery. Event analysis was used to characterise over time the dynamics of fisheries management conflicts in a mixed English inshore fishery and the North Sea cod (Gadus morhua) fishery. Conflict analysis tools to date have not been used in fisheries science but such approaches hold great potential to analyse the relationship between the natural and the human parts of SES and identify leverage points for sustainable marine resource management.

Towards an holistic analysis of social-ecological systems (SES) in the marine realm

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1. Introduction

1.1 Getting started with social-ecological systems

Coastal and marine ecosystems are among the most productive ecosystems on the planet and more than one billion people depend on their goods and services (Agardy et al., 2005). Yet, coastal and marine ecosystems across the globe are affected by multiple anthropogenic impacts including overexploitation of natural resources, pollution and coastal development which alter ecosystem functioning (Visbeck et al., 2013). The degradation of the marine environment occurs from small to global scales (Biermann et al., 2010; Halpern et al., 2008; Rockström et al., 2009), and in turn affects human populations who depend on coastal and marine ecosystems (Adger, 2006; Cinner et al., 2013; Ferrol-Schulte et al., 2013). This ratchet effect has caused rapidly growing concerns about the world's oceans and coasts (Burke et al., 2011; United Nations, 2012; WBGU, 2013).

The term social-ecological system (SES) has been developed in order to emphasize the integrated position of humans in nature (Berkes et al., 1998; Glaser et al., 2012). Originally derived from ecology and analogies of complex systems research (Holling, 1973; Walker & Cooper, 2011), the recognition of intimately connected SESs has gained considerable momentum and an integrated social-ecological perspective is increasingly sought to approach the complex issue of managing natural resources (Anderies et al., 2004; Biermann et al., 2012; Glaser & Glaeser, 2014; Ostrom, 2009). Advances in literature on SES suggest the existence of closely coupled system components, feedback loops and self-organization which typically lead to nonlinear dynamics and unpredictable system behavior (Berkes et al., 2003; Holling et al., 2002). It is argued that the existence of feedback-loops within SESs generates dynamic processes of emergence and decay of structuring variables in a SES (Holling et al., 2002). As a result, a SES constantly changes in response to the different emergent phenomena in the various social and ecological components of the system (Folke et al., 2002; Galaz et al., 2012; Wilson, 2002). The ability of a system to withstand a regime shift, i.e. the flip of a system into a state in which it is characterized by a new set of structures and processes (Folke et al., 2002), is conceptually linked to the notion of vulnerability. Vulnerability means the degree to which a system is able to withstand unexpected internal or external disturbances which may result to a rapid or slow regime shift (Holling et al., 2002). These insights have catalyzed new approaches to environmental governance (Berkes, 2007; Glaser et al., 2012)

1.2 The need to understand the complex nature of social-ecological linkages

Due to close social-ecological linkages in many coastal settings, changes in marine ecosystem dynamics and functioning can have severe consequences and even result in tipping points of the SES at various scales (Bellwood et al., 2004; Hughes et al., 2013; Rockström et al., 2009). In the worst case, social-ecological "traps" occur when feedback mechanisms between societies and the ecological systems lead to unwanted states that are hard to reverse (Cinner, 2011). In order to prevent these tipping points and traps from being reached, the generation of knowledge on linkages and interdependencies in coastal and marine SESs is needed (Cinner et al., 2012; Cinner et al., 2013).

Many contemporary resource governance approaches are still unsustainable (Beddington et al., 2007). With regard to adaptation to and mitigation of environmental problems, transformation of these practices is needed. Several ways of sustainable resource governance have been recognized, among them adaptive, cooperative and collaborative management (Crona & Hubacek, 2010). A first step towards approaching such forms of resource governance is to gain a profound understanding of important social processes inside the SES (e.g. Fulton et al., 2011). Therefore, recent investigations increasingly focused on the relationships among different actors and on stakeholders' influence on the way societies manage their natural resources (Crona & Hubacek, 2010). Nonetheless, understanding complex environmental problems, such as climate change, biodiversity loss, resource depletion and habitat degradation require an integrated view on the SES and their interactions in order to develop holistic solutions for the sustainable use of valuable ecosystems (Binder et al., 2013 and references therein).

The need to build knowledge on the interaction of SES led to the development of a variety of research frameworks and methods for analyzing SES (Binder et. al, 2013 and references therein). Among the most prominent frameworks are Ostrom's diagnostic framework for analyzing SES (Ostrom, 2007; 2009), the study of the resilience of SES (Folke, 2006; Holling, 2001), and the evaluation of ecosystem services (Costanza et al., 1997; Schaafsma & Turner, 2015).

This review focuses on network analysis, an emergent approach for the investigation of relationships in SES (Cinner & Bodin, 2010; Gonzáles & Parrott 2012; Janssen et al., 2006). After an introduction to the mode of operation of network analysis in general (section 2.1), we firstly present the separate analysis of the social and the ecological system using social network analysis (SNA, section 2.1.1) and ecological network analysis (ENA, section 2.1.2), respectively. Secondly, this review presents two approaches for an holistic analysis of SES (section 2.2). Furthermore, we discuss the challenges of these approaches and underline their potential for improving the understanding and holistic management of SES (section 3).

2. Methods to analyze coastal and marine social, ecological and social-ecological systems

2.1 Network Analysis

Network analysis has been applied to both the ecological and the social parts of the marine realm. It analyzes complex systems through deconstructing connections and interactions between the elements of the network. Irrespective of whether these elements are fish stocks and biophysical drivers in ecological networks or fishermen and socio-economic drivers in social networks, the principles of analysis stay the same: The elements of the network are represented as nodes and the interactions between them as arrows forming a graph that describes the real-world system and its dynamics (Fig. 1). Network analysis has the merits of clarifying the elements that are relevant for a system, identifying and - if possible - quantifying the relationships and interactions between the elements, as well as determining different types of flows and central elements of the network such as keystone species or key players.

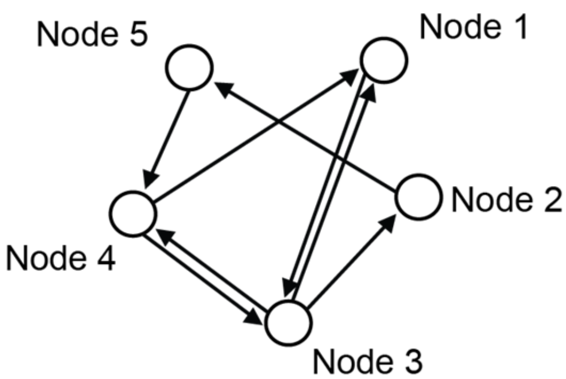

Figure 1. Example of the graphical representation of a network, showing the interactions between five hypothetical network actors (nodes). Nodes represent either ecological elements, e.g. fish stocks, or social elements, e.g. fishermen; arrows represent association or interactions.

2.1.1 Social Network Analysis (SNA)

Social Network Analysis (SNA) is an analytical approach for analyzing the patterns of relationships and interactions among actors in the social system (Prell, 2012). SNA is based on the recognition that connections among individuals or groups are important and form the social environment that constrains or provides opportunity for the actions of individuals (Wasserman & Faust, 1994).

Social actors in SNA are represented as nodes and can be individual persons, groups, institutions, organizations, or other social entities such as “a fishery”. In the marine realm, the identification of the relevant actors for SNA can be complicated because of the intertwining of different marine sectors, levels of government, and the variety of stakeholders (Hartley, 2010). The relationships that connect the actors can be for instance kinship (brother of, mother of), social roles (colleague of, friend of), affective (likes, respects, hates), cognitive (knows, views as similar), actions (talk to, meets with, attacks), flows (number of ship moving between point A and B, money or information transferred between actors), geographical distance (number of miles between), and co-occurrence (are in the same organization) (Wasserman & Faust, 1994).

In fisheries and marine research, the applications of SNA have mainly focused on complete networks and the patterns of interactions within these networks. Complete networks include all nodes and all relationships within given boundaries of a network. The other type of SNA, ego-centric or personal networks that describe the structure, shape and composition of the network of one single individual or node (Marsden, 2002), have to the authors´ knowledge not been studied in the marine and fisheries context. SNA has been applied in marine science to the behavior of social animals

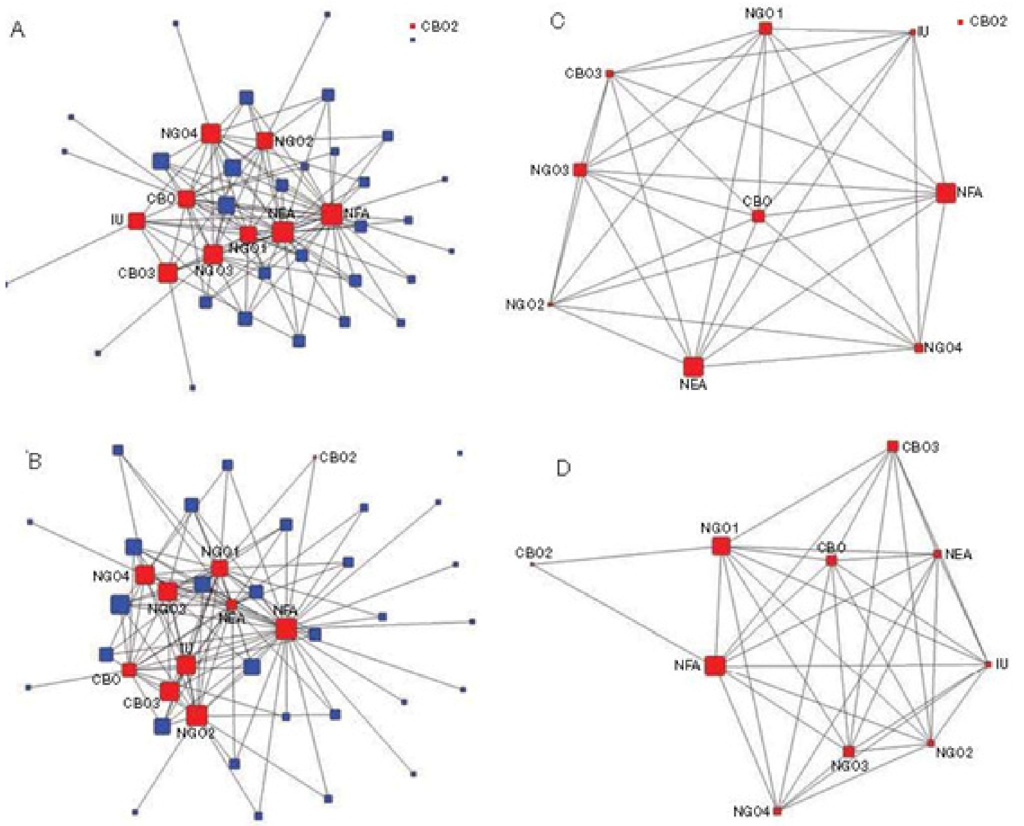

Figure 2. This figure is an example of a social network analysis for examining marine governance networks. It makes use of the Degree and Betweenness Centrality Measures. The network maps illustrate collaboration and knowledge-exchange among actors involved in coastal ecosystem management in the Solomon Islands. Members of the co-management board are represented by red boxes and non-member agencies are depicted by blue boxes. The size of the box is scaled to the centrality measure and lines represent relationships (i.e. collaboration and knowledge-exchange). Agencies are labeled as community-based organization (CBO), international NGO (NGO), international university (IU), national fisheries agency (NFA) and national environment agency (NEA). (A) In-degree centrality based on collaborative relations. (B) In-degree centrality based on knowledge-exchange relations. (C) Betweenness centrality based on collaborative relations. (D) Betweenness centrality based on knowledge-exchange relations. Source: Cohen et al. 2012.

since the early-mid 2000s (Lusseau, 2003; Lusseau & Newman, 2004; Croft et al., 2005) and to patterns of natural resource management and exploitation since the mid-late 2000s (Bodin et al., 2006; Bodin & Prell, 2011; Crona & Bodin, 2006).

The attractiveness of SNA for marine research and particularly the study of SES is that studying the structure of the relationships and the position of the individual actors in the network offers an empirical approach to abstract concepts (Wasserman & Faust, 1994) such as social groups ("cliques"), power, hierarchies, trust, leadership, agency, social capital, resilience, and collective action (Janssen et al., 2006; Bodin & Crona, 2008; 2009; Crona & Bodin, 2010). SNA methods to measure these concepts fall into two categories, metrics that focus on the individual, the connections between individuals and the position of the individual in the network, and metrics that focus on the network or structural level (Hanneman & Riddle, 2005).

On the individual level, the term *degree*, the number of links to other actors in the network, has been used to assess the social capital of members of a fishing community (Bodin & Crona, 2008) the influence that social animals have on their conspecifics (Lusseau, 2007), and the resilience of animal communities to intruders (Jacoby et al., 2010). Key individuals in fishing communities (Bodin & Crona, 2008; Crona & Bodin, 2010) and animal networks (Lusseau & Newman, 2004; Lusseau, 2007) were identified by their *betweenness*, the extent to which an actor is positioned between other actors in the network. For an example see Fig. 2.

On the network level, SNA showed that fishermen using the same gear interact more often (Crona & Bodin, 2006) and that fish were more likely to interact with other individuals that had a similar body shape and shoaling behavior (Croft et al., 2005). This phenomenon is known in SNA as *homophily*, which refers to the tendency of actors to form relations with actors that are similar to themselves (Prell, 2012) and, in the case of human actors, to become more similar to the actors they are connected with over time (Newman & Dale, 2007). The communication patterns and companionship behavior of marine mammals have been shown to have different degrees of *cohesion*, the degree to which individuals are directly connected to each other, so that removal of specific individuals through death or fishing would or would not break the network apart (Lusseau, 2003; Williams & Lusseau, 2006). On the human side, it has been suggested that SNA should be complemented with other stakeholder analysis methods when assessing collaboration, knowledge exchange and social cohesion between stakeholders for successful marine management (Carcamo et al., 2014).

2.1.2 Ecological Network Analysis (ENA)

Ecological Network Analysis (ENA) is a methodology developed to analyze food webs through network theory. ENA ultimately aims at the construction of a quantitative or qualitative model representing biological components of a system as a basis for simulation modelling at the ecosystem level (Ulanowicz, 2004). For this purpose, ecosystems may be defined as networks of direct and indirect interactions between groups of organisms and abiotic components in a system. The nodes of the network correspond to the biotic (organisms) and abiotic (e.g. nutrients, detritus) groups, while the links represent their feeding relationships, i.e. who eats whom and at what rate. Feeding interactions, in fact, rule the flow of matter and energy in food webs (Gaedke, 2008). By including all possible interactions in a system, ENA analyzes functional and structural properties and allows for the determination and quantification of relationships between groups, and identification of hidden processes (Fath et al., 2007; Baird et al., 2009). The applications of this approach are many: description of the trophic dynamics of an ecosystem; comparison of discrete system states or of different systems; understanding of ecosystem functioning and emergent properties of ecosystems (Baird et al., 2009); and estimation of impacts (e.g. fisheries) on the system.

Building and parameterization of the ecosystem network requires the definition of (groups of) species to include: according to similarities in diet or life traits characteristics, species are assembled into functional groups (or nodes) and diet composition may be determined through the analysis of stomach content or stable isotopes. Not all flows can be determined empirically, however algorithms exist to derive the unknown flows under determinate assumptions (typically, the balancing of the system; Christensen & Pauly, 1992; Gaedke, 2008; Fath et al., 2007). Once the network is constructed, structural, and functional properties of the system can be computed through different ecological network analysis indicators (Baird et al., 2009; Heymans et al., 2012; 2014): these are a set of algorithms derived from input–output analysis, information theory, trophic and cycle analysis, and include several techniques which allow to interpret ecosystem structure and functioning, to estimate their size and developmental stage as well as cycles and flows of energy and matter between systems compartments (Allesina & Bondavalli, 2004; Allesina & Ulanowicz, 2004; Patrício et al., 2006). Usually these indicators combine numerous factors into a single value (Patrício et al., 2006), which allow to easily compare among scenarios and systems, and the classification of system states, e.g. in terms of ecosystem stability and stress. Indicators may describe the cycling within the system, i.e. the connectivity among nodes, or system maturity. Several software programs have been developed to perform ENA, among which a prominent example is *Ecopath with Ecosim* (EwE; Christensen & Pauly, 1992; Christensen & Walters, 2004), allowing the user to construct the ecological network of interest as a food web model. Trophic linkages may be analyzed within the Ecopath network, applying several system descriptors and ecological network analysis indicators (Heymans & Baird, 2000; Heymans et al., 2007; 2012; Tomczak et al., 2013). The connection between the ecological network and the social-economics aspects is established within the Ecopath model: fleets or fisheries activities can include information such as costs, selling prices, and number of workers employed, as well as the biomass harvested. Hence, it is possible to understand which fishing activities will benefit and which will suffer from increasing or decreasing biomass of one species (or changes throughout the ecosystem). Management objectives based on maximization of profit, of employment or of ecosystem health can be explored to understand the trade-offs which affect fisheries (and their communities) and the ecosystem (e.g. Cheung & Sumaila, 2008).

A recent case study exemplifies the application of ENA for the analysis of anthropogenic impact on a coastal ecosystem: ENA was applied to determine the impact of bivalve (scallop *Argopecten purpuratus*) bottom aquaculture on a bay system (Kluger et al., under review). The authors used a steady-state model constructed with Ecopath (Fig. 3) to explore the effect of further expansion of aquaculture activities on the ecological community and the overall system by forcing scallop biomass to increase. Consequences for other functional groups were identified and ecological network analysis indicators were used to explore the system’s behavior and to ultimately define the bay’s ecological carrying capacity, i.e. the point at which scallop culture causes “unacceptable” consequences for the ecosystem. This threshold was here defined as the amount of scallop biomass that would not yet cause any other group’s biomass to fall below 10% of its original biomass (Kluger et al., under review). ENA results indicated that a further culture expansion would cause system size to increase, reflecting the increase in total system biomass. The system size is described by the sum of all trophic flows between any two compartments occurring in the system, or “total system throughput”, (TST; Patrício et al., 2006). Cycling within the system, however, decreased, as indicated by a decrease of the Finn’s cycling index (FCI; Finn, 1976). Generally, the higher the cycling is (i.e. the FCI), the higher is the ability of a system to recover from perturbations, thus the higher its stability. Accordingly, this result of the study suggest the system (‘s stability) would suffer from a further expansion of scallop culture. The outcome of this study will be used as the input for the estimation of the bay's social carrying capacity (describing the intensity of bivalve culture that does not yet cause adverse social impacts for any stakeholder group (Byron & Costa Pierce 2013)) to ultimately provide guidance for local managers and decision-makers in their challenging tasks of defining meaningful management measures for a long-term sustainable use of this important marine resource.

.2.2 The holistic analysis of social and ecological systems

Since the success of natural resource management depends on human behavior as much as it depends on ecological dynamics (Ludwig et al., 1993; Redman, 1999; Fulton et al., 2011), several research approaches have been developed to address the interaction between the social and the ecological system in an integrated way (e.g. Chesson et al., 1999; Charles, 2008; and publications reviewed in Binder et al., 2013; Weeratunge et al., 2014).

The particular challenges arising from the simultaneous analysis of the social and the ecological system are the necessity to integrate different types of data, the lack of data from either the social or ecological side, the high degrees of uncertainty about how the human and the natural world interact, and the balance between oversimplification and user-friendliness. Two approaches capable of dealing with these challenges, Bayesian networks (BN) and loop modelling are presented in the following section. Similar to ENA and SNA, BN and loop models represent ecological and social variables as nodes. The difference is that the nodes in BN and loop models are connected

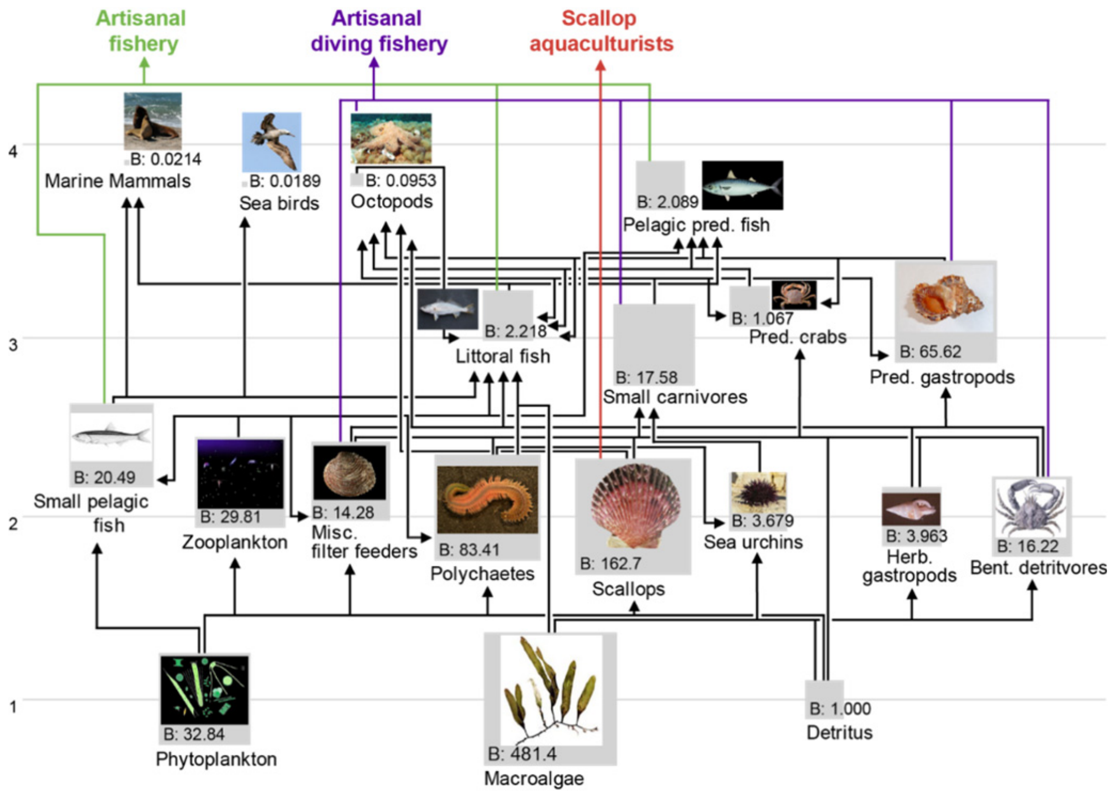

Figure 3. Example of an ecological network (flow diagram) as analyzed by Ecopath. Each box represents one functional group scaled proportional to its biomass. Y-axis shows the calculated trophic level (TL) of each functional group as calculated by Ecopath. Arrows indicate trophic flows. Target species of fisheries are demonstrated for the artisanal fishery (in green), artisanal diving fishery (in purple), and for the scallop aquaculturists (in red) (modified after Kluger et al., under review).

through causal relationships and not through proximity. BN and loop models are used to either represent the available knowledge about social-ecological interactions or to support and integrate management decisions.

2.2.1 Bayesian Networks

Bayesian Networks (BNs) act similar to human minds that have to take decisions on a daily basis without having complete, exact and reliable information to base their decisions on. The strength of the causal relationships between nodes in BNs is expressed as the so-called conditional probability. Conditional probability expresses the likelihood of a node to be in a certain state given the states of the other nodes it is connected to (Chen & Pollino, 2012). To give a simple example, the income from fishing can be modelled as a function of the number of fish caught and the profitability of the fishing operation (Fig. 4). Profitability is understood here as the profit that can be made per unit fish. If income is unknown, fish catch and profitability in this model are independent from each other assuming a global market in which the price per unit fish does not increase if the quantity of catch decreases. If it is observed that the income derived from the fishery increases, it can be deduced that either the fish catch or the profitability have increased. If we further learn that the fish catch has been stable over years, it can be concluded that that the profitability of the fishing operations went up, thus rendering the two variables "fish catch" and "profitability" dependent.

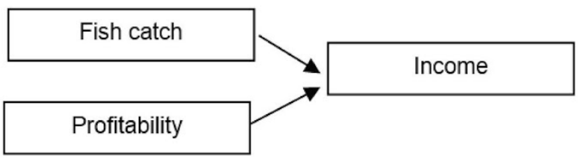

Figure 4. Conceptual model of a Bayesian Network (BN) for the income of fishermen.

The estimation of the relationship between nodes requires the discretization of the states of the nodes, e.g. into catch levels above or below the historic average (Fig. 4). Then the probabilities for each state are added. With no prior information, all states of the independent nodes, fish catch and profitability, are assumed to be equally probable to be true. They determine the probabilities that the fishermen can earn an income and finally make a livelihood. In the hypothetical example, catch levels below average (p= 0.50) in combination with a low (p= 0.33) or medium (p= 0.33) profitability of the fishery lead to an income below the national minimum (p= 0.50 * (0.33+0.33) = 0.33), whereas below average catch and high profitability as well as high average catch levels in combination with any type of profitability lead to an income above the national average (p= (0.50*0.33) + 0.5*(0.33+0.33+0.33) = 0.67). In the hypothetical example, two-thirds of the fishermen earning less than the national minimum income reported to be struggling to make a living. Therefore, an income below national minimum (p= 0.33) was set to result in difficulties to make a living with a probability of 67%. As a result, the initial probability that fishermen are struggling to make a living is 22% (p= 0.33*0.67 = 0.22). This is the initial BN. If we learn now in a national job satisfaction survey, that not 22%, but 40% of the fishermen struggle to make a living, the network can be updated with this information (Fig. 5).

BNs are used for the analysis of SES because they can incorporate incomplete, imprecise and uncertain data (Uusitalo, 2007) by expressing the relationship between nodes as either *frequentist* or *probabilistic*. In the example above, a *frequentist* relationship between income and livelihood can be established based on the

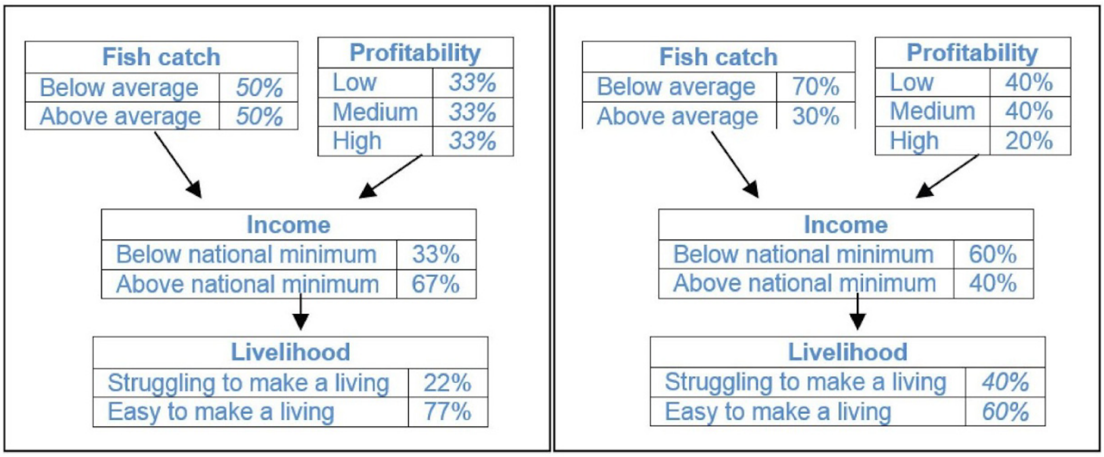

Figure 5. Initial configuration of a Bayesian Network (BN) for the income of fishermen (left) and the updated BN after incorporating the information that 40% of the fishermen are struggling to make a living.

observation that two-thirds of the fishermen earning less than the national minimum income reported to be struggling to make a living. Alternatively, experts may have given the *probabilistic* estimate that they are to 66% sure that a fisherman who doesn´t earn the national minimum wage will have difficulties in making a living.

BN models of SES have been used in freshwater (Marcot et al., 2001; Borsuk et al., 2002; Bromley et al., 2005; Kragt, 2009; Zorrilla et al., 2010), aquaculture (Slater et al., 2013) and marine science to e.g. analyze the commitment of salmon fishermen to sustainable management mechanisms in the Baltic Sea (Haapasaari et al., 2007). In this example, the BN showed that the commitment of fishermen was dependent on their perception of how much they contributed themselves to overexploitation (Haapasaari et al., 2007). A reason for the hesitant adoption of BNs for the modelling SES is the difficulty for BNs to incorporate feedback loops (Uusitalo, 2007). Nonetheless, BNs of entire fisheries could be a valuable tool to enhance communication between stakeholders, identify knowledge gaps and visualize trade-offs between different ecosystem services.

2.2.2 Qualitative loop modeling

Another approach for the analysis of complex SES is represented by loop analysis, which is a robust framework for the assessment of direct and indirect effects in complex systems (after Levins, 1974). The approach focuses on the nominal character of interactions (positive, negative, or zero), the structure of the network, and the dominance of negative and positive feedback loops (Ortiz & Wolff, 2002). It may therefore include both quantifiable and non-quantifiable social and ecological variables. Resulting loop models may be considered an idealized generalization of a system, and its use is especially recommended for cases in which quantitative modelling is inappropriate (Justus, 2006). So far, loop analysis has successfully been applied to a range of different systems (Ortiz & Wolff, 2002, and references therein) and has been used to predict changes in natural systems and their response to disturbance (Ortiz 2008, and references therein).

As for all types of network analysis, the first step for loop analysis is to identify variables of interest, which may be from the ecological (e.g. species), environmental (nutrients, temperature), social (e.g. fishermen), or economic context. Using a $n \times n$ matrix, the effects of each variable on all other (including itself) have to be identified as either positive, negative, or neutral (as described above). Relationships between different components of the system of interest are expressed graphically, with the signs "+", "-", and "0" describing the type of influence variables have on each other (Ortiz & Wolff, 2002). Variables are usually represented as circles, and the connections among them as arrows (Fig. 6).

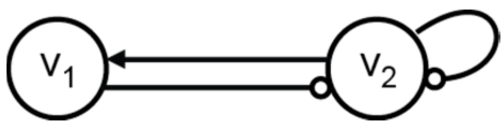

Figure 6. For loop analysis, variables are demonstrated as circles and connections among variables as arrows terminating in an arrowhead (for positive effects) or circles (for negative effects). Here, variable 1 (v1) has a negative effect on variable 2 (v2), while variable 2 exerts a positive effect on variable 1, but a negative one on itself. Figure adapted from Figure 1 in Levins (1974).

The method of loop analysis allows for the identification of how the change in any variable may qualitatively impact any other variable, causing either an increase, a decrease or leave them unchanged (Justus, 2005). These causal connections may be described as paths, i.e. a series of links from variable 1 through one or more other variables, without passing any node twice (Ortiz & Wolf, 2002). Loops, on the other hand, describe closed paths, which return to their starting point after having passed one or several other variables, with the length of a loop described by the number of nodes passed (Ortiz & Wolff, 2002). A *self-loop* depicts a loop starting and ending with the same variable without involving any other one, therefore having the length 1 (Ortiz & Wolff, 2002). A measure of feedback (after Levins, 1974) may be calculated, describing the process by which a change in one variable causes changes in other variables that then affect the variable originally changed. Loop analysis further allows for the estimation of local stability (or sustainability) of the system, calculated as an index (after Puccia & Levins, 1985) using the balance of feedbacks at different levels of complexity and identifying the propagation of direct or indirect effects as a response to disturbance entering the system through variables (Ortiz, 2008).

One example for the application of loop analysis is the recently initiated MAPES project (www.mapes2014.wordpress.com) that studies two SES in climatic extremes within the Tropical Eastern Pacific (TEP) region: the very wet and undisturbed southern Colombian mangroves (Iscuandé) and the very dry and disturbed mangroves in northern Peru (Tumbes). The authors apply qualitative loop modelling to increase knowledge on the linkages between the biological, environmental, and social variables within these two SESs, and aim at understanding the systems' behavior when exposed to environmental disturbances (Castellanos-Galindo & Kluger, unpublished data). First results suggest that the SES in southern Colombia (Fig. 7) may be more resilient to perturbations due to a lower human impact and environmental stress when compared to northern Peru. The comparison of the two SESs that represent climatic extremes will allow predicting how mangrove-associated resources react to the extreme environmental changes that are anticipated for the future.

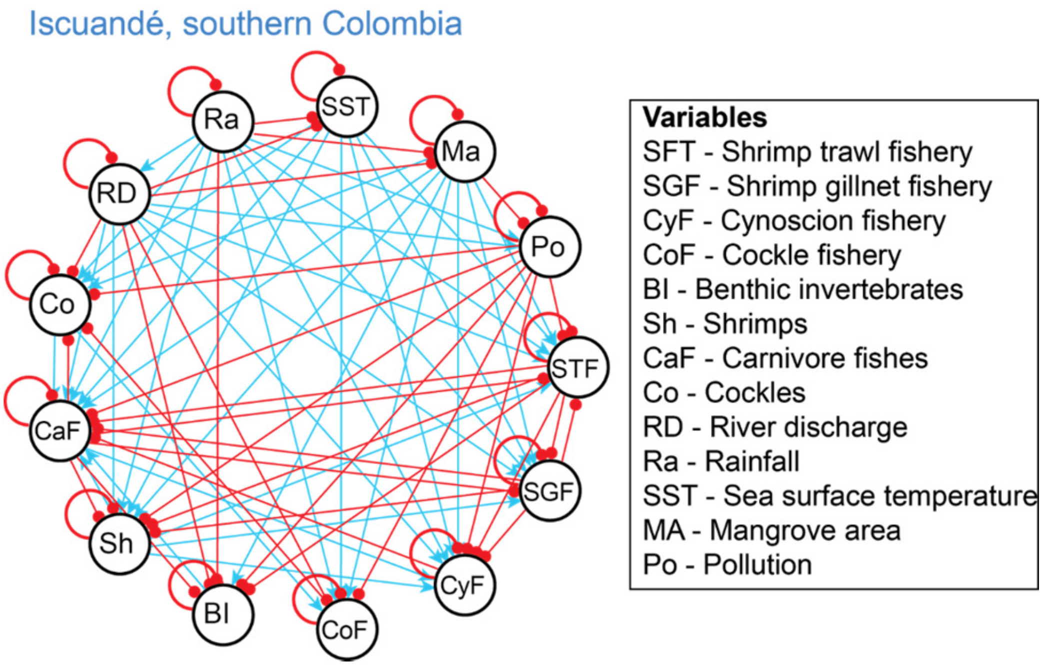

Figure 7. Example of a qualitative loop model, representing a social-ecological system in Iscuandé, Pacific-Colombia. Variables are represented by circles and connections are described as lines, with blue lines (terminating in an arrow) describing positive and red lines (terminating in a circle) depicting negative effects (Castellanos-Galindo and Kluger, unpublished data).

3. Future potential and prospective opportunities

The use of network analysis bears great opportunities to advance understanding of linkages in coastal and marine SES. This review presented Social Network Analysis (SNA), Ecological Network Analysis (ENA), Bayesian Network models (BNs) and Loop Modeling as four network approaches to analyze SES. Among these, ENA is the best-established method in marine sciences, and it can be used to analyze complex ecosystem dynamics. SNA is a relatively new and highly flexible approach that can be applied to individuals´ behavior in natural and social systems alike. BNs incorporate uncertainty and Loop Modelling integrates feedback loops into the modelling of SES. A promising way forward could be the combination of these approaches (Janssen et al., 2006; Koelle et al., 2006; Ortiz, 2008; Johnson et al., 2009; Cumming et al., 2010; Schoenenberger & Schenker-Wicki, 2015). A stronger focus is needed in network studies to integrate both social and ecological components in analyses for a more holistic understanding of cascading effects. Yet, analyzing social and ecological systems are complex tasks on their own. Expanding the analysis to the coupled SES as a whole is not only increasing the number of elements and relationships but also defies established disciplinary boundaries (Oughton & Bracken, 2009). However, the potential benefits arising from considering the social and ecological sub-systems in a combined manner making the challenge worth a try. Such an integrated network approach offers great potential to gain a better understanding of linkages in SES, to learn about interactions between biological, environmental and social elements and to understand the system's dynamic and behavior, feedback mechanisms and other interactions within the system. In addition, it allows for obtaining valuable insights to advance the understanding of system reactions to changes and to project system behavior under dynamic conditions or a potential disturbance. The newly generated knowledge may be a valuable asset for (co-) management of marine and coastal resources and its SES. In particular, this approach might contribute to development of adaptation strategies to (anthropogenic) stressors or climate change, and may be of especial importance in the face of new impacts that lie outside the traditional coping pathways of SES.

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10 | Coral Reefs

Recent approaches in coral reef research: traditional and novel applications towards building resilience

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ABSTRACT

Coral reefs are experiencing an unprecedented global decline due to a range of anthropogenic stressors. To slow this trend, better understanding of underlying mechanisms behind reef degradation is required. Recent efforts in coral reef research emphasize the importance of targeting different levels of biological organization and using innovative applications by complementing traditional ecological approaches with techniques from other disciplines (physiology, biogeochemistry, or microbiology). These efforts will lead to better insights into the complex interactions that build the resilience of the reef ecosystem.

This session includes contributions from different disciplines, ranging from molecular to ecological approaches. The diversity of topics highlights the importance of a holistic understanding of interactions and processes from the organism to the ecosystem level for the development of meaningful management strategies.

ORAL PRESENTATIONS

10.1)	**Jessica Knoop**	Coral-algae contacts on Koh Phangan, Gulf of Thailand
10.2)	**Laura Puk**	Macroalgae browsing fishes on coral reefs in the Gulf of Thailand
10.3)	**Jan-Claas Dajka**	Structural complexity influences coral reef fish ecology on Koh Phangan, Thailand
10.4)	**Lisa Röpke**	Effects of nutrient enrichment and reduced herbivory on the survival of a sexually propagated coral
10.5)	**Sabrina Rosset**	Transmission Electron Microscopic markers indicate nutrient stress in reef corals
10.6)	**Julian Mönnich**	Bioactive coral extracts provide antimicrobial resistance in corals from Guam
10.7)	**Susann Diercks**	Growth and respiration of the scleractinian cold-water coral *Tethocyathus endesa*

POSTER PRESENTATIONS

10.8)	**Felix Rossbach**	*In situ* growth evaluation of scleractinian corals using underwater photography and 3D modeling applications
10.9)	**Kristina Beck**	Effects of large amplitude internal waves and monsoon on coral growth and skeletal density
10.10)	**Stephanie Helber**	Chemical defence in 10 Indian Ocean reef sponges
10.11)	**Valeska Diemel**	Embryonic development and metabolism in two species of clownfish, *Amphiprion ocellaris* and *Amphiprion frenatus*

PROCEEDINGS

Recent approaches in coral reef research: traditional and novel applications towards building resilience

Coral-algae contacts on Koh Phangan, Gulf of Thailand

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ABSTRACT

Coral reefs have experienced a coral cover decline during the last decades, mainly caused by ongoing anthropogenic impacts. In most cases the coral cover decline is accompanied by an increase in macroalgae abundance, leading towards a phase shift from a coral-dominated towards an algae-dominated reef. An important aspect in phase shifts is the competition and interaction between corals and macroalgae, which is a fundamental process in shaping the structure and appearance of coral reefs. Abundance and character of coral-algal contacts were compared between the pristine Mu Ko Ang Thong National Marine Park and a locally impacted reef in Mae Haad on Koh Phangan, using line-point-intercepts. Furthermore, it was examined if the coral growth form is an important factor influencing coral-algal contacts and the development of this competition. Over a period of 13 weeks, corals of four different genera and two different growth forms (branching – *Acropora, Pocillopora*; massive – *Porites, Platygyra*) in natural contact with the cosmopolitan brown alga *Lobophora variegata* were observed in an exemplary reef in Mae Haad, Koh Phangan, Thailand. The monitoring included observation of coral and algal tissue change as well as alteration in coral tissue pigmentation. Nearly twice as much corals in Mae Haad were in contact with algae compared to the Marine Park and contacts were more often harmful. The monitoring of natural contacts between massive and branching corals in contact with *L. variegata* revealed that only massive corals were impacted, while branching corals were unaffected by the creeping growing brown alga. *Porites* was the most impacted coral and was overgrown by *L. variegata*. Furthermore contacts resulted in a bleached tissue area in *Porites* around the coral-algal contact zone and the induction of a pink tissue discolouration with following tissue damage was observed.

Keywords: coral reefs, coral-algal contacts, Gulf of Thailand

Macroalgae browsing fishes on coral reefs in the Gulf of Thailand

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ABSTRACT

Browsing fishes are an important component of coral reef resilience, since in contrast to other herbivorous fishes they are able to feed on established macroalgae. Climate change and local anthropogenic impacts lead to phase shifts in many coral reefs from coral to macroalgae dominance and recent research suggests the potential ability of browsers to reverse such phase shifts. The Gulf of Thailand is subjected to high anthropogenic pressures but research on its coral reefs has been scarce. Therefore, the aim of this study was to identify important species for macroalgae removal and test whether differences between a bay which is subject to frequent fishing and a marine park could be found. Assays of different macroalgal species were filmed for two hours, as camera-based research has been proven a useful tool for observing the impact of individual fishes. Visual census and line-point-intersect transects were used to quantify abundance and biomass of roving herbivorous fishes and benthic coverage in both locations. The assays set up in the fished bay revealed almost no feeding on either macroalgae species deployed, whereas significantly more bites were taken on the assays deployed in the Marine Park. The most important macroalgae consumer in both study sites was the double-bar rabbitfish (*Siganus virgatus*). Visual fish censuses revealed 2.6 times higher abundance and 2.3 times higher biomass of roving herbivorous fish in the Marine Park than in the fished bay. The Marine Park exhibited substantially lower algae cover (7.9%) compared to the fished bay (44.3%). Higher herbivore feeding pressure and less resource availability are likely driving the different macroalgae removal rates. The obtained data suggest a substantial impact of fishing in facilitating phase shifts to macroalgal dominance.

Keywords: marine park, fishing, browsers, herbivory, *Siganus virgatus*, phase shift

Structural complexity influences coral reef fish ecology on Koh Phangan, Thailand

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ABSTRACT

Coral reefs are increasingly degraded by anthropogenic and environmental stressors. Decreases in reef structural complexity result in the reduction of available shelter for many organisms. This may strongly impact and restructure reef associated fish communities. Changes in fish functional groups may affect ecological functions such as herbivory, which are essential for reef integrity. Recent research suggests that a low coral reef structural complexity could select for fish with larger home ranges and less interaction with a small scale habitat than their fish with smaller home ranges. The present study aims to link home range sizes of important fish functional groups (i.e. herbivores and corallivores) to structural complexity and benthic cover of a small scale habitat. Observations were conducted in 30 x 5 m belt transects on the reef crest of Mae Haad, a bay of Koh Phangan situated in the Gulf of Thailand from 24 February to 23 June 2015. Each belt transect was assessed in three ways. Firstly, fish were visually assessed for species, abundance, and size classes. Secondly, structural complexity was assessed by measuring the rugosity of the reef crest via the chain-and-tape method. Lastly, benthic cover was quantified focussing on three-dimensional structural elements (e.g. coral growth forms). Results confirm the suggetions of previous studies. Small scale coral reef habitats of low structural complexity (rugosity ~ 1.4) are associated significantly more by fish with large home range as well as body sizes. This allows to conclude that the interaction with their respective habitat weakens. Corallivory decreases significantly towards the lower end of the complexity gradient while herbivory increases. However, there are no indications that the less complex habitat weakens in functionality. The habitat is made up of resistant massive corals and algal progression is controlled by more and larger herbivores than the more complex counterpart. These findings have the potential to develop spatial and species-specific management tools that assist in sustaining the ecosystem integrity of Koh Phangan's reefs.

Keywords: herbivory, corallivory, ecosystem function, fish-habitat association, fish functional groups

Effects of nutrient enrichment and reduced herbivory on the survival of a sexually propagated coral

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ABSTRACT

Coral population restoration commonly focuses on asexual fragmentation methods or "coral gardening". These techniques require the collection of fragments from healthy donor colonies for nursery stocks, and do not allow the formation of new genotypes better adapted to the present environmental conditions on coral reefs. Sexual propagation of coral larvae reared from field collected gametes and outplanting early settlers onto the reef may overcome these limitations. However, local stressors such as anthropogenic nutrient enrichment and low herbivory levels due to overfishing could compromise these efforts, as they both can promote algal growth. Macro- and turf algae compete with corals for light and space, and inhibit coral growth by releasing toxic allelochemicals. In this study we investigated the influence of these local stressors on the survival of recently settled *Colpophyllia natans*, and how these stressors in turn influence population restoration efforts. Larvae of *C. natans* were settled on artificial clay substrates and placed in a two-factor two-level design *in situ*. The latter consisted of 12 manipulative plots with open or closed cages which were either enriched with nitrogen and phosphorus (NH_3N, PO_4^{3-}) or kept at ambient nutrient concentrations (controls). After 13 weeks in the field, a significant reduction in survival of settlers in nutrient-enriched treatments compared to controls was observed. Elevated nutrients decreased settler survival by promoting turf algae growth, whereas herbivory reduction did not affect survival. The combination of nutrient enrichment and herbivore exclusion on settler survival was not different than the effect of nutrient enrichment alone, thus indicating that nutrient levels are a more important driver of *C. natans* recruitment success than herbivory. The results indicate that turf- and macro- algae dominance is increasingly becoming a negative driver of coral recruitment success on Caribbean reefs, and that the success of restoration efforts depends on the local nutrient environment.

Keywords: brain coral, sexual propagation, coral restoration, *Colpophyllia natans*

Transmission Electron Microscopic markers indicate nutrient stress in reef corals

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ABSTRACT

Increasing evidence indicates that anthropogenic nutrient enrichment, both through primary effects on coral physiology as well as through secondary effects of an altered nutrient environment, has negative repercussions on the resilience of corals to environmental stress. Specifically, the susceptibility of corals to thermal- and irradiance stress induced bleaching increases as a result of a disproportionately high concentration of dissolved inorganic nitrogen compared to phosphate and carbon, such as occurs as a consequence of agricultural runoff into coastal waters. This study aimed to further investigate the impact of an imbalanced nutrient environment on zooxanthellae *in hospite* by culturing *Euphyllia paradivisia* in our experimental mesocosm at the National Oceanography Centre Southampton, allowing for the long term study on the effects of distinctive dissolved inorganic nutrient concentrations on reef corals. Analysis by transmission electron microscopy revealed significant changes in zooxanthellae cell morphology in corals exposed to nutrient stress, specifically under phosphate starvation. The changes in the ultrastructure of zooxanthellae were associated with severe detrimental effects for the holobiont physiology. Our study provides further evidence that, in face of climate change, it is imperative to manage nutrient input into coastal waters in order to support the resilience of corals and thus the conservation of coral reefs.

Keywords: dissolved inorganic nutrients, nutrient imbalance, coral-zooxanthellae symbiosis, resilience

Bioactive coral extracts provide antimicrobial resistance in scleractinian corals from Guam, Mariana Islands

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ABSTRACT

Coral diseases have been increasing in frequency and severity in the last decades. Nevertheless, little is known about chemical defence against putative pathogens via antimicrobial metabolites. We assessed the antibacterial activity of crude extracts from 12 coral species sampled at Guam reefs, including the most common genera *Porites* and *Acropora*. Extracts were screened against 15 bacterial isolates including known coral pathogens and environmental isolates from the proximity of corals. All environmental bacterial isolates were preliminarily identified by 16s rDNA sequence analyses and NCBI BLAST. Bacterial growth inhibition assays were performed in liquid culture and scored by measurements of the optical density, allowing to assess whether the coral extracts act as inhibitor or stimulator of bacterial growth. The majority of coral extracts exhibited a strong antimicrobial activity, with selectivity towards specific bacterial isolates. The antibacterial activity was high for known pathogens as well as environmental isolates, while fewer bacteria were stimulated in growth. Extracts of *Porites lutea* and *Acropora hyacinthus* exhibited the highest antibacterial activity against known coral pathogens *Aurantimonas coralicida* and *Vibrio mediterranei*, which have been associated with diseases like white plague type II or coral bleaching.

Keywords: antibacterial activity, Porites, Acropora, coral disease

Growth and respiration of the scleractinian cold-water coral Tethocyathus endesa

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ABSTRACT

The recently discovered scleractinian coral *Tethocyathus endesa* (Cairns, Häussermann and Försterra, 2005) is a cold-water coral, thriving in the fjord Comau (Chile). It exhibits horizontal and vertical pH gradients resembling values forecasted for the end of this century by the recent IPCC-report (IPCC, 2014). Ongoing ocean acidification and global ocean warming might have harmful impacts on all calcifying organisms such as scleractinians. This study aims for a better understanding of the metabolic response of *T. endesa* in a changing ocean. Measured parameters were *in situ* growth rates and respiration rates as being two of the main factors that can be influenced by ocean acidification. In 2014, test corals were placed at two study sites (inside the fjord with low pH of 7.67 ± 0.05 and outside the fjord with higher pH of 7.87 ± 0.06). For each study site, ten specimens of *T. endesa* stayed at their place of origin to determine the general *in situ* long-term growth rates (one year) as well as to serve as a control for a cross- transplantation experiment. For the latter, additional ten specimens of *T. endesa* were exchanged to the other study site in 2014. One year later, growth rates were determined via buoyant weighing and respiration rates measured with the aid of optodes. So far there is only little knowledge about the *in situ* long-term growth rates and the respiration rates of cold-water corals. To the best of our knowledge this is the first study on the reaction of *T. endesa* towards a changing seawater pH. The findings of this study are therefore crucial to rate the ecological importance of *T. endesa* and its response to future conditions.

Keywords: coral, ocean acidification, climate change, growth, respiration

In situ growth evaluation of scleractinian corals using underwater photography and 3D modeling applications

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ABSTRACT

In order to gain accurate information on coral growth increments, the buoyant weight technique (BWT) is a commonly employed technique. However, this method is not readily applicable for *in situ* studies, as individual coral fragments need to be retrieved regularly to be measured in the lab. The use of 3D photogrammetry on the basis of underwater photography eliminates both of these issues. The pictures as a source for the data can be directly taken from the *in situ* setup with underwater photography. Consequentially, no transfer of specimen to the lab is required, stress is limited for the coral specimen. This new digital tool further enables data acquisition in remote places without laboratory access. The process turning underwater pictures into 3D models involves three steps, including the creation of a 3D model, and the subsequent calculation of its respective volume. Potential pitfalls of this application are discussed. This non-invasive method is beneficial not only for coral reef research but also applicable for projects with other sessile animals.

Keywords: in situ ecology, coral growth, scientific diving, buoyant weight, non-invasive

Effects of large amplitude internal waves and monsoon on coral growth and skeletal density

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ABSTRACT

Large amplitude internal waves (LAIW, or solitons) are known to change environmental factors affecting coral growth. Previous studies have been shown that LAIW have their greatest impact at greater depth. Therefore, we compared the impact of LAIW and monsoon on coral growth and skeletal density between sites exposed to and sheltered from LAIW and at two depths (7 and 20 m) in the Similan Islands near the Thai continental shelf break (Andaman Sea). Coral skeletons of *Porites lutea* were sampled at the exposed (west) and sheltered (east) sides of Ko Miang Island at the centre of the Similan Islands. X-radiography and fluorescence analysis were used to examine the linear extension rate due to the annual density banding in the coral skeletons. Measurements of skeletal micro-density, porosity and bulk density were based on the buoyant weighing technique, calculation of the total enclosed volume and measurement of matrix volume by Archimedean methods. We hypothesize that coral growth is reduced at the site exposed to LAIW as compared to the sheltered east. We further assume that coral growth is significantly reduced at 20 m compared to 7 m depth due to the higher impact of LAIW. In addition, the stronger intensity of internal waves and monsoon at the exposed site is expected to cause higher skeletal densities in *P. lutea* from the respective area.

Keywords: solitons, large amplitude internal waves, coral growth, skeletal density, Andaman Sea

Chemical defence in 10 Indian Ocean reef sponges

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ABSTRACT

Sponges are one of the top spatial competitors on coral reefs worldwide. In the Caribbean there is increasing evidence that coral reefs are shifting from coral dominated to sponge dominated reefs. There are also reports that on some East African coral reefs sponges are becoming the most abundant sessile marine invertebrate as well. The success of sponges is in part dependent on their ability to deter predators, inhibit pathogenic microbes as well as demonstrate competitive dominance towards other sessile benthic organisms. Sponges and their associated microbes yield a wide array of compounds with different biological activities in order to chemically defend themselves. This study assessed if sponge species from Zanzibar's coral reefs were chemically defended against predators and bacteria. Furthermore, it was investigated if observed bioactivity in sponges correlated with their abundance on the reef (e.g. chemically defended sponges should be better protected and might be more abundant). The palatability of the ten most abundant sponge species was tested in feeding assays with the pufferfish *Canthigaster solandri*. Antimicrobial activity of the sponge species was quantified by the disc diffusion assay. Sponge extracts were tested against 27 environmental and 9 pathogenic bacterial strains known to be associated with various coral diseases. Potential cytotoxicity of sponge extracts was assessed using the brine shrimp lethality assay. Among the ten sponge species tested, three species were found to deter predation by *C. solandri*. In addition most sponge species also displayed a wide range of activity when tested against 36 bacterial strains. All sponge species were better defended against potential pathogens compared to environmental strains. No pattern was found between sponge abundance on the reef and degree of deterrence, antimicrobial and cytotoxic activity. This is the first study to give an insight on the chemical ecology of sponges from reefs around Zanzibar.

Keywords: sponges, bioactivity, chemical defences, Indian Ocean

Embryonic development and metabolism in two species of clownfish, Amphiprion ocellaris *and* Amphiprion frenatus

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ABSTRACT

Survival in vertebrates is strongly size-dependent. Therefore, small differences in initial egg size can be critical to survival and further development of offspring. The size of newly hatched larval fish is directly related to egg size. Underlying processes causing size variation in fish offspring are still not entirely understood. Consequently, we investigated whether the spatial position of an individual egg within a clutch potentially affects size variation in two benthic spawning coral reef fishes, the clownfishes *Amphiprion ocellaris* and *Amphiprion frenatus*. To evaluate the effects of within-clutch position on embryonic development, egg growth metrics and protein content were analyzed on day 2, 5 and 8 after deposition. Additionally, activity of the metabolic key enzymes citrate synthase (CS) and lactate dehydrogenase (LDH) were investigated to evaluate the physiological status of the embryos. No significant differences were observed in *Amphiprion ocellaris* between eggs originating from a central or peripheral position, although central eggs showed a strong tendency towards increased length and weight on day 8 (Central eggs: 1.33 mg, 2.26 mm; Peripheral eggs: 1.15 mg, 2,18 mm). In contrast, central eggs of *Amphiprion frenatus* were significantly longer and heavier than peripheral eggs on day 8 (2.07 mg, 2.59 mm; 1.84 mg, 2.49 mm, respectively). Diameter of the eyes were neither different in both fish species nor in different positions at all 3 ages. The protein content of eggs (7.5% of wet weight) was independent from age, position and species. Enzymatic activity was moderate on day 2 and slightly increased on day 5 after deposition. Peak activities were observed for both enzymes on day 8. The range of CS-activity was 0.3 – 13.0 U g^{-1} wet weight and the range of LDH-activity was 0.2 – 71.7 U g^{-1} wet weight. Significant differences in enzymatic activity were observed between age groups, but not between central or peripheral eggs.

Keywords: clownfish, embryogenesis, metabolism, key enzymes, size variation

Recent approaches in coral reef research: traditional and novel applications towards building resilience

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1. Coral reefs in the Anthropocene

Despite thriving in oligotrophic tropical waters, coral reefs are among the earth's most productive and diverse ecosystems (Odum and Odum 1955; Hatcher 1990). They support important goods and services by supplying food and livelihood for coastal communities, coastal protection from hurricanes and erosion, and provision of novel chemical compounds for pharmaceutical purposes (Moberg and Folke 1999; Sale 2008). In recent decades, coral reefs have been degrading and disappearing globally at an alarming rate. Predictions suggest that 60 % of all coral reefs might be lost as early as 2030 (Hughes et al. 2003; Wilkinson 2008). Reasons for coral reef decline are manifold and include global (ocean warming and acidification) and local drivers (e.g. nutrient-enrichment, overfishing, sedimentation). Global stressors are caused by the continuous and increasing emission of greenhouse gases, and have resulted in widespread and long-lasting changes in the physicochemical environment of the world oceans (Howes et al. 2015). The oceans have absorbed approximately 93% of the excess heat caused by global warming between 1971 and 2010 (Rhein et al. 2013). The resulting ocean surface warming increases stratification of the water column, thereby limiting the circulation of water masses. This causes a reduced transfer of deep water nutrients to the surface and poor oxygenation of deeper water layers (Rhein et al. 2013). Further, ocean warming pushes sensitive marine organisms, including scleractinian corals and different ontogenetic stages of other marine invertebrates and fish to their physiological limits (Hoegh-Guldberg et al. 2007). However, thermal stress is not the only consequence of global carbon emissions. In addition to taking up excess heat, the oceans annually absorb approximately 25% of the CO_2 emitted to the atmosphere by human activities (Le Quéré et al. 2010), resulting in increased seawater partial pressure of carbon dioxide (pCO_2), a reduced pH, and reduced carbonate ion concentration. This change in seawater chemistry is termed ocean acidification.

1.1 Effects of global stressors

Coral reefs are affected by both ocean surface warming and acidification. During the past decades, warming periods (e.g. during El Niño years) were increasing in frequency and severity and repeatedly caused widespread coral bleaching and mass mortality in all tropical seas

(Hoegh-Guldberg et al. 2014). Detrimental effects of ocean acidification on coral physiology have been reported in numerous ex situ studies, which found reduced calcification rates in scleractinian corals and on the reef community scale in response to a lower carbonate saturation state resulting from increased pCO_2 (Cohen and Holcomb 2009; Comeau et al. 2014). Additionally, a series of field studies conducted at natural CO_2 seeps have shown changes in benthic community composition (Fabricius et al. 2011) as well as effects of reduced pH on the physiology of benthic calcifying reef organisms (Uthicke and Fabricius 2012; Vogel et al. 2015). Recent molecular (Thurber et al. 2009; Santos et al. 2014) and biogeochemical studies (Rädecker et al. 2014) further confirmed significant effects of ocean acidification on coral-associated microbial communities and activity.

1.2 Effects of local stressors

Besides these global drivers, most coral reef ecosystems are impacted by local drivers acting on a regional scale, such as overfishing and excessive harvesting, nutrient enrichment (eutrophication), sedimentation, or pollution (Burke et al. 2011). Two of these stressors, overfishing and nutrient enrichment, have been nominated most detrimental. Fishing can have wide-ranging effects, including unsustainable harvesting, physical destruction of the coral reef framework by destructive fishing methods, or loss of key functional ecological groups by highly selective fishing gear (Pauly and Chua 1988; McManus et al. 1997; Mangi and Roberts 2006). The removal of predators and herbivores alters the coral reef food web by trophic cascading through prey-release (Campbell and Pardede 2006; Mumby et al. 2006) and may ultimately result in major benthic and/or pelagic community shifts and loss of ecosystem services (Hatcher and Larkum 1983; McClanahan 1994; Campbell and Pardede 2006). Anthropogenic nutrient enrichment is characterized by an increase of inorganic or organic nutrients in coastal waters. Elevated nutrient concentrations may originate from a variety of different sources, including agriculture run-off, untreated sewage water, industrial effluents or fossil fuel combustion (Selman et al. 2008). Nutrient enrichment can have highly deleterious effects on coral reefs from organism- to ecosystem level. Nutrients may affect the corals' physiological performance (Ferrier-Pages et al. 2000; Haas et al. 2009; Fabricius et al. 2013) and reproduction (Koop et al. 2001; Loya et al. 2004), increase disease prevalence (Kuntz et al. 2005; Voss and Richardson 2006), cause structural and functional changes in the coral-associated microbiome (Thurber et al. 2009; Jessen et al. 2013), and lower the resilience of corals to bleaching (Haas et al. 2009; Wiedenmann et al. 2012). The whole reef ecosystem may thereby shift from coral-dominance to dominance of other benthic organisms, such as macroalgae or other invertebrates (Done 1992; Norström et al. 2009).

Typically, not only one, but several drivers affect coral reefs at the same time (Hughes et al. 2003). The presence of multiple drivers may either exacerbate or alleviate the effects of single drivers (Anlauf et al. 2011; Negri and Hoogenboom 2011), which makes it challenging to predict the impacts on individual or species level. Ecosystem-based projections are further complicated by considering species interactions and community level responses to multiple stressors (Howes et al. 2015). As a consequence, a better understanding of mechanisms underlying reef degradation is required. Recent efforts emphasize the importance of holistic approaches that target different levels of biological organization (e.g., molecular, cellular, individual, holobiont, community and ecosystem level) and use innovative interdisciplinary applications by complementing traditional ecological approaches with techniques from other disciplines (physiology, biogeochemistry, microbiology and meta-genomics). These efforts have the potential to contribute to a better understanding of coral reefs and will allow the development of effective and meaningful management measures to preserve coral reefs for future generations.

2. Building towards resilience

2.1 Recent approaches and emerging hot topics in coral reef research

In the past few decades, methodological advances, such as microbial ecology, physiology, and modelling applications have been increasingly integrated into coral reef studies to supplement traditional ecological and socioeconomic approaches. Physiological processes on cell or organism level are nowadays targeted by the use of (meta)genomics and (meta)transcriptomics applications. To address research questions on the population or ecosystem level, new conceptual models are developed, such as functional trait-based and adapted management approaches. Consequently, this has led to a considerable diversification of research questions.

New pathways and functions on organism and ecosystem levels are still being discovered in coral reefs, such as the sponge loop, which facilitates recycling of large amounts of dissolved organic to particulate matter, that is readily available and accessible to other organisms (de Goeij et al. 2013).

Adding to the pool of the extensively-studied local stressors, new threats to coral reefs have been identified which receive increasing attention. Species invasion, particularly the introduction of the predatory lionfish has been in the focus of recent conservation and restoration efforts in the Caribbean (Albins and Hixon 2013). Another emerging issue with still unknown implications for the future of coral reefs is the ingestion of microplastics by corals (Hall et al. 2015).

Recent efforts in coral reef research tackle the dynamics and interactions within the coral holobiont. The coral holobiont is an ecological unit consisting of the coral animal, symbiotic algae of the genus *Symbiodinium*, and a plethora of microbes including bacteria, archaea, viruses, or fungi (Rohwer et al. 2002; Rosenberg et al. 2007). This dynamic meta-organism extends the physiological capabilities of the coral animal alone (Rosenberg et al. 2007), and allows for highly efficient internal nutrient recycling. This enables corals to thrive in oligotrophic tropical seas and retain a high productivity despite limiting nutrient concentrations ("Darwin Paradox"; Darwin 1897, Sammarco et al. 1999). Recent advances in molecular studies are emphasizing the importance of identifying functional changes within the coral holobiont to provide insights into the limitations of physiological adaptation and plasticity in coral holobionts (Thurber et al. 2009; Bay and Palumbi 2015; Rädecker et al. 2015). As high-tech sampling tools and molecular techniques are advancing, specialized coral-endosymbiont communities have been discovered; these specializations include thermal tolerance, as recently found in the "world´s hottest reefs" in the Persian-Arabian

Gulf (Hume et al. 2015), but also to low-light adaptation, e.g. in lower mesophotic reefs (Bongaerts et al. 2015; Ziegler et al. 2015). In order to understand future coral responses to environmental change, the contribution of the different eu- and prokaryotic partners to the adaptation potential of the coral holobiont have to be disentangled.

Recent insights into the effects of anthropogenic stressors on the organism level have been paving the path for an upscaling of experimental designs. Ocean acidification effects are investigated on the entire coral reef community level at CO_2 seeps with natural low pH (Fabricius et al. 2011; Dove et al. 2013). Other studies modeled human impacts on the entire Pacific region (Williams et al. 2015). Modelers are trying to locate the thresholds in environmental conditions or anthropogenic stressors that will determine the fate of a reef between recovery versus regime shift (Graham et al. 2015). It is becoming clear that the trajectory of coral reefs is unavoidable in the long run, which is why recent studies try to predict of how reefs will look like under future climate change scenarios (Riegl et al. 2013). Questions arise if it will be possible to reverse phase shifts or if we will have to accept the changed ecosystems as a novel state (Côté and Darling 2010; Graham et al. 2014).

2.2 Reef resilience and adaptive management

The term “resilience” has increasingly been replacing the concept of sustainability in virtually all fields of ecology, and is an emerging topic of research in coral reef ecology. Ecological resilience is defined as the capacity of an ecosystem to absorb disturbance without shifting to an alternative stable state (Holling 1973). Resilience of an ecosystem thereby consists of 1) the resistance to disturbance, and 2) the recovery potential to a functional system. Resilience of coral reefs has recently been suggested to be highly dependent on the geographic location (Roff and Mumby 2012). The implications of this insight for ecosystem management are substantial, as concepts for one region may not be applicable to another. Adaptive management may help in this context, as it aims to change a system gradually by continuously implementing new insights derived during the management process (Holling 1978). The importance of adaptive management strategies for coral reefs have only been recognized fairly recently (Anthony et al. 2015).

From an ecological but also an economic point of view, it is considered highly desirable to keep or return coral reefs to a functional ecosystem which continues to provide goods and services to mankind (Spurgeon 1999). Novel approaches in coral reef studies have the potential to resolve mechanisms underlying coral reef functioning and to understand organism responses to various environmental drivers. This can eventually lead to the development of promising adaptive management strategies which are able to maintain ecological goods and services of coral reefs.

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11 Aquaculture

Latest developments in landbased aquaculture

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ABSTRACT

Aquaculture now accounts for more than 50% of the world's aquatic production output and the sector is forecasted to keep steady growth well into 2020. Environmentally-friendly aquaculture development is a strategic goal for Europe, and research efforts are constantly finding ways to reduce environmental impact and maximize the use of resources. Fish farming operations on land can help ensure control over the farming environment, isolation of farming stocks from wild populations and provide opportunities for rural development. This paper will offer an analysis of the current state of the land-based aquaculture sector, focusing on current developments in Europe.

ORAL PRESENTATIONS

11.1 Jalil Zorriehzahra	Introduction to important diseases for finfish species in responsible land-based aquaculture
11.2 Lars-Ole Rühmann	Identification temperature stress-induced changes in turbot serum by LC-Ms and LC-MSMS: a proof-of-concept study
11.3 Elham Kamyab	Effects of thermal stress on antioxidant and oxidative stress responses of juvenile *Holoturia scabra*
11.4 Stéphanie C. Michl	Vegetarian diets for obligate carnivores: plant meals for first feeding brown trout
11.5 Melanie Lindner	Performance of Mutag BioChip™ in recirculating aquaculture systems

POSTER PRESENTATIONS

11.6	**Aghil Dashtiannasab**	The efficiency of red seaweed *Lurencia synderidae* extract on growth performance, survival and disease resistance in white shrimp *Litopenaeus vannamei*
11.7	**Shahrouz B. Noveiri**	Growth performance of F2 bester (*Huso huso X Acipenser ruthenus*) with its F1 generation up to 60 days of age
11.8	**Shahrouz B. Noveiri**	Production of big bester (male bester X female beluga) in Iran
11.9	**Lukas Ritzenhofen**	Effects of diets containing green tea extract on Starry flounder

PROCEEDINGS

European land-based aquaculture: a review of the sector and prospects for the future

Introduction to important diseases for finfish species in responsible land-based aquaculture

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ABSTRACT

Land-based aquaculture production has increased rapidly during the past decade due to its high market demand and economic value. However, rapid expansion and intensification of land-based aquaculture has led to disease outbreaks. Disease is one of the most limiting factors in aquaculture. Intensification of land-based aquaculture favors pathogens, which increase disease outbreaks. Diseases are broadly classified into infectious and non-infectious diseases. Infectious diseases are further divided into four main groups based on the nature of the pathogen: viral, bacterial, parasitic or fungal. Non-infectious diseases are divided into neoplastic diseases, genetic and environmentally induced diseases and nutritional deficiency diseases. This speech provides detailed information regarding prevalent diseases of finfish species in land-based aquaculture. Also, responsibly land-based aquaculture, importance of outbreaks, economic loss and eco-epidemiological approach and new global control and prevention methods would be discussed in this lecture.

Identification temperature stress-induced changes in turbot serum by LC-Ms and LC-MSMS: a proof-of-concept study

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ABSTRACT

Aquaculture is the fastest growing aquatic food production sector. Due to this vast production, sustainable culture methods, healthy feed and monitoring of fish welfare are gaining more importance. As current assays to detect stress induced changes in fish like the stress hormone cortisol are biased, identification of stress specific biomarkers should give a possibility to detect and determine the source of the prevailing stress. The aim of this study was to establish a new approach for the identification of temperature stress induced changes in the serum proteome of turbot (*Scophthalmus maximus*).

Fish serum was collected from turbot at three different temperature conditions (0, 4, 16 °C) and pre-purified by gel filtration. In addition to standard analytics (protein, salt and water content) LC-MSMS (Liquid chromatography-mass spectrometry) was used subsequently to detect temperature stress depending changes in the serum proteome.

The protein content in the serum of culture candidates has increased by 9 % corresponding to decreasing temperature conditions while the water content of the samples did not change significantly. In addition LC-MS and LC-MSMS revealed several potential stress biomarkers and the regulation of the protein Wap65-2 were determined explicitly.

A reliable and reproducible purification strategy was established in combination with an LC-MSMS approach, which enables the investigation of the serum proteome of turbot in greater detail. Furthermore, potential biomarkers could be detected; hence the proteomic approach was successfully adapted to the detection of temperature stress in fish from aquaculture.

Effects of thermal stress on antioxidant and oxidative stress responses of juvenile Holothuria scabra (Jaeger, 1988)

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ABSTRACT

Tropical sea cucumbers are overfished for food and pharmaceutical purposes. Although important in sediment enrichment, they are endangered and research on their biology and aquaculture is urgently needed.

The aim of this study was to evaluate sub-organismal alterations and acclimation of juvenile *H. scabra* to temperature changes. For this purpose, antioxidant defenses and oxidative stress responses of 54 *H. scabra* (6-20 g) were analysed. Test specimens were exposed to temperature conditions of 21°C, 27.5 °C (control) and 34°C over a period of 30 days. At each 15 days interval, 6 samples per tank were sacrificed and muscle and respiratory trees of each organism were dissected. Antioxidant defense responses were assessed by measuring CAT, SOD, and GR activities and oxidative damage was assessed by measuring DNA strand breaks and LPO.

Results indicate that depending on cold or warm stress and target tissues, different antioxidant responses are observed. In general, throughout the time of the experiment, both in muscle and respiratory tree antioxidant enzyme activities had a tendency for lower activities in cold treatment, whereas in warm treatment CAT, SOD and GR activities were significantly increased with consequent decreases in LPO and DNA damage levels.

The results of this study show that juvenile *H. scabra* under low temperature stress tend to lower their metabolic rate, whereas in higher and apparently more stressful temperatures, they try to cope with the oxidative stress by increasing the activity of antioxidant enzymes. Furthermore, heeding to the changes in biochemical responses of *H. scabra* over the 30 days of experiment, the idea of chronic alterations rather than acute changes in the sea cucumber acclimation process is supported. It is concluded that assessing different oxidative stress enzymes and endpoints serve as good bioindicators for understanding possible effects of thermal stress in the aquaculture of juvenile *H. scabra*.

Vegetarian diets for obligate carnivores: plant meals for first feeding Brown trout

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ABSTRACT

This study has been conducted in order to evaluate the impact of different plant protein inclusion levels on carnivorous juvenile fish. Brown trout eggs have been hatched in a recirculating aquaculture system (RAS) and fed from first feeding on until fingerling size with three different types of diets: diet A, diet B and diet C. Diet A is completely based on fishmeal, Diet B is an equal mixture of plant and animal based protein sources, whereas diet C is almost completely composed of plant meals. Dry body masses of fish were measured several times during the feeding trial. Specific growth rates were comparable between groups. Average dry body masses of experimental groups A and B did not differ significantly at the end of the experiment, whereas both groups were significantly different from group C. Growth was further analysed in regards to digestive capabilities via evaluation of digestive enzyme activities. At several points in time during the experiment samples were taken and photometrically analysed in order to determine individual activities for amylase and pepsin. Average amylase activities 5 days prior to hatching were statistically equal to activities on hatching day. After hatching, amylase activities in yolk sac fry of Brown trout showed slightly alternating patterns until day 16 post hatch. With the event of first feeding on activity levels were increasing with time. The experimental diets showed no significant influence on amylase activities at any point in time. Pepsin activities have also been assessed. After first feeding pepsin levels were strongly increasing in fry and after the first 10 days of feeding, levels were more than 10 times higher compared to the yolk sac stage. The diets had only a small influence on activities, like a reduced average activity of group C.

Performance of Mutag BioChip™ in recirculating aquaculture systems

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ABSTRACT

An important part of water recirculation aquaculture systems is the removal of ammonia (NH_3) by using a nitrification filter. In MBBR (Moving Bed Biofilm Reactor) sessile microorganisms are located within and on filter media building a bacterial biofilm to oxidize ammonium (NH_4^+) to nitrate (NO_3^-) via nitrite (NO_2^-).

At the Centre for Aquaculture Researches (ZAF) at the AWI new media were tested to reduce the size of nitrification filters. With a specific area of 3,000 m^2/m^3 the Mutag BioChip™ is able to reach nitrification rates up to 0.24 kg NH_4^+-N/m^3 in fresh water which is in comparison to other tested media a high nitrification rate.

The object of this approach is to review the stated nitrification rate in fresh water and to determine the nitrification rate in marine aquaculture systems. Furthermore, a task of this study is to determine the ecological and economical performance of Mutag BioChip™.

Therefore, nitrification filters filled with Mutag BioChips™ are tested under aquaculture conditions in brackish water (15‰) and fresh water recirculation systems (n=3) stocked with Nile tilapia (*Oreochromis niloticus*). Twice a day the nutritive substances and water parameter (salinity, temperature, pH value and oxygen concentration) are recorded to control the systems and the functionality of the nitrification filters. Furthermore, the biofilm attached to the media of all systems is monitored under a binocular investigating the growth among the different trials. In addition, the bacterial densities of all systems are determined by the Most Probable Number Technique to draw conclusions from the nitrification rate.

The efficacy of a red seaweed Laurencia snyderiae extract on growth performance,survival and disease resistance in white shrimp Litopenaeus vannamei

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ABSTRACT

Shrimp aquaculture has expanded rapidly in many countries and this rapid development resulted disease outbreaks and a huge consumption of antibiotics. Use of natural products as antimicrobial has been reported as a resolution problem. The crude extract of a Red seaweed *Laurencia snyderiae* obtained from Persian Gulf was evaluated for shrimp growth performance and to determine in vivo efficacy of this seaweed to prevention of shrimp Vibriosis. The ethanol extract of *Laurencia snyderiae* (EELS) was not toxic to the Artemia instar I when it was fed to them for enrichment. Shrimp *Litopenaeus vannamei* Juvenile fed with these enriched Artemia at 0 mg ml^{-1} (Control group), 200 mg ml^{-1}, 400 mg ml^{-1} and 600 mg ml^{-1} for a 30 days period. Results showed an increase in survival rate in treatment groups compared with control group but was not significantly ($P<0.05$). Shrimps fed with enriched Artemia showed significant improvement in growth parameters when compared to control group. When these juvenile shrimps were challenged to *Vibrio harveyi* (after 30 days) have notably lower mortality than the control. These results indicated that EELS has a good potential in growth-promoting and antibacterial activity against *V. harveyi* that is useful in shrimp aquaculture.

Production of big bester (male bester × female beluga) in Iran

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ABSTRACT

Aquaculture of species for human consumption is being considered as the first substitution to save wild aquatic populations during last decade. Big bester (♀Huso huso × ♂bester) is one of the highly appreciated hybrids among sturgeon hybrids for aquaculture. There is no published data on comparison between growth rates of this fish with its previous (bester) generation. In this study 500 g eggs from a 54 kg female beluga was fertilized by spermatozoa of two male besters (7.3 ± 1.7 kg body weight, with sperm density of $2.47 \pm 1.2 \times 10^9$/ml). Big bester fingerlings were fed by *Artemia* and *Daphnia* and by reaching to about 1 g of weight gradually adapted to concentrated diet (40-50% protein, 15-17% fat, 18-20 MJ / kg). Total length and weight of produces fish were monitored up to 2 months.

Data showed that at 30 days of age, there are significant differences between length and weight of big bester in comparison to a bester generation which has been produced in an earlier study and they grow slower than the bester generation. Meanwhile data after 60 days of rearing showed that there are no significant differences between both length and weight of big bester generation in comparison with bester generation.

Growth comparison of F2 bester (♀Huso huso × ♂Acipenser ruthenus) with its F1 generation up to 60 days of age

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ABSTRACT

Most sturgeon species are close to extinction due to population overexploitation for meat and caviar. Bester is one of the promising hybrids in Acipenseridae to be produced for its meat and caviar. Its caviar is able to tolerate freshwater, grows faster than beluga and get matured in a shorter period of time. In this study we produced a F2 generation of bester with its past generation (F1) and make a comparison between two generations at their weight and length at 30 and 60 days of age.

Spermatozoa ($2.47 \pm 1.2 \times 10^9$/ml) and eggs (85 numbers per g) were obtained from matured F1 bester population. The F2 generation of bester was fed by *Artemia* and *Daphnia* and by reaching to about 1 g of weight gradually adapted to concentrated diet. Total length and weight of produced fish were monitored up to 2 months.

Data showed that at 30 days of age, total length (2.5 ± 0.3 cm) and weight (158 ± 64 mg) of F2 bester are significantly lowered in comparison to F1 generation (9.5 ± 1.1 cm and 490 ± 10 mg respectively). Meanwhile data showed that after 60 days of rearing both length and weight of F2 (10.7 ± 2.2 cm and 5.14 ± 1g respectively) are significantly greater than F1 (9.72 ± 0.8 cm and 4.22 ± 0.86 g respectively) generation.

Effects of diets containing green tea extract on Starry flounder

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ABSTRACT

The rapidly growing aquaculture industry has led to intensive culture systems and rearing methods. Due to evolving problems in intensive rearing conditions, transfers, and management diseases and pathogens outbreaks are facilitated and have become together with antibiotic resistance a major issue affecting industry and potentially the consumer. This development gave rise to the use of prebiotics and probiotics. Animal studies already showed that polyphenols in green tea are potent antioxidants, which can affect health in positive ways. Further feasibility studies are recommended.

Since preventing fish disease as well as achieving high growth rates are top priority, the focus on this approach was to investigate the immunomodulatory effects and the growth performance of fish fed with diets containing green tea extract.

The experiment was set as a feeding trial of 8 weeks in total, control measurements every two weeks. Starry flounder (*Paralichthys stellatus*; Pallas 1788) as a potential new candidate for commercial Asian aquaculture was used to determine the effect of green tea extract as feed additive. 240 starry flounders held in a closed aquarium system (RAS) were divided into three groups of 20 each with four replications. They were fed *ad libitum* with a control diet and diet supplemented with 0.5% and 1% green tea extract. To investigate immunomodulatory effects plasma lysozyme activity was determined by a turbid metric assay.

Results clearly show fish fed a green tea supplement had the significant lowest growth performance (WG, SGR, FCR, DFI) compared to fish fed control diet. In addition, no significant changes in lysozyme activity could be detected. To determine the cause of limited growth of diets supplemented with green tea, it has to be revealed, if green tea extract contains ingredients that starry flounder either dislike or influence digestion to a certain extent where fish cannot anymore properly process the feed.

European land-based aquaculture: a review of the sector and prospects for the future

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Aquaculture now accounts for more than 50% of the world's aquatic production output and the sector is forecasted to keep steady growth well into 2020. Environmentally-friendly aquaculture development is a strategic goal for Europe, and research efforts are constantly finding ways to reduce environmental impact and maximize the use of resources. Fish farming operations on land can help to ensure control over the farming environment, isolation of farming stocks from wild populations and provide opportunities for rural development. This paper will offer an analysis of the current state of the land-based aquaculture sector, focusing on current developments in Europe.

Introduction

Need for aquaculture

The current world population of 7.3 billion is expected to reach 8.5 billion by 2030 and 9.7 billion in 2050, according to a new UN report (United Nations, 2015). In 35 years from now the Food and Agriculture Organization of the United Nations (FAO) is expecting that approximately 70 % more food resources will be needed, in order to avoid millions of people suffering from hunger (Costa-Pierce, 2010).

Proteins, especially of animal origin play a key role in human nutrition. Fish have the highest protein content within their meat in comparison to other animals (Smil 2000, 2002). This is due to the fact that aquatic organisms are extremely effective when converting their food into biomass. In addition they are cold-blooded animals that do not spend energy on keeping their body temperature constant. They also consume less energy for maintaining their posture (Cowey, Mackie, & Bell, 1985). A portion of 150 g of fish can provide about 50–60 % of an adult's daily protein requirements. Especially in developing regions and low-income food-deficient countries fish has already become an important source for the populations protein supply (FAO, 2014).

The increasing demand for aquatic products worldwide, coupled to a chronic stagnation of the world's capture fisheries, leaves aquaculture as the only way to ensure future supply. In their current report about the State of World Fisheries and Aquaculture (SOFIA) FAO predicts an increase of 67 % in global seafood demand until 2030. This represents an increase of the current per capita consumption from just under 20.0 kg to 29.1 kg. Both, aquaculture and capture fisheries together must grow by 104.7 million tonnes in order to satisfy this demand. According to FAO's estimates global fisheries production will only grow by a maximum of 10 - 20 million tonnes. This will leaves a supply gap of 84.7-94.7 million tons in the next decade that can only be closed by aquaculture.

State of world aquaculture

Aquaculture is the fastest growing food production sector in the world. In 2012, aquaculture was supplying around 40 % of the global demand for aquatic products. Excluding aquatic plants this accounts for 66.6 million tonnes of global aquaculture production worth approx. 124.4 billion Euro, another all-time high (FAO, 2014). At its present growth rate, it can be assumed that its share of the total aquatic production will reach 65 % by 2030 (APROMAR, 2014). About 18.9 million people were engaged in fish farming world-wide in 2012 - a plus of 3.8 million people in comparison with 2005. More than 96 %of these were located in Asia (FAO, 2014). A fact that shows how imbalanced aquaculture development and the distribution of its production is geographically. In 2012, 88.0 % of the volume of the world's aquaculture production was provided by Asia. China is by far the world's largest producer with a share of 61.7 % in 2012. India, the second ranked country, only reached a tenth of that production volume (6.3 %) (FAO, 2014). The European Union (EU), comprised of 28 countries, contributed with 1,259,971 t or 1.89 % to the global aquaculture production.

World food fish production (i.e. finfishes, crustaceans, molluscs and other aquatic animals) from aquaculture and fisheries together totalled at 91.3 million tonnes in 2012 (FAO, 2014). 136.2 million tonnes were declared for human consumption.

State of European aquaculture

The EU is the biggest seafood market in the world with a total value of 52.3 billion Euro in 2012. Aquaculture forms a relevant source of aquatic products. Its relative importance for the EU market has increased over the years due to a shrinking fisheries industry. Nevertheless, since 1990 the EU only managed to increase its production capacity by roughly 250,000 tonnes within 22 years. With 2.9 % the European continent in its entirety (e.g. even including Norway) had the lowest average annual growth rate compared to the other continents in the period 2000–2012 (FAO, 2014). In 2012 103,000 people were engaged in fish farming activities in Europe (FAO, 2014). The self-sufficiency in seafood supply accounts for only 45 % in the EU (EUMOFA, 2014). To lower this dependency the European Commission (EC) intends to boost aquaculture through the Common Fisheries Policy reform, development funds such as the European Maritime and Fisheries Fund (EMFF) and research programmes. The EMFF has a budget of 6.4 billion Euro of which 4.3 billion Euro are dedicated to making fisheries and aquaculture more sustainable and profitable (European Commission, 2015). In the last EU research framework programme FP7 more than 103 million Euro, i.e. approx. 0.19 % of total FP7 budget, was awarded to aquaculture research and innovation (Zampoukas & Iglesias, 2014). Within the current research framework programme Horizon 2020 (2014 to 2020) funding is available under societal challenge number two "Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy". The budget for this challenge, 3851 million Euro, more than double compared to FP7. Already in the first round of funding (2014 to 2015) 53 million Euro were assigned to aquaculture related calls under the topics of Sustainable Food Security and Blue Growth (Zampoukas & Iglesias, 2014).

Aquaculture was also named as one of the five main pillars of the EC's Blue Growth Agenda.

Blue Growth is the long term strategy to support sustainable growth in the marine and maritime sectors as a whole. It is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth (European Commission, 2014). In 2013, on this basis, all EU member states had to elaborate national strategic plans for aquaculture development in order to promote growth (European Commission, 2015).

Land-based aquaculture methods

European aquaculture is not a uniform sector, there are various types of aquatic farming. As long as basic biological, physico-chemical and engineering principles are respected, there are virtually no limitations on the design of farming methods. In broad terms, aquaculture production systems can be classified according to the degree of control over the farming environment and according to the amount of animals that can be reared per unit area (in the case of crustaceans and flat fish) or unit volume (in the case of pelagic fish):

- Extensive systems: where the animals are reared with little or no human input, meaning that the biomass is sustained by the pond's ecosystem. Classic examples of extensive ponds are found in Central and Eastern Europe, where carp farming is dominant
- Semi-extensive systems: where formulated feeds are supplied to the animals in addition to naturally-produced food, as the biomass in the system cannot be sustained by the ecosystem alone
- Semi-intensive systems: where animals are reared entirely on formulated feeds and higher levels of environmental control. Trout farming in aerated ponds is a good example of this type of production system
- Intensive and super intensive systems: where animals are reared at high stocking densities with continuous addition of feed and high levels of environmental control Flow-throw systems, partial reuse systems and recirculating aquaculture systems (RAS) are clear examples. Several types of intensive system can be found around Europe:
    - Marine hatcheries employing RAS technology and highly controlled production of live feeds
    - Salmonid hatcheries employing RAS for year-round production of fingerlings
    - Flow-through trout farms
    - Most of the flatfish (turbot, sole) production is undertaken in flow-through systems close to the shore or in RAS
    - In the Netherlands 100% of the finfish production is done in RAS
    - In Denmark the trout industry has been increasingly converting from semi-intensive ponds to RAS, under the concept of the Model Trout Farm
    - In Germany RAS using waste heat from e.g. bio gas plants are being used for the production of pikeperch, African catfish and whiteleg shrimp
    - Aquaponics: coupled hydroponic (plants growing directly in water, without soil) aquaculture systems

Analysis on land-based aquaculture

Materials and Methods

The performance of the EU land-based sector was assessed by determining its share on the total EU per capita seafood consumption (as a percentage) and by determining its degree of self-sufficiency ratio, according to the methodology proposed by EUMOFA (2014). For this work, land-based aquaculture production is defined as all of the aquaculture production undertaken for the top three finfish species that are mostly reared in land-based farms. These species are common carp, rainbow trout and turbot. Other species such as European catfish, Claresse, African catfish, pike perch, sturgeon, Tilapia and Eurasian perch are not included in the analysis as their production volumes are negligible in comparison. Mediterranean species that are mainly reared at sea, but that may be produced on land in some instances, are not included in the analysis either for the same reason. Land- based production data for EU countries (including the UK) were extracted from Eurostat (Eurostat, 2015) and the reports from the Federation of European Aquaculture Producers (FEAP, 2015). Production data is specific for every country and for every species. Trade flow data (exports and imports), the EU per-capita consumption for seafood (fisheries + aquaculture) as well as for aquaculture for the years 2011-2012 were extracted from the database of the EU Market Observatory for Fisheries and Aquaculture products (EUMOFA, 2014). The dataset from 2012 for the 2008-2015 period was used for this analysis as it showed to be the most complete.

Country- and species-specific apparent consumption was calculated as:
aquaculture production + imports - exports.

The total EU production values for each species were added up as well as the value for total overall EU production.

Total EU consumption of land-based aquaculture products was the result of the sum of the entire apparent consumption data for every species and country.

The share of consumption of land-based aquaculture products on the total EU per-capita seafood (fisheries + aquaculture) was calculated as follows: *(land-based consumption*100) / EU per-capita seafood consumption.*

For the share of consumption of land-based aquaculture products on the total EU aquaculture consumption the following formula was used: *(EU land-based consumption*100) / per capita EU aquaculture consumption.*

Finally, the self-sufficiency for land-based aquaculture (%) was calculated as: *Total land-based aquaculture production / total land-based consumption.*

Results

Table 1 shows the compilation of export, import, production and consumption data for rainbow trout, carp and turbot in the EU for 2012.

According to EUFOMA (2014), the total EU seafood consumption for 2012 was 12.32 million tonnes, with 2.9 million tonnes coming from aquaculture alone. This results in an EU wide per capita consumption of 24.53 kg for seafood and 5.79 kg for aquaculture products. Within this scenario, land-based aquaculture in the EU supplies 9.27 % of the EU's demand for aquaculture products and 2.18 % of the demand of total aquatic products (fisheries and aquaculture). On a per-capita basis, 2.27 kg of the average European's seafood consumption per year are coming from land-based farms within the EU. Finally, by comparing the total EU land-based production and the total EU land-based consumption, it can be observed that the land-based sector is largely self-sufficient, i.e. 99.40 % of all rainbow trout, carp and turbot that are consumed within the EU are being produced within the EU.

Table 1: Compilation of export, import, production and consumption data for rainbow trout, carp and turbot in the EU for 2012. Blank cells correspond to non-existent production records. Negative values are shown in cases where the reported export volumes are larger than the reported import volumes. Such occurrences must be due to incomplete data reporting, as volume trade flows by definition cannot be negative. Data sources: [a] (EUMOFA, 2014); [b] (Eurostat, 2015) or (FEAP, 2015) where data from Eurostat was missing; were no data source is given values were calculated.

COUNTRY	FLOW TYPE	Rainbow trout	Carp	Turbot	Totals (calculated)
Austria	Export [a]	3.627.600	39.300	900	3.667.800
	Import [a]	8.175.800	795.800	70.900	9.042.500
	Production [b]		590.000		590.000
	Consumption	**4.548.200**	**1.346.500**	**71.800**	**5.966.500**
Belgium	Export [a]	583.100	143.400	125.800	852.300
	Import [a]	2.354.700	217.200	237.200	2.809.100
	Production [b]				
	Consumption	**1.771.600**	**73.800**	**363.000**	**2.208.400**
Bulgaria	Export [a]	692.000	21.700	4.500	718.200
	Import [a]	1.239.000	1.584.000	7.800	2.830.800
	Production [b]	2.651.000	1.313.600		3.964.600
	Consumption	**3.198.000**	**2.875.900**	**12.300**	**6.086.200**
Cyprus	Import [a]	120.500	43.400		163.900
	Production [b]	55.000,00			55.000
	Consumption	**175.500**	**43.400**		**218.900**
Czech Republic	Export [a]	309.800	8.171.300	0,00	8.481.100
	Import [a]	1.642.400	460.500	3.600	2.106.500
	Production [b]	380.000	17.972.000		18.352.000
	Consumption	**1.712.600**	**10.261.200**	**3.600**	**11.977.400**
Denmark	Export [a]	25.808.300	96.100	0,00	25.904.400
	Import [a]	1.829.000	68.500	39.400	1.936.900
	Production [b]	31.462.000		2.000	31.464.000
	Consumption	**7.482.700**	**-27.600**	**41.400**	**7.496.500**
Estonia	Export [a]	2.368.700	2.400		2.371.100
	Import [a]	6.481.900	4.600	100	6.486.600
	Production [b]	245.000	38.000		283.000
	Consumption	**4.358.200**	**40.200**	**100**	**4.398.500**
Finland	Export [a]	2.868.700	0,00	300	2.869.000
	Import [a]	10.196.200	39.700	2.100	10.238.000
	Production [b]	11.275.000			11.275.000
	Consumption	**18.602.500**	**39.700**	**2.400**	**18.644.600**
France	Export [a]	5.154.100	296.100	527.600	5.977.800
	Import [a]	2.927.300	632.500	1.600.800	5.160.600
	Production [b]	30.627.000	4.200.000		34.827.000
	Consumption	**28.400.200**	**4.536.400**	**2.128.400**	**35.065.000**
Germany	Export [a]	2.077.400	148.000	278.800	2.504.200
	Import [a]	22.462.900	3.313.600	647.000	26.423.500
	Production [b]	19.996.000	9.634.000		29.630.000
	Consumption	**40.381.500**	**12.799.600**	**925.800**	**54.106.900**
Greece	Export [a]	1.034.700	11.000	47.700	1.093.400
	Import [a]	69.300	177.600	200	247.100
	Production [b]	1.970.000	42.000		2.012.000
	Consumption	**1.004.600**	**208.600**	**47.900**	**1.261.100**

Hungary	Export a	10.600	900.900	1.900	913.400
	Import a	218.800	351.800	3.500	574.100
	Production b	45.000	9.985.000		10.030.000
	Consumption	**253.200**	**9.435.900**	**5.400**	**9.694.500**
Ireland	Export a	857.100	79.700	56.900	993.700
	Import a	870.000	101.000	227.900	1.198.900
	Production b	781.000			781.000
	Consumption	**793.900**	**21.300**	**284.800**	**1.100.000**
Italy	Export a	8.175.500	118.200	208.000	8.501.700
	Import a	1.814.200	1.362.900	2.027.800	5.204.900
	Production b	34.366.000	151.000		34.517.000
	Consumption	**9.989.700**	**1.395.700**	**2.235.800**	**13.621.200**
Latvia	Export a	1.440.800	75.000	7.900	1.523.700
	Import a	2.196.000	150.600	3.600	2.350.200
	Production b	3.000	475.000		478.000
	Consumption	**758.200**	**550.600**	**11.500**	**1.320.300**
Lithuania	Export a	**738.000**	**1.188.600**		**1.926.600**
	Import a	1.571.300	92.400	2.600	1.666.300
	Production b	115.000	3.259.000		3.374.000
	Consumption	**948.300**	**2.162.800**	**2.600**	**3.113.700**
Malta	Export a		15.200		15.200
	Import a	15.100	1.100		16.200
	Production b				0
	Consumption	**15.100**	**-14.100**		**1.000**
Netherlands	Export a	875.200	176.000	2.376.300	3.427.500
	Import a	1.795.300	125.300	704.000	2.624.600
	Production b				0,00
	Consumption	**920.100**	**-50.700**	**3.080.300**	**3.949.700**
Poland	Export a	4.376.100	1.877.000	25.900	6.279.000
	Import a	7.776.700	4.052.900	6.200	11.835.800
	Production b	10.724.000	18.317.000		29.041.000
	Consumption	**14.124.600**	**20.492.900**	**32.100**	**34.649.600**
Portugal	Export a	286.800	1.100	4.319.700	4.607.600
	Import a	275.000	18.000	173.000	466.000
	Production b	479.000		4.406.000	4.885.000
	Consumption	**467.200**	**16.900**	**259.300**	**743.400**
Romania	Export a	2.000	100	8.300	10.400
	Import a	2.331.600	797.100	28.000	3.156.700
	Production b	1.074.000	355.000		
	Consumption	**3.403.600**	**1.152.000**	**36.300**	**3.794.900**
Slovakia	Export a	37.200	100		1.189.200
	Import a	314.600	797.100		1.111.700
	Production b	763.000	355.000		1.118.000
	Consumption	**1.040.400**	**1.152.000**		**2.192.400**
Slovenia	Export a	8.100	11.200	2.600	21.900
	Import a	410.300	69.500	25.100	504.900
	Production b	557.000	137.000		694.000
	Consumption	**959.200**	**195.300**	**27.700**	**1.182.200**
Spain	Export a	7.173.100	1.337.200	5.465.10	13.975.400
	Import a	5.355.900	1.409.400	5.322.600	12.087.900

	Production [b]	16.302.000		7.758.000	24.060.000
	Consumption	**14.484.800**	**72.200**	**7.615.500**	**22.172.500**
Sweden	Export [a]	8.478.500	1.900	70.700	13.945.500
	Import [a]	4.515.300	59.900	223.300	9.897.800
	Production [b]	10.499.000			18.257.000
	Consumption	**6.535.800**	**58.000**	**294.000**	**14.209.300**
United Kingdom	Export [a]	1.164.400	361.200	264.500	1.790.100
	Import [a]	777.800	2.641.800	141.500	3.561.100
	Production [b]	14.591.000	259.000		14.850.000
	Consumption	**14.204.400**	**2.539.600**	**406.000**	**17.150.000**
Total EU land-based consumption [kg]		**180.534.100**	**71.378.100**	**17.888.000**	**269.800.200**
Total EU land-based production [kg]		188.960.000	67.082.600	12.166.000	268.208.600
Self-sufficiency of EU land-based aquaculture (trout, carp and turbot combined) [%]					99,40
Total EU aquaculture and fisheries consumption [a] [kg]					12.325.855.000
Total EU aquaculture-only consumption [a] [kg]					2.909.756.000
Total aquaculture and fisheries consumption in the EU per capita [a] [kg]					24,53
Aquaculture-only consumption in the EU per capita [kg]					5,79
Per capita land-based consumption of EU's three main species combined (trout, carp, turbot) [kg]					2,27
EU's land-based aquaculture share on total EU aquaculture and fisheries consumption [%]					2,18
EU's land-based aquaculture share on total EU aquaculture consumption [%]					9,27

Discussion

Traditional pond rearing methods have been part of the European culture for centuries starting as early as 2000 years ago for carp (FAO, 1988). Modern techniques, such as intensive pond systems, intensive flow-through systems etc. were developed within the last century. Traditional techniques, despite requiring significant amounts of space and water, have been suitable for rural areas. This suitability, coupled with the development of modern hatchery techniques, have contributed to the growth of the trout (188.960 tonnes EU-wide production in 2012) and carp (67.083 tonnes EU-wide production in 2012) sectors in Europe today.

The history of turbot as a relevant species is more recent, starting in the early 90's, shortly after the development classic marine hatchery protocols used today. Turbot was initially selected for aquaculture due to its commercial value and its high-potential growth rate (Person-Le Ruyet, 2010). It is mostly grown in onshore facilities which continuously pump water from the sea. In some cases even RAS are used, with some experiences done in cages (Person-Le Ruyet, 2010). The first production records start in 1994 (APROMAR, 2014). Since then, development has been rapid and production peaked in the EU at 12.166 tonnes in 2012. Together with a steady EU fisheries production, which represented 33 % of the total European production of the species in 2012 (APROMAR, 2014), the relatively small EU-market for turbot has achieved self-sufficiency. This is underlined by the fact that prices for turbot have been decreasing over the years on the face of increased EU production and no imports from producers outside the EU (EUMOFA, 2014).

Around 25% of all fish (including crustaceans, shellfish etc.) products consumed in the EU come from aquaculture (i.e. EU aquaculture production plus imports of aquaculture products) according to a 2012 background paper of the European Commission (European

Commission, 2012). Nevertheless, the land-based sector's share of total aquaculture output in the EU is rather small. With a total production volume of 268.209 tonnes it contributes only 2 % to the entire seafood consumption. This is despite the fact that the EU is almost entirely (99 %) self-sufficient when it comes to the three main species for land-based production. A look at total seafood consumption in the EU reveals that it is only 45 % self-sufficient, partly covered by fisheries production. The trade flow deficit in the EU for seafood, which amounts to 15 billion Euro, is largely due to imports of tunids (a fisheries product), salmonids (mostly Atlantic salmon from Norway), crustaceans (mostly shrimp from the tropics and lobsters from the North Atlantic) and groundfish (pollock and cod from fisheries in the North Atlantic) (EUMOFA, 2014).

The whole of the EU aquaculture sector experiences chronic stagnation since achieving a production peak in 1999, whilst the demand for aquatic products has increased (APROMAR, 2014). Increasing regional aquaculture production will ensure more access to fresh, high quality seafood products to the European citizens, generate employment and boost economic growth. However, in order to achieve growth, the sector must solve four main constricting issues: 1) excessive regulatory hurdles, which detract investments into aquaculture activity, 2) increasing competitiveness so as to gain more market acceptance against import products, 3) improving access to space and water and 4) exploiting the competitive advantages due to high quality, health and environmental standards in order to justify higher prices against non-European competitors (European Commission, 2015).

To some extent, land-based aquaculture is not limited by current regulatory frameworks, environmental problems and land-use conflicts more commonly related to open sea farming systems. In turn, land-based aquaculture ventures might require additional capital for land development, infrastructure, water transport networks and waste treatment solutions. In addition, red tape, especially for small and micro-enterprises, can create significant obstacles without contributing to achieving a substantial and beneficial policy goal.

The competitiveness of the land-based aquaculture sector relies on its capacity to offer quality and affordable products that are also widely accepted by the consumers. In the EU, land-based aquaculture has the advantage of short supply chains from source to customer thus providing highly fresh products. However, consumers are often unaware of this. Some prejudices remain both in relation to farmed fish and to aquaculture industry in general due to a lack of knowledge and the novelty of some techniques. The sector is occasionally associated with threats such as pollution, excessive use of antibiotics/chemicals, cheap industrial mass production and habitat destruction while the quality of wild fish is perceived as healthy, fresh, familiar, trustworthy (Lofstedt & Schlag, 2010). In order to increase the popularity of farmed products tradition (e.g. whole, fresh seabream in the Mediterranean), strong marketing and promotion (e.g. Atlantic salmon in filleted, frozen and smoke forms), low prices (e.g. Pangasius fillets from Vietnam) or a combination of these factors play a crucial role.

Conclusion

The analysis in this paper leads to a number of conclusions:

Official fisheries and aquaculture statistics can be used as rapid tool to assess the levels of self-sufficiency on certain aquaculture commodities. From these statistics, the size of a market for a particular species or product can be determined.

The supply of the three species mainly produced on land largely matches their demand. Only in the case of turbot, that demand is partially fulfilled by fisheries production.

Self-sufficiency in the case of EU fisheries and aquaculture production can be used as a predictor of market saturation. This can be used by newcomers to the sector to assess the feasibility of their business, if common aquaculture species are to be produced.

A number of factors point at increasing future opportunities for land-based production to develop further. The seafood industry will face a big gap in supply in the next decades that can only be filled by aquaculture production. The EU included aquaculture into its strategic growth plan and appointed substantial research and non-research funds to it. Unlike sea-based production land-based enterprises are not in competition for space with other industries and suffer less from regulatory issues. However, competition against import products and improved marketing will be necessary for aquaculture on land in order to tap its full potential.

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14 | Aquatic Plastic Pollution

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ABSTRACT

Plastic debris and its degradation products (microplastics) are known to accumulate in marine and freshwater ecosystems worldwide, and have been recognized as an emerging problem. Their persistence, ubiquity and high potential to cause physical harm and toxicological effect in biota has been highlighted in a large amount of studies. Plastics further facilitate transport of invasive species and pathogens, and have been identified as a cause for a series of ecological, economic and societal issues. However, knowledge is still limited, potential effects insufficiently studied, proper analytical methods missing and applied research for feasible solutions is needed as scientific insight into aquatic plastic pollution is becoming increasingly important.

We therefore invite young researchers and early career scientists to present their work on aquatic plastic pollution, its physical and eco-toxicological effects on marine organisms. We especially encourage researchers working on solutions to the problem as well as those working on improving analytical methods for identifying and quantifying microplastics.

ORAL PRESENTATIONS

14.1	**Maike S. Ladehoff**	Microplastic Quantification in Marine Samples using µ-Fourier Transform Infrared Spectroscopy
14.2	**Lisa-Henrike Hentschel**	Pollution of marine ecosystems by plastic debris – Can science help to manage the problem?
14.3	**Sarah Piehl**	Applicability of Remote Sensing Methods for Monitoring Floating Microplastic
14.4	**Magnus S. Nerheim**	Microbial degradation? Diversity of plastic-associated marine biofilms

POSTER PRESENTATIONS

14.5	**Lena C. Heel**	Effects of microplastics on the tropical benthic invertebrate *Isognomon radiatus*
14.6	**Lena C. Heel & Sinja Rist**	Microplastics in coastal sediments – A comparison across seven locations worldwide using a global approach
14.7	**Andrea Stolte**	Microplastic concentrations along the German Baltic Coast

PROCEEDINGS

Aquatic Plastic Pollution

Microplastic Quantification in Marine Samples using µ-Fourier Transform Infrared Spectroscopy

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ABSTRACT

Over the past years, increased scientific interest has revealed the widespread presence of microplastics (< 5 mm) in marine environments. Yet, little is known about real *in-situ* concentrations, abundance of plastic types or spatial patterns. Major concerns about microplastic contaminants include accumulation in natural habitats and physical impact on marine wildlife. Only recently microplastic particles were recognized as serious contaminants and included in international marine protection frameworks as an indicator of current environmental status. Up to today, there are no standardized, reproducible procedures to quantify microplastic contaminants – especially for particles < 500 µm. Visual sorting is a commonly applied method, but is prone to error due to its reliance on the visual characterization. Focal plane array (FPA)-based µ-Fourier-Transform Infrared (FTIR) spectroscopy, which was used in the present study, represents the most promising method for reliably identifying microplastics in marine environmental samples but the analysis depends on methods to separate the microplastics from the biological material. A density separation with zinc chloride and an enzymatic purification method to isolate microplastics from marine water samples was applied and its efficiency validated. A reduction efficiency rate of 98.3 % could be demonstrated and has proven the suitability of this method in order to prepare the samples for the FPA-based µ-FTIR analysis. Furthermore, sea surface samples of the Southern North Sea were investigated. Eight microplastic types were identified and total concentrations varied from 0.041 to 3.731 particles/m^3. The most abundant types (87.6 % of all detected microplastics) were polystyrene, polyethylene and polyamide. The most frequent sizes accounting for 89.2 % were in the range of ≤ 150 µm and 2.5 % were > 300 µm. Polyethylene, polystyrene and acrylnitrile butadiene styrene were the types most widely distributed and have been found leastwise at six stations.

Pollution of marine ecosystems by plastic debris – Can science help to manage the problem?

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ABSTRACT

Assessing the potential impacts of microplastics on marine ecosystems is a pressing but complex task, since the effects may not only vary with polymer type and particle size but also with the species, communities and habitats affected. We want to summarize how marine biological sciences dealt with this topic in the past 10 years and to which extent the information that were collected by scientists, entered the agendas of governmental and non-governmental organizations as well as environmental guidelines and management strategies. Furthermore, the role of science and the scientific system will be reflected in order to indicate barriers and opportunities of science to contribute to marine litter reduction. Science is and has been contributing to knowledge awareness and problem understanding (basic research) and is now more and more challenged by questions on how to manage the ongoing problem of pollution by plastics in a good way as well as to find alternatives (applied research).

Moreover, knowledge gaps and only unreliable data exist regarding the amount of plastic entering the aquatic system as well as that the timescales of degradation still remain under debate. However, despite the preponderance of evidence these uncertainties should not hinder any action to reduce potential threats of marine debris (precautionary approach).

On the one side we want to draw from our scientific experience, but give an emphasize on what role different stakeholders (Science, Politics, Public, Industries, etc.) play in the debate and action about plastic management. A focus lies on the scientific perspective and examples will be chosen to illustrate the contribution of scientists to mitigate plastic pollution and to highlight the need of interdisciplinary, holistic and responsible science.

Applicability of Remote Sensing Methods for Monitoring Floating Microplastic

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ABSTRACT

Recently, there have been intensified research efforts to get reliable information about sources, sinks, and transportation pathways of plastic debris in aquatic environments. But due to the high spatiotemporal variability of these systems, our knowledge is still limited. Earth remote sensing is a key technology within the field of environmental monitoring having provided a unique tool for large area observations. The project "Contamination of aquatic ecosystems with plastic debris: Global and local monitoring using remote sensing methods" aims to assess the potential of remote sensing technologies as monitoring tool for macro- and microplastic debris.

As floating microplastic is probably influenced by the same driving mechanism as non-motile plankton or particulate matter, a spatial relationship between microplastic and specific water parameters is assumed. In-situ water parameters (Chl-*a*, cDOM, suspended particulate matter), microplastic, and in-situ derived spectral measurements (ASD FieldSpec) were taken during a first field campaign along the river Trave in Germany in 2014. Water samples for microplastic were taken with a manta-trawl. Organic material was removed by enzymatic digestion and remaining microplastic was analyzed with the hyperspectral imaging spectrometer HySpex SWIR-320m-e (down to a size of 250 µm). To test our hypothesis, correlation analysis will be conducted to analyze the relationship between in-situ microplastic concentrations and in-situ measured water parameters. In a next step the potential of remote sensing sensors will be assessed through correlation analysis of in-situ microplastic measurements and in-situ spectral measurements. First results will be presented at the conference.

If a spatial relationship between water parameters and microplastic exists, remotely sensed water parameters could be used as proxy for floating microplastic abundances. Thus, monitoring through remote sensing could be an innovative method to collect more comprehensive spatial and temporal data, contributing to better knowledge about sources, sinks, and distribution patterns of floating plastic debris in aquatic environments.

Microbial degradation? Diversity of plastic-associated marine biofilms

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ABSTRACT

Plastic-associated microorganisms likely mediate the fate of plastic pollution in the marine environment, and are expected to impact several key processes including degradation, buoyancy, chemical adsorption and colonization or ingestion by larger organisms.

The relative bacterial abundances on eight different plastic polymers, exposed for 6 weeks in a marine environment, were determined using molecular techniques. The beta-diversity of the associated marine biofilms was investigated and related to several factors, including depth, polymer type and properties, and pollutant load.

Differences were found between bacterial communities which localized on plastic deployed on the surface and seafloor. No significant difference was observed between the communities occupying different plastic types or glass at the same depth, nor were there any differences due to the properties of each plastic. Pollutant loads were higher in plastic samples deployed on the seafloor but this did not explain the community structure on different plastic types.

Surface deployed samples contained a large variety of macro scale taxa, ranging from algae to cnidarians. SEM micrographs showed no indication of physical microbial-plastic interactions.

Overall, these results clearly show the presence of diverse biofilm communities on plastic pollution in a marine environment. Their interaction with the substrate and its associated chemicals will prove important in understanding the future of marine plastic pollution.

Effects of microplastics on the tropical benthic invertebrate Isognomon radiatus

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ABSTRACT

Microplastics (< 5 mm), which also accumulate waterborne organic pollutants, can be taken up by a wide range of benthic invertebrates what possibly impairs their performance. Although the consequences could be far reaching, there are so far only few studies that investigated the mechanical and/or chemical effects of microplastic ingestion. Furthermore, their ecological significance is limited due to the use of exaggerated microplastics' and/or contaminant concentrations and short exposure periods of hours to days. Our study aimed at investigating the potential effects of PVC microplastics (160 µm) applied in various concentrations (34.6, 346, 3464 and 0 mg/l) on Lister's tree oyster *Isognomon radiatus* under laboratory conditions over the course of 8 weeks. To account for the effects of a possible contamination by organic pollutants, particles were partly coated with fluoranthene. This resulted in a fully crossed experimental design with two factors: 'Particle Concentration' with 4 levels and 'Contamination' with 2 levels (i.e. yes/no). Survival, food consumption as well as filtration and respiration rates were assessed throughout the exposure period. In addition to this, the tolerance of *I. radiatus* to hypoxic conditions was assessed afterwards. Mortality among individuals of *I. radiatus* during exposure to microplastics was significantly higher in the presence of fluoranthene, while no further effects of the microplastic particles or of the contaminant emerged. In summary, *I. radiatus* seems to be robust towards pollution by non-contaminated microplastic particles at least at the time scale of weeks, while the presence of fluoranthene on the particles impaired its performance. This hints at the relevance of microplastics as a vector that can increase the bioavailability of organic pollutants.

Microplastics in coastal sediments – A comparison across seven locations worldwide using a global approach

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ABSTRACT

In the frame of the international research and student training program GAME (Global Approach by Modular Experiments) we assessed the abundance of microplastic particles in coastal sediments (driftline and shallow subtidal) at locations in the Southwestern Atlantic (Brazil), Southeastern Pacific (Chile), Indopacific (Indonesia), Northwestern Pacific (Japan), Caribbean (Mexico) and Northeastern Atlantic (Portugal, Wales). For this, we identified the number of particles in a size range of 0.5-5 mm in sediment samples which were taken with corers (10x10 cm). Corer samples were subsequently divided into two layers, i.e. 0-5 cm and 5-10 cm. Microplastics were separated from the mineral fraction by mixing the sediment with a hypersaline solution (360 NaCl g/l) and the supernatant was subsequently filtered using glass microfibre filters under vacuum filtration. The number of particles as well as their shape was then recorded visually with a stereo microscope. Microplastics were found at all locations, but their number differed largely between sea areas, ranging from 2.4 particles/kg dry sediment in Indonesia to a maximum of 60 particles/kg in Mexico. At most sites plastics were more abundant in the deeper sediment layer, possibly due to bioturbation and a more frequent washing-off of particles from the surface layers. A further striking similarity between sampling sites was the dominance of fibres over other particle shapes. A possible source for them could be fishing gear, since fishing activities were frequently observed at all stations.

Although the differences that we found between sites indicate that presumably various factors can influence the abundance of microplastic particles, our results also suggest that some sources are ubiquitous.

Microplastic concentrations along the German Baltic Coast

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ABSTRACT

During the past few years, the increasing number of studies on marine microplastics has raised awareness on the omnipresence and possible environmental influence of small polymer particles on the marine life cycle. As a consequence, the EU requests microplastic monitoring in the Marine Strategy Framework Directive. One of the challenges in the monitoring efforts is the extraction of microplastic particles and fibres from sediment samples. As spectroscopic polymer identification is available only in rare locations, less costly and more time efficient methods are likely to be used for large-scale monitoring of microplastics.

From March to July 2014, we monitored the microplastic concentration in beach sediments along the German Baltic coast. The monitoring campaign consisted of two parts: 1) testing and improving extraction methods for microplastics from sediments (centrifugation, air-venting in saline solution), and 2) spatio-temporal analysis of coloured particles and fibres as the most likely synthetic contaminants.

In my poster, I will present the simplistic methodology employed for microplastic sampling, which allowed the analysis of a large amount of samples. The observed spatial variation of the detected microplastic concentrations will be discussed in the context of likely entry pathways of microplastics into the Baltic Sea environment along the German coast.

Aquatic Plastic Pollution

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The oceans of the world cover more than 70% of the earth's surface, host substantial biodiversity, and constitute important sources of living and non-living resources. Human welfare is intricately linked to the world's oceans as they provide food and revenue for billions of people worldwide (FAO, 2014). However, the ecological balance is increasingly strained by man-made pressures such as eutrophication, ocean warming, ocean acidification, or the growing exploitation of resources (IPCC, 2014). In addition, a drastic increase of man-made debris, including items made of glass, metal, paper, or fabrics, in all marine ecosystems was observed within the past hundred years (GESAMP, 2015). Since the 1950s, these marine debris, defined as "any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment" (Galgani et al., 2010), progressively consist of plastics. Today, these plastic debris make up the largest proportion (80%) of all litter found in the ocean as highlighted in various studies (e.g. Chen & Liu, 2013; Pham et al., 2014).

First reports about plastic debris date back as early as 1947, when birds were found entangled in them (e.g. Jacobson 1947). In 1960, the first plastic items were detected in the stomachs of sea birds (Harper & Fowler, 1987) and at the same time, floating plastic waste was discovered in the world's oceans (Venrick et al., 1973; Morris, 1980). However, these observations remained largely unnoticed until Carpenter and Smith (1972) addressed the increasing disposal of plastic waste in the marine environment. By now, plastic items have accumulated ubiquitously around the world: in coastlines, the water column, as well as in the seabed (OSPAR, 2009; Galgani et al., 2015). Plastic particles can even be found in the most remote areas of the world, such as the polar regions (Bergmann & Klages, 2012), deep sea (Woodall et al., 2014) or remote and non-industrialized islands (Barnes, 2005; Ivar do Sul et al., 2013). In a research paper published in 2014, Eriksen et al. estimated that "at least 5.25 trillion plastic particles weighing 268,940 tons are currently floating at sea" (Eriksen et al., 2014). Of these, most are in the size of only nano- and micrometres – so-called microplastics (e.g. Morét-Ferguson et al., 2010; Browne et al., 2011; Law et al., 2014; also see below).

Since microplastics can persist in the marine environment for hundreds of years, their availability to marine organisms across multiple trophic levels, combined with evidence supporting the deleterious effects from ingestion, heightens the urgency to determine and evaluate their potential impact and consequences on marine ecosystems (Rochmann et al., 2013; GESAMP, 2015). However, despite the increasing number of studies focusing on this topic that have been published within the last 5 years (Browne et al., 2015; Van Cauwenberghe et al., 2015), many questions remain largely unanswered.

The age of plastics – a threat to the marine environment

The term plastic, derived from the Greek word 'plastikos' meaning 'flexible' or 'malleable', is used to describe a class of materials composed of semi-synthetic or synthetic organics. Those include materials called polymers, which are obtained through the polymerization of hydrocarbon monomers, usually derived from petrochemicals such as oil or gas (Thompson et al., 2009). Polymers are of high molecular weight due to their long chain-like architecture and can be grouped into two main groups, namely thermoplastics and thermosets (GESAMP, 2015).

Industrial mass production of these plastics began in the 1940s with ever improving inexpensive manufacturing technologies. Since then, annual production continuously rose from 1.7 million tons (Mt) in 1950 to about 299 Mt in 2013 (PlasticsEurope, 2015). Future increase is estimated to account for approximately 4 % growth each year and if demand remains unchanged could reach 33 billion tons in 2050 (PlasticsEurope, 2015; Rochmann et al., 2013).

The success of plastics is due to its many beneficial properties. Plastics are lightweight, easily mouldable, relatively inexpensive, and most of all very durable. This is the feature it was initially designed for (Goldberg, 1994; Andrady & Neal, 2009; Andrady, 2011). In addition, numerous chemical additives such as thermal or UV stabilizers, plasticizers, processing aids, flame-retardants, and colorants enhance the material's performance, as well as their chemical resistance to biodegradation and mineralization. Therefore, plastics quickly replaced conventional materials such as wood, glass, metal, and paper (Thompson, 2006; Andrady & Neal, 2009; Andrady, 2011) Today, plastics are utilized for countless purposes making it a '*sine-qua-non*' material inseparably linked to our modern lifestyle (Thompson, 2006; Andrady & Neal, 2009; Browne et al., 2011).

Instead of being turned into a high quality material, about a third of the plastics, most commonly thermoplastics, are used as packaging material for disposable short-lived ´throw-away' products (Rios et al., 2007; Barnes et al., 2009; Hopewell et al., 2009). On a global scale, plastics account for about 10 % of the total amount of waste, which itself was estimated to account for 3.5 Mt per day in 2010 (Thompson et al., 2009; Hoornweg et al., 2013). After its use packaging material can be recovered through recycling or energy recovery processes or it gets disposed. 62 % of post-consumer plastics waste was reprocessed in Europe in 2012 (PlasticsEurope, 2015), but many countries still lack or do not even possess adequate management strategies for recycling or waste disposal systems. This applies particularly to many poor countries, but even in the USA only 9 % of plastic materials were recycled in 2012 (Gourmelon, 2015). Accordingly plastic waste increasingly ends up in the environment (Pham et al., 2014), and there are 20 countries which are the primary contributors according to Jambeck et al. (2015). Since it is assumed that plastics may persist up to hundreds of years in nature or even never truly degrade at all (Barnes et al., 2009), their initially highly acclaimed longevity now constitutes a serious environmental threat (e.g. Sheavly & Register, 2007; UNEP, 2014).

It is assumed that marine plastic litter reaches the marine environment primarily via land-based sources, e.g. from landfills, sewage overflows, public litter or accidental loss, from where it is transported via wind or rivers into the ocean (Andrady, 2011; Wright et al, 2013). Studies indicate that marine plastics from these sources constitute about 80% of the total. Another 20% derive from ocean-based sources through the direct disposal at sea, e.g. by vessels, aquaculture sites or offshore installations as well as lost or abandoned fishing gear (Gregory, 2009), which in the case of the eastern North-Pacific even accounts for the majority source of found particles (Galgani et al., 2015). Factors, as for example current patterns, seasonality as well as the proximity to urbanized or industrialized areas, influence the amount and type of plastics found in the ocean (Browne et al., 2011; Heo et al. 2013; Galgani et al., 2015). In general, most commonly materials encountered in the marine environment include polyethylene (PE, high and low density), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET) as well as nylon. Hence, they represent the most commonly produced plastics (Wright et al., 2013). However, the amount of plastics that eventually end up in the marine environment is obviously very hard to determine. For example, a study published this year by Jambeck et al. (2015) suggested that 13% to 35% of plastics produced in 2012 eventually ended up in the ocean, which is higher than the prior 10% estimated by Thompson (2006).

Apart from the aesthetic aspects of marine litter, the omnipresence of plastic debris causes multiple threats to marine ecosystems' functioning and marine wildlife. These include: a) Inhibition of gas exchange between pore and overlying waters, b) entanglement and injury, e.g. in discarded or abandoned fishing gear, c) smothering of debris on the seabed impacting its flora and fauna, d) direct and indirect ingestion, either intentionally or accidentally and e) vector of transport for species dispersal as well as invasive pests (e.g. Goldberg, 1995; Moore, 2008; Kühn et al., 2015). So far, more than 550 species were reported to be negatively affected by marine plastic debris accounting for more than 80% of impacts associated with wildlife (Browne et al., 2015; Kühn et al., 2015).

Microplastics in the marine environment

Since plastics persist in the environment for a long time, they are exposed to various biological, chemical and physical processes which can reduce their structural integrity, resulting in the degradation into successively smaller fragments (Andrady et al., 1990; Thompson et al., 2004; Moore, 2008). This can be caused through digestion processes of organisms (Yang et al., 2014) or by abiotic factors such as the mechanical fragmentation by sand or wave action (Andrady, 2011). One important factor depicts photo-degradation by UV solar radiation, which initiates oxidation reactions of the polymer matrix (Celina, 2013). Subsequently, surface cracks and pits arise, plastics become weak and 'embrittle', and eventually break apart into successively smaller pieces (Handy & Shaw, 2007; Cooper & Corcoran, 2010). Photo-oxidative-degradation is especially effective on land. In the ocean, however, it significantly slows down with increasing depth until reaching aphotic zones, where only little degradation is expected due to low oxygen concentration (Andrady, 2011). Low temperatures, certain additives such as antioxidants in the plastic materials and biofouling additionally impede the process (Artham et al., 2009; Gross, 2015).

Biodegradation and mineralization only occur with few plastics (Sivan, 2011; Harshvardhan & Jha, 2013; Yang et al., 2014). Hence, the term degradation rather refers to the limited structural alteration of plastics in regard to the marine environment than to a complete degradation.

Beyond a certain size range, plastic fragments are denoted as microplastics. Even though no agreed-on nomenclature exists, microplastics are most commonly defined as particles smaller than 5 mm to account for those particles which can be readily ingested by biota while macroplastics (>5 mm) cause hazards such as entanglement (GESAMP, 2015). In the case of the above-mentioned degradation process, plastic fragments are referred to as 'secondary microplastics'. Fibres from synthetic clothing, released during washing, are another important source of secondary microplastics (Browne et al., 2011). Plastic particles intentionally manufactured to be that size are called 'primary microplastics'. This includes plastic powders and nanoparticles used for industrial purposes, microbeads in cosmetics, as well as virgin resin pellets produced for refining plastic products (Fendall & Sewell, 2009). Due to their small size, these particles can easily pass through the filters of sewage systems and enter the environment, which is referred to as 'discrete point sources' (Norén & Naustvoll, 2010; Gouin et al., 2011). Direct point sources include the direct release into the ocean, e.g. by transport losses or processing plants (Derraik, 2002; Cole et al., 2011).

Through the continuous release of plastic litter into the ocean and continuous fragmentation, micro-sized items are now ubiquitous in all marine compartments, thereby outnumbering larger macrodebris (e.g. Morét-Ferguson et al., 2010; Browne et al., 2011; Collignon et al., 2012; Reisser et al., 2013; Law et al., 2014). Particularly high amounts can be detected in sediments close to industrialized or urbanized coastlines, as well as in enclosed seas and the so-called 'gyres', where they concentrate due to oceanographic features (Moore, 2008; Claessens et al., 2011). For the North Pacific Subtropical Gyre for instance, Moore et al. (2001) showed that the mass of microplastic particles even outweighs that of plankton by about six times.

In general, the distribution of microplastics highly depends on the plastics' density in comparison to the seawater's. Whereas microplastics that exceed seawater's density (>1.02 g cm^{-3}) such as PVC are more prone to sink quickly, larger or air-filled items as well as low-density microparticles (e.g. PP and PE) can be transported larger distances by ocean currents (Ivar Do Sul & Costa, 2014). Other particles are washed back ashore accumulating in estuaries, bays, and on the beach (Liebezeit & Dubaish, 2012; Smith & Edgar, 2014). The abundance of microplastic particles reported from beach sediments range from less than ten to a few thousand items per l kg of sediment for different locations around the world (Van Cauwenberghe et al., 2015). Increased biofilm formation further influence their buoyancy so that eventually even particles that are less dense than seawater eventually (may) sink (Barnes et al., 2009; Morét-Ferguson et al., 2010; Reisser et al., 2014). For this reason it is hypothesized that the seabed is the ultimate repository for most microplastics (Law et al., 2010; Cózar et al., 2014). However, since methods, techniques, and units to quantify these findings are not uniformly applied yet, data cannot be compared directly for a global synthesis. Given the high concentration and increasing entries of plastics into the marine environment, this issue surely requires further attention. Microplastics and their impacts on marine organisms

By now, a wide range of marine taxa such as marine mammals, sea birds, and fish have been shown to ingest microplastics in natural environments (see table 4.1(a-g) pp. 32-42 in GESAMP, 2015). However, more worryingly is that the potential of plastics to fragment into countless microscopic particles and thus occupying the same or smaller size range as sand grains or plankton (Fendall & Sewell, 2009), has extended the effects of plastic pollution down to the base of the marine food chain (Wright et al., 2013). For example, planktonic organisms have been confirmed to ingest microplastics smaller than 100 µm (e.g. Setälä et al., 2014). As well, marine benthic invertebrates are particularly exposed to microplastics which mostly sink to the seabed eventually (Andrady, 2011; Ivar Do Sul & Costa, 2014).

Depending on their feeding strategy, marine invertebrates are thought to ingest plastics either via water filtration, sand ingestion or by confusing them with natural food (Wright et al., 2013). Even exposure through the organism's skin and subsequent translocation into body tissue or organs seems reasonable (Browne et al., 2008). Thus, invertebrates could likewise endure the same adverse physical effects as already documented for many higher trophic-level organisms, such as internal abrasion, clogging of feeding appendages, decreased reproduction, incorporation into body tissue, and ultimately death (Wright et al., 2013). Indeed, a few species have been shown to ingest microplastic particles. The first research was carried out by Thompson et al. (2004) and confirmed the uptake of microplastics (20 - 2000 µm) within a few days by the amphipod *Orchestia gammarellus*, the barnacle *Semibalanus balanoides* and the lugworm *Arenicola marina*. Besseling et al. (2013) further observed subsequent weight loss and reduced feeding behaviour for the deposit feeding *A. marina*. Ingestion of different sizes of microplastics as well as the translocation from the digestive system into hemolymph and haemocytes was further confirmed for the filter-feeding bivalve *Mytilus edulis* (e.g. Browne et al., 2008), which is the most commonly studied marine invertebrate in terms of microplastic uptake. Moreover, a recent study by von Moos et al. (2012) confirmed direct uptake of items (< 80 µm) via gills followed by the transfer into the hepatopancreas causing inflammatory responses. Those findings indicate the deleterious effects of microplastic ingestion on invertebrates. Many marine invertebrate species are adapted to cope with the consumption of non-food particles like sand grains through a variety of abilities to select, dispose or pass non-digestible materials unimpaired (e.g. Thompson, 2006; Wright et al., 2013). Thus, effects might be very species and/or particle specific. However, since the number of studies concentrated only on a few species so far (e.g. GESAMP, 2015), further research to determine potential effects is urgently required.

In addition, most plastics are not pure or pristine but contain several chemical additives as mentioned above. Of these, many are classified as hazardous by the UN's Globally Harmonized System (Lithner et al., 2011). Additives, monomers, or by-products leach from the polymer matrix in the digestive track or tissue and possibly act as e.g. endocrine disruptors and carcinogens (Teuten et al., 2009; Oehlmann et al., 2009). Microplastics may thus act as carriers of organic contaminants which potentially intoxicate species upon ingestion (Koelmans et al., 2014). Moreover, plastics may act as adsorbents for hydrophobic organic chemicals (HOCs) which are available in the seawater, for example due to river run off, oil spills, or fuel combustion (Rios et al., 2007). One common group of HOCs is persistent organic pollutants (POPs) which may bio-accumulate in the marine environment due to their longevity. This includes petroleum hydrocarbons, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), of which most are classified hazardous due to their carcinogenic, mutagenic, and/or endocrine disruptive properties (Rios et al., 2007; Cole et al., 2011). Their presence on plastic debris has been observed in different locations by International Pellet Watch: Concentration of PAHs, for instance, ranged from 39 to 1200 ng per g plastic (Takada, 2006; Ogata et al., 2009). HOCs adsorb onto the hydrophobic surface of plastic polymers due to their lipophilic properties and accumulate until reaching equilibrium. This is influenced by polymer class, size, age, type of contaminant, as well as the concentration of the phases (e.g. water or tissue) (Teuten et al., 2009). Therefore, especially aged microplastics with a high surface area per unit mass can have a concentration of organic pollutants reaching up to 10^6 times higher than surrounding water (Mato et al., 2001). These particles can be taken up by marine invertebrates with subsequent desorption of the contaminant from the plastic into gastrointestinal tracts (Lee et al., 2014). To assess if microplastics act as vehicle for HOCs, Besseling et al. (2013) exposed *A. marina* to extremely high concentrations (~7.4%) of PS (400 - 1300 µm) and PCBs. Bioaccumulation was confirmed, accompanied by reduced feeding activity and growth rate. However, since absorption is concentration dependent, HOCs from already contaminated organisms can partition back and be excreted (Koelmans et al., 2014).

In summary, plastic debris represents a potential multivariate stressor to marine organisms with both, physical and chemical adverse effects upon ingestion. Microplastics add to the distribution of HOCs, increase their persistence and as a consequence, their bioavailability to marine organisms with potentially severe consequences (Teuten et al., 2009). Since invertebrates serve as prey for higher trophic levels, food-web bioaccumulation and bioavailability of contaminants and microplastics represent a further threat by possibly increasing negative impacts, starting at the individual level and then expanding to the population level and lastly affecting the whole ecosystem (Arthur et al., 2008; Cole et al., 2011).

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15 Poster Session

POSTER PRESENTATIONS

15.2	**Joeline Ezekiel**	Spatial and seasonal variability of phytoplankton blooms in the german bight
15.3	**Jasmin Groß**	Microplastics in coastal sediments – A comparison across seven locations worldwide using a global approach
15.4	**Alberto Rovellini**	Impact and efficiency of selective fishery: a spatially-explicit modelling approach
15.5	**Anita B. Ameyaw**	Analysis of the Role of Women in Fisheries and Their Contribution in Fisheries Development: A Case Study in the Western Region of Ghana
15.6	**Johanna Zimmerhackel**	Catch, bycatch and discards of the Galapagos small-scale handline fishery

Spatial and seasonal variability of phytoplankton blooms in the German Bight

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ABSTRACT

We have used remote-sensing data to characterize spatial and inter-annual variations of pythoplankton bloom areal surface coverage in the German Bight and we have investigated the influence of environmental factors (Elbe River discharge and wind field) on bloom areal surface area variations. Remote-sensing observations of chlorophyll *a* (Chl-*a)* (proxy for phytoplankton presence) were obtained from Medium Resolution Imaging Spectrometer (MERIS) for the period between 2008 and 2011. The technique developed by Shutler et al. (2010) was applied to retrieve phytoplankton surface areal coverage. Analysis of the spatial and temporal variations of blooms in the German Bight revealed high bloom surface areal coverage in April and May. Correlation of bloom areal surface coverage with Elbe River discharge was significant (r_s=0.75, n= 157, p-value=$7.68*10^{-5}$) but not significant between bloom surface areal coverage and wind speed. Comparison of the blooms areal surface coverage with the Helgoland Time Series Chl-*a* concentration and Sylt Chl-*a* Time series data shows that Chl-*a* concentration in the German Bight is generally high and above 2 mg m^{-3}. Wind direction plays a major role in the spatial and temporal distribution of bloom coverage in the German Bight rather than the magnitude of wind.

Keywords: phytoplankton, bloom, ocean color, MERIS

Size Frequency Distribution of Snow Crab and Arctic Lyre Crab

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ABSTRACT

The abundant snow crab *Chionoecetes opilio*, and the fairly abundant Arctic lyre crab *Hyas coarctatus* are part of the extensive epifaunal community in the Chukchi Sea, Alaska. Gaining a better understanding of the distribution and growth of both species, which is impacted by mesoscale environmental gradients, will be important in the light of climate change and the potential for a future commercial fishery of *C. opilio*. Carapace width of both species and environmental variables were measured during four summer cruises, and the data were used to show temporal and spatial trends in the size frequency distribution of *C. opilio* and *H. coarctatus* from 2009 to 2013. Growth and mortality of both species were determined through a growth model. Temporally, the mean size of both species decreased from 2009 to 2013, with rare maximum sized organisms decreasing significantly in size to near absence in the latter two study years. Spatially, the mean size of both species showed a latitudinal trend, decreasing from south to north. Growth of both species was linear over the sampled size range, and mortality was highest in the latter two study years. The environmental parameters that significantly correlated with the size frequency distribution of both species varied among years, but temperature, the sediment carbon to nitrogen ratio and sediment grain size correlated with the size frequency distribution of both species in multiple years. Findings from this study show that temporal and spatial size frequency distribution patterns of *C. opilio* and *H. coarctatus* vary on an interannual basis. Further research will be necessary to discern if the near absence of mature crabs in the latter two study years is caused by ontogenetic migrations, interannual fluctuations or if it is an early indication for a further northward range extension, a shift in the southern distribution limit, or a regime shift in the Chukchi Sea.

Keywords: Decapoda, benthos, temporal variability, spatial variability, latitudinal cline

Impact and efficiency of selective fishery: a spatially-explicit modelling approach

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ABSTRACT

Modern fishery regulations are strongly based on the highest possible selection of the catch, especially concerning species and size. This philosophy promises to minimize the harvest of species with poor commercial value and of immature individuals, while maximizing the economic yield of the fishery. In the last years, however, questions arose about its ecological impact and efficiency over long periods. Size-selectivity is acknowledged to determine the truncation of populations at a certain body size or age, with evolutionary and trophic consequences, whereas species-selectivity may alter the composition of communities and therefore their dynamics, inducing biomass fluctuations deleterious for fisheries and for the trophic functions of the system. The relative rarity in fishery science of individual-based community models with a continuous size spectrum, especially of those that benefit of a continuous spatial definition, suggests building such a tool to back up the existing research on the aftermaths of fishing.

In our ongoing study, we develop a spatially-explicit, individual-based model of an exploited multi-species fish food web. Our goal is to determine whether fishing selectively is sustainable for community conservation, and whether this policy is actually beneficial in terms of amount of catch and economic revenues. In the model, fishery acts locally and it is applied in four regimes: on species, on size, on both, and unselectively. Each of these regimes is tested in three degrees of intensity. We compare two robust indicators, the evenness index and the size spectrum, of a theoretical community exposed to the aforementioned regimes of exploitation, in order to assess the ecological impact of each strategy on biodiversity and size composition, and we compute the amount of harvested biomass per species. The results produced by such a novel approach are expected to encourage speculation on the delicate issue of selective versus unselective fishery.

Keywords: selective fishery, individual-based models, spatial interactions, food webs

Analysis of the role of women in fisheries and their contribution in fisheries development: a case study in the western region of Ghana

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ABSTRACT

Gender can be referred to as a social role based on resources and responsibilities of women and men as they relate to one another and to their natural environment. Women have long been involved in fisheries and their roles is evident in many fishing nations across the world as fishers' wives, processors, traders, operators in processing factories, managers and administrators in fishing companies. However, women's contributions in fisheries are usually unacknowledged. The concept is important to gain a better understanding of the fishery functions to ensure a sustainable livelihood especially at the community level. In this study, 240 surveys were conducted in two fishing communities along the western coastline of Ghana, Dixcove (4°48' N, 1°57' W) and Aboadze (4°58' N, 1°37' W) to ascertain women's contributions in Ghanaian fisheries, constraints impeding fisheries as a livelihood for women, dependency level of women on fishery resources, markets forces influencing their livelihood, and if they are involved fisheries management and decision making processes at the community level. Majority of the interviewee were women as women were mainly targeted as key informants in this study though a few men were interviewed as well. Women spent substantial number of hours in a day on fisheries related activities. Women spent between 6 and 8 hours on fish processing and almost half of a day at markets on bad sales day (8.5 ±1.9 and 11 ± 1.7, Dixcove and Aboadze, respectively). Fish gets to the markets mainly through the fish wives and fish mammies who are also the fish processors. The majority of women engaged in petty trading as an alternative and supplementary source of livelihood to support the household during the lean season when fish catches are low. Women's dependency on fish was found to be almost total. Health issues was the prominent difficulty faced by women in both study sites. Inadequate capital and ban on chemical fishing were the most anticipated needs of the women from the government. The study demonstrated that there are efforts by national government and other non-governmental organizations to improve the livelihood of women. However, the lack of actively involving women from the onset of projects could defeat the purpose of developmental structures. Government needs to acknowledge women's role and needs officially, needs to actively involve women from the onset of developmental projects and enforce the ban on illegal fishing methods.

Keywords: West Ghana, Fish mammies, fish processing, social capital, fisheries management

Catch, bycatch and discards of the Galapagos small-scale handline fishery

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ABSTRACT

Fisheries bycatch is a significant marine conservation issue as valuable fish are wasted and protected species harmed with potential negative ecological and socio-economic consequences. Even though there are indications that the small-scale handline fishery of the Galapagos Marine Reserve has a low selectivity, information on its bycatch has never been published. We used onboard monitoring and interview data to assess the bycatch of the Galapagos handline fishery by estimating the bycatch ratio, determining species compositions of landings and bycatch, identifying fishers' reasons for discarding certain individuals, and revealing historical trends in the bycatch ratio. The estimated bycatch ratio as a function of biomass of 0.40 and a diverse species composition of target catch and bycatch confirmed the low selectivity of this fishery. Most individuals were not landed for economic motivations, either because species (77.4%) or sizes (17.7%) are unmarketable or for regulatory reasons (5.9%). We found that bycatch contributes to growth overfishing of some target species because they are discarded or used as bait before reaching their first maturity. Moreover, over half of interviewees perceived a historical decrease in bycatch ratios that was explained by a diversification of the target catch due to the reduction in abundance of the traditionally most important target species. As some target species show signs of overfishing and to date there are no specific regulations for the finfish fishery species in place, we recommend the implementation of a series of management measures to protect critical life stages of overexploited species and to improve the selectivity of the Galapagos handline fishery.

Keywords: Galapagos Marine Reserve, small-scale fisheries, bycatch, multispecies fisheries, discards

Conference Schedule

POSITION	STARTING TIME	ENDING TIME	ROOM	WHO
	Wednesday 16th Sep 2015			
FINET workshop	10:30	16:30	**ZMT, self organized by FINET**	preYOUMARES organized by FINET, sign up for join.finet@gmail.com!!!
DGM & YMR Boating-time	17:30 (cast-off)	20:30	**MS Hanseat, Martinianleger**	Welcome by YMR team, DGM, ZMT; registration is opened!
	Thursday 17th Sep 2015			
Registration	7:45	9:00	**glass entrance**	YMR crew
Official welcome	8:00	8:30	**Room A**	Speaker DGM - Prof. Dr. Boris KOCH
				Speaker IUP - Dr. Oliver HUHN
				Speaker ZMT - Prof. Dr. Matthias WOLFF
				YMR crew
Session 14: Aquatic Plastic Pollution (75min)	**8:30**	**9:45**	**Room A**	14.1 Maike S. Ladehoff
Lene Heel				14.2 Lisa H. Hentschel
Magnus Svendsen Nerheim				14.3 Sarah Piehl
				14.4 Magnus S. Nerheim
Session 2: Genetics for sustainability (75min)	**10:00**	**11:15**	**Room A**	2.1 Ramona Brunner
Alfonso Pita				2.2 Patricia Kaiser
				2.3 Alfonso Pita
				2.4 Peggy Weist
Session 3: Cephalopods and Society (75min)	**9:45**	**11:00**	**Room B**	3.1 Giovanna Ponte (invited)
Rita Melo				3.2José Seco
Sílvia Lourenço				3.3 Carla Bertapelle
				3.4 Pascal Carlier (invited)
Coffee-break/poster session/graduate schools	**11:00**	**11:45**	**all over**	
Session 4: Monitoring pollution (90min)	**11:45**	**13:00**	**Room A**	4.1 Deni Ribičić (invited)
Titiane Combi				4.2 Esther Thomsen
Abel Anderson de Souza Machado				4.3 Rafael Gonçalves-Araujo
				4.4 Milad Adel
				4.5 Stefan Partelow
GROUP PHOTO	**13:00**	**13:10**	**MEETING POINT glass entrance**	
Lunch-Break/poster session/graduate schools	**13:10**	**14:00**	**self-supply**	
Session 8: Marine Social-Ecological Systems (90min)	**14:00**	**15:15**	**Room A**	8.1 Lotta Kluger, Sophia Kochalski, Philipp Gorris
Lotta Kluger				8.2 Ivonne Vivar
Sophia Kochalski				8.3 Stefan Koenigstein
Miriam Müller				8.4 Rafael León
et al				8.5 Ricarda Reuter
Coffee-break/poster session/graduate schools	**15:15**	**15:30**	**all over**	
Workshops	15:30	17:30	**Several rooms and places; The YOUMARES crew guide you to the destination!! MEETINGS POINT glass entrance.**	Universum
				Bologna
				Aquaculture/MAREE
				MARUM
				Aldebaran
				Springer
WTW programm	17:30	21:30	**glass entrance**	WTW evening and official poster session, also YOUMARES AWARD ceremony

	STARTING TIME	ENDING TIME	ROOM	WHO
POSITION	Friday 18th Sep 2015			
Registration	7:45	9:00	glass entrance	YMR crew
Session 11: Latest developments in land-based aquaculture (90min)	8:30	10:00	Room A	11.1 Jalil Zorriehzahra (invited)
Carlos Espinal				11.2 Lars-Ole Rühmann
Björn Suckow				11.3 Elham Kamyab
				11.4 Stéphanie C. Michl
				11 5 Melanie Lindner
Session 6: Invasive species (90min)	8:30	10:00	Room B	6.1 Stephan Gollasch (invited)
Merle Bollen				6.2 Floriaan Devloo-Delva
Simon Jungblut				6.3 Nicole Schwartz
				6.4 Frederike Peiffer
				6.5 Tom J. Langbehn
Session 5: ScienceTainment 60min)	10:00	11:00	Room A	5.1 Henry Goehlich
Jasmin Heiden; Christina Hörterer				5.2 Johanna S. Zimmerhackl
Coffee-break/poster session/graduate schools	11:00	11:30	all over	
Discussion "Women in (polar) research"	11:30	13:00	Room A	Participation of
Claudia Hanfland				Amelie Kirchgäßner
				Birgit Piechulla
				Caroline Robertson von Trotha
Poster session (parallel)				
Lunch-Break/coffee-break/poster session/graduate schools	13:00	13:45	self-supply	
Session 7: Remote sesing (105min)	13:45	15:30	Room A	7.1 Andrew Davies
Matthias Biber				7.2 Ingrid Angel-Benavides
				7.3 Michael Ginzburg
				7.6 Stefan Raimund
				7.4 Sebastian Menze
				7.5 Alfred Schumm
Session 10: Coral reef (120min)	13:45	15:45	Room B	10.1 Jessica Knoop
Elena Barth				10.2 Laura Puk
Claudia Pogoreutz				10.3 Jan-Claas Dajka
Ines Stuhldreier				10.4 Lisa Röpke
				10.5 Sabrina Rosset
				10.6 Julian Mönnich
				10.7 Susann Diercks
Coffee-break/poster session/graduate schools	15:45	16:15	all over	
Awards etc	16:15	16:45	Room A	Award ceremony, closing words by YMR crew
PARTY @ Römer	21:00	open end		Postconference-clubbing at Römer