ICES SYMPOSIUM

Effects of fishing on benthic fauna, habitat and ecosystem function

PROGRAM AND ABSTRACTS

June 16–19 • 2014 • Tromsø • Norway

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

ICES
CIEM

Introduction

Understanding the impacts of fishing activity to the seafloor is a key element in the development of sustainable *ecosystem-based marine resource management.* Any bottom contact fishing will impact the sea floor to some extent, depending on the seabed type and the gear type used. In some cases impacts are clear; bottom trawling can cause immediate and long-lasting damage to deepwater coral, sponge and sea pen communities. In other cases impacts are not even apparent; beach seining of shallow sandy habitats has continued for centuries without obvious change. It is only recently that we have begun to appreciate the extent of this variability and initiate research aimed as understanding *how disturbance caused by fishing affects ecosystem function, biodiversity, productivity, vulnerability and resilience*. Longer term ecosystem and community responses to indirect impacts of fisheries, such as discards, are hardly understood at all. There is a growing need to develop indicators of ecological status, including seabed integrity and we generally lack predictive models of recovery for most ecosystems. Technical solutions aimed at minimising seabed impacts are starting to appear, but their efficacy remains to be tested in many ecosystems.

This symposium will review the physical and biological effects of fishing activities to sea bottom ecosystems, look at various technical conservation measures designed to mitigate these effects and ultimately try to quantify the overall ecosystem impact. The aim is to develop tools for use in informed ecosystem-based fisheries management.

The symposium program is structured around fisheries impacts on different seabed types and communities. The sessions will be divided into the following themes:

- Soft bottom/infauna (macrobenthos) community composition
- Mixed bottom/epifauna and habitat forming megafauna
- Gear effects and development

Publication

The proceedings of the symposium will be published in the peer-reviewed journal *Marine Biological Research*. Papers based on oral and poster presentations may be submitted for review and it is anticipated that publication will be within 15 months after the symposium.

ICES Symposium "Effects of fishing on benthic fauna, habitat and ecosystem function" June 16 – 19, 2014, Tromsø, Norway

Organized by: Institute of Marine Research, Norway

Organizing Committee:

Lene Buhl-Mortensen (IMR-Norway)
Børge Holte (IMR-Norway)
Carsten Hvingel (IMR-Norway)
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Technical support: ICES Secretariat/IMR

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Program overview

Including 44 oral presentations and 28 posters

MONDAY June 16		TUESDAY Effects of fishing on benthic fauna		WEDNESDAY Fishing gear impact and technical development		THURSDAY Effects of fishing on benthic fauna	FRIDAY June 20
	09:00-09:10	*Director General Arne Benjaminsen*	09:00-09:40	*Barry O.Neill*	09:00-09:40	*Michel J. Kaiser*	**Excursion possibility**
	09:10-09:45	*Poul Degnbol (ICES)*	09:45-10:10		09:45-10:10		
	09:45-10:25	*Simon Thrush*	10:10-10:35		10:10-10:35		
	10:30-10:55		10:35-11:00		10:35-11:00		
	11:00-11:15	**Coffee break**	**11:00-11:15**	**Coffee break**	**11:00-11:15**	**Coffee break**	
	11:15-11:40		11:15-11:40		11:15-11:40		
	11:40-12:05		11:40-12:05		11:40-12:05		
	12:05-12:30		12:05-12:30		12:05-12:30		
	12:30-12:55		12:30-12:55		12:30-12:55		
	13:00-13:50	**LUNCH**	**13:00-13:50**	**LUNCH**	**13:00-13:50**	**LUNCH**	
	13:50-14:30	*Adriaan Rijnsdorp*	13:50-14:30	*John Willy Valdemarsen*	13:50-14:30	*Malcolm Clark*	
	14:35-15:00		14:35-15:00		14:35-15:00		
Registration	15:00-15:25		15:00-15:25		15:00-15:25		
	15:25-15:50		15:25-15:50		15:25-15:50		
15:00-18:00	**15:50-16:05**	**Coffee break**	**15:50-16:05**	**Coffee break**	**15:50-16:05**	**Coffee break**	
	16:05-16:30		16:05-16:30		16:05-16:30		
	16:30-16:55		16:30-16:55		16:30-16:55		
	16:55-17:20		16:55-17:20		16:55-17:20		
	17:20-17:45				17:20-17:45		
	17:45-18:30	**Discussion management implications**	17:20-18:05	**Discussion management implications**	17:45-18:30	**Discussion management implications**	
Icebreaker	18:30-19:30	**Poster exhibition and NGOs**	18:05-19:00	**Poster exhibition and NGOs**	18:30-19:30	**Closing**	
18:30	20:00	**Excursion and small dinner**	20:00	**Conference dinner**			

MONDAY 16 th EFFECTS OF FISHING ON BENTHIC FAUNA

REGISTRATION: 15:00 – 18:00

At the conference hotel

ICEBREAKER 18:30 –

At the town hall. Serving of snack (Herring tapas) and welcome greetings by the Mayor in Tromsø.

TUESDAY 17 th EFFECTS OF FISHING ON BENTHIC FAUNA

OPENING: 09:00 – 09:45

Opening: Director General Arne Benjaminsen (The Ministry of Trade, Industry and Fisheries)

Opening keynote: Future challenges in understanding and managing fisheries impacts on marine ecosystem: Poul Degnbol (ICES)

EFFECTS ON SOFT BOTTOM COMMUNITIES 09:45 – 12:55

Keynote: Implications of fisheries impacts to seafloor biodiversity and Ecosystem-Based Management: Simon F. Thrush

Habitat-specific effects of fishing disturbance on benthic species richness in marine soft sediments: P. Daniël van Denderen

Bottom trawling impacts on the deep-sea benthic communities from the SW Portuguese continental slope (NE Atlantic): Sofia P. Ramalho

The effects of commercial dredging and trawling on epifaunal benthic communities associated with weathervane scallops in Alaska: Jessica Glass

Predicting benthic community patterns using environmental gradients and the significance of fishing intensity: a case study in the English Channel: Claire Catherall

Determining the impacts of trawling on benthic function in European waters: a biological traits approach: Andrew Kenny

Evaluation of chronic bottom trawling disturbance on continental shelf benthic communities in the Southern Tyrrhenian Sea, a Mediterranean case study: M. Cristina Mangano

EFFECTS ON MIXED BOTTOM COMMUNITIES 13:50 – 17:45

Keynote: Assessment of trawling impacts on benthic ecosystems with particular reference to mixed sediment bottom fauna on shelf ecosystems: Adriaan D. Rijnsdorp

The impact of trawling on the functional composition of coastal and shelf macrofaunal and megafaunal benthic assemblages in the Eastern Mediterranean: Chris Smith

Context dependency of the magnitude of fishing impact on temperate epibenthic assemblages: Implications for fisheries closed areas: Marija Sciberras

Deep-sea suprabenthic assemblages in the Blanes canyon and adjacent open slope (NW Mediterranean): diversity and spatio-temporal variations in important fishing grounds: Clara Rodrigues

Development of a model of disturbance and recovery dynamics for marine benthic ecosystems: Carolyn Lundquist

Developing an indicator of the state of offshore habitats: a UK case study using a spatially-explicit vulnerability model: Ana Jesus

Bottom fisheries closures introduced by Atlantic high-seas bottom fisheries and regulatory frameworks to facilitate sustainable resource utilization and conserve vulnerable marine ecosystems: Odd Aksel Bergstad

PANEL DISCUSSION MANAGEMENT IMPLICATIONS 17:45 – 18:30

Discussion leaders: Poul Degnbol, Simon F. Thrush, Adriaan D. Rijnsdorp

POSTER SESSION AND EXHIBITIONS 18:30 – 19:30

EXCURSION WITH SNACK 20:00 –

WEDNESDAY 18 th FISHING GEAR IMPACT AND TECHNICAL DEVELOPMENT

BOTTOM IMPACT FROM FISHING GEAR 09:00 – 12:55

Keynote: The physical impact of towed demersal fishing gears on soft sediments: Barry O'Neill

Physical impact of beam trawling revisited: sediment resuspension and disturbance of tickler chain and pulse beam trawling: Jochen Depestele

Estimation of seafloor impact from demersal trawls, seines and dredges based on gear design and dimensions: Ole R. Eigaard

The impact of electrical pulses on benthic invertebrates: Maarten Soetaert

Comparing apples and oranges: a statistical approach to compare the impact of active and passive fishing gears on epibenthic communities: Kris Hostens

The impact of deep-sea bottom longline and handline on Vulnerable Marine Ecosystems: Telmo Morato

Reducing seabed impact of trawling: Can off-bottom floating bridles be used to reduce seabed contact and flounder by catch in shrimp and haddock trawls? Pingguo He

GEAR DEVELOPMENT 13:50 – 17:20

Keynote: Mitigation options to reduce impact of trawling on benthos: John Willy Valdemarsen

Gear modifications to a shrimp trawl to reduce seabed impacts in the Atlantic Canada inshore shrimp fishery: Paul Winger

Do semi-demersal trawls catch cod? A comparison of a semi-demersal and demersal trawl, and how density/visibility may play a role: Melanie Underwood

Performance and seabed impact of new fishing gears alternative to boat seine fisheries: A. Sala

Biological impact of beam trawling revisited: A comparison of direct mortality of benthic fauna between tickler chain and pulse beam: Lorna Teal

High-resolution mapping of European fishing pressure on the benthic habitats: Ole R. Eigaard
A systematic review and meta-analysis on the effects of mobile bottom fishing on the benthos: Kathryn Hughes

PANEL DISCUSSION MANAGEMENT IMPLICATIONS 17:20 – 18:05
Discussion leaders: Barry O'Neill & John Willy Valdemarsen

POSTER SESSION AND EXHIBITIONS 18:05 – 19:00

CONFERENCE DINNER 20:00

THURSDAY 19 th EFFECTS OF FISHING ON BENTHIC FAUNA

EFFECTS ON SOFT BOTTOM COMMUNITIES 09:45 – 12:55

Keynote: Effects of towed bottom fishing gear on benthic biota: current knowledge and future research priorities: Michel J. Kaiser

Ecological significant effects of bottom trawling revealed by functional trait analysis of macrobenthic communities: Paul Whomersley

Indirect effects of otter trawling on the condition and trophic level of *Nephrops* and flatfish in the Kattegat: Jan Geert Hiddink

Fishing effects on distribution and trophic guild structure of the benthic assemblages in the South of Portugal (NE Atlantic): Clara F. Rodrigues

Fishing impacts on benthic-pelagic coupling: the scaling up of ecological functioning experiments: Drew Lohrer

Community consequences of bottom trawl fisheries in demersal food webs: Tobias van Kooten

Benthic habitats of the West Greenland shelf: What is the impact of shrimp trawling?: Kirsty Kemp

EFFECTS ON MIXED BOTTOM COMMUNITIES 13:50 – 17:45

Keynote: The impacts of deep-sea fisheries: their effects on the megabenthos, and lessons for sustainability: Malcolm Clark

Effects of trawling on sessile megafauna and evaluation of the efficacy of management strategies: C. Roland Pitcher

Trawling impact on megabenthos and sediment in the Barents Sea: use of satellite vessel monitoring and video: Lene Buhl-Mortensen

The Bottom Line on Bottom Trawling: A Review of the Scientific Literature: Les Watling

Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing: Gwladys Lambert

Indicator species of the vulnerable marine ecosystems in the Barents Sea: Denis Zakharov

Quantitative risk assessment of benthos & bycatch sustainability in a tropical shelf trawl fishery: C. Roland Pitcher

An approach to link changes in benthic community structure with the delivery of ecosystem services in trawling grounds: Alba Muntadas

PANEL DISCUSSION MANAGEMENT IMPLICATIONS 17:45 – 18:30

Michel J. Kaiser & Malcolm Clark

CLOSING 18:30 – 19:30

FRIDAY 20 th EXCURSION POSSIBILITIES

Private excursion arrangements can be made, information is available at the conference hotel.

ABSTRACTS IN PRESENTED ORDER

TUESDAY 17 th EFFECTS OF FISHING ON BENTHIC FAUNA

Opening Keynote: Future challenges in understanding and managing fisheries impacts on marine ecosystems

Poul Degnbol, Head of Advisory Programme, ICES

European fisheries policy has for many decades focused on bringing and maintain the exploitation of single stocks within sustainable limits. This would in itself also contribute to reducing the ecosystem impacts of fisheries. In the last decade important progress has been made in reducing the overall pressure on North East Atlantic fish stocks and focus is therefore now increasingly on means beyond that to reduce the impacts on marine ecosystem. This development, and the need to integrate fisheries policies with marine environmental policies, brings the subject of the symposium to the centre stage of future fisheries policy. The presentation will demonstrate this development and discuss the challenges this raises for science, both in relation to understanding impact processes and to operationalise such knowledge in a policy context, and the data required to do so.

ABSTRACTS ON EFFECTS ON SOFT BOTTOM COMMUNITIES 09:45 – 12:30

Keynote: Implications of fisheries impacts to seafloor biodiversity and Ecosystem-Based Management

Simon F. Thrush,

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Biodiversity has many elements that both support fisheries and are often impacted by it. However, to date the potential knowledge generated by biodiversity research has not been fully incorporated into mainstream fisheries science. This has important consequences for our ability to assess risks and make choices. Biodiversity research by definition addresses heterogeneity and this influences the nature of questions the science seeks to address and how empirical studies are designed. There are many key roles for different forms of biodiversity to influence ecosystem function. In this talk I will focus on resilience and ecosystem function and ecosystem service connections. I will discuss recent studies on the impacts of disturbance on the seafloor and their implications for and the time scale of recovery and cumulative impacts. I will illustrate how β–diversity can be used as a measure of ecological connectivity and thus inform our understanding of cumulative degradative change to seafloor ecology. I will also illustrate patterns of diversity decline and implications why changes in fish communities can matter to seafloor biodiversity. Finally I will consider the implications for Ecosystem-Based Management for decision making in a wicked world, where marine ecosystems are subjected to multiple uses and multiple values.

Habitat-specific effects of fishing disturbance on benthic species richness in marine soft sediments

P. Daniël van Denderen [1, 2], Niels T. Hintzen [1], Adriaan D. Rijnsdorp [1, 2], Piet Ruardij [3] &Tobias van Kooten [1]

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3. Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, The Netherlands

Abstract: Around the globe, marine soft sediments on continental shelves are affected by bottom trawl fisheries. In this study we explore the effect of this widespread anthropogenic disturbance on the species richness of a benthic ecosystem, along a gradient of bottom trawling intensities. We use data from 80 annually sampled benthic stations in the Dutch part of the North Sea, over a period of 6 years. Trawl disturbance intensity at each sampled location was reconstructed from satellite tracking of fishing vessels. Using a structural equation model, we studied how trawl disturbance intensity relates to benthic species richness, and how the relationship is mediated by total benthic biomass, primary productivity, water depth, and median sediment grain size. Our results show a negative relationship between trawling intensity and species richness, which is also negatively related to sediment grain size and primary productivity, and positively related to biomass. Further analysis of our data shows that the negative effects of trawling on richness are limited to relatively speciose, deep areas with fine sediments. We find no effect of bottom trawling in shallow areas with coarse bottoms. These condition-dependent effects of trawling suggest that conservation of benthic biodiversity might be achieved by reducing trawling intensity only in a strategically chosen fraction of space, while allowing bottom trawl fisheries to continue in areas where there is limited effect on species richness.

Keywords: Benthic invertebrates; biomass; bottom trawling; trawl disturbance; marine soft-bottom environments; primary productivity; species richness

Bottom trawling impacts on the deep-sea benthic communities from the SW Portuguese continental slope (NE Atlantic)

Sofia P. Ramalho[1,2,] Marina R. Cunha[1], Lidia Lins[2], Ellen Pape[2], Eliana Alfaro Cordova[2], Nikolaos Lampadariou[3], Ann Vanreusel[2]

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Fisheries, notably bottom trawling, are considered the most widespread anthropogenic source of physical disturbance in deep-sea sediments. However, the extent of the impact is not yet fully comprehended. Recent studies showed that persistent bottom trawling results in long-term alterations of the benthic habitats and major losses of faunal diversity and biomass. In this study we aimed to investigate the effects of trawling on the benthic assemblages from the SW Portuguese continental slope, integrating different benthic groups: meio-, macro- and megafauna. Trawling in this area has occurred regularly, targeting several species of deep-water crustaceans of high commercial interest, with great levels of bycatch and discarding. During cruise 2013/17 WIM aboard the RV Belgica, 2 ROV video surveys were made covering areas with different levels of impact (fished - non-fished - fished) between 500m to 200m depths. Initial findings showed flattened seafloor appearance in the deeper fished areas, low bioturbation, many trawl marks and scattered faunal distribution composed mainly by anemones and fish. The non-fished sites were characterized by higher sediment heterogeneity, bioturbation marks (burrows, mounds, foraging tracks), highest fish diversity (incl. cartilaginous species) and many pagurid crabs. The second fished site displayed high numbers of the polychaete Hyalinoecia tubicola, mostly associated with crab and other food remains, possibly resulting from discards. Meiofaunal abundances differed significantly between fished and non-fished areas. Nematodes and copepods were the dominant taxa in all samples. Additionally, sediment cores from the fished and non-fished area were incubated on board for 1 week and provided with 13C labelled algae to investigate bacterial production, bioturbation and pore-water irrigation. Only pore-water irrigation seemed to differ between the areas, with highest irrigation in sediment from the non-fished area. Community data from all benthic size groups will be compared in terms of abundance, structural and functional diversity.

Keywords: fisheries, deep-sea, sediment disturbance, trawl marks, discards, benthos, abundance, structural and functional diversity.

The effects of commercial dredging and trawling on epifaunal benthic communities associated with weathervane scallops in Alaska

Jessica Glass

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We conducted an analysis of the spatial and temporal variation in benthic communities in areas targeted by the commercial weathervane scallop (*Patinopecten caurinus*) fishery off Alaska's coast.
Fish and invertebrates are incidentally caught in commercial scallop dredges and sampled by onboard observers. Some species are commercially valuable, including walleye pollock (*Gadus chalcogrammus*) and Tanner crab (*Chionoecetes bairdii*). Using observer bycatch data collected during 1996-2012, we examined spatial patterns in community composition on weathervane scallop beds, as well as changes over time. We were also interested to know whether those patterns could be related to fishing effort (scallop dredging and groundfish trawling). Non-parametric tests, including nonmetric multidimensional scaling and analysis of similarity, were used to conduct multivariate analyses. The overlap of commercial groundfish trawling on commercial scallop beds ranged from 0 – 22% from 1996-2012, with the highest amount of overlap occurring in the Bering Sea. Scallop dredging comprised a larger and more consistent component of fishing effort on scallop beds. Spatial variation in scallop dredging effort, as well as environmental variables, may contribute to observed differences in the relative abundance of benthic communities on individual beds. Significant temporal changes in community composition occurred during 1996-2012, possibly due to changes in the observer program or altered fishing behavior. Weathervane scallop catch per unit effort has generally been stable over time, suggesting that scallop populations in Alaska are robust to the levels of fishing mortality since 1996. Other benthic species exhibited varying abundance levels. Results from this study inform our understanding of the extent to which benthic community composition in Alaska has changed over the past two decades with repeated disturbance. The effects of scallop dredging had not previously been analyzed in Alaskan waters.

Predicting benthic community patterns on scallop fishing grounds: a case study in the English Channel

Claire Catherall

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The king scallop (*Pecten maximus*) fishery is the second most valuable in the UK, with a first landings value of £70 million in 2012. UK scallop fishing effort has more than doubled in the last decade and the productive scallop beds in the English Channel are the focus for the UK fleet. To improve management of this valuable resource the UK Scallop Association funded research; which includes investigating the impacts of the fishery on associated species and habitats, in line with the requirements for Marine Stewardship Council (MSC) accreditation.

To investigate the impact of scallop dredging on benthic communities in the English Channel benthic epifauna was sampled at eight sites across the eastern and western Channel. Sample sites covered a gradient of environmental parameters. These parameters were bed shear stress and 'Scope for Growth' (a combination of surface Chlorophyll a concentration, water stratification and seabed temperature range and variability, based on Kostylev & Hannah 2007). VMS data for the years 2005 to 2012 was used to select sites across a gradient of dredge fishing intensity (as a measure of total hours fished). Benthic species abundance, biomass and community composition data was obtained from beam trawl samples, king and queen scallop dredges and underwater video. Statistical models were used to evaluate the ability of relative fishing intensity, bed shear stress and 'Scope for Growth' to predict indexes of species diversity and total biomass. Patterns in community composition and biological traits were also investigated using multivariate analysis.

The models indicated that bed shear stress and 'Scope for Growth' explained a greater proportion of variation in species richness, diversity and total biomass than the relative dredge fishing intensity. The most abundant species in terms of biomass were similar across all sample stations with the dominance of those species affected at varying levels by the three parameters tested. The findings indicate that despite the known impacts of dredge fishing on the seabed; within the gradient of pressure exerted by the commercial fishery in the English Channel, the level of dredge fishing intensity does not appear to have significant impacts on species diversity, total biomass, scallop biomass or the functional diversity on 'traditional' scallop fishing grounds in the English Channel. Further investigations with recent (2013) VMS data will be carried out as part of the research.

Determining the impacts of trawling on benthic function in European waters : a biological traits approach

Stefan Bolam[1], Andrew Kenny[1], Clement Garcia[1], Jacqueline Eggleton[1], Grete E. Dinesen[2], Lene Buhl-Mortensen[3], Chris Smith[4], Vicky Kalogeropoulou[4], Aysun Gumus[5], Jan Gert Hiddink[6], Gert Van Hoey[7], Tobias Kooten[8], Jorgen Hansen[9]

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One of the most widespread yet manageable pressures we impose on the seabed is disturbance of the substrate by towed demersal fishing gear (bottom trawling and dredging). Over the past forty to fifty years, many studies have been conducted specifically aiming to understand the impacts of such fishing gear on the seabed communities. Their outcomes have demonstrated dramatic effects of bottom trawling on the structure of marine ecosystems although impacts tend to be wide-ranging, depending upon the gear, intensity, spatial area and the nature of the seabed habitats. However, understanding the functional impacts of this activity (as opposed to impacts on the structure of benthic assemblages) has only recently been attempted. Advances in the application of biological traits analysis (BTA) wherein the assemblages are described in terms of their life history, behavioural and morphological characteristics, have allowed us to better understand the interactions between the benthic fauna and their environment at a functional level.

We present the initial findings of work conducted under the auspices of the EU-funded project 'BENTHIS' which aims to improve our understanding of the impacts of trawling on benthic ecosystem functioning over much larger spatial scales than previously undertaken. Biological traits information from 887 stations across European waters (Norwegian, UK, Belgian, Dutch, Danish waters, the Mediterranean and Black Sea) were analysed to: i) quantify the relationships between infaunal trait composition and environmental variables (depth, sediment granulometry); ii) determine the relationship between traits and habitat type (EUNIS level 4); and iii) assess the relationships between trawling pressure (using data derived under BENTHIS; see Eigaard et al., this volume) and traits composition.

Keywords: trawling impacts, benthic habitats, benthic function, traits, European waters

ABSTRACTS ON EFFECTS ON MIXED BOTTOM COMMUNITIES 13:25 – 17:45

Keynote: Assessment of trawling impacts on benthic ecosystems with particular reference to mixed sediment bottom fauna on shelf ecosystems

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A generic framework to quantify the impact of bottom trawling on benthic fauna is presented. The framework will be illustrated for mixed-sediment habitats and associated biota on shelf ecosystems. Trawling impacts will be determined by (1) the characteristics of the fishing gear used and the intensity and temporal pattern, and (2) the sensitivity of the habitats and biota and their relationship with other biota. Key mechanisms involved in this interaction will be reviewed and key metrics relevant for the integrated analysis will be discussed.

Evaluation of chronic bottom trawling disturbance on continental shelf benthic communities in the Southern Tyrrhenian Sea, a Mediterranean case study

M. Cristina Mangano[1], Michel J. Kaiser[2], Erika M. D. Porporato[1] and Nancy Spanò[1]

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The continental shelf represent the most exploited ecosystem in the Mediterranean basin, indeed since long time the majority of trawl fisheries activities occur in this area. The overexploitation of the continental shelf habitats is more evident on the seabed in which this ecosystem is less extent, often reduced to a coastal fringe, as occur off the Southern Tyrrhenian Sea along the Northern Sicilian coast. Aimed by the need to understand how otter trawl activity affects the benthic communities inhabiting this area, the current study analyse the epibenthic and infaunal communities' responses to a gradient of fishing intensity. Fishing intensities were ascertained post-hoc from vessel monitoring system data (VMS). Epifaunal samples were collected as part of 4 experimental otter trawl surveys carried out in the study area in May to July from 2010 to 2013 (non-target epibenthic component of the animal community incidentally caught by the net and considered as commercially unimportant species). Infaunal and sediments samples were contextually collected. The study take advantage by the presence of a fishery exclusion zone (EFZ), the Gulf of Patti, a large bay from which trawling has been excluded for 22 years. The density and biomass indices together with the main biodiversity metrics have been analysed showing the major differences between the fishery closure area compared with other exploited continental shelf sites. More vulnerable organisms, bioturbators, slow-growing and fragile bioengineering species occurred mostly within the EFZ. Fished sites were dominated primarily by burrowing deposit feeding worms, small bivalves, species with lower mortality rates, resilient species and scavenging biota. The study provides important insights into the responses of benthic communities' components to trawl disturbance, emphasising the importance of adopting an ecosystem approach to fisheries management (EBFM), strongly recommending to manage non-commercial organisms and habitats also in the evaluation of the impact of fishing activities.

Keywords: epifauna, infauna, Vessel Monitoring System, Fishery Exclusion Zone, Ecosystem-Based Fisheries Management

The impact of trawling on the functional composition of coastal and shelf macrofaunal and megafaunal benthic assemblages in the Eastern Mediterranean

Chris Smith[1,] Vasiliki Kalogeropoulou[2,] K.-Nadia Papadopoulou[1]

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The impacts of demersal trawling have been investigated on macrofaunal and megafaunal assemblages in the southern Aegean Sea (Eastern Mediterranean), traditionally an area of high diversity but low abundance and biomass, characteristic of oligotrophic systems. An investigation into the chronic impact of trawling was carried out on a 200m deep muddy bottom sampled within a commercial trawl lane (effort approx. 750-2300 daysxGT/year) and adjacent control sites during both the open trawling season (October-May) and the closed period (June-September). In another investigation on the acute impact of trawling, on a 70 m sand/maerl seabed, sampling was carried out prior to and for 4 months following an experimental trawling period (14 consecutive trawls over a 100 x 1000 m lane). In both areas extensive replicate sampling was carried out for control and impact stations: this included macrofauna samples (5 x 0.1 m2 Smith-McIntyre grab/stn), megafauna (5 x 2m Agassiz trawl/stn) as well as grain size, sedimentary organic carbon and chlorophyll pigments over the different time periods. The resultant species abundance matrices were further detailed, by assigning species to a range of trait categories, known to represent important ecological functions, covering; size, morphology, longevity, reproduction, living habit, sediment position, feeding mode, mobility, bioturbation and bed forming. A fuzzy coding approach was used, to describe the affinity of a species to the different trait categories allowing for flexibility within species life-histories. A Biological Traits Analysis (BTA) was carried out to relate the impact of trawling to loss of macrofaunal and megafaunal biological traits, temporal functional shifts and changes in functional diversity, both directly and related through changes in environmental characteristics. The results from this functional approach are also compared to the outcomes of traditional analysis on species abundance and community structure based on taxonomy and compared to results from other more eutrophic ecosystems.

Keywords: trawling impacts, megafauna, macrofauna, traits, Eastern Mediterranean, BTA analysis, ecosystem functioning.

Context dependency of the magnitude of fishing impact on temperate epibenthic assemblages: Implications for fisheries closed areas

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Fisheries closed areas Fishing with bottom towed gear is widely considered an invasive form of fishing in terms of its impacts upon seabed habitats and fauna. The fishing grounds around the Isle of Man and Cardigan Bay in the Irish Sea have been extensively exploited by scallop dredgers for over 30 years. To examine the effects of scallop dredging on target species (*Pecten maximus* and *Aequipecten opercularis*) and the epi-benthos, we conducted underwater camera surveys within these two fishing grounds and in nearby closed areas to scallop dredging. The abundance of *P. maximus* and taxa such as hydroids, bryozoans and anthozoans were on average two to three times lower in the fishing ground relative to the closed area in the Isle of Man. In contrast, no differences were detected between the fished and closed area at Cardigan Bay. Examination of modelled wave-induced bed shear stress across the Irish Sea and of side scan sonar images, suggested a highly dynamic environment strongly influenced by both tides and waves at Cardigan Bay. Unquestionably, dredges disturb the seabed and the communities that they support. However, results indicate that the magnitude and extent of fishing impact is influenced by background levels of natural disturbance. Gauging the impact of mobile fishing gear therefore requires an understanding of how natural disturbance affects benthic communities. Furthermore, the effect of protection from mobile fishing gear on the habitat structure and biological communities must be scaled against the magnitude and frequency of seabed disturbance due to natural causes. The imposition of fisheries closed areas without due consideration of the natural environmental conditions and the biology of species concerned may result in negative effects on fisheries and limited conservation benefits, particularly if fishing effort is displaced to previously non-fished areas.

Keywords: Scallop dredging, Fishing impact, Scallop dredging,Epifauna, Natural disturbance

Deep-sea suprabenthic assemblages in the Blanes canyon and adjacent open slope (NW Mediterranean): diversity and spatio-temporal variations in important fishing grounds

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The multidisciplinary RECS project aimed to study the benthic communities in the Blanes canyon (Northwestern Mediterranean Sea). The lower depths of the canyon and adjacent areas are exploited by fisheries for the red shrimp Aristeus antennatus. In this context, the macrofauna living in the vicinity of the bottom (suprabenthos) was sampled in order to study diversity and distribution patterns in the canyon and open slope in relation to environmental variables and fishing pressure. This fauna is composed by mobile animals (small crustaceans) that perform daily or seasonal migrations and are known to be source of food for megafauna species, including those with commercial value. Sampling was conducted seasonally (March 2003-May 2004) in fishing and non-fishing areas in the open slope (at approx. 800m) and inside the canyon in two areas trawled for fisheries (at approx. at 500m). The samples were sorted and identified to the lower taxonomic level, counted and weighed. Biodiversity, densities and biomasses were estimated between canyon and open slope and between fished and non-fished areas. Trophic structure and life styles were also compared. Considering the fishing areas, preliminary results indicate higher diversity and evenness in open slope assemblages and higher dominance and densities in the canyon assemblages. The multivariate analysis supports a significant difference between canyon and open slope stations. For the analysis between fished and non-fished areas, even so the multivariate analyses did not detected significant differences between the two areas, lower densities and higher diversity was found in the open slope stations impacted by trawling. The analysis is not completed yet, even so the preliminary results indicate that there is a "canyon effect" on suprabenthos and fishing pressure could be an additional factor structuring these communities.

Keywords: deep-sea; suprabenthos; canyons; diversity; disturbance; bottom fisheries

Development of a model of disturbance and recovery dynamics for marine benthic ecosystems

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Marine soft sediment habitats are modified by disturbances from fishing, mining and other human and natural disturbances. However, the difficulty and expense of sampling in these habitats make it challenging to evaluate the success of different strategies to manage disturbance impacts. Here, we present a seascape model of disturbance/recovery dynamics in benthic communities dominated by both infaunal and epifaunal taxa. We define eight functional species groups, each with different parameters for dispersal, age of maturity, age of mortality and interactions with other species, resulting in varying timelines of recovery from disturbance for each functional group. We use data from field surveys of benthic communities to validate the model using a fuzzy logic approach to translate functional traits of organisms into the eight model functional groups, using inshore surveys from Tasman and Golden Bays, South Island, New Zealand, and offshore surveys from the Chatham Rise and Challenger Plateau in New Zealand's EEZ. Our long term goals are to use the model to correlate spatial and temporal rates of disturbance with the persistence of functional groups in soft sediment ecosystems, thus informing management scenarios to minimise disturbance impacts on seafloor communities.

Developing an indicator of the state of offshore habitats: a UK case study using a spatially-explicit vulnerability model

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Keywords: state indicators; benthic habitats; habitat sensitivity; fishing pressures; vulnerability assessment model

Assessments of the state of marine biodiversity are required to deliver national and international reporting obligations, as well as informing management, both at the regional seas scale and within Marine Protected Areas [1]. However, a lack of data and operational biological indicators are major constraints when assessing benthic habitats. Despite ongoing work to improve these aspects across Europe, there is a strong case to be made for an interim assessment framework that maximises use of best available scientific information and expert judgement, to meet assessment and reporting requirements such as the MSFD.At the Joint Nature Conservation Committee, we are exploring the use of a spatially-explicit vulnerability assessment model as an indicator of habitat condition[2]. Vulnerability is defined as a measure of the degree of exposure of the feature to a pressure to which it is sensitive (see Figure 1). Sensitivity is dependent on the intolerance of a feature to damage from an external factor (resistance) and the time taken for its subsequent recovery (resilience). Our work builds on previous UK assessment frameworks[3] and research by the wider scientific community[4]. We will discuss how this model can test multiple scenarios using different assumptions and input variables. This discussion covers how and when vulnerability assessments can be of benefit, by considering data requirements, the factors that most influence the sensitivity of the model and how scientific research can help improve the robustness of the model.

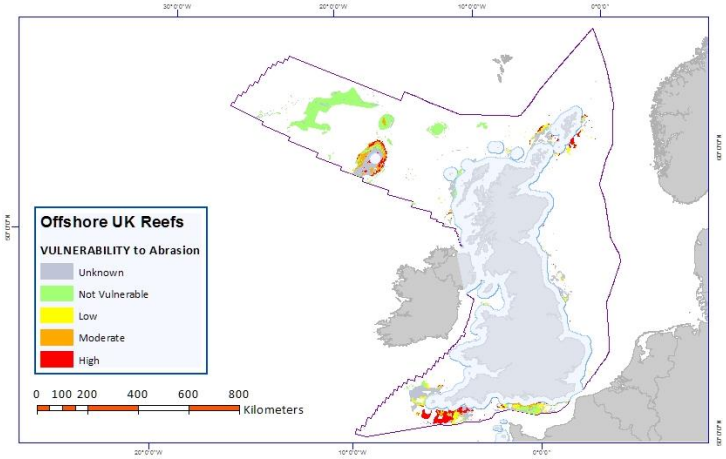

Figure. Spatial pattern of the vulnerability of offshore Annex I Reefs to the pressure physical abrasion

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Bottom fisheries closures introduced by Atlantic high-seas bottom fisheries and regulatory frameworks to facilitate sustainable resource utilization and conserve vulnerable marine ecosystems

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During the past decade, efforts to regulate Atlantic fisheries for deepwater resources in areas beyond national jurisdiction increased significantly. Conservation of vulnerable benthic invertebrate species and fish resources were key aims, maintaining also a potential for continued or future sustainable resource utilization.
Governments and relevant international fisheries management organizations introduced comprehensive classical fishery management measures, including closure of sub-areas to certain fisheries and practices. Background and principles underlying current regulations are explained and discussed, including the interaction between science and management, and between management organizations with complimentary authorities and roles.
A need for an analysis of the effectiveness of the new regulatory framework is recognised. Such a review would have consider the relative impacts of new regulations and other factors such as rising fuel costs, reduced subsidies, and enhanced fishing opportunities elsewhere.
A provisional evaluation of current fishery trends in view of recent regulatory efforts suggests that the incentive to fish unsustainably on the high seas is significantly reduced. Spatial management, including area closures to bottom fisheries, introduced by regional fisheries management organizations constituted just one of several regulatory elements together creating a new environment for deepwater fisheries on the high seas.

WEDNESDAY 18 th FISHING GEAR IMPACT AND TECHNICAL DEVELOPMENT

ABSTRACTS ON BOTTOM IMPACT FROM FISHING GEAR 09:00 – 12:20

Keynote: The physical impact of towed demersal fishing gears on soft sediments

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An improved understanding of the physical interaction of towed demersal fishing gears with the seabed has been developed in recent years, and there is a clearer view of the underpinning mechanical processes that lead to the modification and alteration of the benthic environment.
The physical impact of these gears on soft sediments can be classified broadly as being either geotechnical or hydrodynamic in nature: penetration and piercing of the substrate, lateral displacement of sediment and the influence of the pressure field transmitted through the sediment can be considered geotechnical; whereas the mobilisation of sediment into the water column can be considered hydrodynamic.
A number of experimental and numerical approaches have been used to gain better insights of these physical processes. These include small-scale modeling in towing tanks and sand channels; large-scale modeling in the field; measurements behind full-scale towed gears at sea; numerical/mathematical modeling of sediment mechanics; and numerical/mathematical modeling of hydrodynamics. Here we will briefly review this research, and that in associated fields, and show how it can form the basis of predictive models of the benthic impact of trawl gears.

Physical impact of beam trawling revisited: sediment resuspension and disturbance of tickler chain and pulse beam trawling

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Beam trawling uses heavy gear combined with tickler chains that are dragged across the seabed disturbing the upper layers of sediment and causing damage or mortality to benthic organisms. Recently, Dutch fishermen have replaced the tickler chains of the beam trawls by electrodes as alternative stimulation for catching flatfish. The pulse is claimed to have less of an in impact on benthic organisms than the traditional beam. In June 2013, sea trials were conducted in Dutch coastal waters to compare and quantify the direct mortality of the traditional beam and the pulse gear on benthic fauna. Fauna was sampled using a triple-D sledge before and after trawling by beam and pulse trawls with a non-fished area for comparison (BACI). Densities were calculated before and 48 hours after trawling. Boxcore samples measured the depth distribution of infauna. As individual species showed no particular patterns of impact in relation to the two trawling types, all species were combined into one analysis and categorised by traits. Each species was assigned to one of the groups based on a traits database: Resistant, intermediate or susceptible to trawling. Results showed that the area was populated by a community of mostly resistant species prior to the experiment, which may explain the difficulty in identifying direct mortality effects. However, overall a decrease in densities was observed following trawling, mostly due to a decrease in the group categorised as susceptible. Although the pulse trawl not show a lower impact than the beam trawl, the beam trawl area had been fished with a lower intensity and it may be concluded therefore that the beam has a larger impact. Nevertheless, it is also evident that impacts of trawling in an area with mostly resistant species appear minimal. The context-dependency of trawling impacts should therefore always be taking into account."

Estimation of seafloor impact from demersal trawls, seines and dredges based on gear design and dimensions

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This study estimates the seafloor impact of towed fishing gears from a bottom-up perspective. Traditionally fishing pressure, often in terms of indicators, is calculated top-down using the fishing effort information available in large-scale statistics such as logbook and VMS data. Here we take a different approach using the gear itself (design and dimensions) for understanding and estimation of the physical interactions with the seafloor at the individual fishing operation level. With reference to the métier groupings of EU logbooks, we defined 17 distinct towed gear groups in European waters (11 otter trawl groups, 3 beam trawl groups, 2 demersal seine groups, and 1 dredge group), for which we established seafloor "footprints". The footprint of a gear was defined as the relative contribution from individual larger gear components, such as the trawl doors, sweeps and ground gear, to the total area and severity of the gear impact. An industry-based vessel and gear survey covering 13 different countries provided the basis for estimating the relative impact-area contributions from individual gear components, whereas seafloor penetration and resuspension was estimated for different sediment types based on a review of the scientific literature. For each defined gear group a vessel-size (kW or total length) – gear size (total gear width or circumference) relationship was estimated to enable the prediction of gear footprint area and sediment penetration from vessel size. The implications for the definition and monitoring of fishing pressure indicators are far-reaching, and are discussed in context of an ecosystem approach to fisheries management (EAFM).

Keywords: physical impact, fishing effort, gear footprint, towed gears, vessel size

Acknowledgements: The above described work has been funded through the EU-FP7 project 'BENTHIS'

The impact of electrical pulses on benthic invertebrates

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Pulse trawling is the most promising alternative for conventional beam trawls targeting sole, meeting both the fisherman's aspirations and the need for ecological progress. The application of electrical pulses in flatfish fishery can reduce the fuel consumption and (benthos) discards with more than 50% and hence increasingly gains international public and political attention, especially with the upcoming discard ban in Europe. However, engendered information about possible side effects of electric pulses on benthic invertebrates is imperative to enable the further development/application/promotion of electric pulses, which provides the rationale for the current research. The present experiments adopted brown shrimp (*Crangon crangon* L.) and sandworm (*Nereis virens* S) as model species for crustaceans and polychaetes, respecitvely. These animals were exposed in a homogenous field to electric pulses with varying values of parameters: frequency (5-200 Hz), field strength (150-200 V/m), pulse polarity, pulse shape, pulse duration (0.25-1 ms) and exposure time (1-5s) in order to determine the range of safe pulses. Behaviour during exposure, 14-d survival rates and histological examination were used to evaluate possible side-effects. No significant increase in mortality or injuries was encountered for the broad range of pulse parameters tested. However, the score attributed for the presence of intranuclear baculoform viruses in brown shrimp was significant higher for the group exposed to 200 V/m. But, seen the much shorter exposure times, it is unlikely that this effect would occur in the field. Nevertheless, strengthened by the reduced physical impact, these results indicate a smaller effect of pulse trawls on benthic invertebrates compared to conventional beam trawlers.

Acknowledgements: The author wants to thank the Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT), the Flemish Scientific Institute for Agricultural and Fisheries Research (ILVO), the European Fisheries Fund (EVF) and the crew of the RV Simon Stevin.

Comparing apples and oranges: a statistical approach to compare the impact of active and passive fishing gears on epibenthic communities

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The Belgian marine fishing fleet is dominated by beam trawling, an active fishing method under considerable pressure due to its known ecological effects (fish bycatch, bottom disturbance..). Passive fisheries, such as trammel nets are prompted as gear-related mitigation measures to catch the same commercial target species. But how to judge whether one technique has a higher impact on the epibenthic community than the other? We developed a methodology allowing for a direct comparison of both fishing techniques (both targeting sole), by standardizing discards of epibenthos species per kg marketable sole, based on samples from Belgium and UK waters. We also looked at other potential predictors to explain discard variation, like population size of the discarded species in the fished areas, fishing location, time, depth and sediment type.
More epibenthic species and individuals are discarded per kg sole by beam trawlers (e.g. 50 times more *Liocarcinus holsatus* and 100 times more ophiuroids), while discard rates of Cancer pagurus were higher for trammel netters. Discard rates of C. pagurus also increased with higher abundance of this species in the fished area, while for *Asterias rubens* no such correlation was found for trammel nets. For trammel nets, higher discard rates were found in deeper waters and outside the major sole fishing season (March-May). Areas with high abundances of non-target species seem to be avoided by commercial beam trawlers.
A DISTLM analysis showed that 42 % of the variation in discard composition could be explained by the combination of gear, depth, latitude and longitude. This means that fishermen themselves can minimize the discard rates by actively using this information to judge where and how to fish or to quit fishing, dependent on the used gear, area and time frame. The potential implications are further discussed in the light of results-based management.

Keywords: Beam trawl, trammel net, epibenthos discards, results-based management

The impact of deep-sea bottom longline and handline on Vulnerable Marine Ecosystems

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Bottom trawl fishing threatens deep-sea ecosystems (1, 2), modifying the seafloor morphology and its physical properties (3), with dramatic consequences on benthic communities (4). Conservation of Vulnerable Marine Ecosystems (VMEs), including cold-water corals and sponge fields is a global priority (5) and hence increasing pressure is being made to ban bottom trawling in the deep sea (1). Consequently, the future of deep-sea fishing relies on alternative techniques that maintain the health of deep-sea ecosystems and tolerate appropriate human uses of the marine environment (6). We assessed the impact of deep-sea longline benthic communities using data collected aboard commercial fishing vessels, experimental fishing surveys and underwater footage and compared with the known impact of bottom trawling. We demonstrated that deep-sea bottom longline fishing has little impact on vulnerable marine ecosystems, reducing bycatch of cold-water corals and limiting additional damage to benthic communities. Bycatch of cold-water corals was common in longline sets, but the number of organisms per unit effort was very small; indicating fishing to occur on habitats hosting diverse communities but also that longline fishing has not totally eliminated such organisms from fishing grounds. However, longline will mostly impact organisms with a complex morphology having therefore an unbalanced impact on the ecosystem. We found that slow-growing vulnerable species were still common in areas subject to more than 20 years of longlining activity and estimate that one deep-sea bottom trawl will have a similar impact to 296-1,719 longlines, depending on the morphological complexity of the impacted species. Given the pronounced differences in the magnitude of disturbances coupled with its selectivity and low fuel consumption (7), we suggest that regulated deep-sea longlining can be an alternative to deep-sea bottom trawling in many parts of the world's oceans and can help achieving sustainability of deep-sea fisheries.

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GEAR DEVELOPMENT 13:25 – 17:20

Keynote: Mitigation options to reduce impact of trawling on benthos

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"Bottom trawling is the far most sensitive fishing method that impacts benthos, by removal as catch, partly damage to the benthos itself and by modification of the habitat as such. Bottom trawling is a globally widespread and diversified fishing method used from very shallow areas and down to 2500 m depth, on all kind of bottom habitats ranging from smooth sandy and muddy to stony and rocky substrates. Options to reduce trawling impact include increased use of off-bottom trawling techniques, to reduce impacted trawling area while towing, to reduce pressure on the bottom habitat of trawl gear components and not least to improve trawl efficiency such that trawling effort to catch the allowed quota is minimized. Increased use of fishing methods with less benthos impact and avoidance of particular sensitive habitats when trawling, is two important additional measures to reduce impact of trawling on benthos.
Successful modification of trawl gears and operational trawling method are reviewed in this presentation, followed by proposals for further development that might reduce bottom habitat impact to an acceptable and sustainable level. Trawl modifications include to switching pelagic trawling which partly can replace bottom trawling when targets are off-bottom, semipelagic trawl rigging where parts of the trawl components have clearance to the bottom and various ground gear concepts that are lighter and have fewer bottom contact points than traditional ground gears. Other options reviewed include the use of navigational equipment that can position the trawl gear with clearance to sensitive habitats and not least to use instruments that can facilitate the control of proper bottom contact without having to use heavy ground gear weights to obtain proper bottom contact. In conclusion the author believe that future trawling can be conducted much smarter than at present with much less bottom impact but still be economical viable.

Reducing seabed impact of trawling: Can off-bottom floating bridles be used to reduce seabed contact and flounder bycatch in shrimp and haddock trawls?

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Bottom-tendering mobile fishing gears, including otter trawls, may alter physical structure and biological composition of the seabed, and damage to benthic organisms through their interaction with the substrate. Reducing seabed contact area of the gear will reduce such impact. This paper will review recent advances in gear designs and fishing operations that are intended to reduce seabed impact of fishing gears while maintaining capture efficiency for target species. Alternative fishing gear rigging with less or no seabed contact such as pelagic or semi-pelagic trawls, or trawls with floating bridles may be used instead of traditional heavily gears in some fisheries where herding of target species by sandclouds and bridles is less critical or not desired. This representation reports two research projects where synthetic floating sweep/bridles were used instead of steel wires or rubber-encased ground cables in a shrimp trawl and a haddock trawl in the northeastern US. The use of synthetic floating bridles reduced trawl contacted areas by as much as two-thirds, reduced bycatch flounders and skates, while maintained catch of targeted northern shrimp (Pandalus borealis) and haddock (Melanogrammus aeglefinus). The paper illustrates on how new and innovative fishing gear designs may be used with positive environmental consequences without compromising in catch efficiency.

Gear modifications to a shrimp trawl to reduce seabed impacts in the Atlantic Canada inshore shrimp fishery

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"This study investigated whether modifications to the ground gear of a shrimp bottom trawl can reduce seabed contact area while not compromising catch rates and body size of shrimp, or increasing bycatch of non-targeted species. The ground gear of trawls can have detrimental impacts to structurally complex seabed ecosystems. As a result, bottom trawling fisheries are facing increasing restrictions, area closures, and bans in many regions around the world which all proves very challenging to the fishing industry. Canada is one of the world's leading producers of coldwater shrimp, particularly northern shrimp (*Pandalus borealis*) and bottom trawling is currently the only economical means to harvest this species to meet market demand.

In this study, the ground gear of an experimental trawl was modified to have a 48% reduction in seabed contact area compared to the ground gear of a standard shrimp trawl. Results of comparative at-sea fishing trials of both the experimental and standard trawls demonstrated that catch rates and size of shrimp were comparable between both trawls, however the experimental trawl captured a greater abundance of non-target species. Evidence of mud caked on the experimental trawl ground gear and presence of mud in the catch suggested that the experimental trawl possibly dug into the seabed for several fishing tows. While the experimental ground gear holds promise, modifications are recommended in order to improve performance.

Do semi-demersal trawls catch cod? A comparison of a semi-demersal and demersal trawl, and how density/visibility may play a role.

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The gadoid trawl fishery in the Barents sea utilizes demersal trawls to capture cod, however this results in unwanted trawling impacts to the seabed. Research efforts have focused on the design of lower impact trawls to minimize seabed impacts. One method to reduce seabed impact is to raise part/all of the trawl off of the seabed. However, this can potentially reduce the capture efficiency of demersal species such as cod. To test the catching efficiency of semi-demersal trawls compared to traditional demersal trawls, alternate haul comparisons were carried out in the Barents Sea in October 2012 (high density/low visibility) and 2013 (low density/high visibility). The demersal trawl was rigged with the doors on and approximately 10m off the seabed. A 300kg weight was placed on each side of the front part of the footgear when the doors were off the seabed to obtain consistent bottom contact of the footgear. The semi-demersal trawl resulted in a third of the contact with the seabed than the demersal trawl (35m verses 110m swept area). In the high density and low visibility area the difference in catches were low (semi-demersal trawl caught on average 45% of the total comparison catch), while in the low density and high visibility area, the efficiency of the demersal trawl out-performed the semi-demersal trawl by 2:1. Observations of the entrance pattern using a scanning sonar saw a difference in the two years, indicating fish may switch to a hearing stimuli in low visibility or high densities. This study indicates that high densities are needed in order to maintain the same capture efficiency. Future experiments should focus on maintaining the swept area of a trawl while reducing the number of contact points along the trawl wires (i.e., bobbins along the sweeps to slightly lift the groundgear), to herd cod.

Keywords: semi-demersal trawl, cod, fish behaviour, herding

Performance and seabed impact of new fishing gears alternative to boat seine fisheries

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Ligurian Sea commercial fishery is mainly represented by the small-scale coastal fishery, operated basically with traditional fishing gears as boat seine. Since June 2010, EC Regulation 1967/2006 identified boat seine as a towed gear, leading to this fishing gear the same restrictions applied to bottom trawls. These restrictions have effectively crippled boat seines fishery, as this fishery is operated at short distance from the coast, shallow waters and by very small mesh size net. Considering the existing difficulties to obtain local management plans for this fishery, in this study alternative fishing gears have been assessed and experimented at sea. An experimental surrounding net without purse line and particular fish pots have been compared to the traditional fishing gear in terms of performance and physical seabed impact. Boat seine has been the most efficient fishing gear in catch quantities (estimated in kilograms per hour) with an average of 70 kg/h, significantly higher than that obtained with the experimental gears, ranging from 8 (purse seine) to 18 kg/h (fish pots). Catch Comparison analysis have shown how the traditional fishing gear was also the most efficient gear regardless of species captured, resulting however, less selective. The experimental purse seine was more species-selective and the most abundant catch has been recorded for the saddled seabream (*Oblada melanura*), a mid-water living species. The fish pots were highly selective, mainly targeting eel species with low commercial value as Mediterranean moray (*Muraena helena*) and the European conger (*Conger conger*). Physical impact on the seabed has been monitored by underwater video observations which showed furrows left by leadline of boat seine on sandy bottoms. Regarding the impact on *Posidonia* mats, the boat seine leadline lightly brush meadows, even if seagrass tufts were frequently observed on board after hauling operations. On the other hand, experimental purse seine showed no physical impact on the seabed, because of positive buoyancy of the gear did not allow leadline to touch the bottom. Physical impact of fish pots on the sea bed was also negligible.

Keywords: Boat seine; Surrounding nets without purse line; Fish pot; Seabed impact; Ligurian Sea.

Instantaneous and physical changes to the benthic ecosystem caused by fishing activity

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Beam trawling causes physical disruption to the seafloor through physical contact of the gear components on the sediment and the resuspension of sediment into the water column in the turbulent wake of the gear. Recently Dutch beam trawlers have replaced tickler chains by electrodes as alternative stimulation for catching flatfish. It is claimed that benthic impacts are reduced. Here we report on trials in a medium sand fishing ground to compare the physical impact of a conventional 4m commercial tickler chain beam trawl with that of the new commercial "Delmeco" pulse trawl. We use a Kongsberg EM2040 multibeam echo sounder (MBES) to measure the extent to which the beam trawls modify the topography of the substrate and a particle size analyser (LISST 100X) to measure the concentration and particle size distribution of the sediment mobilized into the water column. MBES measurements reveal that the disturbed sediment in the trawl track was on average located at a centimetre deeper after trawling of the conventional beam trawl than after pulse trawling. Particle size distributions of the sediment plumes were measured at 25m, 45m and 65m behind the gear and did not reveal any differences in concentrations between the two trawls. Whereas the empirical data serve comparative purposes, their lack of predictive capacity limits extrapolation to fleet level. Finite element (FE) models have shown to overcome this for otter trawls by predicting the penetration depth and sediment displacement associated with each gear component in different sediment types. In this study, FE models were developed for the conventional tickler chain beam trawl and the pulse trawl. Predictions were validated by results obtained during sea trials. As such, this study attempts to provide the basis for future predictions of physical impacts of beam trawling and its technical advances on a larger spatial scale.

Keywords: beam trawling, modelling, physical impact, pulse, sea trials

High-resolution mapping of European fishing pressure on the benthic habitats

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Mapping and monitoring of pressure from fishery on the marine benthic environment is necessary to support an ecosystem approach to fisheries management (EAFM). In many cases this need is not reflected in official fisheries statistics and logbooks, where focus typically is on catch rather than effort. Consequently, most logbook information is not well suited for quantitative estimation of seafloor impact (swept area and impact severity) of the different gears and trips. We present a method to overcome this information deficiency of official statistics and develop high-resolution large-scale maps of benthic fishing pressure covering the EU, Norwegian and Turkish waters. First individual logbook observations from 13 countries were assigned to 17 different functional gear groups (métiers) based on target species and gear type information. Secondly, relationships between gear width and vessel size (e.g. trawl door spread and vessel kW) for each métier were used to assign quantitative information of bottom contact to each logbook trip by translating vessel size information into measures of gear size. Thirdly the extended logbook data was merged with high-resolution activity data (VMS) and gear width estimates were assigned to individual interpolated vessel tracks based on VMS data. The outcome was European wide high-resolution fishing intensity maps (total yearly swept area within grid cells of 1*1 minutes longitude and latitude) for 2010, 2011 and 2012. Finally the high-resolution fishing pressure maps were overlaid with existing marine habitat maps to identify areas of potential ecosystem service conflicts.

Keywords: benthic fishing pressure, high-resolution mapping, VMS, logbook data, gear type, habitat maps

Acknowledgements: The above described work has been funded through the EU-FP7 project 'BENTHIS'

The MSC's Consequence Spatial Analysis: A risk-based approach for assessing habitat impacts

Effects of seabed protection measures; total or partial fishing gear modification and technical conservation measures.

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Current best practice fisheries management requires a comprehensive ecosystem based understanding of the short, medium and long term impacts and effects of bottom fishing practices for sustainable exploitation. Moreover, there exists a complex interaction between gear type, habitat, the degree of natural disturbance as well as a specific response between biotic groups or taxa. There is a need for an up to date and comprehensive review of bottom fishing impacts on the benthos considering: new publications in the scientific literature since the last review; the increased availability of effort data such as vessel monitoring system (VMS) data and an increase in the amount of seabed habitat mapping data, since the last review. The up-to-date global systematic review and meta-analysis presented here will be used to underpin best practice in fisheries management as part of the "Trawling best practices" group led by Ray Hilborn, Mike Kaiser and Simon Jennings. The aim of this systematic review is to assemble a comprehensive database on the impacts of bottom fishing on benthic biota from primary published and grey literature. Meta-analysis includes investigation into the effects of different gear types and different habitats (as well as the gear x habitat interaction), on the response of marine benthos to bottom fishing impacts using a mixed effects model.

THURSDAY 19 th EFFECTS OF FISHING ON BENTHIC FAUNA

EFFECTS ON SOFT BOTTOM COMMUNITIES 09:45 – 12:20

Keynote: Effects of towed bottom fishing gear on benthic biota: current knowledge and future research priorities

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The impact of towed bottom fishing gear on the seabed is a ubiquitous source of human distance to global benthic ecosystems. This disturbance occurs against a background of natural disturbance regimes that vary with the environmental context at each location. Similarly, the variety of different fishing methods used mean that each potential gear-type x habitat interaction could lead to different outcomes and recovery trajectories for the impacted benthic community. This complexity has spawned considerable research effort focused on experimental manipulations of fishing impact leading to >120 published studies to date. These individual specific studies can be synthesised using systematic review and meta-analysis to derive general predictions about the response of benthos to different gear types in different environmental settings. Validation of these predictions has been undertaken using small-scale controlled experiments and larger-scale comparative studies undertaken at the scale of commercial fleets. In general both approaches support the earlier inferences derived from experimental manipulations. Moving forward from this solid baseline of understanding, current policy needs demand that the science community consider more closely the impacts of fishing on the provision of ecosystem processes such as nutrient cycling that are closely coupled with the benthos and microbial community within sediments. Key gaps in our knowledge relate to limitations in the extent of our knowledge of fishing impacts for some habitat types and the functional relationship between key benthic descriptors and ecosystem processes.

Ecological significant effects of bottom trawling revealed by functional trait analysis of macrobenthic communities

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Bottom trawling causes chronic and widespread disturbance to the seabed in shelf seas. Benthic fauna may be impacted directly or indirectly by this disturbance as the passage of trawls may cause immediate mortality or displacement, change sediment structure and geochemistry and/or affect the abundance of predators and competitors.
We used an experimental approach to investigate the effects of bottom trawling on the taxonomic and functional (i.e. trait) diversity and community structure of macrobenthic infauna (>1mm) on real fishing grounds. Gridded Vessel Monitoring System (VMS) data and modelled seabed sediment maps were used to identify two sites, one in the Eastern English Channel and one in the Outer Thames that exhibited similar disturbance regimes (fishing effort gradient) and substrate type.
A set of predictive variables which included fishing effort and substrate characteristics, were calculated and a mean relative absolute error (MRAE) statistic used to assess their performance in predicting the observed variability in the taxonomic structure of benthic communities as well as their trait makeup.
Differences in sedimentary parameters, including sediment group, silt (%), and organic carbon content, rather than fishing pressure, were the predominant factors driving the observed variability in the taxonomic composition of assemblages, suggesting that the levels of fishing disturbance at the study sites may have been insufficient to cause marked community changes against a background of natural variability.
In contrast results from the biological traits analysis revealed several highly significant correlations between fishing effort and the prevalence of certain traits. Increased fishing pressure correlated with a trend towards smaller-sized species, a decrease in the number of long-lived species, an increase in species with exoskeletons (gastropod shells) and an increase in subsurface deposit feeders which, in turn, was related to an increase in burrowing species. Many of the observed functional changes were linked ecologically to known effects of bottom trawling on other ecosystem components. The results suggest that using only taxonomic analyses to infer the effects of bottom trawling on biota omits key functional attributes that need to be considered when assessing the ecological significance of subtle changes in community composition.

Indirect effects of otter trawling on the condition and trophic level of Nephrops and flatfish in the Kattegat

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The fishing gear used in bottom trawl fisheries cause mortality of benthic invertebrates and this can decrease the long-term availability of prey to exploited fish species by reducing the abundance of benthic invertebrates. Alternatively, low trawling levels could increase food production for species that feed on small invertebrates that are released from competition with large invertebrates by trawling. Both outcomes may have consequences for biodiversity, the food-web and the sustainability of fisheries. We assessed the impact of bottom trawling on the food availability of fish by comparing the condition (as weight-at-length) and trophic level of the fish Pleuronectes platessa, *Limanda limanda*, *Hippoglossoides platessoides* and the crustacean *Nephrops norvegicus* in an area with strong variation in commercial otter-trawling effort owing to the presence of MPAs with different levels of protection in the Kattegat (Sweden and Denmark). The results show that the abundance and body size of *Nephrops* was much higher in the fully closed areas, whereas that of the flatfish was less affected. The condition and trophic level for *Nephrops* were highest on intensively trawled areas suggesting that trawling reduces competition and increases food availability for *Nephrops*. In contrast, the condition of the flatfish species was the highest at low levels of trawling. This study therefore suggests that high effort levels of bottom trawling have a negative effect on the prey availability and thus on the condition of some of the target species, but not others, and that low levels of trawling might positively affect food availability for some flatfish species. Alternatively, flatfishes might avoid areas with high densities of large *Nephrops*.

Fishing effects on distribution and trophic guild structure of the benthic assemblages in the South of Portugal (NE Atlantic)

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During the last 60 years, otter trawling targeting Norway lobster (*Nephrops norvegicus*), has occurred on a continuous base in the Southwest coast of Portugal (Western Iberian Margin). The area includes fishing grounds with different levels of impact (from no fishing to intense trawling and fixed nets). Over time, fishing pressure has probably induced significant changes in the benthic assemblages from the area, but the extent of those changes are unknown. Within the framework of the project IMPACT (Universidade do Algarve) via a Eurofleets cruise, this study aimed to investigate the impact of continued trawling on benthic macrofaunal assemblages from deep muddy grounds by comparing towed (Area 1, two stations; Area 3, two stations) and untowed (Area 2, three stations) stations regarding their biodiversity, density, biomass, trophic structure, life style and body size spectra. The multivariate analysis supported a significant difference between Fished and Non-fished areas, with nonlinear results regarding the biodiversity (number of families, H', EF(n)), density and biomass in towed and untowed zones. Overall Fished zones showed a decrease in the heterogeneity of biodiversity, density and biomass as clear changes on the trophic structure, life style and body size spectra. In fact, these three last traits seemed to be the best indicators of change in the benthic assemblages. Nevertheless, the interpretation of the observed taxonomic and trophic structure of the assemblages is complex and must take into account sources of variability and habitat heterogeneities in the study area. Overall this study provides new knowledge on the biodiversity and structure of benthic assemblages from the upper slope of the Portuguese continental margin, with relevance for the understanding and assessment of bottom trawling impact on marine ecosystems.

Fishing impacts on benthic-pelagic coupling: the scaling up of ecological functioning experiments

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'Ecosystem' functions such as primary production and nutrient recycling are often inferred from small scale experimentation without testing the validity of extrapolation across scales. In 2004, we initiated experiments to understand relationships between ecosystem functioning and the densities of *Echinocardium cordatum*, a key benthic bioturbator, because of the susceptibility of these sediment-dwelling urchins to benthic trawl fishing disturbance and their influence on sediment characteristics and benthic-pelagic coupling. Increased densities of burrowing urchins, which are consumers of microphytobenthos (MPB), counter-intuitively increased rates of MPB primary production in shallow coastal sediments. The increased availability of limited inorganic nutrients (e.g., ammonium released from sediments due to urchin excretion and bioturbation) was our hypothesized explanation. We assessed the scalability of these findings by (1) measuring ammonium efflux and benthic primary production at 5 coastal sites in northeast New Zealand, (2) assessing the MPB response to long-term manipulations of urchin density in consecutive years, and (3) examining relationships between urchin density and MPB abundance on 14 occasions (8 sites, muddy and coarse sands, different years and seasons). Evidence for a positive effect of *Echinocardium* on MPB was demonstrated in short term flux chamber experiments, and this translated to longer term positive effects of *Echinocardium* on MPB abundance in one of the two manipulative experiments. The strength of the *Echinocardium* effect on MPB is scalable, and apparently depends on the balance of positive and negative ecological interactions mediated by factors such as habitat type (stronger in muddy vs coarser sands) and light availability at the seabed (which is the ultimate determinant of MPB production). Thus, it appears that our findings based on relatively short-term incubations (3-4 hr) in small chambers (0.25 m^2) can be scaled up to larger scales (km, months) and used to understand the implications of trawl fishing on marine ecosystem functioning.

Community consequences of bottom trawl fisheries in demersal food webs

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Bottom trawls are a globally used fishing gear that physically disturb the seabed and kill non-target organisms, including those that are food for the targeted fish species. There are indications that ensuing changes to the benthic invertebrate community may increase the availability of food and promote growth and even fisheries yield of target fish species. If and how this occurs is the subject of ongoing debate, with evidence both in favour and against. We model the effects of trawling on a simple ecosystem of benthivorous fish and two food populations (benthos), susceptible and resistant to trawling. We show that the ecosystem response to trawling depends on whether the abundance of benthos is top-down or bottom-up controlled. Fishing may result in higher fish abundance, higher (maximum sustainable) yield and increased persistence of fish when the benthos which is the best quality fish food is also more resistant to trawling. These positive effects occur in bottom-up controlled systems and systems with limited impact of fish feeding on benthos, resembling bottom-up control. Fishing leads to lower yields and fish persistence in all configurations where susceptible benthos are more profitable prey. Our results highlight the importance of mechanistic ecosystem knowledge as a requirement for successful management.

Keywords: bottom trawl fishery; bottom-up control; ecosystem-based fishery management; marine soft-bottom community; maximum sustainable yield; top-down control

Benthic habitats of the West Greenland shelf: What is the impact of shrimp trawling?

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The shrimp trawl fishery is a major contributor to the economy of Greenland, and has been in operation since the 1930s. The fishery has applied for Marine Stewardship Council (MSC) certification, but needs to demonstrate both sustainability of stocks and that there are no significant damaging impacts on the environment. As part of this process we have been asked independently to document, map and examine the benthic habitats of the West Greenland continental shelf and assess the impact of trawling activities on their diversity and structure. We present results from three years of camera surveys (2011-2013) conducted aboard M/T Paamiut, alongside 10 years of historical surveys dating from 1976-1985. These images document a wide variety of benthic fauna and complex habitats including the presence of potentially vulnerable marine ecosystems. We compare community composition and diversity to fishing effort of shrimp trawlers to assess whether there are detectable impacts of the fishery. Environmental conditions such as depth, temperature and currents are considered to determine which factors best explain observed patterns. Currently the scientific support of the MSC certification process is performed either by institutional researchers or commercial consultancies. Guidelines detailing what this research should accomplish are interpreted in different ways. Direct observations of the target habitats, conducted over prolonged time period, is an ideal approach.

EFFECTS ON MIXED BOTTOM COMMUNITIES 13:25 – 17:45

Keynote: The impacts of deep-sea fisheries: their effects on the megabenthos, and lessons for sustainability

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In recent decades deep-sea trawl fisheries have developed on the upper continental slope and offshore seamounts in many parts of the world's oceans. Major commercial fisheries occur, or have occurred, for species like orange roughy, oreos, cardinalfish, grenadiers and alfonsino, but most deep-sea stocks have shown strong and rapid declines.

However, as well as concerns about the sustainability of the fisheries, the impact of fishing on deep-sea habitats has become a major issue. These fisheries often use heavy bottom trawl gear, and this can cause severe damage to benthic communities. A review of published literature, as well as results from specific studies on seamounts off New Zealand and Australia, show that most megabenthos is removed, potentially causing the loss of biogenic habitat from large areas. Some taxa have natural resilience due to their size, shape and structure, and some can survive in natural refuges inaccessible to trawls. However, the dominant mega-faunal components of deep-sea systems, such as corals and sponges, are highly vulnerable. This is especially the case for sessile fauna on seamount features, where there is both a high proportion of hard substrate and favourable environmental conditions, yet also concentrated fishing effort. Many deep-sea invertebrates are long-lived and have slow growth rates, and consequently low productivity. The overall resilience of deep-sea communities is low and even following complete closure of seamounts to fishing, benthic assemblages show no sign of recovery in the short term.

The low tolerance of many deep-sea benthic communities to human disturbance has important implications for management of deep-sea ecosystems. In order to balance exploitation and conservation, elements of spatial management are required, with closed areas to protect biodiversity and deep-sea ecosystem productivity, as well as open areas for sustainable fisheries.

Effects of trawling on sessile megafauna and evaluation of the efficacy of management strategies

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A series of related research projects over 15 years assessed the impact rates on sessile megafauna of bottom trawling for prawns on the Great Barrier Reef shelf; monitored their subsequent recovery rates and measured natural dynamics; mapped the distribution of seabed habitats and megabenthos species; and integrated these results with spatiotemporal fishery effort data together with industry management in a dynamic modelling framework to estimate the regional scale time-series of status for megafaunal species. By simulating trawl impact and recovery on the predicted species distributions, based on the empirical estimates of rates and recorded trawl effort distribution and intensity, the model estimated the regional scale cumulative changes due to trawling. By simulating management, the model also evaluated the expected outcomes for sessile megabenthos sustainability as a result of the major interventions implemented over a ~10 year period, including closures, effort reductions and protected areas. The presentation will report direct impact rates and cumulative changes, temporal trends in trawling footprint, and effects of management and conservation.

Trawling impact on megabenthos and sediment in the Barents Sea: use of satellite vessel monitoring and video

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Bottom-trawl fisheries expand into deeper habitats and high latitude ecosystems but few documentations of impact in these areas exists. The ecological importance of habitat forming megafauna and their vulnerability to fisheries is acknowledged but studies on effects from fisheries are few. This study presents an investigation of chronic effects of otter-trawl fishery on substratum and megabenthos in the southern Barents Sea, at 50-400 meters depth. In total 154 video-transects were inspected for trawl marks, substratum composition, and megabenthos (> 2 cm). Yearly mean number of recorded trawling vessels (hourly VMS-records) with in a 2 km radius of the video station was used as proxy for fisheries intensity (FI). Density of trawl marks and megafauna composition was compared with FI using linear regression, generalized linear model and ordination. Abundance of trawl marks was not directly related to FI but reflected substratum softness. Megafauna density and diversity decreased significantly with increased FI and effects was indicated even for low FIs 2-3 recorded trawling vessels per year. On hard bottom and sand megafauna density was < 40 individuals per 100 m2 and diversity < 30 taxa per video where more than 15 trawling vessels were recorded yearly. Particularly vulnerable were the sponges: *Antho dichotoma, Craniella zetlandica*, and *Phakellia*/*Axinella* while scavenging large gastropods and some asteroids increased with FI. Redfish showed a negative relationship to FI, while cod showed a positive relation. These results are discussed in relation to the descriptors “Biological diversity” and “Seafloor integrity” in the EU Marine strategic framework directive (MSFD).

Keywords: Megabenthos, fishing pressure, Video transects, Management, Barents Sea, trawling impact, mega fauna, sponges, trawl marks, resilience, MSFD, VMS

The Bottom Line on Bottom Trawling: A Review of the Scientific Literature

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The scientific literature documenting impacts of bottom trawls on marine benthic communities was collated and investigated for common trends and patterns. We examined a total of 224 papers published in the peer-reviewed literature. Each study was characterized in the following ways: where it was conducted; the type of bottom habitat in the study area; the type of bottom gear used; the target species of the fishery in the area; whether the study was a comparative observation of fished versus unfished areas or involved experimental trawling of an area; and what were the conclusions regarding habitat impact. Of the 224 papers, 179 represented studies conducted in shallow bays or on the continental shelf and 45 in the deep-sea, either along the continental slope or on seamounts. Most of the studies were conducted in the North Atlantic or the SW Pacific, with a few taking place in the NE Pacific, SW Atlantic, and Indian Oceans. Substrates examined were primarily soft sediments on the continental shelf but dealt with rocky and sandy bottoms on deep slopes and seamounts. Whether experiments or comparative observations, virtually all studies documented reduced species diversity and habitat complexity in areas that had been trawled versus those that had not. In the deep sea, hard substrates were very heavily modified with very little epifauna present in the trawled areas. In areas where the results were more equivocal, as one study pointed out, that result could have been because there was a long term history of trawling in the area and it was unknown whether the study plots had been affected.

Keywords: trawling, impacts, science, review

Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing

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1. The Ecosystem Approach to Fisheries requires that managers take account of the environmental impacts of fishing. Towed bottom-fishing gears disturb seabed habitats and cause mortality of benthic invertebrates. Measurements of recovery rates of marine habitats after fishing disturbance can provide insight into spatial variations in resilience and may be used to assess the sustainability of these fishing impacts and inform the development of appropriate management strategies.
2. To measure recovery on real fishing grounds at fishery- and management- relevant scales we measured the post-disturbance recovery rates of epifaunal marine benthic communities on coarse and hard substrata across >4000 km² of seabed where the patchy distribution of bottom fishing in space and time creates a mosaic of habitat patches at different stages of recovery.
3. The history of fishing events at each location was described using satellite vessel monitoring system (VMS) data. Recovery rates were extrapolated from the relationship between time since the last fishing event and abundance of epifaunal benthic invertebrates with life history traits that are expected to make them sensitive to fishing.
4. Recovery of abundance of all species and functional groups (medium-large size, medium to long life span, low mobility and suspension feeding species) was estimated to take 10 years, with faster recovery in areas with faster tidal currents.
5. The recovery of large species and species with high body flexibility was faster when conspecifics were abundant within a radius of 6 km suggesting an important role for maintaining a source of recruits to repopulate impacted areas.
6. Synthesis and applications: We used a new method to show that multiple site-specific recovery trajectories can be used to estimate the recovery rate of benthic communities and to describe spatial differences in sensitivity to fishing. Bottom fishing in areas that facilitate fast recovery will minimise overall fishing impacts, while a pattern of fishing that leaves unfished patches of seabed will enhance recovery rates of benthos in fished areas. We conclude that management plans which limit bottom trawls and dredge fisheries to more resilient areas and maintain unfished patches in these areas will minimise the collective impacts of a given amount of fishing effort on seabed habitats.

Indicator species of the vulnerable marine ecosystems in the Barents Sea

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Barents Sea is the area of extremely active bottom trawl fishery. Large sessile and slow-moving species-edificators are the most vulnerable to bottom trawling, their abundant population builds up so called Vulnerable Marine Ecosystems (VMEs). According to the classification of NAFO and NEAFC, abundant population of certain species of colonial corals and sponges refer to indicators of the VMEs. At present 137 species of sponges and 45 species of anthozoans inhabit the Barents Sea, among which 41 species of sponges and 9 species of colonial corals can be classified as indicators of the VMEs. According to the ecosystem survey conducted by PINRO and IMR in the period 2005-2013, catches of sponges over 300 kg were found in the south-western part of the Barents Sea shelf (up to 5 t/nmi) and in the north-eastern area of the continental slope (up to 4 t/nmi). Large specimens of the *Geodia* sponges form the dense populations in these areas. Most of the anthozoan species from the given VMEs list were observed on the Barents Sea shelf singularly and in small quantities. Exception applies to the sea pen *Umbellula incrinus* forming dense population in the north-eastern part of the Barents Sea in the western slope of the Saint Anna Trough. Catches of the *U. incrinus* up to 135 kg/nmi were observed in this area. Populations of the sea pen Funiculina quadrigularis were observed in the upper part of the bathyal slope (around 500 m) in area of the Frantz Joseph Land. Also fragments of skeletons belonging to the colonies of Gorgonaria (sea fans) were found in trawling in this area. Thus most of VMEs in the Barents Sea are located in far northern areas outside of the active fishery, except the south-western part of the sea where dense populations of sponges were observed.

Quantitative risk assessment of benthos & bycatch sustainability in a tropical shelf trawl fishery

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Indicators of trawl exposure were developed for habitats, assemblages and >800 species of bycatch and benthos, on the Great Barrier Reef shelf, by analysing their spatial distributions in relation to management zones, overlap with trawl grounds, and the intensity of trawl effort — and estimating the proportion of their distributions exposed to trawling in 2005. Exposure to trawl intensity as a swept-coverage was a more sensitive indicator than exposure to trawled grounds or exposure as permitted by management zones. Most habitats, assemblages and species had low exposure to trawl effort. For species, the proportion of populations caught annually (exploitation rate) was estimated by using the exposure estimates with relative catch rates. Few species had high estimated exploitation rates. A quantitative indicator of absolute sustainability was estimated using available natural mortality rates to calculate the proportion of fishing mortality at maximum sustainable yield (FMSY) and assess against three reference points: a limit reference point (1.0×FMSY), conservative reference point (0.8×FMSY) and a second conservative reference point (0.6×FMSY). Few species exceeded these reference points. The assessment was repeated for 2009 after a decreasing trend in trawl effort; a comparison of these results will be presented. Uncertainties in the approach will also be discussed.

An approach to link changes in benthic community structure with the delivery of ecosystem services in trawling grounds

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Species interactions and their biological traits determine the function of benthic communities and hence the delivery of ecosystem services. Trawling activities modify the benthic community structure, which might imply alteration of species interactions, traits composition and indirectly the ecosystem function (Bremner, 2008). In order to investigate these patterns in trawled ecosystems, we studied epifaunal functionality in 13 sites from 6 different soft bottom areas across the Mediterranean which were subjected to different levels of fishing effort. Fourteen biological traits were assigned to epifaunal species and based on these traits 17 Ecosystem Service Providers (ESP) were designed. These ESPs were characterised by traits related with five key ecosystem functions in the study areas and each type contributed qualitatively differently to functional performance. For example, the ESP "high bioturbators" were large subsurface bioturbators highly contributing to nutrient cycling, i.e. a regulating ecosystem service. Abundance and biomass of species assigned to the same ESP were summed and effects of environmental variables, such as fishing disturbance, sediment granulometry, temperature, depth, etc. were assessed through General Additive Models in order to search for environmental effects on functional processes. Fishing effort and sediment had significant effects on most organism types (Fig. 1), and these effects were slightly different for abundance and for biomass estimates, highlighting the importance of the chosen metric in assessing function performance and ultimately the delivery of ecosystem services.

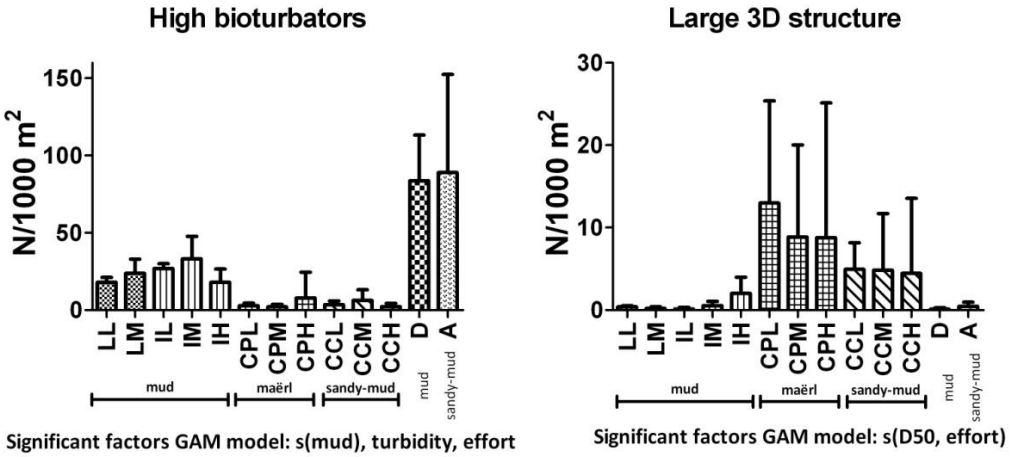

Figure 1. Abundance variability among sites of two different ESP

Bremner, J. (2008). Species' traits and ecological functioning in marine conservation and management. Journal of Experimental Marine Biology and Ecology, 366(1-2), 37–47. doi:10.1016/j.jembe.2008.07.007

Keywords: Biological traits, Ecosystem function, Ecosystem services, Mediterranean, Trawling

POSTER ABSTRACTS NUMBERDE IN PRESENTED ORDER

1. Development of indicators of ecological and community change

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Fisheries discards generate a major food source for scavenging seabirds and have been shown to significantly affect seabird ecology. Seabirds scavenge mainly on specific types of discards. Roundfish for instance are more easily swallowed than benthic invertebrates with protrusions. This implies that the amount of discards that becomes available to other marine scavengers, notably benthic communities, substantially depends on seabird consumption. Given that discard composition varies greatly amongst fisheries and spatio-temporal factors, the provision of edible discards shows great variability in space and time. So far, most studies estimated the consumption of discards by seabirds over vast areas such as the North Sea. Local effects were generally levelled off. This study developed an approach whereby the finest spatial and temporal resolution was determined for discard and seabird distribution in a single region, i.e. the Bay of Biscay (ICES Division VIIIa/b). The French fisheries that contributed the major part of discards in this area in 2009-2011 were included, namely fish bottom trawlers, *Nephrops* trawlers, gill netters, longliners and pelagic fisheries. The attraction of scavenging seabirds to fishing vessels was assessed by the seabird scavenging index, relating seabird densities to the number of ship followers. Attraction was highest for large gulls in April to September, followed by northern gannets during the rest of the year. Discard consumption rates of ship followers were estimated through an experimental trial on-board the RV Thalassa. Data gaps were resolved with estimates from literature, which served as a validation of our experimental estimates as well. Northern gannets consumed the highest proportions of discards with a strong preference for roundfish. The mechanistic model applied in this study highlights that food subsidies to benthic communities follow a spatio-temporal pattern. Our understanding of these patterns is a key aspect in the improvement of the management of discards and benthic habitats.

Keywords: benthic effects, discard consumption, food subsidies, seabirds, spatial effects

2. Fishing impacts on benthic ecosystems: Evidence requirements for effective fisheries management in Marine Protected Areas (MPAs)

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As a statutory adviser to the Government, Natural England is responsible for providing evidence-based advice on the potential impacts of fishing activities on habitats and species – for which MPAs have been, or will potentially be, designated (~25% of inshore waters). There is a wealth of research on the physical and ecological impacts of the most damaging fishing activities (e.g. scallop dredging) on habitats/species considered to be most sensitive (e.g. reef, seagrass, Maërl). Natural England have been working with UK regulators (Inshore Fisheries and Conservation Authorities (IFCA) and the Marine Management Organisation (MMO) to provide evidence based conservation advice and develop management measures for these high risk interactions in UK inshore waters. The focus has now shifted to the lower risk interactions to ensure the UK MPA network is effectively managed by 2016. However, the limited evidence base on which to inform management needs for less sensitive habitats (e.g. sandbanks) or less damaging activities (e.g. potting) still poses significant challenge. Determining thresholds at which a fishing activity will result in an unacceptable level of modification, damage, or loss therefore remains an elusive task. These thresholds would enable the managers to make an informed decision around maintaining or reducing activity levels at or to an acceptable limit. In the absence of a sound evidence-base to inform such practically implementable advice and decision-making, Natural England and the fisheries regulators face a challenging balancing act between over-application of the precautionary principle – potentially leading to complete prohibition of all activity and possible unnecessary loss of fishermen's livelihoods – and utilising adaptive (essentially experimental) management and monitoring approaches in an attempt to address the uncertainties over time. The latter approach could be adopted with a view to tailor the restrictions as required by the emerging evidence, but could potentially leave protected features at risk of damage in the meantime.

3. Mapping inshore fishing activity using aerial, land and vessel based sighting information Start

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Information on the distribution and intensity of inshore fishing activity is needed, both to inform marine spatial planning and to assess fisheries interactions with the environment and other industries. Even though fishing vessels under15 metres (overall length) account for 98.4% (2011 value) by number of the European fleet, information on inshore fishing activity in Europe is very limited as there is no statutory satellite monitoring of smaller vessels (<15 m length before 2012, < 12 m thereafter). Here, we develop, present and apply a method which uses sightings-per-unit-effort estimates calculated from fisheries enforcement data to describe the distribution and intensity of inshore fishing activity off the coasts of England and Wales. Fishing activity estimates are presented with an assessment of uncertainty, to account for spatial differences in enforcement activity. The method described is a simple, robust and repeatable way to estimate the distribution and intensity of inshore fishing activity and the outputs complement estimates of offshore fishing activity based on satellite vessel monitoring.

Keywords: fishing activity, inshore, sightings, spatial planning, sustainable management, data

4. The New Zealand management approach to assessing direct benthic impacts from fishing

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Assessing the impact of fisheries is a legislated component of New Zealand's fisheries management. Fishing gear that contacts the seafloor is known to impact upon seafloor biota, particularly for structural biota (e.g. sponges, corals). Impacts will however differ depending on many factors including fishing gear contact frequency and habitat type. Assessing the impacts of fishing over the scale of New Zealand's Exclusive Economic Zone (>4 million km2) requires a complex approach that includes mapping of habitats, trawl footprints and consideration of the impacted biology. Firstly we divide the seafloor into biologically realistic units. For example in the deepwater fisheries, in the absence of detailed habitat mapping the Benthic-Optimised Marine Environment Classification (BOMEC) was used to predict 15 benthic classes based upon both environmental (e.g. temperature, depth) and benthic invertebrate population distribution information. Trawl footprints are then generated over the relevant time periods that reporting allows in different areas around New Zealand. The overlap of this trawl footprint with the relevant habitat classes was then calculated. Analyses have shown levels of overlap between trawling over 20 years and the 15 BOMEC classes in the deepwater fisheries to vary between ~0 and 73%. Acceptable levels of benthic impact upon these habitat classes are a societal/political decision, but should be informed by science about the intensity of trawling and the vulnerability, connectivity and recoverability of the benthos. This presentation will outline relevant findings, ongoing research and areas for improvement in this research.

5. Mapping pressures and impacts on the benthos in the Barents Sea

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Mapping and monitoring of benthic pressure from human activities, including commercial fishing, is necessary to support an ecosystem-based management of marine resources. This enables documenting impact on benthic communities, which can in turn inform the management of those activities and help ensure that marine biodiversity and habitats are not compromised. We have tested the methodology suggested by the MESMA* framework, and created maps of pressures and impacts using GIS data on the distribution of human activities and ecosystem components in the Barents Sea, Norway. This methodology is based on the concept that the total impact on a given ecosystem component (e.g., deep-sea sponges) at a given location depends on the total pressure from all human activities combined, and the sensitivity of that ecosystem component to these pressure categories. First we defined relevant pressures using the MarLIN database (e.g. substratum loss, smothering, suspension of sediment). We then ranked all activities according to how much they accounted for each pressure so as to scale pressures. Experts were consulted to quantify sensitivity of each ecosystem components to the different pressures. Then, for each location (grid cell) we summed over all pressures multiplied by their corresponding sensitivities to create impact maps for benthic communities. The exercise was very informative but the methods need to be developed because the pressure-impact relationship is not based on quantified and scientifically proven causal relations.

*MESMA (Monitoring and Evaluation of Spatially Managed Areas) was an EU-FP7 project that ran from 2009 to 2013.

Keywords: pressure, impact, mapping, MESMA, marine spatial planning

6. Vulnerability of benthic communities to bottom trawling in the Barents Sea

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Benthos is an important part of the marine ecosystem, and trawling activity may have a strong impact on benthos communities through removal of species providing substrate, space and structure to the benthic habitat, refuge from predation, and food and reproductive areas for a wide variety of fishes and invertebrates of all life stages.
All benthic organisms are not equally vulnerable to trawling, and the vulnerability of a benthic community to trawling depends on its species composition and abundances. Sessile, large bodied, stiff, fragile epifauna and habitat forming megafauna species living on the sediment surface are more vulnerable to bottom trawling than mobile, burrowing, small bodied species with a fast retractable and flexible body. In this study, we scored the vulnerability of 354 benthic species in the Barents Sea based on 5 factors: size, habitat, speed, shape and texture. Then, using species composition and abundance data obtained from 391 trawl samples taken in the Barents Sea during the ecosystem survey in summer 2009, we first mapped the distribution of total biomass of benthos organisms. We then mapped the “vulnerability of benthic community to pressure” which integrates information on species composition and species vulnerability. Considered jointly, these two maps reveal areas where (i) the benthic community is abundant and (ii) mostly composed of species sensitive to trawling disturbance. This informative synthesis is of direct relevance for management, as it identifies critical areas where specific management actions may be required for the protection of benthic communities.

7. Fishery Restricted Areas and Marine Protected Areas – is trawling a major pressure and how much of the Mediterranean is protected?

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The ecosystem approach and marine conservation are high on the Mediterranean regional agenda as seen through recent targeted data calls and directives. For the EU Member States, obligations arising from the Habitats Directive (e.g. for the protection of regional priority habitats) and the recent Marine Strategy Framework Directive (e.g. for the achievement of GEnS) are significant additional drivers for mapping the status, as well as the extent and frequency of pressures acting on predominant and sensitive habitats. Within the framework of the DG MARE MEDISEH Mediterranean Sensitive Habitats project and the MAREA Consortium, regional experts have worked together to review and map a) existing marine NATURA 2000 and other MPAs, b) MPA network proposals, and c) Mediterranean Fishery Restricted Areas (FRAs). FRAs include applied EU and national gear specific closures (e.g. for trawl, purse seines) and measures with a spatio-temporal dimension aiming to protect marine species and habitats from fishing activities in the Mediterranean basin. The overarching aim was to relate findings to sensitive and priority Mediterranean habitats and the CBD objective (Aichi target 11) to protect 10% of coastal and marine areas by 2020, with well connected systems of protected areas and other effective area-based conservation measures. Our review highlights the still limited extent and mainly coastal nature of MPAs, the considerably larger extent of FRAs that mainly protect very deep grounds from trawling, and the still limited and geographically patchy efforts to map sensitive and essential fish habitats. In the Mediterranean, where spatial control is the one of the key pillars of an effort-based management system, we discuss the difficulties in accessing national management measures that cover existing fishing gear spatial restrictions in an area with a large variety of species, gears, economies, cultures and languages.

Keywords: Fishery Restricted Areas, trawling, MPAs, spatial controls, Mediterranean

8. Using habitat suitability models to assess the impact of shrimp trawling on the distributions of benthic species

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The continental shelf of West Greenland contains an economically important shrimp trawl fishery. This fishery is under consideration by the Marine Stewardship Council for certification of sustainability. In order to understand the potential impact of the fishery we must first document the habitats of the area and their extent. Comprehensive field surveys can be difficult and expensive, so alternative approaches to estimate distributions of key species or habitats are often required. Habitat suitability modelling is one such approach. Here we use observations of key habitats and species based on bycatch and benthic camera surveys to establish a baseline of distribution. These data are used in combination with environmental conditions such as depth, temperature and current speeds to develop models of habitat suitability, which provide estimates of likely species distributions. Models incorporating fishing effort as a predictor variable were developed to test whether fishing effort has a significant impact on observed species distributions. Anecdotal reports from local fisherman suggest that large habitat-forming species such as Gorgonian corals used to be caught as bycatch in some areas, but are found there no longer. This may be caused by changing environmental conditions or the direct impact of fishing. Species distribution models can tell us whether incorporating fishing effort into predictive variables leads to better predictions of distributions than those based solely on environment conditions. If this is the case then this may be evidence that fishing effort is affecting distributions.

9. Impacts of trawling activity on specific elements of the biotope complex: the sea pen populations off the Northern Sicilian coast (Central Mediterranean Sea)

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Sea pens are well known to create aggregations, fields, especially in homogeneous sandy muddy habitats commonly targeted by trawlers. These fields constitute vulnerable marine ecosystems very sensitive to bottom trawling activities. In fact, the sea pens are sessile animals which, projecting above the sediment surface, are clearly subject to be damaged or uprooted by the passage of trawl. Even though these organisms represent an important portion of megafaunal filter feeders, widely recognised as essential in terms of: habitat complexity increasers, bioturbators, nurseries' areas and refuge providers, their ecology and biology remain still poorly studied in the Mediterranean Sea. The study aims to show the presence of sea pens, in term of biomass, along a gradient of fishing pressure. The spatial and temporal trends of fishing intensity were ascertained post-hoc using the Vessel Monitoring System data analysis. The common sea pen *Pennatula phosphorea* Linnaeus, 1758, the spiny sea pen *Pteroeides spinosum* (Ellis, 1764) and the tall sea pen *Funiculina quadrangularis* (Pallas, 1766) were gathered during experimental trawl surveys conducted along the continental shelf and the upper slope among fishing grounds (non-target fraction incidentally caught by the net). Generally the highest biomass values of the three sea pens species were recorded in proximity to the two Fishery Exclusion Zones, or to the less exploited areas. The obtained results testify the vulnerability of sea pen populations to trawling disturbance and the high presence of these as by-catch fraction usually discarded at sea. The study highlights the importance to monitor this peculiar ecosystem both through fishery dependent data collection and using remote control systems. In a context of Ecosystem-Based Fisheries Management and following the Marine Spatial Planning requirements, the study might provide basic information to the drafting of future management and protection plans, already existing in several countries for the same sea pen species.

Key words: Southern Tyrrhenian Sea; pennatulaceans; VMS data; GIS

10. Impact of otter trawl fishing activity on the feeding behaviour of two benthivorous species *Mullus barbatus barbatus* (L. 1758) and *Lepidotrigla cavillone* (Lacepède, 1801) in the Southern Tyrrhenian Sea

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Trawling activities generate numerous consequences including changes in the ecosystem structure and species interactions. A growing number of studies suggest that changes in the benthic invertebrate communities, generated by trawling, may increase the availability of food and promote growth and, possibly, the fisheries yield of target fish species. Both short-term availability of trawl-damaged prey, and longer-term shifts in benthic prey community composition, could potentially affect feeding opportunities and realised dietary preferences of bottom-feeding (benthivorous) fish. To investigate the effects of otter trawl fishing activity on the feeding behaviour of the red mullet, *Mullus barbatus barbatus*, and the large-scaled gurnard, *Lepidotrigla cavillone*, we compared the feeding intensity, diet composition and diet diversity testing several trophic indices along a gradient of fishing intensity. Fishing intensity was quantified using vessel monitoring system data analysis (VMS). The red mullet was chosen as representing one of the most exploited commercial fish species in the Western Mediterranean basin, instead, the large-scale gurnard represents one of the main targeted species of the demersal fisheries but with no commercial value. The study was carried out along the northern coast of Sicily encompassing the Gulf of Patti, a Fishery Exclusion Zones in which the otter trawling activity has been historically banned. Specimens were collected from 50 to 100m depth on muddy bottoms; comparisons between diets along the fishing intensity gradient were made for a size class from 11 to 15 cm TL for both species. The greatest differences in diet composition and diversity were detected between the specimens from trawled and un-trawled area. Generally the highest feeding intensity was recorded at the EFZ and, an increase of benthic scavenger invertebrates was recorded in more intensively fished areas. The results meet the need to improve our understanding of those ecosystems disturbed by commercial trawling, and adequately protect them. key words: Mullidae, Triglidae, Feeding intensity, Trophic ecology, Trawling disturbance, Fishery Exclusion Zone

11. Impacts on coral reefs from bottom fisheries in the Southern Barents Sea and evidence of recovery

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Fifteen Lophelia reefs from one offshore and two coastal areas off northern Norway were studied with video. Health status of corals (degree of impact, percentage living tissue, and colony size), occurrence of trawlmarks and lost fishing gear, and associated mega and macrofauna, was analyses for 66 video transects. Offshore reefs have been more exposed to bottom trawling than coastal. This is reflected by VMS (Vessel Monitoring System) data, as well as from direct seabed observations. In the coastal areas around 1% of the reefs were impacted, whereas 6%in the offshore. The most visible effect on the reefs was breakage and displacement of coral colonies. At some places there were only scattered small fragments of live corals, an indication that the area was recently trawled. The mean colony height at impacted sites was around half the size at intact sites.The offshore reefs in this study was protected against bottom trawling in 2009, but a general ban against trawling on known coral reefs was established in 1999. Based on the type of lost trawl gear observed and the size of re-growth of colonies combined with assumed growth rates, most of the damage is older than 10 years. Some areas showed signs of possible re-growth with a “carpet” of evenly sized small *Lophelia* colonies. The species richness was about twice as high for intact coral habitats compared to impacted, whereas the abundance of invertebrates was higher on impacted than intact. The high abundance was commonly caused by the actinarian *Protanthea simplex* and unidentified brittlestars. This may indicate that some opportunists can quickly colonize the free space generated by habitat damage.

12. Epibenthic diversity and productivity in shallow Barents Sea bank (Tromsøflaket) – comparing trawled and undisturbed areas

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Shallow banks in the Barents Sea are characterized by strong depth gradients and dynamic physical processes which interact to generate high productivity. Tromsøflaket, located at the southern entrance of the Barents Sea, appears to be similar to other Barents Sea banks as it is also home to rich communities of epifaunal organisms, including long-lived and potentially vulnerable sponges and corals, and is an important spawning area for some species of commercial fish. Due to sampling challenges, however, benthic communities here have not been well-studied in terms of composition or function. In order to determine how this shallow bank functions in the Barents Sea ecosystem, we used a combination of video and trawl/dredge sampling to describe components of the benthic community, and calculate secondary production of dominant epifaunal organisms (including sponges and corals). Several locations on Tromsøflaket were sampled in August 2008 aboard the RV Oceania by means of trawls and dredges in order to collected benthic epifauna. Additionally, the sea bed conditions and epifauna were recorded and photographed using ROV equipped with zoom- and wide-angle video cameras. Organisms collected by dredge were identified to the lowest possible level, measured, and weighed, and on the base of this information, species (or lowest possible taxa) identity observed on the video were confirmed, and biomass was determined using the empirical relationships calculated from dredge samples. Secondary production values were also calculated using the multiple regression model of Brey (2001). Since tracks from trawling have been registered at all of the surveyed fields, epifaunal biodiversity and production were compared between trawled and undisturbed sites. Altogether almost 50 epibenthic taxa were identified and sponges were an important part of the surveyed benthic communities. There were differences in diversity and production among sampling areas, mainly related to the sediment type and intensity of trawling activities. The most diverse (34 taxa) and productive (2.6 gC m^{-2} y^{-1}) was Alke Nord area, characterized by gravel, crushed stones and soft sediment bottom while Alke Sor area, characterized by gravel and sand/mud bottom, had lower diversity and production of only 0.07 gC m^{-2} y^{-1}. 26 taxa and production of 0.78 gC m^{-2} y^{-1} were noted in Gamma area, characterized by relatively heterogeneous sea bed, with muddy and sandy soft bottom areas, and elements of hard bottom areas, mainly consisting of crushed stones. Trawling had some negative influence in some surveyed areas on the epibenthic fauna, and on sponge communities in particular. The results are also contrasted with results from a similar project conducted on Svalbard Bank in 2009.

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13. Discard trends of bottom trawl fishery along the Samsun Shelf Area of the Turkish Black Sea Coast

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Trawl fishery is the major fishing method in the Turkish Black Sea. One of the most important problems with bottom trawl fishery is by-catch and discard in the Samsun Shelf Region. A large proportion of the catch on board is sent back to the sea after the removal of the target species. The thrown part of this yield creates great losses by two ways; the first is bio-economical and the second is ecological. Considering the fishery economy; the fisherman is not satisfied with the catch per unit effort. And reputedly, this unsatisfaction induces illegal fishing methods. The littoral zone of the Black Sea including Samsun shelf area (SSA) discharged by two big rivers Kızılırmak and Yeşilırmak was treated with intense trawling for a long periods. The destroying effect of bottom trawling on commercial and non-commercial benthic and demersal fauna has always been a matter of debate in Turkey. It is aimed to identify how to gain the basic fishery data in our country and to improve a basic monitoring programme with a methodology peculiar to conditions of Turkey. This study aimed to determine the basic fishery parameters for the target species of bottom trawling in the Samsun Shelf Region, to estimate the rate of landing and discard using data from a seasonally open commercial trawl fishery in the Turkish Black littoral, over a period of about last four years; 2010, 2011, 2012 and 2013. The period between the mid of April and the mid of September is the closed season for trawl fishery in Turkish Black Sea. The study area includes the near shore water of three miles where the fishermen operate illegally. Seasonal samplings were carried out within the depth range of 30 and 120 m by using meshes varying between 400 and 900 and 40 mm diamond mesh size in codend in traditional bottom trawl. The monthly samplings were realized by two kind of vessels in size > 18 m (12-17 m) and <18 m (18-32 m) which are common for Black Sea trawl fishery fleet. In each sampling period, the catches were recorded on board from at least two commercial vessels representing the study area. Fieldwork included estimating the total catch and the relative fractions per haul and recording the faunal composition as standardized for per haul duration or per day. The rate of discard for two target species of bottom trawl fishery was estimated 17%, 24%, 35% and 40% for red mullet in 2010, 2011, 2012 and 2013, respectively. The rates were as 31%, 49%, 51% and 54% for whiting in these four successive years, respectively. The relatively low discard rate of red mullet may be due to its relatively high market price and almost whole of the catch is marketable. The reasons for the heavy pressure on red mullet and whiting populations were the low selectivity of meshes and the long operation durations. The high exploitation rate generally causes the catch of relatively small and immature individuals. Though the rate of discarded catch in weight is lower than the marketed catch, as it is considered in number of individual the discarded portion is larger than the market. The age composition of red mullet was composed of 0 and 1 age groups and of whiting are 0, 1 and 2 age groups. The discard rates in relation to the marketed catch seemed to be an indicator of the exploitation state of the demersal species. The differences between the discarded and marketed fractions were high at the beginning of the fishing season (autumn) and winter, but they are getting decrease in winter and by the end of the fishing season (spring). These changes could be attributed to alternative discarding strategies for certain species in response to increased cumulative fishing mortality. According to results obtained from whiting and red mullet fishery, the factors specifying the targeted catch and discard trends can be outlined as; yearly fluctuations in population, fishing period, depth of operation, accurate/ideal time closures, net design and implementations of selective mesh size, duration of operation, market effects (supply-demand relations). Though the rate of discard by weight seems less than of landings, the rate of discard by individual number is significantly high and cause great bio-economic losses.

14. By-catch in a tropical shrimp fishery: are TEDs effective in excluding rays?

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Tropical shrimp trawling generally produces significant amounts of by-catch, including endangered marine species. To avoid incidental capture of marine turtles, Turtle Excluder Devices (TEDs) are now widespread. TEDs are effective in avoiding turtle by-catch and theoretically exclude all organisms large enough not to pass in between the TED's vertical bars. Rays (Batoidea; Chondrichthyes: Elasmobranchii) are particular in this respect, because even large sized individuals might pass through a TED as a result of their flattened body shape. Several ray species are listed as threatened and they are very vulnerable to fishing mortality due to their life-history characteristics. By-catch of rays in tropical shrimp trawling is thus highly undesirable. The current study assessed the potential of TEDs in reducing ray by-catch in the seabob shrimp (*Xiphopenaeus kroyeri*) fishery in Suriname. Sixty-five catch-comparison hauls were conducted, comparing ray by-catch in trawls fitted with TEDs (test-net) and without TEDs (control-net). Overall, catch rate of rays was reduced by 36% in the test-net. Rays caught in the test-net were on average 21% smaller than those in the control-net meaning larger ones were indeed able to escape, while smaller individuals passed through the TED, ending up in the codend. As such, TEDs were most efficient in excluding *Dasyatis geijskesi*, the largest ray species, while no significant reduction was observed for the small-sized *Urotrygon microphalmum*. A GLMM was fitted to calculate exclusion-at-size for the two most abundant species. Exclusion of *Dasyatis guttata* reached 100% for individuals over 50cm (body width), while *Gymnura micrura* only approached 80% exclusion even for the largest individuals (70cm).

Keywords: seabob shrimp, trawling, Turtle Excluder Device, by-catch, rays

15. Discarding Characteristics of Trawl Fishery in Aegean Sea

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This study aimed to determine the by-catch species of trawl fishery and their seasonal distribution in the middle Aegean Sea which is one of the most important demersal fisheries zones in the Mediterranean. The surveys were conducted by a commercial trawler and seasonal samplings were carried out 88-450 m depth by using 1200 meshes modified demersal trawl net. Finally, 110 species were included in the total catch composition and 72 of those were always discarded regardless of their sizes. Moreover it was observed that 38 species took place in the commercial catch composition. Furthermore discard ratio was calculated as 27.8%. Group based analyse of by-catch composition showed that bony fishes (Osteichthyes) dominated the by-catch composition with a percentage of 52% and followed by cartilogenus fishes (Chondrichthyes) (27%), crustaceans and cephalopods (9%) and other groups (3%), respectively. *Scyliorhinus canicula, Lampanyctus crocodilus, Hoplostethus mediterraneus, Chlorophytalmus agassizi, Parapenaeus longirostris, Argentina sphyraena* dominated the discard composition of Aegean Sea trawl fishery. Summer samplings were carried out in international waters of Aegean Sea representing the least exploited area of the study because of current legislations. Therefore results obtained from summer samplings differed from the other seasons. Seasonal catch per unit effort (CPUE) values for commercial catch was statistically significant.

16. Trawl-turtle interaction: a pilot study in the Adriatic sea

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Incidental catch represent the major threats to the survival and to the general decline of loggerhead turtle (*Caretta caretta*) in the Mediterranean Sea. More than 60.000 turtles are estimated to be caught annually as a result of fishing practices, mortality rates ranging from 10 percent to 50 percent of individuals caught. Bottom trawl is considered among different fishing gears as one of major sources of impact on sea turtle populations especially in the Gulf of Gabés, northern Adriatic Sea, South Turkey and Egypt, where the continental shelf is large and turtles in demersal phase are regularly found, also in winter time. Four adult-sized Loggerhead turtles, captured incidentally by bottom trawls in the Central-Northern Adriatic Sea were kept in captivity in rescue centres, tagged with satellite transmitters and released when completely rehabilitated. Bottom trawl tracks data obtained from vessel monitoring system (VMS) were analysed by VMSbase R suite to define the area with intensive effort. The turtle tracks were finally overlapped with the fishing areas most impacted in order to identify habitats of distribution of C. caretta that deserve special attention for the potential impact on the marine turtle population in the Central-Northern Adriatic Sea.

17. Coral by-catch in shrimp bottom trawl surveys in West Greenland waters (2010 – 2012)

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There have been zoological expeditions in Greenland waters since the 19th century documenting the sea life, including cold water corals. Coral trees (vernacular name for *Paragorgia arborea*) are mentioned as early as 1741 in the first natural history book about Greenland (Egede 1741). Due to the many expeditions and opportunistic collections by Greenlandic fisheries surveys, the species composition of West Greenlandic corals is fairly well known (Tendal and Heiner 2002), although observations of species new to Greenland are still being made (Jørgensen et al. 2013, Tendal et al. 2013). The earlier collections of corals were not systematic and distribution patterns are poorly understood. Thus, more recently the Greenland Institute of Natural Resources started to collect cold water corals in a more systematic way to document the occurrence of corals in the bottom trawls made for the annual shrimp stock assessments. A total of 628 hauls were conducted covering an area of 17.1 km2. Sixty-six hauls contained corals and of these 13 hauls had two or more species of corals. Only two hauls contained more than one kilo of coral, which were in each case comprised of one only species. The identification of the corals is based on Kenchington et al. (2009). The identification of many specimens has further been verified by Ole Tendal (Zoological Museum, Copenhagen) on the basis of frozen samples.

Few corals, mainly soft corals (Alcyonacea) and sea pens (Pennatulacea), were found in the depth range within which shrimp are fished. This first analysis suggests that dense fields of Sea Pens and patches of octocorals occur in the depth range and within the area covered by the shrimp fishery.

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18. Using small meshed collecting bags on trawls to quantify trawls seabed disturbance of aquatic organisms

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NGOs have become active at uncovering and illustrating potential problems of the environmental and ecosystem impacts of fishing activities, especially demersal trawling, exerting considerable pressure on decision makers and subsequently, fisheries. The environmental impact of demersal trawling activities has been documented by collecting samples before and after the fishing process or by comparing areas of different fishing intensity. These investigations are expensive and labor demanding and are inappropriate for documenting effects of smaller technological changes aimed at reducing trawling impact on commercial fishing grounds. In this study we develop and test small-meshed collecting bags designed to retain juvenile fish and benthic megafauna. The collecting bags are mounted in the wings and body of the trawl. The catches in the collection bags provide information of the species and size of organisms that encounter the trawl, but are not retained by it. Such catch represents an unaccounted trawl disturbance of the organisms associated with the seabed. In combination with knowledge on behavior and habitat utilization of these organisms, their presence can be used to indicate differences in the mechanical effect, such as penetration depth of the ground gear of different trawl designs. Collecting bags are also mounted to the different sections of the trawl in pairs, one to collect the organisms that pass through the trawl meshes and one to collect the population. Standard selectivity analyses thereby allow us to estimate the size-selection of the caught organisms in different parts of the trawl.

19. Dropper Chain Footgear: A new approach to environmentally friendly inshore Northern shrimp fishery in Newfoundland and Labrador, Canada.

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Northern Shrimp (*Pandalus borealis*) are considered a very important component of the Canadian fishing industry, particularly in Atlantic Canada where over 700 fishing vessels are engaged in the fishery. While concern over the impacts of bottom trawls is widespread due to their potential for adverse ecological impacts, the development of a low impact trawl footgear for the Northern shrimp fishery is advisable. The purpose of this study is to develop a modified footgear (i.e., dropper chains) which is expected to reduce bycatch and seabed contact area of a traditional rockhopper footgear shrimp trawl used in Newfoundland and Labrador, Canada. A 1:8 scale model with a dropper chain footgear was first constructed and tested in a flume tank at the Fisheries and Marine Institute of Memorial University of Newfoundland in January 2012. Comparative at-sea fishing trials using the alternate tow method were carried-out onboard the commercial vessel Nautical Legend on the northeast coast of Newfoundland in August 2013 to compare catch rates of shrimp and bycatch. Further flume tank tests and comparative fishing experiments are scheduled for 2014. This presentation and paper will discuss results to date and relevance to the northern shrimp industry.

20. Resuspension of sediments by prawn trawling: Temporal variation and distribution in turbidity in relation to protected core reef areas

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Trawling the seafloor resuspend sediments due to the penetration of the otterboards, groundgear and the drag created by the trawl gear when towed over the bottom. Increased sediment levels and redistribution of particles is of concern to conservation of biodiversity since some organisms, e.g. suspension feeders like sponges and corals are vulnerable to increased levels of sediment particles in the water column. We investigated the vertical distribution of turbidity and show that it varies in relation to trawling and periods when trawling is stopped. The study was done in the Kosterhavet National park on the Swedish west-coast. Prawn trawling is allowed here in zones of the park, and voluntarily regulated with Friday to Sunday closures. We show that background levels are increased at the depths of trawling during periods of activity by prawn fishers in the area. Using CTD, current meter and turbidity sensors moored for 2 weeks, we show that the turbidity increase also in an adjacent core protection zone for sensitive reef habitats. The results provide useful input to the management considering the impact of trawling on the seafloor, and in particular insights into the efficiency of buffer zones for protection of sensitive habitats when the concern is sediment resuspension.

Keywords: sediment, resuspension, benthic fauna, marine protected area, trawling, turbidity, benthic-pelagic coupling

21. Electrotrawling for brown shrimp: short-term effects on various adult fish species

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Pulse trawling is used to a growing extent in the North Sea and considered as one of the most promising alternatives to increase the sustainability of demersal trawl fisheries. The pulse trawl for brown shrimp selectively induces a startle response in shrimp. Consequently other benthic organisms are left untouched and can escape underneath a hovering trawl. Extensive testing of this device revealed a lower discard rate up to 65% and a reduction of seabed contact by 80%. Nevertheless, effects of suchlike electric field on marine organisms are largely unknown. To fill this gap in knowledge that could enable to revalue the standing ban on electric fishing in the EU, plaice, sole, cod, bull-rout, pogge and dragonet, 20 individuals per species, were exposed under laboratory conditions for five seconds to this heterogeneous shrimp pulse. Until 30 minutes after exposure behavioral reactions were recorded. After 24 hours all fish were macroscopically inspected, subsequently necropsied and samples for histological analysis from the gills, liver, spleen, kidney, intestine, heart and dorsal muscle were taken. To investigate possible spinal injuries also X-rays were taken of each fish. No mortality nor spinal injury were observed in all investigated species. Behavioral reactions were variable and species dependent. Round fish species, cod in particular, were mostly excited during and after exposure, displaying more active and fast swimming patterns. The flatfish species showed only minor behavioral reactions, although 15% of the exposed soles swam upwards during exposure. Mild multifocal petechial hemorrhages on the tail were equally present in exposed and control individuals of flatfish. In five exposed animals, two plaices, two soles and one bull-rout, a focal small hemorrhage between muscle fibers was found, which was never encountered in control animals.

Acknowledgments: The research leading to these results has received funding and support from the Agency for Innovation by Science and Technology in Flanders (IWT), The European fisheries fund (EFF) and the The Norwegian Institute of Food, Fisheries and Aquaculture Research (NOFIMA).

Keywords: Pulse fishing, impact, short-term, adult fish

22. Electrotrawling for brown shrimp: impact on embryonated eggs, larvae and young juveniles of cod (*Gadus morhua*)

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The application of electric pulse fields in fishing gear is considered to be one of the most promising alternatives to increase the sustainability of demersal trawl fisheries. The pulse trawl for brown shrimp selectively induces a startle response in the shrimps. Other benthic organisms are left untouched and can escape underneath a hovering trawl. Extensive testing of this device in the North Sea revealed a lower discard rate up to 65%, and a reduction of seabed contact by 80%. In addition, exposure and survival experiments seem to indicate that this pulse has no immediate harmful effect on different adult fish and invertebrates. However, the impact on other marine life stages is still unknown. As brown shrimp are caught in coastal zones and estuaries, important nurseries or spawning areas for a wide range of marine species, electrofishing over these grounds could therefore harm embryos, larvae and juveniles. Because cod is considered as a vulnerable species to electrical pulses, experiments were carried out on different developmental stages of this round fish. Three stages of embryonated eggs, four larval stages and one juvenile stage were exposed to a homogeneous worst-case electrical field of 150V.m-1 during five seconds. Survival, injury and development were inspected until two weeks after metamorphosis. No significant survival or hatching differences could be established between control and exposed groups in the egg stages. Also in the juvenile stage, no difference in mortality was observed, as well as in the larvae exposed in the endogenous, mixed and metamorphosing stage. Although in the exogenous larval stage, there was a significant difference with the exposed animals exhibiting a higher mortality rate. To elucidate these findings, a morphological analysis on sampled larvae is on-going focussing on yolk resorption, size and possible deformations.

Keywords: Pulse fishing, life stages, survival, development

Acknowledgments: The research leading to these results has received funding and support from the Agency for Innovation by Science and Technology in Flanders (IWT), The European fisheries fund (EFF) and the The Norwegian Institute of Food, Fisheries and Aquaculture Research (NOFIMA).

23. Danish Seine – An Environmental Friendly Fishing Method?

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Today, extensive research is devoted to assess the effects of demersal trawling on the marine ecosystem, but only few of such studies considered the Danish seine. Danish seines and bottom trawls are grouped together in the legislation. Trawling is more common and responsible for the major part of the total landings where the seine fleet and catches are decreasing. The Danish seine is a specific type of encircling net to catch demersal fish. It is characterized by moderate fuel consumption and no use of heavy weights or doors, probably resulting in a relatively gentle bottom-contact and low interactions with the seabed compared to e.g. traditional trawling. However, the assumptions on the more environmental friendliness in seining are not sufficiently addressed.
The present study aims at increasing the knowledge on Danish seining including its effect on the benthic ecosystem. The study starts with a comparison of existing catch data for Danish seines and trawls and continues with several substudies:

Detailed description of all stages of the seining process to get a basis for the following investigations
Selectivity trials to support existing data, whereby both economically valuable and economically non-valuable species will be regarded
Estimation of potential interactions of the gear with the sea bottom
Assessment of survival chance of discarded animals
Observation of fish behavior during capture process
Combination of all single parts to provide an overall picture of effects of the Danish seine fishery on the marine environment

This study may contribute to increase understanding the catching process in the seine fishery and the gears interaction with seabed during the different stages of the fishing process. The outcome of such studies will be highly relevant in future discussions on the impacts Danish seining may has on the marine environment and the faunal diversity and to maintain viable fisheries in the future.

Keywords: Danish Seine, demersal fishery, trawling, selectivity, discards, impacts on benthic ecosystem, impact on faunal biodiversity

24. Effects of non-commercial fish and invertebrates discards on the benthic ecosystem in the Danish small-scale set nets fisheries

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Although the fleet has reduced since the mid-1990s, the Danish gill- and trammel nets fleet is still of importance and is likely to gain increasing interest in the coming years in response to economic issues (rising fuel prices) and political context (strong support for environmentally friendly practices from consumers and environmental organizations). However, very little information is available on the effects of gillnets on habitats as well as on fish or invertebrates.

In a context of a progressive implementation of a discard ban within the European Union fisheries, additional information on ecosystem effect of set nets discards is required. Beyond direct effect on the living resource, discarding can have indirect ecological effects. Indeed, dead or fatally damaged discarded species can become available as a food resource for seabed-living invertebrates, or be decomposed and recycled to the food web. These ecological interactions can be of importance for the surrounding ecosystem, especially regarding small-scale fisheries which take place in relatively shallow waters. Previous studies on gill- or trammel nets discards mostly focus either on commercially valuable fish, or on incidentally caught rare or protected species.

Data collected by observers aboard commercial fishing vessels gives a first insight into the discards of non-commercial fish and invertebrates in the Danish small-scale set nets fisheries.

Keywords: gillnet, trammel net, discard, non-commercial fish, invertebrates, benthic ecosystem

25. Fishing gears: immediate and delayed mortality of the discard fraction (North-western Adriatic Sea)

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The discard fraction is difficult to quantify, leading to greatly underestimate its consequences. Death of individuals may occur on the deck (immediate mortality), or following their release (delayed mortality). It can be direct, as a result of damages and / or physiological stress, or indirect, due to decreased chances of survival. The aim of this study was to evaluate the impact of the main fishing gears, operating in the Chioggia's fleet, on discarded fauna. In particular, both passive (gillnets, traps, longlines) and active (hydraulic dredges, bottom-otter trawls) gears, operating within 3 nM from the coastline, were considered. Data were collected on board (47 total surveys), without interfering with usual fishing operations. The discard respect to the commercial catch was estimated. Data showed that bottom otter-trawl produced the highest rate of discard compared to total catch (79% on average) and had the highest rate of immediate mortality (above 65% on average). On the other hand, hydraulic dredges showed similar high discard quantities, that greatly decrease (to 38%) when compared to commercial catch. Moreover, dredges presented a relative low immediate mortality (below 24%). All passive gears were characterized by a much lower discard production, even compared to commercial catch (all below 23%), and a relative low immediate mortality (23% - 33%). However, gillnets showed a slightly higher mortality (42%), related to nets cleaning procedures. To investigate the delayed mortality, the vital discard fraction was then classified considering a three-scale index of increasing damage. The active gears showed the highest percentage of wounded individuals (above 35%); among passive gears, gillnets again showed a relatively high percentage of high-damaged organisms (23%). Finally, we performed reflex impairment tests, modified to be realized during on-board sampling, on the most abundant taxa: swim test (for Teleostea), body-flex, leg-flare, chela-closure and eye-retraction (for Decapoda). Wounded individuals showed significantly lower performance in all the tests, proportionally to the severity of injuries suffered. All these results strengthen the importance, in a comparative analysis of the impacts of different fishing gears, of considering not only the biomass of discard produced, but also the conditions of the organisms returned to the sea.

Keywords: fishery impact, reflex impairment test, damage index, benthic fauna

26. Assessment of hydrodynamic performance and impact of otterboards in wind tunnel trials

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We present a methodology for exploiting wind tunnel facilities in otterboard testing. Flume tank tests are expensive and very restrictive in terms of what can be measured and the accuracy they can provide. Instead, wind tunnel tests allow for accurate control of velocity, angle of attack and sideslip, and for precise measurement of forces and moments in all three axes. This information is essential for a full understanding of the way otterboards, especially pelagic- and semipelagic-, but also bottom-doors, behave in real full scale conditions. Assessing and minimizing their impact on the seabed is tightly dependent on knowledge of their hydrodynamic behaviour which flume tank experiments do not provide in full. We exemplify the methodology and compare our wind tunnel measurements with available flume tank results.

27. An outlook of the sieving selection of striped venus clam (*Chamelea gallina*) in the Mediterranean hydraulic dredge fisheries

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The infaunal bivalve striped venus clam (*Chamelea gallina*) is the target of a large fleet of hydraulic dredgers operating in the sandy coastal bottoms of the Northern and Central Adriatic Sea (Mediterranean). Despite the resource is now showing strong signs of depletion and overexploitation relatively little scientific work has been done to assess the selectivity of the hydraulic dredges. Selective process in the hydraulic dredge fisheries mostly occurs on board the vessel during sieving operations rather than at sea while fishing is in progress. We investigated the striped venus clam (*C. gallina*) selectivity occurring during the sieving process on board the hydraulic dredge in the Adriatic Sea fisheries. The sieving tool consists of sequential holed grids made with holes of different diameters that select clams on the basis of their size. This study was undertaken to analyse both the effect of sieve-diameter and the speed of sieving on the clam selectivity. Selectivity was measured using the same approach followed in the covered codend technique taking into account the between-haul variation in selectivity. The results attained in the present study can assist fisheries managers in the revision of current legislation.

28. A science-industry collaboration assessing the impacts of a 100+ year old trawl fishery.

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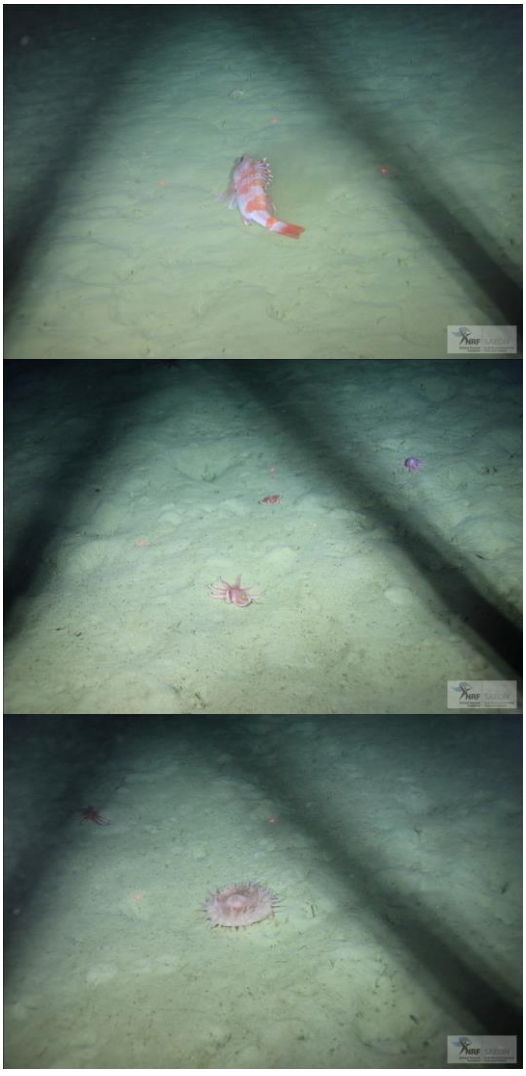
Offshore benthic biodiversity and ecosystem functioning are poorly understood in South Africa. Understanding the impacts of offshore activities, specifically demersal trawling, on these ecosystems is a national research priority. The impacts of demersal fishing have been cited as one of the largest global anthropogenic sources of disturbance to the seabed and its biota but does this apply in the context of the 100+ year-old South African hake (*Merluccius* spp.) trawl fishery? Trawling impacts are known to vary with habitat and trawling practice, necessitating a site specific experimental approach to assess such impacts. The eco-certification initiative of the Marine Stewardship Council has been driving changes in the knowledge base and associated management of South Africa's hake trawl fishery since 2004. Through conditions set during the certification process, the fishery has allocated a 6x15 nm experimental area at depths of up to 510m within the west coast fishing grounds for research on trawl impacts relating specifically to this sector.



The first baseline seabed survey was recently conducted in the experimental area using a towed camera sled and a benthic grab. This survey enabled the first visual verification of South Africa's Southern Benguela shelf habitats using epifaunal data. Species diversity, abundance and distribution were used to characterise the habitats. Subsequent to the baseline survey, a portion of the experimental area was closed to trawling, thereby removing associated impacts and enabling a long-term assessment of potential changes in benthic communities. With baseline conditions now captured, annual surveys will track benthic changes that may occur in the areas closed to trawling permitting comparisons with those areas still open to trawling. This experiment highlights the opportunities for long-term, co-operative research through collaborations between industry and scientists.

Keywords: deep-sea benthic biodiversity, trawl impacts, habitat verification, eco-certification

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