INCISE

INTERNATIONAL NETWORK FOR SUBMARINE CANYON INVESTIGATION AND SCIENTIFIC EXCHANGE

Conference handbook

5th International Symposium

14th - 18th June 2021, University of Gibraltar

The 5th INCISE Symposium is being held as an online event organised by the **University of Gibraltar** and is sponsored by **Technicap** and **Ocean Networks Canada**.

INCISE organisation

Jaime Davies (University of Plymouth)
Veerle Huvenne (NOC, Southampton)

INCISE committee

Rob Hall (University of East Anglia)
Joshu Mountjoy (NIWA)
Peter Harris (GRID-Arendal, Norway)
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Local organising committee

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Welcome to INCISE 2021

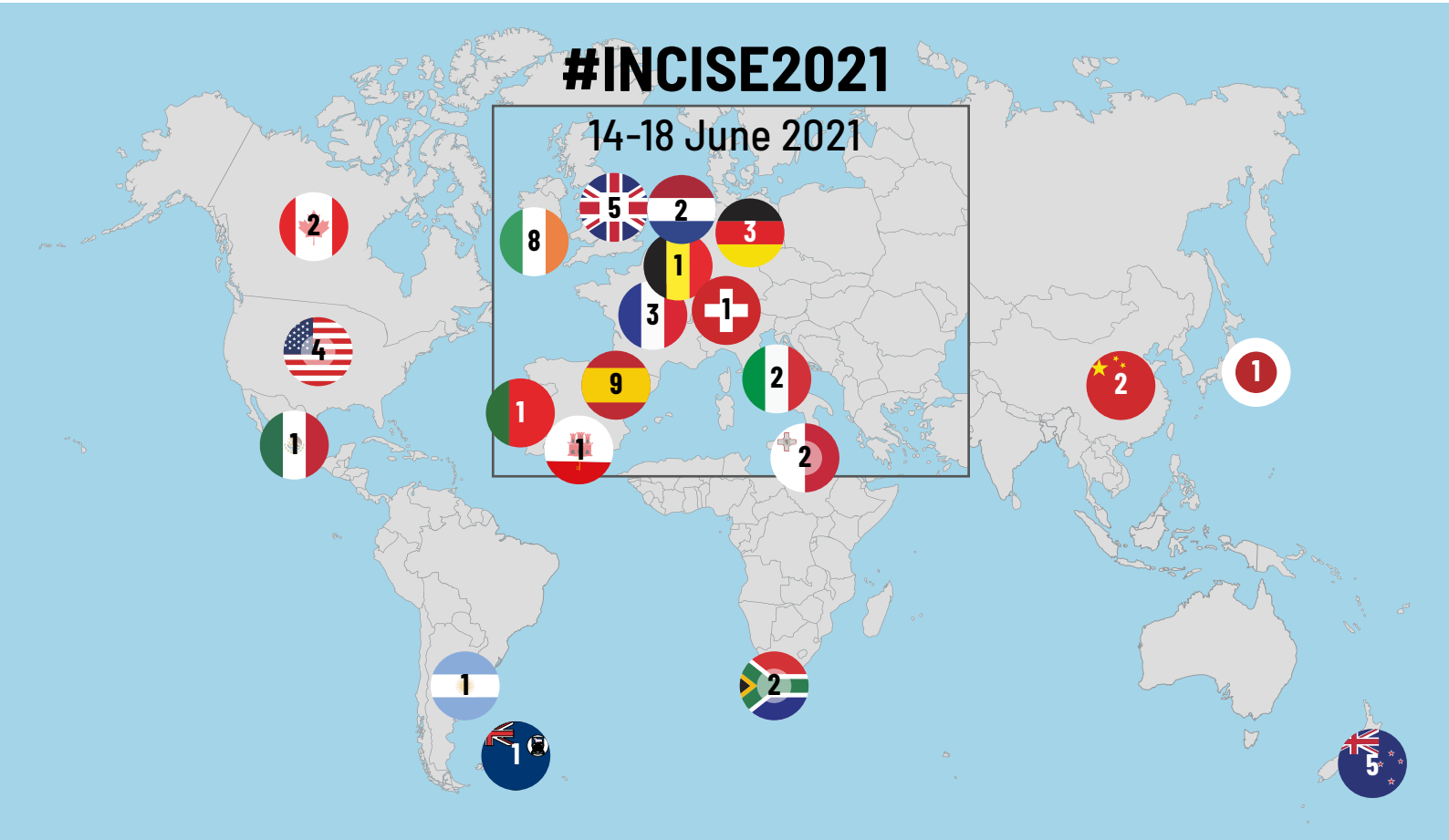
Dear INCISE Network and conference participants,

The University of Gibraltar is proud to host the INCISE 2021 online conference. We wish we could welcome you to Gibraltar, however, against the backdrop of a global pandemic, it is only right that we hold an online conference whilst the fight against Covid continues.

This year's conference is focussing on '**Human connections to the deep sea**' with topics ranging from oceanographic processes in canyons, use of technology, sediment processes, faunal diversity and anthropogenic impacts such as underwater noise, trawling and marine litter. With over 50 presentations from 21 countries delivered by students, Early Career Researchers and Senior Scientists, INCISE 2021 will be an exciting showcase of research on Submarine Canyons.

We look forward to meeting you all and hope you enjoy the conference!

Awantha Dissanayake
Local INCISE Organising Committee



Introduction

Submarine canyons are important features along the world's continental margins. They create heterogeneity in the terrain and provide the main pathway for sediment and pollutant transport from the shelf to the deep sea. Although long known, their study has always been a challenge because of their complicated morphology and extreme terrain.

The main goal of the INCISE network is to create **a platform for the exchange of ideas and research insights** regarding submarine canyons. We do this through several initiatives, including through a regular symposium, organised every other year in different part of the world. We also coordinate a series of working groups focussing on specific questions or topics related to submarine canyons, and creating relevant outputs for science and the wider community. INCISE is a friendly, interdisciplinary group mainly consisting of researchers, yet also reaching out to policy-makers, industry partners, wider stakeholders in the marine environment interested in submarine canyons.

Due to the ongoing pandemic, **the 5th INCISE Conference will now take place online**. Although it is a shame we cannot meet in person, we are looking forward to all the interesting and promising contributions, and hope the talks and posters will stimulate further discussion and research ideas. The online conference is hosted by the **School of Marine and Maritime Science** at the University of Gibraltar, the event includes a series of talks, workshop and working group discussion sessions.

The INCISE 2021 conference will encompass:
Submarine Canyons Workshop – 9 and 10 June 2021
INCISE 2021 Conference – 14 to 18 June 2021
Public Engagement event – 16 June 2021

Given the current uncertainties and worldwide travel disruption caused by the pandemic, INCISE2021 will be an online conference. To avoid online fatigue and to give everybody around the world the chance to follow at least part of the conference during reasonable daylight hours, we plan to split the conference into manageable blocks, with **two sessions of 2.5 hours per day**. Despite INCISE2021 being an online meeting, it has been planned to allow incorporation of elements of in-person meeting. The conference format will consist of two 2.5-hour sessions per day over the course of the week. Each session will consist of **oral presentations** (12 minutes with 3 minutes for questions) and a **poster session**.

To ensure maximum visibility of posters, submitted posters will be available to download a week prior to the meeting from the INCISE website, and participants will have 3 minutes to give a summary of their posters. During the conference there will be a dedicated breakout room running to facilitate open discussion between participants. This will open after the conference session closes to facilitate discussion and will close 15 minutes after the conference session.

INCISE has had working groups since 2012 and they have produced many outputs (see INCISE website for more details). During the conference there will be two dedicated working group sessions i.e. an AM and a PM slot.

Keynote speakers

Dr Joshu Mountjoy

Monday 14 June 9:25 CEST (GMT+2)

Resetting the system. Scale, impact and implications of submarine canyon flushing.

Marine Geologist, Wellington, New Zealand

Joshu Mountjoy is a Marine Geoscientist and Programme Leader for SSIF Programme Marine Physical Processes and Resources. Joshu completed his PhD jointly with the University of Canterbury and NIWA and then took up a scientist position at NIWA. He has a broad interest in seafloor geomorphology spanning submarine canyons, landslides, active tectonics, gas and gas hydrate systems and lakes. Joshu is passionate about science communication and believes scientists are beholden to communicate what they do as broadly as possible.

He recently featured in the National Geographic show Drain the Oceans https://www.imdb.com/title/tt8680494/.

When not being a scientist Joshu enjoys mountain biking, surfing, skiing, cooking and tinkering in his shed.

Dr Martina Pierdomenico

Tuesday 15 June 16:40 CEST (GMT+2)

The key role of canyons in funnelling litter to the deep sea.

Researcher at the Institute for the Study of Anthropic Impact and Sustainability in the Marine Environment of the Italian National Research Council (CNR-IAS)

Martina Pierdomenico's research focuses on the study of seafloor habitats, with a specific emphasis on the interplay between geological and sedimentary processes, anthropogenic stressors and biological communities in complex environments such as submarine canyons, volcanic islands, coralligenous build-up and cold-water coral mounds. Her multidisciplinary approach combines a wide range of methodologies.

These include geo-acoustic data, ROV surveys, sediment samples and oceanographic measurements, to obtain a comprehensive characterization of seafloor environment to provide understanding for the sustainable management and conservation of marine ecosystems located from the continental shelf to the deep-sea areas.

Dr Kostas Kiriakoulakis

Friday 18 June 9:10 CEST (GMT+2)

Organic matter in submarine canyons: Investigating its biogeochemical and ecological role.

Senior Lecturer in biogeochemistry, Liverpool

Kostas Kiriakoulakis is a Senior Lecturer in Environmental Sciences in the School of Natural Sciences and Psychology. His research expertise is in biogeochemistry specialising in the origin, transformations and fate of organic matter in natural systems. Kostas teaches mainly on the BSc Geography and Wildlife Conservation Programmes offered by the School of Natural Sciences and Psychology. Research interests are in:

- Carbon cycling
- Biological carbon pump
- Biogeochemical impact and ecological significance of underwater topographies (e.g. submarine canyons)
- Marine ecosystem functioning
- Cold water corals
- Chemical proxies in environmental change
- Marine pollution (microplastics)
- Biogeochemistry of salt marshes

Public engagement event

Wednesday 16 June 13:00 – 14:00 CEST (GMT+2)

Astounded by the Grand Canyon in Arizona, USA? Now imagine canyons in the deep sea! Submarine canyons are important geological features of the sea and they act as a link between shallow water environments and the deep sea. We are exploiting the marine environment for many resources such as oil, gas and fisheries to name but a few. Canyons serve as important structures within the marine environment and act as nursery habitats and due to complex currents serve as 'hotspots' for biodiversity and feeding grounds for larger animals such as tuna and cetaceans. In a world's first, the INCISE society is hosting a **global free public engagement event** where you can hear from world's experts on submarine canyons.

Dr Peter Harris

GRID-Arendal, Norway

Peter Harris is a marine geoscientist with 30+ years experience working in marine science and management. Since 2014 Peter has been the Managing Director of UNEP/GRID-Arendal, a foundation based in Norway established to assist developing countries with solving their environmental problems. He has been the leader/co-leader of over 30 research voyages and conducted research on the Great Barrier Reef, the Fly River Delta in Papua New Guinea and on the geological record of Antarctic bottom water formation and ice sheet advance/retreat. Peter has a keen interest in submarine canyons and is a regular attendee of the INCISE meetings. He co-authored the first global synthesis of submarine canyons in 2011 and the first digital global seafloor geomorphic features map (GIS database) of the oceans in 2014. Since 2014 Peter has been the Managing Director of UNEP/GRID-Arendal, a foundation based in Norway established to assist developing countries with solving their environmental problems.

Dr Veerle Huvenne

National Oceanography Centre, UK

Veerle A.I. Huvenne is based at the National Oceanography Centre, Southampton, UK, where she coordinates the Seafloor and Habitat Mapping Team. She was Principal Investigator on the ERC Starting Grant CODEMAP and has >15 years of experience in habitat mapping and sediment dynamics, mainly focussing on complex deep-sea environments such as submarine canyons, cold-water coral settings, hydrothermal vents and seamounts. She has extensive expertise working with new technologies and marine robotic systems such as AUVs and ROVs (Autonomous Underwater Vehicles and Remotely Operated Vehicles) and often works closely with the engineering teams on the development of new sensor or vehicle capabilities.

Dr Jaime Davies

University of Plymouth

Dr Jaime Davies is an associate research fellow at the University of Plymouth with over 10 years' experience as a deep-sea benthic ecologist, acting as lead biologist on several research cruises. Working in the field of conservation, with an interest in the ecology and mapping of vulnerable species/habitats, providing data to government agencies to use for proposing/designating Marine Protected Areas in UK and French waters. With an interest in cold-water corals, Jaime works closely with coral taxonomists and has organised many international cold-water coral identification training workshops. She is a co-founder of the INCISE network, a working group leader of the INCISE conservation working group and editor of a special issue on submarine canyons.

Ivan Hernandez

University of Gibraltar

Ivan recently graduated from the University of Gibraltar having completed an MSc Marine Science and Climate Change. For his dissertation he worked with Dr Jaime Davies, Dr Veerle Huvenne and Dr Awantha Dissanayake on assessing marine litter in submarine canyons. From his body of work he will publish several scientific papers. Ivan recently delivered a workshop on identifying and enumerating marine litter in the deep sea to the current cohort of international MSc Marine Science students.

Programme

Session 1. Monday 14 June AM

All times provided are CEST (GMT+2)

Start	Speaker	Title
9:00	Welcome and housekeeping	
9:10	Welcome address minister	
9:25	**Joshu Mountjoy**	**Resetting the system. Scale, impact and implications of submarine canyon flushing.**
9:55	Coffee break	
10:10	Biwen Wang	Seismic stratigraphy of the Yitong submarine canyons and fan apron system in the lower continental slope to adjacent abyssal plain, northern South China Sea.
10:25	Katherine Maier	A continental margin-scale study of submarine canyon and channel morphology along the South Westland margin, South Island/Te Waipounamu, Aotearoa New Zealand.
10:40	Sally Watson	Tectonic and geomorphic controls on the distribution of submarine landslides: why do landslides cluster within submarine canyons?
10:55	Coffee break	
11:10	Cecilia Cabrera	A 16-year morphobathymetric evolution of Blanes and Cap de Creus submarine canyon heads (NW Mediterranean Sea).
11:15	Lotte Verweider	A first insight into the origin and evolution of the Gollum and Kings channel systems, Porcupine Seabight, NE Atlantic, based on geomorphology and geophysical data.
11:20	Gemma Ecrilla	Onset and sedimentary evolution of the Almanzora-Alias-Garrucha canyon (SW Mediterranean Sea): a complex interplay between geological processes.
11:25	Ivan Hernandez	A case study of marine litter in the Dangaard and Explorer Canyons in The Canyons MCZ, SW Approaches.
11:30	J Sánchez/Gemma Ecrilla	Bedforms and sedimentary processes along the Garrucha and La Linea canyon axis (SW Mediterranean Sea).
11:35	Irene Diez	Capbreton canyon hierarchy (SE Bay of Biscay).

Session 2. Monday 14 June PM

Start	Speaker	Title
16:30	Welcome and housekeeping	
16:40	Kerry Sink	Deep Connections: South African Canyon Research, Literacy and Protection.
16:55	Sinothando Shibe	Deep Forests: the role of canyons in shaping benthic epifaunal communities in South Africa.
17:10	Jill Bourque	Regional comparison of macrofaunal communities in U.S. Atlantic submarine canyons and their relationship to geochemical processes.
17:25	Coffee break	
17:40	Ivane Pairaud	Physics of the Cassidaigne canyon in the NW Mediterranean Sea: modelling and observing strategies.
17:55	Rob Hall	Internal tide dynamics of Whittard Canyon: integrating ocean glider observations and numerical model simulations.
18:10	Karina Ramos Musalem	The impact of initial tracer profile on the exchange and on-shelf distribution of tracers induced by a submarine canyon.
18:25	Coffee break	
18:40	Meri Bilan	Characterization of water masses in Blanes Canyon in relation to biodiverse CWC communities and potential connectivity pathways in the Mediterranean Sea.
18:45	Tabitha Pearman	Internal tides as a structuring factor of faunal patterns in submarine canyons.
18:50	Felix Butschek	Oceanographic Controls on Cold-Water Coral Mounds of the upper Porcupine Bank Canyon.
18:55	Luke O'Reilly	Mapping, Modelling and Monitoring Key Processes & Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro)

Session 3. Tuesday 15 June AM

Start	Speaker	Title
9:00	Welcome and housekeeping	
9:10	Marta Ribo	Large coarse-grained turbidity current sediment waves in Kaikōura Canyon: geomorphological characterisation and classification.
9:25	Ken Ikehara	Possible tsunami-induced sediment transport from coral reef to deep-sea through a submarine canyon at forearc slope of the southern Ryukyu islands, Japan.
9:40	Lewis Bailey	Predicting turbidity current timing and frequency in submarine canyons.
9:55	Coffee break	
10:10	**Sponsor talk - Technicap**	
10:25	Maarten Heijnen	The underappreciated role of land-detached submarine canyons in deep sea sediment transport: New direct monitoring of powerful turbidity currents in the Whittard Canyon.
10:40	Bernard Dennielou	Sediment dispersal in canyon and on adjacent slope: using Bauxite residue (red mud) as artificial tracer (Cassidaigne canyon, Western Mediterranean).
10:55	Coffee break	
11:10	Claudio Lo Iacono	Evidence of human impact on the NW Sicilian Canyons (western Mediterranean): marine litter vs bottom-trawling footprint.
11:30	Ruth Duran Gallego	High-resolution bathymetry of the Blanes Canyon (NW Mediterranean).
11:35	Ruth Duran Gallego	A brief introduction to the TrawledSeas Project: Bottom Trawling as a Driver of Seascape Transformation.

Session 4. Tuesday 15 June PM

Start	Speaker	Title
16:30	Welcome and housekeeping	
16:40	**Martina Pierdomenico**	**The key role of canyons in funnelling litter to the deep sea.**
17:10	Ivan Hernandez	Marine litter in submarine canyons: a systematic review and critical synthesis.
17:25	Coffee break	
17:40	Ellie Jones	Distributions of microplastics and larger anthropogenic debris in Norfolk Canyon, Baltimore Canyon, and the adjacent continental slope (Western North Atlantic Margin, U.S.A.).
17.55	Sarah Paradis	Natural vs. trawling-derived transport of sediment and particulate organic matter in Palamós Canyon, NW Mediterranean.
18:10	Marta Arjona-Camas	Natural vs. trawling-induced water turbidity and sediment transport variability in Palamós Canyon (NW Mediterranean).
18:25	Coffee break	
18:40	**Sponsor poster - Fabio De Leo**	
18:45	Stephanie Byford	Assessing the sensitivity of The Canyons MPA to climate change pressures.
18:55	Alexa Parimbelli	Video analysis: a valuable tool to gather data about deep-sea associations?
18:55	Brenda Doti	An INTERdisciplinary view on Argentine CANYON systems using isopod crustaceans of the Mar del Plata canyon as surrogate.
19:00	Neus Campanya i Llovet	Echinoderm food web in Barkley Canyon (NE Pacific).

Session 5. Wednesday 16 June AM

Start	Speaker	Title
9:00	Welcome and housekeeping	
9:10	Guangfa Zhong	Distribution and origin of benthic plastic litter in the Xishabei submarine canyons of the northwest South China Sea.
9:25	Javier Cerrillo Escoriza	Anthropogenic activity indicators in three shelf-incising submarine canyons in the Alboran Sea: Origins and impacts.
9:40	Martin White/Eoghan Daly	PANiC – Investigating the role of a canyon in anthropogenic noise propagation across the continental margin.
9:55	Coffee break	
10:10	Working group discussions.	

Session 6. Wednesday 16 June PM

Start	Speaker	Title
16:30	Welcome and housekeeping	
16:40	Marie-Claire Fabri	Virtual reality to study deep-sea coral habitats in Lacaze-Duthiers Canyon, from geological settings to individual specimens.
16:55	Pere Puig	High-resolution morphological surveys of canyon-wall benthic habitats in Blanes Canyon (NW Mediterranean).
17:10	Ashley Nicoll	Autonomous landers as a tool for studying nearshore submarine canyon ecology.
17:25	Coffee break	
17:40	Working group discussions	

Session 7. Thursday 17 June AM

Start	Speaker	Title
9:00	Welcome and housekeeping	
9:10	Saskia Brix	Habitat variability and faunal zonation at the Aegir Ridge, a canyon-like structure in the deep Norwegian Sea.
9:25	Declan Morrisey	The diversity of calcaxonian octocorals from the Irish margin.
9:40	Katie Bigham	Time-series imagery shows megafauna resilience to turbidity flow in submarine Kaikōura Canyon (Aotearoa/New Zealand).
9:55	Coffee break	
10:10	Larissa Oliveira	3D Classification of Cold-Water Coral Reefs in the Porcupine Bank Canyon: A Comparison of Classification Techniques for 3D Reconstructions of Cold-Water Coral Reefs and Seabed.
10:25	Luke O'Reilly	Temporal Variability of Cold-water Coral Habitats from the Porcupine Bank Canyon, NE Atlantic.
10:40	John Appah	Health screening of the reef forming scleractinian cold-water corals Lophelia pertusa and Madrepora oculata in a remote submarine canyon on the European continental margin, NE Atlantic.
10:55	Coffee break	
11:10	Working group updates	
11:20	Working group updates	

Session 8. Thursday 17 June PM

Start	Speaker	Title
16:30	Welcome and housekeeping	
16:40	Beatriz Arrese	Morphological characterisation of pockmarks in the surrounding areas of Capbreton canyon.
16:55	Aaron Micallef	Does offshore meteoric groundwater play a role in submarine canyon formation?
17:10	Anne Berhardt	Where and Why Do Submarine Canyons Remain Connected to the Shore During Sea-level Rise? Insights from Global Topographic Analysis and Bayesian Regression.
17:25	Coffee break	
17:40	Marina Dottore Stagna	Formation of giant deep-water canyons in offshore northern Tanzania as a result of Neogene tectonics.
17:55	Stepen Dobbs	Increased frequency of out-of-channel sediment gravity flows are coincident with Late Pleistocene falling sea-level offshore Morro Bay, California.
18:10	Jason Chaytor	Guayanilla Canyon, Offshore Southwest Puerto Rico: An Earthquake Created Canyon System?
18:25	Coffee break	
18:40	Working group updates	
18:50	Working group updates	

Session 9. Friday 18 June AM

Start	Speaker	Title
9:00	Welcome and housekeeping	
9:25	**Kostas Kiriakoulakis**	**Organic matter in submarine canyons: Investigating its biogeochemical and ecological role**
9:40	Scott Nodder	Organic carbon transfer in submarine canyon and deep-sea dispersal systems around Aotearoa New Zealand.
9:55	Coffee break	
10:10	Furu Mienis	Whittard Canyon as pathway and sink for organic carbon.
10:25	Emma Smith	Tracing particulate organic matter pathways in deep-sea ecosystems: Food supply and partitioning in Whittard canyon walls cohabitated by Acesta excavata (Bivalvia: Limidae) and cold water corals (Scleractinia).
11:40	Sofia Ledin	Does the presence of nepheloid layers in the most Eastern Branch of Whittard Canyon influence the bacterial community composition and abundance?
10:55	Coffee break	
11:10	Joshu Mountjoy	INCISE 2023
11:25	Closing remarks	

Programme legend

- Welcome and closing remarks
- Oral presentation
- Poster presentation
- Keynote speaker
- Sponsor talk
- Working group discussions
- Coffee break

Exploring all aspects of submarine canyons

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The University of Victoria's **Ocean Networks Canada** monitors the west and east coasts of Canada and the Arctic to continuously deliver data in real-time for scientific research that helps communities, governments and industry make informed decisions about our future. Using cabled observatories, remote control systems and interactive sensors, and big data management ONC enables evidence-based decision-making on ocean management, disaster mitigation, and environmental protection.

Abstracts

Seismic stratigraphy of the Yitong submarine canyons and fan apron system in the lower continental slope to adjacent abyssal plain, northern South China Sea

Biwen Wang[1], Guangfa Zhong[1], Liaoliang Wang[2], Benduo Zhu[2], Min He[3], Yiqun Guo[2], Huodai Zhang[1,2]

1. State Key Laboratory of Marine Geology, Tongji University, Shanghai, China
2. Guangzhou Marine Geological Survey, Guangzhou, China
3. Research Institute of Shenzhen Branch, CNOOC China Limited, Shenzhen, China

Yitong submarine canyons in the lower continental slope of northern South China Sea feed an apron of submarine fans at the foot of the continental slope and adjacent abyssal plain. Here we used high-resolution multibeam bathymetric data and multichannel seismic profiles to investigate the morphology and seismic stratigraphy of the canyons and fan apron system.

The "Yitong submarine canyons" is the general name of 12 submarine canyons, which are 5.9-53.0 km long and 1.4-11.4 km wide. The average incision depths range from 62 m to 364 m, and the average thalweg slope gradients vary between 1.6° and 4.5°. Most of the canyons are V-shaped on transverse profiles. The submarine fan apron shows a slightly convex-upward morphology. Crescent-shaped features prevail around the canyon heads and on the inter-canyon sedimentary ridges, and they are concave downslope or face towards the thalwegs, which are interpreted as failure scars.

Six seismic sequences were identified, which are dated as Quaternary, Pliocene, upper, middle, lower Miocene and Oligocene by tying to adjacent IODP drilling sites. Based on reflection configuration, amplitude, continuity and external form, we recognized seven types of seismic facies, which are interpreted in terms of depositional elements as shelf-edge delta, creep typed sediment waves, slumps, submarine canyon fillings, submarine fan lobes, debris-flow lobes, and channel-levee complex.

The Yitong canyons are headless and slope-confined. They could begin in the late Miocene or even earlier. Sediment failures are speculated to control the formation and development of the canyons, and the downslope-eroding gravity flows are important for shaping the canyons and forming the submarine fan apron.

This research was funded by the National Natural Science Foundation of China (grant numbers 41876049, 91528304, and 41676029).

A continental margin-scale study of submarine canyon and channel morphology along the South Westland margin, South Island/Te Waipounamu, Aotearoa New Zealand

Katherine L. Maier[1], Helen Neil[1], Alan Orpin[1], Scott D. Nodder[1], Helen Bostock[1,2], Clark Alexander[3]

1. National Institute of Water and Atmospheric Research, Wellington, New Zealand
2. School of Earth and Environmental Sciences, University of Queensland, Australia
3. Skidaway Institute of Oceanography, University of Georgia, USA

Submarine canyon heads located near mouths of high-sediment-yield rivers are conduits for terrestrial sediment and contaminants to enter the deep ocean. Approximately 0.5% of global sediment delivery to the oceans is generated along the western Southern Alps/Kā Tiritiri o te Moana, South Island/Te Waipounamu, Aotearoa New Zealand. Datasets spanning nearly 5 degrees latitude offshore this region compiled over the past 15 years include extensive multibeam bathymetry (25-m grid) and backscatter datasets, multichannel seismic-reflection and chirp sub-bottom profiles, sediment cores, and sedimentary analytical data. Seafloor imaging reveals that large submarine canyon-channel-fan systems extend >500 km from within few km of river mouths in ~50 m water depth, across the flanks of the Challenger Plateau, and into the Tasman Basin, where they deposit terminal lobes in water depths >4600 m. Numerous adjacent canyons trend generally westward.

These canyons comprise the Hokitika-Cook system north of 43.5°S and the Moeraki-Waiatoto system to the south. Distal channel and lobe morphologies appear similar between the northern and southern systems, but canyon morphology differs markedly. The Hokitika-Cook is fed by small tributary channels and displays greater sinuosity, more frequent meander bend cut-offs, smaller channel width and relief, and fewer, smaller canyon wall landslides than the Moeraki-Waiatoto. Differing morphology between the adjacent canyon systems is interpreted as largely driven by channel gradient and the sediment sources during glaciations. The Hokitika-Cook canyon system traverses the relatively low-gradient Challenger Plateau and was likely fed by fluvial systems through the LGM and Holocene.

Conversely, the Moeraki-Waiatoto canyon system crosses the southern extremities of the lower flank of the Challenger Plateau, has overall higher gradient, and appears to have been directly fed by laterally extensive glaciers during the LGM. Canyon and channel confluences include steps between merging channel floors in the Hokitika-Cook but not the Moeraki-Waiatoto systems, possibly driven by modern sediment delivery and sediment transport activity. This study provides a margin-scale compilation of detailed imaging across two contrasting dispersal systems that comprise numerous submarine canyons and extensive submarine channels to document the morphology, drivers, and modern processes critical to their formation and evolution.

Tectonic and geomorphic controls on the distribution of submarine landslides: why do landslides cluster within submarine canyons?

S.J. Watson[1], J.J. Mountjoy[1], G.J. Crutchley[2], S. Woelz[1], J.I.T. Hillman[3]

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2. GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
3. GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, 5011, New Zealand

Submarine landslides occur on continental margins globally and can have devastating consequences for marine habitats, offshore infrastructure and coastal communities due to potential tsunamigenesis. Therefore, understanding landslide magnitude and distribution is central to marine and coastal hazard planning. We present the first submarine landslide database for the eastern margin of New Zealand comprising >2200 landslides in water depths from c. 300–4000 m. Landslides are more prevalent and, on average, larger on the active margin compared with the passive margin. We attribute higher concentrations of landslides on the active margin to tectonic processes including uplift and oversteepening, faulting and seamount subduction.

Irrespective of margin type, our data show that submarine landslide scars are concentrated around canyon systems and close to canyon thalwegs. The prevalence of landslides within canyon settings suggests that not only does mass wasting play a major role in canyon evolution, but also that canyon-forming processes may provide preconditioning factors for slope failure.

On average along the entire margin, submarine landslides within canyons are smaller (in volume) than those in other geomorphic settings (e.g., the open continental shelf or thrust ridges). However, in the Southern Hikurangi Canyons, we observe a concentration of several large (>1 km3 volume) landslides that have demonstrated tsunamigenic consequences (modelled ~5 m wave height at the coast). To investigate the relationship between submarine canyons and landslides, we will use recently collected ultra-high resolution multibeam and sub-bottom profiler data to perform a detailed characterisation of the morphological structure and evolution of large landslides (>1 km3) within the Southern Hikurangi Canyons.

Results of this study offer unique insights into the spatial distribution, magnitude and morphology of submarine landslides across different geological settings, providing a better understanding of the causative factors for mass wasting in New Zealand and around the world.

A 16-year morphobathymetric evolution of Blanes and Cap de Creus submarine canyon heads (NW Mediterranean Sea)

C. Cabrera[1], R. Durán[1,2], P Puig[1], J Guillén[1], A. Muñoz[3], M. Demestre[1], A. Palanques[1]

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2. Marine Geology & Seafloor Surveying, Department of Geosciences, University of Malta, Malta
3. TRAGSATEC-Secretaria General de Pesca. Madrid, Spain

Shelf-incised submarine canyon heads are dynamic environments sensitive to oceanographic processes that enhance the erosion and transport of sediment from the shelf into the canyon, even in the sea level highstands. High-resolution (4 m grid size) multibeam seafloor bathymetry was obtained in 2004 during the ESPACE project and in September 2020 during the CRIMA cruise at the heads of the Blanes and Cap de Creus submarine canyons. The comparison of the two datasets revealed a noticeable short-term morphological evolution at the shelf-to-canyon transition.

The Blanes canyon head, which incises a succession of relict (Holocene) sediment bodies, showed a prevalence of erosion in the western canyon rim, and a non-deposition in the eastern canyon rim. The continental shelf in the vicinity of Cap de Creus canyon head is characterized by a rocky substratum (Paleozoic) with a limited sediment coverage and numerous erosive features that evidence relative sand starvation. Even so, the excavation of pre-existing erosive structures was evidenced in the south western canyon rim, where the shelf becomes narrower and coincides with the zone of bottom current intensification. Both canyon heads are located at shallow water depths and at short distances from the shoreline, so their morphological evolution is related to the sediment dynamics prevailing on the adjacent continental shelf. Several strong storms and dense self-water cascading events occurred during the studied 16-year time interval, which likely were the main triggering factors reshaping the canyon head rims. The different morphological evolution in both canyon heads seems to be linked to the local geological characteristic of the subsurface deposits over the continental shelf and the presence erodible sedimentary bodies, as is the case of Blanes canyon head. In spite of the greater erosive resistance of the shelf sediments surrounding the Cap de Creus canyon head, small changes in the shelf bedforms indicate that such high-energetic oceanographic processes also modify the fine-scale seafloor morphology.

A first insight into the origin and evolution of the Gollum and Kings channel systems, Porcupine Seabight, NE Atlantic, based on geomorphology and geophysical data

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The Gollum Channel System (GCS) is a submarine channel system stretching from the Irish Shelf to the Porcupine Abyssal Plain. Even though it is one of the few lengthy channel systems on the NE Atlantic margin and the only major system in the Porcupine Seabight, it has received relatively little research attention, especially compared to the Armorican canyons. These have been investigated extensively with regard to the deglaciation history of the European Ice Sheet. However, the GCS is thought to have served as a drainage system to the Irish Sea and therefore, the dynamics of the British-Irish Ice Sheet might be better resolved in this system. Additionally, since canyon-channel systems are the major pathways for material transport from shelf to basin, the temporal and spatial variability of their activity might have significant regional consequences. Bathymetric, 2D reflection seismic and oceanographic data are used here to provide first insights into the evolution of the GCS and the neighbouring, smaller, Kings Channels System (KCS). The GCS and KCS represent an area where bottom currents, turbidity currents, slope failures and hemipelagic processes have interacted in variable proportions throughout the Neogene and Quaternary periods.

The initial seafloor topography of the two systems was shaped by a laterally extensive erosional event representing a late Miocene-late Pliocene hiatus. Sediment transport within the channels was probably most active during Quaternary glacial periods, with terrigenous sediment sources situated closer to the channel heads. Sediment carried downslope by turbidity currents was likely thieved and transported northwards by contour currents, supplying material to the Belgica cold-water coral mounds.

Onset and sedimentary evolution of the Almanzora-Alias-Garrucha canyon (SW Mediterranean Sea): a complex interplay between geological processes

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The combination of high-resolution bathymetry, seismic (parametric, airguns) and image (hull mounted & AUV multi-beam echo sounders, ROV) records have allowed to decipher the onset and sedimentary evolution of the Almanzora-Alias-Garrucha canyon (hereafter, Garrucha Canyon) in the SW Mediterranean Sea. The onset of this canyon occurred in subaerial conditions during the Messinian Salinity Crisis at the end of the Miocene. The Plio-Quaternary stratigraphy and depositional architecture of the canyon floor and their deposits indicate that: canyon incision has predominated in the upper reaches; the widening of the canyon floor started at the beginning of the Quaternary; the canyon-fill deposits point to longitudinal and lateral relocations of the valley; predominance of sedimentary instability deposits that result from repeated near-surface slope failures in both margins; and the present-day canyon floor is affected throughout by cyclic steps associated with the passage of recent/subrecent gravity driven flows favoured by the canyon head interaction with coastal and fluvio-marine processes. Also, mass-transport deposits involving metric blocks, erosive scour fields and slide scars have been locally mapped.

The history of the Garrucha canyon system results from the interplay between the Messinian salinity Crisis event; the tectonic southeastwards tilting of the continental margin due to the coastal tectonic indentation of the Arc of Aguilas; the sea-level changes during the Plio-Quaternary; the semiconfined configuration of the subbasin where the canyon incises; and the interception of canyon head with the coastal and fluviomarine processes.

A case study of marine litter in the Dangaard and Explorer Canyons in The Canyons MCZ, SW Approaches

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Submarine canyons are conduits for the transport of organic matter and sediments and connect the continental shelf with deep-sea basins. The transport processes involved in those movements are also responsible for the transport of litter into submarine canyon areas, which due to the increased substrate heterogeneity and complex morphology make it difficult for litter to escape, making canyons passive accumulation zones.

A comprehensive case study was carried out using high-resolution data provided by a 2017 survey of The Canyons MCZ in the SW Approaches (Celtic Sea) to map broad-scale habitats, using a drop frame camera. The canyons studied were the Dangaard Canyon and the Explorer Canyon, tributaries of the Eastern branch of the Whittard Canyon complex and are part of the Grand Sole drainage basin. There were 153 stations throughout the MCZ area of 661 km^2, encompassing different morphologies (interfluves, canyon floors and canyon flanks), of which 150 had video data amounting to 77 hours of footage.

Video data were analysed using BIIGLE soft-ware and litter was classified using the classification system provided by OSPAR standardised by the MSFD. Data analysis revealed a mean litter density of 7,268 items/km^2 ±17,378 in the SW Approaches. This is driven by high mean densities on the interfluves, with 5.1 times higher density on the interfluves (9446 items/km^2± 17570) than inside the canyon areas (1835 items/km^2 ±2551). ANOSIM analyses support these findings and show significant differences between groups inside and outside of the canyons when looking at depth and morphological settings. The differences between areas were driven by litter density variations, as the composition of litter was more homogenous between the canyons and in different parts of the canyons. Over 97.3% of the litter is composed of derelict fishing gear, the highest proportion of any canyon studied to date, demonstrating that the MCZ area is very much affected by fishing activities. The results are yet unpublished and will be part of a larger study encompassing other surveys of the area and require further statistical tests such as PERMANOVA.

Bedforms and sedimentary processes along the Garrucha and La Linea canyon axis (SW Mediterranean Sea)

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The combination of high resolution bathymetry, seismic (parametric) and image (hull mounted & AUV multi-beam echo sounders, parametric profilers, ROV) records have allowed to describe the morphological elements and sedimentary processes that characterise the axis of two submarine canyons located in the SW Mediterranean Sea: The Almanzora-Alias-Garrucha canyon (Palomares Margin) and La Linea (Alboran Margin).

The statistical analysis of morphometric parameters together with acoustic facies characterization allowed to establish three general types of bedforms in both systems;

a) quasi-symmetric

b) upslope asymmetrical and

c) downslope asymmetrical.

These bedforms are interpreted as cyclic steps, formed by turbidity flows. They would be related to the important rivers/streams discharges favoured by the proximity of the canyon heads to the coast and erosion of canyons margins. The general gradient of the canyons axes and characteristics of the turbidity flow (energy, sedimentary load) seem to exert the main control. The morphological comparison of “cyclic steps” in both canyons indicates that the downslope asymmetrical forms would be associated with higher energy flows and the upslope asymmetrical forms with lower energy flows. It also points out that their formation would be related to muddy turbidity flows in the Almanzora-Alias-Garrucha canyon and sandy/silty flows in La Linea. The spatial variability of the cyclic step in each canyon could respond to the coexistence of today/subrecent bedforms with deeper relict forms formed during the last period of low sea level.

Capbreton canyon hierarchy (SE Bay of Biscay)

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Submarine canyons host high biodiversity and priority habitats to protect. One of the aims of the Spanish Institute of Oceanography is to increase the number of marine protected areas through the LIFE IP INTEMARES project. This is the case of Capbreton submarine canyon, located in the eastern part of the Bay of Biscay, whose peculiarity is its route parallel to the Cantabrian Margin along 300 km, from its head located on the coast of Aquitaine (France) to its end off the coast of Cantabria (Spain). The present contribution presents the outcomes of the analyses carried out to go beyond the determination of the morphology already described for submarine canyons (Shepard, F., 1972).

To gain knowledge on the canyon dynamics, it is necessary to know the operating mechanism of channels in the main canyon and the tributaries, which influences the processes of sedimentary transport and erosion. In addition, it determines the morphosedimentary dynamics, which is key to the development of some benthic ecosystems, in conjunction with other oceanographic processes. The influence of each channel overall depends, to a large extent, on its form, shape and position on the continental margin and respect to the other submarine canyons (Huang et al., 2014).

For Capbreton, not only have obvious differences detected in the tributary canyons, but there are even differences within the main channel. To obtain a classification of the channels, a hierarchy method has been used to establish the classification using GIS tools. With the aid of maps of flow direction and flow accumulation a classification of the channels was created taking into account their situation on the margin and morphology. According to the contribution made by the channel, it is possible to delimit the Capbreton submarine canyon system differentiating the area of the main channel, the tributary channels that flow into it and the multiple channels formed on the flanks by gullies.

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Deep Connections: South African Canyon Research, Literacy and Protection

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Multi-disciplinary research in the submarine canyons of South Africa was catalysed with the discovery of a living population of coelacanths Latimeria chalumnae in Jesser Canyon on the east coast 21 years ago. In 2002, multibeam surveys revealed 23 canyons including 6 shelf-breaching canyons in the iSimangaliso Wetland Park World Heritage Site and canyon exploration was initiated by submersible and ROV. Biodiversity surveys over 21 years revealed distinct invertebrate and fish communities on the margin, upper and lower slope and thalweg. A total of 34 individual coelacanths have been recorded with more than 70% of sightings at one site of one location. Coelacanths are now known from six Indian Ocean canyons on the eastern margin in addition to the original coelacanth capture site off East London where a coelacanth was trawled adjacent to the newly discovered Gxulu Canyon. Invertebrate communities at Gxulu are distinct from those in the northern canyons.

New work on the western margin of South Africa has added 14 canyons to the Cape Valley and Cape Canyon, the largest known canyon in the country and distinctive canyon morphology in the Southeast Atlantic reflects unique fluid flow features. The national map of marine ecosystem types now includes more than 44 canyons in four distinct ecoregions with contrasting margin and slope biota in the Southern Benguela, Agulhas, Natal and Delagoa Ecoregions. Canyon exploration played a key role in securing new marine protected areas (MPAs) and margin and upper canyon habitats are now represented in MPAs in all 4 ecoregions. Five types of potential Vulnerable Marine Ecosystems have been found in association with submarine canyons including dense seapen and thistle coral fields (*Cavernularia*, *Virgularia*, *Pteroides* and *Umbellulifer* spp.), glass sponge aggregations (*Pheronema* and *Sclerothamnus* spp.), seafan groves (*Nicella*, *Astromuricea*, *Melithid* spp. and *Narella* spp.); anemone beds, and diverse assemblages characterised by sponges, octocorals, stylasterine lace corals and bryozoans. Submarine canyons were included in a new ocean literacy initiative with canyon communication focused on the role of these important ecosystems in connecting South Africa's shelves to the deepsea and the role of canyons and the deepsea in South African society.

Deep Forests: the role of canyons in shaping benthic epifaunal communities in South Africa

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This study aimed to investigate the influence of submarine canyons on adjacent epifaunal communities on soft sediment habitats in two provinces in South Africa.

The study included 6 shelf-indenting canyons present in the iSimagaliso Wetland Park World Heritage Site in Northern KwaZulu Natal and replicate non-canyon associated sites on the outer shelf. It also aimed to investigate whether proximity to the large Gxulu canyon head influenced species richness and densities of epifaunal communities in the Eastern Cape. This was achieved by analyzing ROV footage from sites at varying distances from canyon margins in both regions.

Multivariate analyses of epifauna data showed a significant difference between canyon and non-canyon sites in KwaZulu-Natal. Results showed that unconsolidated habitats adjacent to canyon ecosystems were more species rich and had higher epifaunal densities with octocorals being the most common group of animals and seapens (Order *Pennatulacea*) in particular, having the highest observed densities. These dense seapen assemblages were only found in association with canyon margins. At least nine seapen species were found in these assemblages with *Veritillum*, *Virgularia* and an unidentified genus being particularly dominant. Epifaunal communities present in habitats further away from the Gxulu canyon head in the Eastern Cape were less species rich compared to those closer to the canyon head but patterns were less clear. Depth, canyon proximity, substrate and current emerged as the key likely drivers of epifaunal assemblages in this region. The importance of epifaunal communities associated with South African canyon ecosystems in South Africa is summarised including their role in habitat provision, ecosystem functioning and as potential fish nursery areas. New work is underway to collect octocorals in the region in collaboration with expert taxonomists to improve field identification, integrated taxonomy, reference image databases and invertebrate atlasing efforts.

Regional comparison of macrofaunal communities in U.S. Atlantic submarine canyons and their relationship to geochemical processes

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Submarine canyons are major conduits of organic matter along continental shelves, promoting gradients in food resources, turbidity flows, habitat heterogeneity, and areas of sediment resuspension and deposition. The complex interaction of environmental factors structures biological communities, often resulting in high levels of biodiversity and abundance within canyons. Differences in geomorphology, sediment transport activity, oceanographic conditions, and regional productivity among canyons supports the current evidence that no two canyons are alike. However, regional patterns in environmental conditions may result in similarities among canyon communities for canyons located in close proximity to one another. Here we investigate five submarine canyons located within a small region (120 km) along the U.S. margin of the western Atlantic. Sediments were sampled between 2016 and 2017 using CTD-mounted monocorers at depths ranging from 281 to 1538 m.

Macrofaunal (> 300 µm) density, diversity, and community composition were assessed in relation to environmental factors, water-column hydrodynamics, and sediment geochemistry. Macrofauna abundance generally decreased with depth; however, high variability occurred at discreet depths mid-canyon. The three northernmost canyons exhibited similarities in density patterns with depth and overall similar community composition that differed from the two southernmost canyons. The role of sediment geochemistry and food availability in structuring communities within and between canyons will be discussed, and overall patterns compared to previously studied western Atlantic canyons. This study provides a comprehensive look at the ecology of canyon systems in the western Atlantic, increasing our understanding of canyon ecosystem function and facilitating ecological comparisons to other habitats within the region.

Physics of the Cassidaigne canyon in the NW Mediterranean Sea: modelling and observing strategies

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The Cassidaigne canyon is located in the North Western Mediterranean Sea, at the entrance of the gulf of Lions. For 50 years, exogenous residual red mud from the industrial treatment of bauxite ore was rejected in the canyon, which generated deposits and shed light on the area, its artificial turbiditic system and its impact on ecosystems (e.g. cold water corals). The circulation in the Cassidaigne area is mainly forced by the wind, which induces a strong upwelling, by the local bathymetry and by the ocean general circulation (Northern Current and associated meso-scale structures). The characteristics of the physical processes at play, the way they interact with each other and the influence of extreme events is still an open question.

In order to study this complex area, an approach combining appropriate observational and modeling strategies was adopted. A two-way nested configuration of the MARS3D model of the canyon, named CASCANS (Fabri et al., 2017), and using a 80m horizontal resolution and 60 vertical levels, was set up. Observations were acquired using traditional hydrological and current measurements as well as innovative strategies (ADCP on AUV, Moving Vessel Profiler, low cost thermistor lines) during several oceanographic campaigns (BATHYCORE 2014, UPCAST 2017 and CASSISED 2019). In particular, during the Cassised cruise, three moorings were deployed at 420, 1628 and 1906 m of water depth, from March to August 2019. Moorings were mounted with downward-looking ADCPs at least 100 m above the sea bed. A fourth ADCP, looking upwards, was deployed on the platform close to the canyon head. Four low cost thermistor lines were deployed over the shelf and close to the canyon head, but only 1 was recovered. Upwelling events were found to induce up to 10 degrees of temperature decrease over a few days to a few weeks in late summer. The difficulties associated with the observation of physics in the hostile environment of this canyon will also be addressed, together with the possibility to get information on the hydrodynamics from the sedimentary patterns.

Internal tide dynamics of Whittard Canyon: integrating ocean glider observations and numerical model simulations

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Internal tides are tidal-frequency waves between density layers within the ocean and are a common hydrodynamic feature of submarine canyons in many regions of the world. Most canyons that have been studied with respect to internal tides are simple linear incisions or have meandering morphology. The dynamics of internal tides in dendritic (branching) canyons has not previously been investigated. We will present a summary of two papers from a combined observational and numerical modelling study of the internal tide in Whittard Canyon, a large, dendritic submarine canyon system that incises the Celtic Sea continental slope. The study was in collaboration with CODEMAP and instigated at INCISE 2014.

An autonomous ocean glider was deployed in the eastern limb of Whittard Canyon to map the internal tide variability, understand the local dynamics, and validate a high-resolution internal tide model. The model was then used extrapolate our new understanding to the whole canyon system. Key results that will be summarised are:

- The Whittard Canyon internal tide is primarily generated to the southeast, along the Celtic Sea shelf break.
- Some limbs of Whittard Canyon are net sources of internal tide energy; other limbs are net sinks.
- The internal tide in the eastern limb is a partly standing wave not a progressive wave.
- The internal tide drives elevated levels of turbulent mixing and particle resuspension in the upper canyon.

We hope to return to Whittard Canyon in the future for a full-scale investigation of shelf break exchange processes.

The impact of initial tracer profile on the exchange and on-shelf distribution of tracers induced by a submarine canyon

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Submarine canyons enhance cross-shelf mass exchanges, which are a key component of on-shelf nutrient budgets and biogeochemical cycles. Previous studies assume that canyon-induced tracer flux onto the shelf only depends on canyon-induced water upwelling. In this work we investigate the validity of this assumption for nutrients, carbon and dissolved gasses. To estimate the canyon-induced tracer upwelling flux and its spatial distribution on the shelf, we performed numerical experiments using the community model MITgcm simulating an upwelling event near an idealized canyon, adding 10 passive tracers with initial profiles representing nutrients, carbon and dissolved gasses.

We find that tracer upwelling depends on the mean initial vertical tracer gradient within the canyon, the depth of upwelling and the upwelling flux. We identify a pool of low oxygen and high nutrient concentration, methane, dissolved inorganic carbon and total alkalinity on the shelf bottom, downstream of the canyon. The horizontal extension of the pool depends on the canyon-induced advective fluxes feeding the pool and the initial background distribution of tracers on the shelf. This canyon-induced distribution of tracers has the potential to impact demersal and benthic ecosystems by lowering dissolved oxygen levels and spreading corrosive waters along the shelf.

Characterization of water masses in Blanes Canyon in relation to biodiverse CWC communities and potential connectivity pathways in the Mediterranean Sea

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Cold water corals (CWC) in the Mediterranean Sea are frequently found in submarine canyons incising the continental margins. Due to their geomorphology, submarine canyons change local oceanographic conditions, enhancing the export of organic matter towards the canyon interior. They constitute suitable habitats for CWC by providing hard substrate for coral larvae settlement, food availability needed for growth, and steep morphologies that increase current speed ensuring gamete and larvae dispersal. Submarine canyons can provide refugia from direct impacts of bottom trawling as coral species are able to thrive on the steep canyon walls that are inaccessible to nets.

Reports of CWC distribution in the Mediterranean Sea have been related to the warm (13.5–13.8°C) and saline (> 38.5) Levantine Intermediate Water (LIW). The LIW is formed by surface evaporation and densification in the Eastern Mediterranean basin and flows through the Mediterranean at a depth range 350-600 m depth.

Blanes Canyon, located on the Catalan margin (NW Mediterranean), supports a biodiverse community of CWC between 450-1100m depth (scleractinian, antipatharian and gorgonian species), exceeding the depth range of LIW and including the colder (< 13.5°C) Western Mediterranean Deep Water (WMDW). In order to better understand the environmental factors that support the high biodiversity of CWC in Blanes Canyon, we performed a detailed characterization of the water masses during ABRIC-1 cruise in February 2020. CTD casts, ranging from the surface to 1200m depth, were performed after the ROV dives, in the vicinity of confirmed living CWC communities. Water samples were taken at 5 fixed depths: 5, 50, 100, 200 meters above bottom and at the depth of chlorophyll maximum. The analysis includes nutrients, chlorophyll and particulate organic matter (POM) concentration.

Here, we present the main characteristics of the water masses found in Blanes Canyon. This study contributes to the overall understanding of environmental factors shaping CWC distribution in the Mediterranean, and more specifically, it provides a detailed snapshot of benthic communities and environmental conditions found in the Blanes Canyon.

Internal tides as a structuring factor of faunal patterns in submarine canyons

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Submarine canyons are listed as topographical features that may support vulnerable marine ecosystems (VMEs), including cold-water coral reefs. Effective spatial management and conservation of VMEs requires accurate distribution maps and a deeper understanding of the processes that generate the observed distribution patterns. Canyons are recognised as sites of intensified hydrodynamic regimes, with internal tides linked to enhanced mixing and nepheloid layer production: processes associated with faunal distributions. Canyon faunal distributions also respond to physical oceanographic (water mass characteristics and hydrodynamics) gradients. Internal tides generate large local variations in water mass characteristics by their movement along the canyon.

Despite the growing evidence for the role of internal tides in generating heterogeneity in environmental conditions parameters of internal tide dynamics have rarely been included in studies of canyon fauna. Here we investigate if spatial patterns in internal tide dynamics and associated environmental variability induced by the internal tide, explain variation in spatial patterns of species richness and assemblages in a deep-sea canyon. We take an interdisciplinary approach utilising biological, oceanographic and bathymetric derived datasets to undertake high-resolution predictive modelling and community analysis of epibenthic assemblages within Whittard Canyon. Results show that spatial variability in depth (and its covariates), seafloor characteristics and internal tide dynamics interact at different scales to determine spatial patterns in epibenthic fauna. The results further support the role of the internal tide as a structuring force of assemblages and diversity by generating both spatial and temporal gradients in food supply and water mass characteristics.

Oceanographic Controls on Cold-Water Coral Mounds of the upper Porcupine Bank Canyon

Felix Butschek[1,2], Aaron Lim[3], Andy J. Wheeler[1,2,4]

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Submarine canyons are critical pathways for particulate matter from shelf to deep sea environments (Liu et al., 2016) as well as important hotspots for generating internal tides (Aslam et al. 2018). The Porcupine Bank Canyon (PBC) hosts a diverse assemblage of biological communities and geomorphological facies characterised by framework-building cold-water corals (e.g. Lim et al. 2020, Appah et al. 2020).

Eight landers equipped with ADCPs were deployed to measure current speed and direction, water temperature, as well as hydrostatic pressure across the PBC over 2.5 months in summer 2019. Ship-based multi-beam bathymetric surveys and photogrammetric reconstructions from ROV video-dives provide details on the canyon's geomorphology and habitats.

Tidal current maxima correspond to high surface tide and coincide with periods of upwelling, cooler water extending from the canyon onto the shelf. Auto-correlation analysis identifies a semi-diurnal tidal signal in temperature, current speed and direction at the head and flank of the upper PBC, while the tidal periodicity is diurnal in the deep canyon. Preliminary evidence and live coral orientation reported by Lim et al. (2020) suggest that the amplified tidal flow favours coral growth and survival on the leeward side of the mounds.

These findings attribute a significant role to internal tides in structuring coral mounds of the upper Porcupine Bank Canyon.

Mapping, Modelling and Monitoring Key Processes & Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro)

A.J. Wheeler[1,2] , L. O'Reilly[1], A. Lim[3], J. Appah[1], L.M Oliveira[1], L. Conti[4], O.J. O'Connor[5,6]

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The Porcupine Bank Canyon (PBC), in Irish waters 370 km SW of Mizen Head, is disconnected from terrigenous influences being isolated from river and across shelf sediment/watermass influences. Unlike all other European submarine canyons, the PBC and its smaller neighbours, represent a natural laboratory for studying oceanographic changes unimpaired by changes in the terrestrial (human dominated) environment. The Mapping, Modelling and Monitoring Key Processes & Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro) programme is a habitat-approach based study of the upper Porcupine Bank Canyon in order to understand the controls on the biodiverse and high biomass cold-water coral habitat that flourishes there. This habitat has a major impact on canyon-wide processes and is itself controlled by canyon hydrodynamics. Understanding the interaction between canyon abiotic controls and ecosystem response will better allow us to responsibly interact with this valued ecosystem and enact effective management policies within a changing world.

The programme utilises 5 dedicated researchers to carry out 4 individual but interdependent research programmes. These 4 research projects co-jointly aim to understand the spatial and temporal habitat development, thresholds and processes of a range of cold-water coral dominated habitats within the canyon. These habitats include individual coral colonies, coral gardens, coral mounds and vertical cliff faces. In a wider context, the programmes utilises and, in turn, refines a number of novel technologies and techniques including 3D photogrammetry, ROV-mounted multibeam, ROV-vibrocoring, lander systems in submarine canyons and CT-scanning of core. This poster serves as a summary of findings of the research programme so far.

THE IMPORTANCE OF SUBMARINE CANYONS

Submarine canyons act as **conduits** for the transport of organic matter, nutrients and sediments, connecting the continental shelf with deeper basins, playing a vital role in **carbon sequestration**

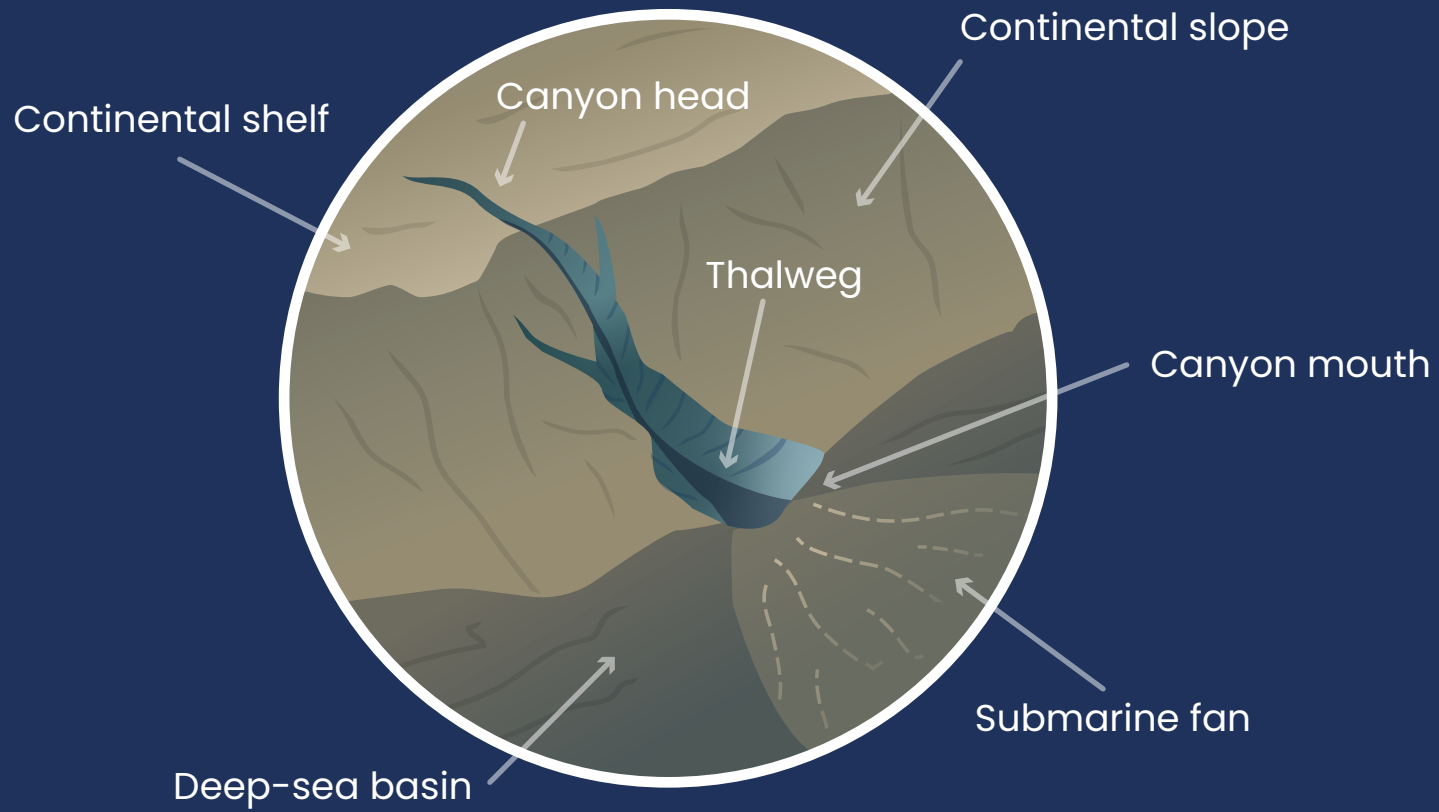
9,477

Medium to large sized canyons found in all seas, oceans and continental shelves

11.2%

Of the global ocean continental slope area is occupied by submarine canyons

Structure of a submarine canyon



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Large coarse-grained turbidity current sediment waves in Kaikōura Canyon: geomorphological characterisation and classification

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Coarse-grained sediment waves are commonly formed by confined flows in submarine canyons or channels. These large-scale (typically ~300 m wavelengths and ~20 m heights) bedforms are interpreted to be deposited by large-volume high-concentrated density flows, and changes in their morphology might result from reworking of coarse sediment by later, low-density turbidity flows.

Over the last decade, advances in seafloor mapping acquiring higher resolution (~1 m) multibeam data have enabled detailed measurements of bedforms in deep-waters. Based on the increased availability of high-resolution bathymetry, several global databases of coarse-grained sediment waves in submarine canyons and channels have been published. Yet to be included in these worldwide classifications are the large coarse-grained sediment waves observed within the Kaikōura Canyon, New Zealand. These sediment waves, with wavelengths of 250 m and wave heights of 20 m, are formed by turbidity currents and composed by cobble and boulder-size gravel material. After the 2016 Kaikōura Mw 7.8 earthquake the pre-existing sediment waves moved down-canyon by up to 560 m during the canyon flushing event.

In October 2020, new high-resolution (1 m) multibeam data within the Kaikōura Canyon axis was acquired using an Autonomous Underwater Vehicle (AUV), revealing the morphology of the sediment waves in detail for the first time. Here, we present a detailed geomorphological analysis, providing information regarding bedform dimensions and their relationship with environmental variables (i.e., depth, slope, rugosity) within the submarine canyon. Our results show variations in the geometry and changes in the planform sediment wave crest shape throughout different sections of the submarine canyon (mid and lower canyon). Moreover, the new high-resolution AUV data reveal the presence of superimposed small-scale bedforms over the large sediment waves in the lower canyon. These findings suggest that changes in the dynamics of the turbidity currents flowing down-canyon form, modify, and move the coarse-grained sediment waves.

Results from this study will be used to introduce the sediment waves mapped in the Kaikōura canyon to the global classification of large coarse-grained sediment waves in submarine canyons, and will contribute to a better understanding of coarse-grained sediment transport processes and their role in shaping submarine canyons globally.

Possible tsunami-induced sediment transport from coral reef to deep-sea through a submarine canyon at forearc slope of the southern Ryukyu islands, Japan

Ken Ikehara, Toshiya Kanamatsu, Kazuko Usami

Geological Survey of Japan, AIST; JAMSTEC; Japan NUS Co. Ltd.

Tsunamis are generally considered to rework surface sediments, and change seafloor environments. However, the sediment transport from shallow marine to deep-sea by such extreme wave events has not been fully understood. Huge tsunamis have repeatedly hit the coral reef of the southern Ryukyu Islands and have transported large coral boulders from reef to shore. Thus, huge tsunami and its backwash in this region has a potential to rework and transport coral reef sediments to deep-sea. Here, we examined sediment cores collected from and around a slope apron fan at mouth of shelf-incised submarine canyon on the forearc slope of the southern Ryukyu arc. Many calcareous turbidites, containing coral and mollusca fragments and coral reef benthic foraminifera, were recognized in the cores from the slope apron fan.

Spatial distribution of turbidites indicated that depositional area of turbidites has been shifted on the slope apron fan. Only a few calcareous turbidites were found in basin floor cores, further downslope of the apron fan, suggesting that most of calcareous grains derived from shallow marine area were deposited on this fan. Depositional intervals of turbidites were calculated as ~400–1000 years, which is well-coincided with recurrence intervals of huge tsunamis estimated from onshore tsunami deposits. Thus, the tsunami is an important mechanism for surface sediment reworking in coral reef in this region, and shelf-incised submarine canyon may play an important role in the effective transport of shallow marine calcareous grains to deep-sea.

Predicting turbidity current timing and frequency in submarine canyons

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University of Southampton and National Oceanography Centre, Southampton

Turbidity currents in submarine canyons dominate the global transport of sediment, nutrients, pollutants and organic carbon from the terrestrial realm to the deep sea. Individual flows can runout for hundreds of kilometres and can reach velocities up to 20 ms^{-1}, therefore posing a significant threat to seafloor infrastructure. Understanding the factors that trigger turbidity current is therefore key to our knowledge of flow frequency which, in turn, provides an insight into global sediment flux and hazard assessments for critical seafloor infrastructure. Technological advancements have recently enabled the direct monitoring of turbidity currents at field-scale. Direct monitoring offshore from river deltas has revealed that a combination of multiple environmental factors, such as tidal elevation and river discharge are more common triggers for turbidity currents than isolated external triggers. However, the limited number of turbidity currents recorded at previous monitoring sites has only permitted the use of univariate statistics.

Such approaches are used test the significance of individual triggering factors in isolation, but do not allow us to investigate multiple coincident environmental factors that combine (often in a non-linear manner) to trigger flows. Here, we analyse a large monitoring dataset from an active submarine channel in Bute Inlet, British Columbia, where 113 turbidity currents were recorded. We analyse this sufficiently large dataset using multivariate statistics to quantify the relative roles played by tidal elevation and river discharge on the triggering of turbidity currents. We train a statistical model on a subset of the monitoring data, and develop a predictive model that successfully hindcasts almost 90% of turbidity current activity (i.e. the occurrence of flows and non-events). This model is then tested at two similar, but unrelated sites (Squamish and Fraser Deltas, both British Columbia) at which we did not train the model; remarkably predicting >84% of turbidity current activity.

We conclude by discussing how this model, or a modified version, may be used to predict turbidity current activity in submarine canyons globally, potential limitations and the implications for geohazard assessment and quantification of deep-sea sediment fluxes.

The underappreciated role of land-detached submarine canyons in deep sea sediment transport: New direct monitoring of powerful turbidity currents in the Whittard Canyon

Heijnen S. Maarten, Michael A. Clare, Furu Mienis, Andrew R. Gates, Brian J. Bett, Corinne A. Pebody, James E. Hunt, Ian Kane, Stephen M. Simmons, Veerle A.I. Huvenne

National Oceanography Centre, UK

Submarine canyons and the seafloor-hugging flows (turbidity currents) that pass through them are an important pathway for sediment, nutrient, pollutant, and organic carbon transport to the deep sea. Furthermore, these systems can be biodiversity hotspots, while the flows that traverse them pose a hazard to seafloor infrastructure. Many submarine canyons are currently detached from land as a result of sea level rise following the last glacial maximum. These land-detached systems have often been assumed to feature no or only minor turbidity current activity. One such land-detached canyon is the Whittard Canyon in the NE Atlantic, whose head lies about 300 km from shore. Here we present new high resolution, direct monitoring data, which reveals that not only do turbidity currents frequently transit through the deep-water Whittard Canyon, but also that their frequency and magnitude is equivalent to powerful flows measured in major land-connected canyons such as the Congo and Monterey canyons. Two ADCP mooring deployments over one year reveal the occurrence of six turbidity currents that reached velocities of up to 5 m/s, lasting several hours at water depths of up to 2500 m. While some turbidity currents were coincident with passing storms, most occurred outside of the winter storm season and did not obviously coincide with meteorological or oceanographic variations.

There are no indications that the Whittard Canyon is unique, hence our results imply that many previously-assumed dormant land-detached canyons may feature similarly frequent and powerful turbidity currents. We conclude by discussing how land-detached canyons may play a globally, but previously-underappreciated role in the deep-sea transport of organic carbon, nutrients, and pollutants.

Sediment dispersal in canyon and on adjacent slope: using Bauxite residue (red mud) as artificial tracer (Cassidaigne canyon, Western Mediterranean)

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Canyons are major drivers of sediment dispersal from the source to the continental margins and abyssal plains. They particularly act as fast track conduits by funnelling the sediment, such as for turbidity currents, but other parameters such as the dynamics of the water column, controlled by seasonal and event meteorological episodes, play also a major role, largely unquantified. Though sediment dispersal can be recorded and quantified in "real-time" by instrumented mooring lines, its expression on the seabed mostly relies on past geological records where the imprint of events or seasons is commonly obliterated by the bioturbation, diagenesis and other geologic processes. Flume tank experiments on deposits are a common alternative to overcome this gap but scaling issues can also bias results.

Massive quantities, in order of 20 to 30 Mt, of bauxite residue, commonly called red mud, were dumped into the Cassidaigne Canyon head (Western Méditerranean) between 1967 and 2015 (48 years). Released fluxes have commonly reached 1 Mt.yr-1, which is one order of magnitude higher than the annual solid discharge of small western Mediterranean rivers (Hérault, Têt, Agly) and only one order or magnitude lower than the Rhone River annual solid discharge. Therefore, during red mud dumping the Cassidaigne Canyon was like an artificial river-fed canyon, similar to a natural size flume tank experiment.

Red mud deposits mimic natural sediment morphologies and characteristics associated to canyon and slope environments. Observed features include (1) in the canyon head, a channel characterized by knickpoints and a levee to the left, indicative of dispersal by mudflow similar to turbidity currents ; (2) lateral gullies indicative of lateral advections ; (3) deposits on elevated terrasses and a sedimentary ridge (300 to 600 m high) on the canyon right hand side indicative of dispersal by overflow and possibly enhanced by bottom currents and Coriolis force.

An attempt to determine a depositional budget shows that at least 5,5 Mt of red mud was dispersed and deposited by gravity processes and overflow in the canyon head and that about 3 Mt was dispersed to the west, possibly by along canyon overflow processes, bottom current and Coriolis Force.

Evidence of human impact on the NW Sicilian Canyons (western Mediterranean): marine litter vs bottom-trawling footprint.

Claudio Lo Iacono[1], Martina Pierdomenico[2], Andrea Gori[3], Pere Puig[1], Veerle A.I. Huvenne[4], Katleen Robert[5], Tommaso Russo[6], ISLAND Cruise Team

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3. University of Barcelona, Faculty of Biology, Spain
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6. University of Rome Tor Vergata, Italy

We attempt here to explore marine litter distribution along the submarine canyons of the NW Sicilian margin (western Mediterranean) and its potential relationship with the effects of bottom-trawling pressure. Most of the NW Sicilian canyons breach a narrow continental shelf, 2 to 7 km wide, and have their heads closely located to coastal areas with large urban populations. Data were collected across a depth range of 150–800 m in the Gulfs of Palermo and Castellammare during the ISLAND expedition (ExplorIng SiciLian CAnyoN Dynamics - EU-Eurofleets2 Project), and include ROV footage and a 5-month long time-series from a mooring located at 730 m depth within the Oreto Canyon axis, close to trawling grounds. The analysis of Vessel Monitoring System (VMS) data showed that trawling activities persist on the open slope around the canyons and in some cases within them. Integration of VMS data with multibeam and ROV videos shows trawling is altering seascape heterogeneity, smoothing the morphology of small gullies, and causing a general reduction of biological diversity. Moreover, almost all the sediment resuspension events registered by the mooring were of anthropogenic origin, induced by trawlers within the Oreto Canyon.

We observed significant differences in the amount of litter between trawled and untrawled canyons. Whereas trawled canyons of both gulfs show paucity of litter, the untrawled Eleuterio Canyon (Gulf of Palermo) hosts a considerably higher amount of litter, widespread and often organized in small mounds, 1 to 3 m wide. Here, several interactions of litter items with benthic and demersal fauna include both disturbance effects, such as coverage or entanglement, and exploitation of litter, used as shelter or growing substratum.

The Eleuterio Canyon, whose head is only 2 km from the coast, most probably functions as a sink for marine debris, transported by channelized bottom currents up to the explored depth of 800 m. This compelling evidence confirms that submarine canyons close to densely populated coasts, like many in the Mediterranean Sea, are often susceptible to the effects of human pressure, with an evident impact at different spatial and temporal scales.

High-resolution bathymetry of the Blanes Canyon (NW Mediterranean)

Ruth Durán[1,2], Pere Puig[2],Meri Bilan[3], Jordi Grinyó[2,4], Cecilia Cabrera[2], Claudio Lo Iacono[2], Araceli Muñóz[5], Veerle Huvenne[6], Marie-Claire Fabri[7], Charline Guerin[7], ABRIC Cruise team

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6. National Oceanography Centre (NOC)
7. Institut français de recherche pour l'exploitation de la mer (Ifremer)

Submarine canyons are complex geomorphological features that have been identified as potential hotspots of biodiversity, which has led to many canyons being mapped and studied at high resolution (tens of meters). In this work, we present the first complete very-high resolution mapping of the Blanes submarine canyon in the northwestern Mediterranean, based on a compilation of swath bathymetry data acquired during different cruises, spanning between 2011 and 2020. The integrated data set completes and extends previous bathymetric datasets on the canyon rim and adjacent continental shelf acquired during the ESPACE programme in 2004. The grid spacing of the compilation map varies from 4 m for the canyon rim and adjacent shelf, 15 m for the head and upper canyon region and 25 m for the middle and lower canyon region.

The Blanes Canyon deeply incises the continental shelf, showing an orientation parallel to the coastline at its head. Down-canyon, it displays a meandering course with a strong structural control, showing rectilinear canyon portions characterized by a flat-floored axis and steep terrains (>50°) on both canyon flanks, with the presence of networks of gullies and sub-horizontal layered walls. The high resolution map has allowed to identify potential areas along the submarine canyon flanks that might provide suitable environmental conditions for hosting benthic ecosystems, particularly cold-water corals (CWCs). These sites were recently explored during the ABRIC Spanish National Project using the hybrid remotely operated vehicle (H-ROV) Ariane and the inspection-class ROV Liropus to explore the benthic communities and to collect specimen samples, complementing the previous ROV dataset acquired during the ABIDES Project. Collected data allowed for the compilation of an inventory of the most representative and relevant benthic species and communities observed within the Blanes Canyon.

This information will be shared with the Blanes fishermen's guild in the framework of an outreach project funded by the Fisheries Local Action Groups (GALP), to provide awareness of the presence and abundance of such vulnerable marine ecosystems in the Blanes Canyon, and to expand the spatial information provided by the ROV surveys by adding the local fishermen knowledge.

A brief introduction to the TrawledSeas Project: Bottom Trawling as a Driver of Seascape Transformation

Ruth Durán[1], Aaron Micallef[1], Nicole J. Baeten[2], Margaret Dolan[2], Lilja R. Bjarnadottir[2], Pere Puig[3], Claudio Lo Iacono[3], Araceli Muñoz[4], Joshu Mountjoy[5], Geoffroy Lamarche[5], Fabio de Leo[6,7]

1. University of Malta
2. Geological Survey of Norway (NGU)
3. Institute of Marine Sciences (ICM-CSIC)
4. Tragsa for General Secretariat of Fisheries
5. National Institute of Water and Atmospheric Research (NIWA)
6. Ocean Networks Canada (ONC)
7. University of Victoria

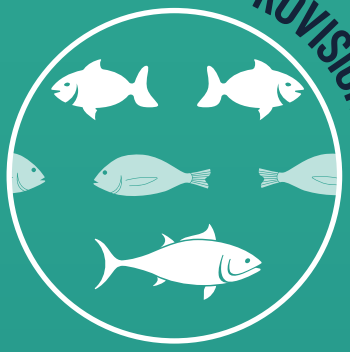
Bottom trawling is one of the most widespread fishing practices in the world's oceans. It involves towing of nets to harvest benthic and demersal living resources. The dragging of trawling gears along the seafloor results in scraping and ploughing the seabed, which leads to the formation of turbid plumes of resuspended sediments, changes in the sediment erosion/accumulation rates and modifications of their fluxes and budgets, which results in measurable alterations of the submarine geomorphology. As submarine canyons are increasingly targeted by trawlers, there is a growing need to quantify, monitor and mitigate the impacts of bottom trawling in these environments.

The TrawledSeas Project aims to quantitatively characterise the contribution of bottom trawling on the geomorphic evolution of submarine canyons, over a range of spatial scales, from fine (m–dam) to mesoscale (5–100 km). To address this objective, a new automated marine landscape mapping technique is being developed to quantify the morphological signature of bottom trawling, based on the analysis of high-resolution multibeam data implemented in a Geographic Information System (GIS). The proposed methodology integrates standard general (e.g. curvature, rugosity, roughness or fractal dimension) and specific (e.g. object-based image methods) geomorphic techniques with new ones developed in this project in a multiscale approach. It combines GIS open source tools with bathymetric dataset at different resolutions, from hull-mounted multibeam data to compare the large-scale morphology of trawled and untrawled areas, to Remotely Operated Vehicles (ROV) and autonomous underwater vehicle (AUV) bathymetric data to identify and quantify trawl marks at small spatial scale. Additionally, data from repeated surveys will be used to assess potential temporal changes in the seafloor morphology of new fishing grounds.

The implementation of these geomorphological tools in different study sites incised by submarine canyons (e.g. Catalan, Malta-Sicilian, Norwegian, Canterbury, Patagonian and W Canadian continental margins), will allow to characterise the differential impact of bottom trawling on the canyons' seafloor, in terms of extent, rates and volume change in different geologic and climatic settings.

SUBMARINE CANYON ECOSYSTEM SERVICES

FOOD PROVISION



Canyon areas represent important well-known local fishing grounds, essential for local economies.

PRIMARY PRODUCTIVITY

Nutrients upwelled from the deep sea enhance primary productivity in canyon areas causing trophic cascades.

BIODIVERSITY AND BIOMASS

Hotspots for biodiversity and biomass containing species not found on slope areas, increasing local diversity.

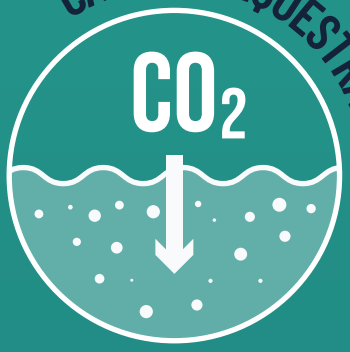
SHELTER, REFUGIA & NURSERIES

Sheltered conditions within the canyon are beneficial for larval development and the creation of fish nurseries.

NUTRIENT CYCLING

Complex hydrodynamic and sediment transport processes cycle nutrients between the deep sea and shallower waters.

CARBON SEQUESTRATION



Uptake and storage of organic matter within the canyon is unlikely to be released for decades or even centuries.

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Marine litter in submarine canyons: a systematic review and critical synthesis

Ivan Hernandez[1], Jaime Davies[2], Veerle Huvenne[3], Awantha Dissanayake[1]

1. University of Gibraltar
2. University of Plymouth
3. National Oceanography Centre, UK

Marine litter is ubiquitous and poses serious environmental problems on the seabed. Its presence is of concern in submarine canyons where the oceanographic processes responsible for the transport of sediments and organic matter are also responsible for litter moving into submarine canyons making them passive accumulation zones, although research in this area is still in its infancy.

A critical synthesis and literature review selecting studies with primary data of benthic marine litter at depths of over 50 m (2001-2020) revealed important gaps in the knowledge, with information on the impact of macroplastics in deep-sea environments still scarce. Less than 1% of medium to large submarine canyons mapped have been studied in any measure for marine litter, with over 91% of the canyon studies located in European waters. The use of ROVs is now the main tool used for sampling overtaking trawling methods despite the continued growth of the latter for marine litter deep-sea research. Enumeration of litter was diverse although over 75% using abundance to quantify litter. Over 73% of studies did not use any established regional litter protocols to classify, quantify, enumerate or identify marine litter, and classification systems provided were partially used by those that did follow a protocol. Fishing-related categories do not feature as a top-level category in the classification hierarchy in any of the protocols, yet over 50% of publications featured fishing materials as a main category, pointing to a more intuitive activity-based categorisation of litter instead of a materials-lead approach from the established protocols. Interactions between litter and the surrounding environment and biota are very much under-reported with little or no consensus between how the data is provided.

There were no discernible patterns between litter density, composition and broad geographical location of canyons, with individual topographical characteristics, hydrodynamic regimes and anthropogenic activities being determining factors in how submarine canyons are affected by litter. There is an urgent need to standardise and unify methodologies with new or established protocols to fully understand the impact of marine litter in submarine canyons over time.

Distributions of microplastics and larger anthropogenic debris in Norfolk Canyon, Baltimore Canyon, and the adjacent continental slope (Western North Atlantic Margin, U.S.A.)

Ellie S. Jones, Steve W. Ross, Craig M. Robertson, Craig M. Young

Oregon Institute of Marine Biology, University of Oregon

Anthropogenic debris has been reported in all studied marine environments, including the deepest parts of the sea. It is important to find areas of accumulation and methods of transport for debris to determine potential impacts on marine life. This study analyzed both sediment cores and ROV video from Norfolk Canyon, and ROV video from Baltimore Canyon to determine the density and distribution of anthropogenic debris, including both micro- and macroplastics. The average microplastic density in Norfolk Canyon sediment was 37.30 plastic particles m^{-2} within the canyon and 21.03 particles m^{-2} on the adjacent slope. In video transects from both Norfolk and Baltimore canyons, the largest amounts of macroplastic were recorded near the canyon heads. We suggest that canyons and their associated benthic invertebrate communities are areas of concentration for human-generated debris and microplastics, and that canyons might be conduits for microplastics to the deep sea.

Natural vs. trawling-derived transport of sediment and particulate organic matter in Palamós Canyon, NW Mediterranean

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Submarine canyons are important conduits of particulate organic matter to deeper environments, especially during natural high-energy events such as storms or river flooding. However, there is increasing evidence that anthropogenic activities such as bottom trawling can also displace large volumes of sediment into canyons, modifying natural fluxes. The contribution of downward particle fluxes in Palamós Canyon (NW Mediterranean) linked to natural events and bottom trawling was assessed by deploying two moorings during 2017, covering a trawling closure (February) and trawling activities (March-December). A first mooring equipped with a downward-looking ACDP and several turbidimeters was deployed in a canyon-flank tributary below a trawling ground, at 900 m depth, while a second mooring equipped with a near-bottom sediment trap, current meter and turbidimeter was deployed at the tributary and canyon axis confluence, at 1200 m depth. Temporal variations in the quantity and composition of sinking particulate organic matter in the canyon axis were assessed through the analysis of organic carbon (OC), total nitrogen (TN) and several biomarkers.

During the trawling closure in February, large downward particle fluxes (60-100 $g \cdot m^{-2} \cdot d^{-1}$) with high terrigenous and marine organic matter content were registered in the canyon axis sediment trap, associated to seasonal storms and torrential river floods that occurred in coincidence with high productivity in surface waters. Although no major natural events occurred during the following summer months, near-daily sediment gravity flows were registered at the tributary site, in coincidence to the passage of fishing vessels.

As the trawling period unfolded, these sediment gravity flows decreased in magnitude, although highly-concentrated events (> 250 $mg \cdot L^{-1}$) were still sporadically recorded. Only the sediment gravity flows that generated the highest sediment fluxes reached the canyon axis, leading to high downward particulate fluxes (80-125 $g \cdot m^{-2} \cdot d^{-1}$) of coarse sediment. The composition of OC transferred during these events was impoverished in all biomarkers and had a greater degree of degradation, indicating the transferal of eroded and organic matter-poor sediment towards the canyon axis. Our results reveal that bottom trawling along canyon flanks enhances natural sediment fluxes and modifies the composition of particulate OC, which may affect the fragile deep-sea ecosystems dwelling within.

Natural vs. trawling-induced water turbidity and sediment transport variability in Palamós Canyon (NW Mediterranean)

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Submarine canyons are considered preferential pathways for the effective transport of suspended particulate matter between coastal areas and deep-sea environments. Increases of water turbidity and sediment fluxes within Palamós Canyon (NW Mediterranean) have been associated with exceptional oceanographic events such as storms or dense shelf water cascading (DSWC), and also with deepsea trawling activities. To assess the temporal variations on the sedimentary dynamics in Palamós Canyon linked to natural (storms and DSWC) and anthropogenic (bottom trawling) processes, a mooring equipped with an autonomous hydrographic profiler as well as a near-bottom current meter and turbidimeter were deployed from February to June 2017 in the canyon axis (929 m depth), adjacent to the trawling grounds. The recording period covered a trawling closure period (February) and the restart of the regular trawling season (March-June). To determine the spatial variation in water column turbidity, a CTD transect across the canyon head was also conducted in June, after the mooring recovery.

Periods of enhanced water turbidity during the trawling closure were associated with storms and DSWC events, causing the arrival of turbid waters (>1 mg L^{-1}) into the canyon. Afterwards, the water column displayed low background suspended sediment concentrations (~0.3 mg L-1) until the trawling season began in early March, which was characterized by the presence of concentrated particulate matter detachments (1-4 mg L^{-1}) observed mainly at the water depths where trawling grounds are located (400-800 m). Storms and DSWC events caused high instantaneous sediment fluxes (31-44 g m^{-2} s^{-1}) into the canyon, which were some orders of magnitude higher than those induced afterwards by periodic and more frequent trawling activities (0.1-1.4 g m^{-2} s^{-1}) in March-June. Despite the contrasting sediment fluxes, recurrent bottom trawling on the same fishing ground produced a total cumulative transport of similar magnitude to that generated by a sporadic natural process such as DSWC in Palamós Canyon.

The capacity of bottom trawling to produce similar accumulated impacts to those resulting from sudden and sporadic natural highenergy events highlights the necessity of addressing the effect of anthropogenic activities in studies of sediment dynamics in deep-sea environments where fishing activities are practiced.

Assessing the sensitivity of The Canyons MPA to climate change pressures

E. Last, L. Robson, L. Matear, H. Tyler-Walters, S. Garrard, S.Byford

Joint Nature Conservation Committee, UK

The Canyons Marine Protected Area (MPA) is located in the south-west corner of the UK's continental shelf and contains two large canyons that indent the shelf break, adding to the topographic complexity of the seafloor. The MPA includes protection for four deep-sea habitats: cold-water coral reefs, coral gardens, sea-pen and burrowing megafauna communities and the deep-sea bed. JNCC has a statutory remit for the MPA and provides advice on the conservation and management of the site, specifically on the potential impacts of activities and associated pressures on the protected features, and methods to mitigate against these. A key gap in our understanding, however, relates to the sensitivity of MPA features to pressures associated with climate change and the functional role of MPA features in supporting mitigation and adaptation to climate change.

To address this, JNCC and MBA have assessed the sensitivity of the deep-sea biotopes within The Canyons MPA to two climate change pressures, ocean warming and ocean acidification. Benchmarks for these pressures were developed using greenhouse gas emission scenarios, based on a range of climate change projections. Existing literature was reviewed to assess the resistance and resilience of the key species associated with each biotope, and therefore their sensitivity to these pressures. These assessments have enabled JNCC to determine the overall sensitivities of The Canyons MPA features to climate change pressures. This evidence will inform decision-making around adaptive management of MPAs in relation to climate change in the context of the wider marine environment.

Video analysis: a valuable tool to gather data about deep-sea associations?

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In the deep sea, several species develop associations with other organisms. These associations are mostly studied when the specimens can be collected. However, more and more information about deep-water organisms comes from videos. Video analysis is not a widespread tool for the study of deep-sea associations, as it comes with important limitations, such as the impossibility to identify some organisms to a low taxonomic level or to determine the nature of the observed relationship. Our aim was to investigate the possibility of raising new knowledge about deep-sea associations just from the use of videos.

In 2018, we collected about 110 hours of high-definition ROV videos from a variety of deep-water habitats, including submarine canyons, on the Irish Continental Margin, from 816 to 2700 m. Here we present the most recurring associations observed with Porifera and Cnidaria, along with an analysis of the influence of host taxon, and environmental factors such as depth and substrate composition.

From videos, we were able to report new and poorly investigated deep-sea associations. We also demonstrated that factors such as the taxon of the host, depth and, to a lesser degree, substrate influence both the presence of associations and the phyla of the associates.

Given the current threats that the deep sea is facing, gathering information about interactions between deep-sea species is becoming more and more urging. Inaction could result in the loss of host species, which can be critical for the survival of the associated organisms. Therefore, all data should be exploited, and we advocate that video analysis is a valuable tool for the collection of new data on deep-sea, and that its implementation will have important implications for deep-sea research and conservation management.

An INTERdisciplinary view on Argentine CANYON systems using isopod crustaceans of the Mar del Plata canyon as surrogate

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While the Argentinian shelf has been studied in more detail, the benthic communities of the submarine canyons placed along the Argentine Continental Margin remain almost unexplored. More recently, there were three expeditions (Talud Continental I–III; RV Puerto Deseado) to the Mar del Plata submarine canyon. As a result of these expeditions several new species and new records on different phyla were reported. In addition, we carried out a pilot study with data and samples collected during cruise SO260 with RV Sonne in 2018 around the Mar del Plata Canyon. Bathymetric and PARASOUND data of 10 stations were analyzed and compared with grain size data from surface samples revealing that the station locations clustered into four types of morpho-sedimentary environments, namely, “Drift Deposit”, “Terraces, Channels, Depressions”, “Canyon Terrace” and “CWC (Cold Water Corals)”. Based on these morpho-sedimentary environments, a preliminary biological dataset based on boxcorer samples shows a correlation of the benthic faunal assemblages with potential CWC reefs in case of peracarid crustaceans.

In addition to the samples taken during the cruise SO260 in 2018, we have several samples taken on board the Argentinean RV Puerto Deseado. These stations will be used as comparison to evaluate the changes in the community structure with the bathymetric range from the slope and along the canyon (from 250 m to 3282 m depth). This analysis is aimed to set the baseline of the planned INTERCANYON project (INTERdisciplinary view on Argentine CANYON systems). As starting point, we aim to study the changes of benthic communities along the Mar Del Plata canyon, focusing mainly on isopods (Crustacea: Peracarida) as surrogate group. In particular, we propose:

1) to evaluate differences in the benthic isopod communities along the bathymetric range of the canyon;

2) to study the isopod assemblages in the different morpho-sedimentary environments of the canyon; and

3) to evaluate the isopod diversity inside and outside the canyon.

Echinoderm food web in Barkley Canyon (NE Pacific)

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We aimed to identify food sources of echinoderms, a dominant megafaunal taxa in deep-sea sedimentary habitats, in Barkley Canyon (NE Pacific), where complex topography results in patchy food distributions. Using an ROV, we collected aggregated echinoids and nearby holothurians at the canyon head (200 m), and at 400 m we collected sea urchins and amphipods associated with kelp detritus. Deeper in the canyon at 1500 m, we collected field-forming sea pens with associated ophiuroids as well as various sizes/ages of sea pigs. At all depths we collected sediment and suspended particulate organic matter and (opportunistically) kelp detritus for stable isotope (C and N) analysis. Sediments where sea urchins aggregated differed in isotopic signature from sediments without urchins at the same depth. However, similar isotopic signatures in echinoids and holothurians at 200 m within or outside the aggregation suggest an aggregation related to a sporadic feeding event or to a reproductive event that resulted in sediment reworking that changed sedimentary isotopic signatures. We observed distinct differences between the different tissues of echinoderms at 200 and 400 m (gonads, intestines, and muscles), with greater nitrogen and carbon enrichment in muscles compared to intestines and gonads, which were also more depleted in C^{13}. The intestines presumably contained the most recently incorporated organic matter and the gonads require relatively fresh pigments to ensure offspring survival and production.

At 400 m similar $\delta^{13}C$ in echinoids and amphipods and kelp suggest it can comprise an important part of their diet as well as sedimentary organic matter. Ophiuroids living on sea pens at 1500 depth did not feed on sea pens, given differences in $\delta^{13}C$ signatures (> 4 ‰ $\delta^{13}C$ difference), and perhaps utilized the sea pens to elevate them within the benthic boundary layer. Adult and juvenile sea pigs feed at the same trophic level but utilize different carbon sources. Barkley Canyon offers a variety of food sources used by echinoderms and incorporated differently into various body tissues depending on their purpose. Occasional kelp blades contribute to echinoderms diet sporadically.

HYDRODYNAMIC PROCESSES AND NUTRIENT, SEDIMENT AND ORGANIC MATTER TRANSPORT

Enhanced primary productivity

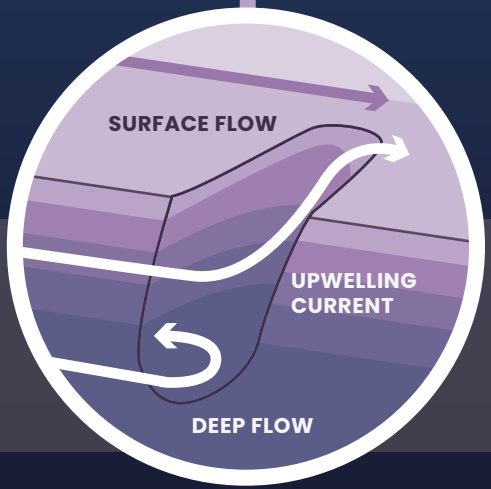
Seasonal heat loss and evaporation from cold dry winds cause cascades of cold dense shelf water

Organic matter is transported to the deep by downward transport processes

Turbidity currents from slope failures, wind and wave action, and land input

Upward transport of nutrients by upwelling currents*

Downward transport of sediments and organic matter



Nepheloid layers

Layers where sediment particles stay suspended in mid-water containing nutrients that promote growth of large sessile organisms and in turn increase biodiversity

Internal waves and tides cause sediment resuspension and nepheloid layers

*Adapted from Allen, S. E., and Hickey, B. M. (2010), Dynamics of advection-driven upwelling over a shelf break submarine canyon, J. Geophys. Res., 115, C08018, doi:10.1029/2009JC005731.

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Distribution and origin of benthic plastic litter in the Xishabei submarine canyons of the northwest South China Sea

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Manned submersible dives were used to investigate the distribution and origin of benthic plastic litter in three N-S-oriented submarine canyons in the northwest continental margin, South China Sea. A total of nine dives were carried out by the Chinese manned submersible "Shenghaiyongshi" during 2018-2020.

Our dive observations revealed that litter items in the canyons occur in two general types: scattered litter items and litter piles. Statistics show that 88% of the scattered litter items and all the litter piles are distributed in a few scours of the canyons. More than 70 litter piles were delineated, which were 2-61 m long, 0.5-8 m wide, and 0.1-1.2 m high. Litter items that accumulated on the upstream side of obstacles suggest that they were transported by down-valley flows. The majority of the litter piles were distributed in the upstream-dipping slopes downstream of the scour centers. This pattern is tentatively linked to turbidity currents, which accelerated down the steep upstream slopes of the scours and underwent a hydraulic jump toward the scour centers before decelerating on the upstream-facing flank. Associated seabed sediment consists of clayey and sandy silts, with unimodal or bimodal grain-size distributions that are typical for turbidites, supporting the interpretation.

Inter-canyon comparison shows that the middle canyon has the highest litter abundance, followed by the east and west canyons, respectively. The wide differences in litter distribution among canyons may be explained by the supply or availability of litter items. Noted that the middle canyon is shelf-indented, with head intruding for more than 20 kilometers into the shelf. The east canyon also intrudes into the shelf, but at a shorter distance. The west canyon is overall slope confined. We speculate that distance of the canyons intruding into the shelf affects the supply and therefore the abundance of litter items in the canyons. The farther the canyons intrude into the shelf, the more plastic items from the supply of various shelf currents may be caught, since the shelf is a dense area of maritime activity and has a high density of plastic litter.

This research was funded by the National Natural Science Foundation of China (grant numbers 41876049, 91528304, and 41676029).

Anthropogenic activity indicators in three shelf-incising submarine canyons in the Alboran Sea: Origins and impacts

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Litter enters the seas mostly from coastal and marine anthropogenic activities and travel long distances before being stranded at the seafloor, where is influenced by the seafloor geomorphology as well as oceanographic and sedimentary processes. Submarine canyons constitute the main pathways for the sediment transfer, flux of contaminants and waste to the deep ocean. Therefore, canyons represent the most significant seafloor litter sink. The seafloor can be seriously affected by transport and accumulation of marine litter generating impacts on the habitats and associated biota that may be also exacerbated by other anthropogenic activities such as fishing.

In this work, the distribution and density of anthropogenic activity indicators in three submarine canyons (Motril, Carchuna and Calahonda) on the northern margin of the Alboran Sea are characterized focused on fishing distribution, marine litter potential sources, and the impact on canyon seafloor habitats. To achieve these goals, we used (1) seafloor imagery collected with a Remote Operated Vehicle, (2) benthic fauna, sediment and litter samples collected with different dredging devices, and (3) multibeam bathymetric data for interpreting both, geomorphology and trawl marks..

In the Motril and Calahonda canyons, marine litter is found along the thalweg and canyon walls. Overall, the litter is dispersed, very degraded, semi-buried and colonized by organisms. It comprises plastics (>60%), metals and fishing gears. Bottom trawling is pervasive in these two canyons. In contrast, due to the Carchuna Canyon, is deeply incised into the shelf, there is greater amount and variety of litter (plastic debris, fishing gear, metals, wood, etc.). Litter accumulations of 0.8 to 7.5 m^2 in extent are found along its thalweg. Overall, the litter is less degraded than that in Motril and Calahonda canyons.

The difference in litter abundance between these nearby canyons suggests that they have played different roles in litter transport and accumulation to the deep sea. The Carchuna Canyon shows a greater anthropogenic influence, since it seems to be more active as a litter sink, and it likely funnels a significant amount of coastal litter. Additionally, other possible litter sources such as marine traffic routes and fishing need to be considered, taking into account the proximity of the Motril Port.

PANiC – Investigating the role of a canyon in anthropogenic noise propagation across the continental margin

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Anthropogenic noise is classed as a pollutant, therefore an assessment of noise propagation at the continental margin is necessary due to biological impacts, economic importance, and regulatory commitments. An acoustic noise experiment (PANiC – Propagation of Acoustic Noise in Canyons) at the continental margin of SW Ireland was undertaken in the vicinity of a small canyon to assess the role a canyon incision makes in cross margin noise propagation characteristics.

An array of hydrophones was deployed; three along the axis of a 20 km long canyon and two on an adjacent slope. A small airgun source was towed around the array to provide contrasting noise pathways along and across the canyon and open slope regions. Noise propagation from adjacent deep water was stronger through the canyon axis relative to the adjacent slope, with significant sound levels reaching further towards the shelf when equivalent sound was essentially at ambient noise levels on the open slope. Noise propagation along the margin indicated the canyon plays a more complex role, enhancing received noise as a function of propagation direction. It is suggested that the complex topographic (and sub-seabed structure) are responsible, with internal dynamic water column effects adding further complexity.

The hydrophones also recorded the activity of a nearby trawler operating over the head of the canyon. Trawling noise, particularly when modelled from the trawl gear itself, was found to be considerably louder than ambient noise levels and the nearby research vessel conducting the experiment. Measurements indicated the submarine canyon focussed trawling noise through both main, and potentially side channels of the canyon, inferring a role for such features to enhance down slope noise propagation to deeper water at levels potentially disturbing to marine mammals.

Overall, the results suggest a role for canyons as a conduit for enhanced noise propagation across the ecologically sensitive continental margin in both directions. Increased anthropogenic activity at the outer continental shelf is likely to impact on deeper acoustic habitats. Such variability is hard to ascertain fully given the complex nature of some margin topography and assessment can potentially be augmented through, large computer resourced, 3D modelling.

VULNERABLE MARINE ECOSYSTEMS (VMEs)

What are VMEs?

Habitats such as cold-water coral (CWC) reefs, coral gardens and sponge communities that can be vulnerable to impacts from fishing activities. Species within these habitats are considered **VME indicator species**.

What makes a VME indicator species?

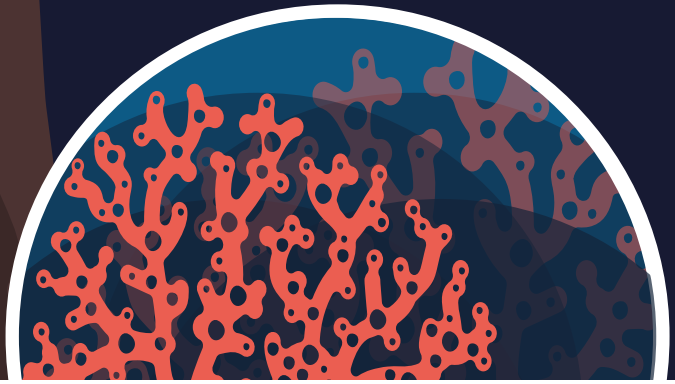
This is determined by the life history traits of the individual species, such as **slow growth**, **late maturity**, or **slow recovery** from damage.

Where are VMEs found?

Complex topographical features such as **seamounts**, **ocean ridges** and **submarine canyons** are known to harbour VMEs and indicator species.

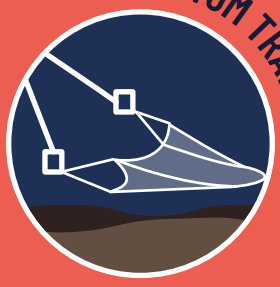
> 4000 y
Oldest recorded black coral

5000 m
Depth at which some CWCs can be found



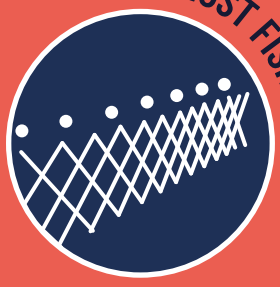
THREATS TO VMEs

BOTTOM TRAWLING



The most destructive and non-selective type of fishing activity, wiping everything in its path, causing mass resuspension events that can cause suffocation or inhibit organisms' ability to feed, even in other parts of the canyon.

GHOST FISHING



Derelict or abandoned fishing gear continue to entrap, entangle, and potentially kill marine life, non-selectively and indefinitely. Fishing lines and nets are the most common type of abandoned fishing gear in submarine canyons.

MARINE LITTER

Causes further stress to habitats by being vectors for other pollutants, can inhibit organisms' ability to feed, cause abrasion, breakages, mechanical or physical damage, necrosis, entanglement, and even death.

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Virtual reality to study deep-sea coral habitats in Lacaze-Duthiers Canyon, from geological settings to individual specimens

Marie-Claire Fabri, Olivier Dugornay, Xavier de la Bernardie, Charline Guerin, Pierre Sanchez, Aurelien Arnaubec, Tim Autin, Pere Puig

Ifremer Centre de Méditerranée

Lacaze-Duthiers canyon is located in western Mediterranean Sea and is long known for hosting cold-water coral colonies at the canyon head region, at depths ranging from 250 to 550 m. Three kinds of virtual reality approaches were applied in 2019 during the CALADU cruise in order to better understand the coral colonies distribution and their habitats, including the associated fishing impacts, and to assess the coral skeleton construction. These new results will be compared to previous data acquired in the same canyon.

1. Canyon's flanks were mapped using Hull mounted and ROV Multibeam Echosounders. Digital terrain models were build and examined in three dimensions. ROV bathymetric data collected on canyon's flanks made it possible to highlight a series of structures being identified as sedimentary strata, on which coral colonies were preferentially growing along.

2. Coral assemblages were explored at four locations and photographic images were assembled using structure from motion technics in order to build photogrammetric models. Coral assemblages reconstructed in 3D enable to geo-localize and recreate coral colonies on virtual scenes. Two species, *Madrepora oculata* and *Desmophyllum pertusum* were plotted and measured. Coordinates and depth of colonies were used to calculate density of populations and were reported on bathymetric models to allow interpretation of their location at the scale of the canyon. Sizes of colonies were measured to analyse structure of populations of both species and lost fishing gears (long lines) were measured and reported for each photogrammetric model.

3. Five deep-sea scleractinian species were collected and micro-tomographic scans were computed to enable a view of their skeleton intrinsec organisation. Micro-CT scans of *Madrepora oculata*, *Desmophyllm pertusum*, *Desmophyllum dianthus*, *Caryophyllia smithii*, and *Dendrophyllia cornigera* enabled virtual longitudinal and transversal cuts highlighting morphological criteria for species identification and multidirectional examination of specimen.

High-resolution morphological surveys of canyon-wall benthic habitats in Blanes Canyon (NW Mediterranean)

Pere Puig[1], Ruth Durán[1,2], Marie-Claire Fabri[3], Charline Guerin[3], Cecilia Cabrera[1], Claudio Lo Iacono[1], Veerle Huvenne[4], Meri Bilan[5], Jordi Grinyó[1,6], ABRIC Cruise team

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5. University of Salento
6. Royal Netherlands Institute for Sea Research (NIOZ)

Deep-incising canyons are characterized by steep terrains, containing vertical to overhanging bedrock exposures, which represent important substrates where biologically diverse benthic ecosystems, including cold-water corals (CWCs), may settle and develop. During the ABRIC and 3DHAB projects, and using information acquired during the previous ABIDES project, a detailed mapping and characterization of steep seafloor habitats in Blanes Canyon (NW Mediterranean) was accomplished with the mapping tools offered by the Ifremer hybrid remotely operated vehicle (H-ROV) Ariane. Based on the hull-mounted, shipboard multibeam seafloor digital terrain model (25 m grid) from this canyon, three study sites ranging from 460 to 870 m water depth were selected and mapped with unprecedented detail (i.e., 0.5 m resolution) using Ariane's forward tilted (45º) multibeam system. They included:

i) a narrow gorge at the head of the canyon,

ii) a steep wall at the western canyon flank, and

iii) a canyon tributary on the eastern canyon flank.

This contribution aims to provide the preliminary information acquired during these fine-scale morphological surveys, and to highlight the strong potential and capabilities of such robotic mapping tool. Several detailed morphological structures and features could be identified, which provided spatial information of the outcropping strata incised by the canyon, where benthic communities mostly develop, insights on the mechanisms contributing to the canyon-wall erosion (e.g., rills and rock avalanches), and the occurrence and distribution of bottom-trawl marks next to the canyon-walls. The bathymetric surveys by the H-ROV Ariane were followed by dives of the inspection-class ROV Liropus, aimed to obtain video footage of the CWC communities and to collect samples of benthic organisms. Both robots navigated along the same transects and the combination of both types of information will be used to conduct habitat mapping studies at very high resolution and to assess fine scale spatial differences and species distribution on these benthic canyon ecosystems.

Autonomous landers as a tool for studying nearshore submarine canyon ecology

Ashley Nicoll, Kevin Hardy, Phil Hastings, Natalya Gallo

Scripps Institution of Oceanography

Nearshore submarine canyons are unique bathymetric features that bring the deep sea close to shore, provide keystone structures for local fisheries, and potentially function as highways connecting shallow and deep-sea ecosystems. Currently 27% by area of large canyons in California are protected by government agencies, but this does not include smaller canyons, most of which are unprotected and understudied. To evaluate protection of smaller submarine canyons, we first identified all small canyon features along the coast of California, defined as a minimum depth of 200 m and incising 100 m into the slope. Applying this definition, we identified 23 additional smaller submarine canyons along the coast of California, with these features being concentrated along the Central and Southern coast. To better understand the ecology of nearshore submarine canyons, we developed two low-cost, spatially flexible autonomous lander systems: the Nanolander DOV BEEBE and Picolander DOV LEVIN. The Nanolander has three spherical housings containing a camera system, an acoustic communication system, as well as a ZebraTech Moana sensor to measure temperature and pressure over several weeks. The smaller, two-sphere Picolander is equipped with a ZebraTech sensor, camera system, and timed release for 24 to 48-hour deployments. Both systems are positively buoyant and deployed by hand from a small boat.

We used the La Jolla Canyon as a test bed for the Nanolander framework as a tool to study nearshore submarine canyons. The landers collected high-frequency environmental and seafloor community data at depths of 100-500 m. Using data collected from six exploratory Picolander deployments and five week-long baited Nanolander deployments we have assessed patterns in community structure over time and between depths. Patterns in community structure were assessed with respect to time of day, temperature, and oxygen and then compared across the deployment depths. Because small autonomous landers collect paired biological, physical, and biogeochemical data in hard to access areas, they can serve as powerful tools to help answer a great diversity of questions from animal behavior to community responses to the environment. Then these data can be applied to inform management decisions.

FORMATION AND EVOLUTION OF SUBMARINE CANYONS

Downwards formation of submarine canyons

Erosion by turbidity currents sourced from the continental shelf (can be associated to riverine systems)

1 Channel formation

2 Erosion by turbidity currents

3 Fully mature meandering shelf-incising canyon that cuts into the continental slope

Upwards formation of submarine canyons

Headward erosion of the continental slope by mass wasting and retrogressive slumping

1 Submarine landslide on lower continental slope

2 Repeated landslides eating back into the continental slope forming a blind canyon (contained within the slope)

3 Further headwards erosion incising into the continental shelf forming a shelf-incising canyon

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Habitat variability and faunal zonation at the Aegir Ridge, a canyon-like structure in the deep Norwegian Sea

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The Aegir Ridge System (ARS) appears as a canyon-like structure in the Norwegian Sea, but is an extinct spreading axis extending from the upper slope northeast of Iceland as part of its EEZ to a depth of ~ 3800 m in the Norwegian Basin. The main objective of this study was to characterize benthic habitats along the ARS based on macro- and megabenthic communities, substrate, depth and water mass variables. During the IceAGE3 expedition (Icelandic marine Animals: Genetics and Ecology) onboard the RV Sonne, in June 2020, the benthic communities of the ARS were surveyed and physically sampled by means of a remotely-operated vehicle (ROV KIEL 6000, GEOMAR) and an epibenthic sledge (EBS). For this purpose, two working areas were selected, including abyssal stations in the northeast and bathyal stations in the southwest of the ARS. Qualitative video and still images of the seabed were used to describe benthic habitats based on the presence of habitat-forming taxa and the physical environment. These biological data were complemented by high-resolution bathymetry data acquired with the vessel's multibeam echo sounder system. First results do identify differences in macro- and mega-faunal communities associated with a depth gradient. A biological canyon effect became evident in dense aggregates of megafaunal filter feeders and elevated macrofaunal densities. Finally, the presence of several Vulnerable Marine Ecosystem (VME) indicator taxa (e.g. sponges and corals) highlights the importance of our study in support of sustainable management of parts of the ARS towards the long-term conservation of its biodiversity and associated ecosystem services.

The diversity of calcaxonian octocorals from the Irish margin.

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Deep-water octocorals are prevalent on the Atlantic margin but tend not to be identified to species due to a global deficit in taxonomic skills. Our aim was to determine how many species of the suborder Calcaxonia (families Chrysogorgiidae, Primnoidae, and Isididae) are present in Irish waters. We collected tissue samples and morphology vouchers from 74 Isididae (bamboo corals), 22 Primnoidae, and 20 Chrysogorgiidae colonies during two expeditions of RV Celtic Explorer to the Irish slope. We extracted DNA and sequenced four mitochondrial gene regions: MutS, COI+igr1, 16s-nad2, and igr4. Using a concatenated 3389 bp sequence, we built haplotype networks and a phylogenetic tree. We discovered 25 haplotypes of Isididae, nine haplotypes of Primnoidae, and five haplotypes of Chrysogorgiidae. Some haplotypes contained more than one distinct morphotype. For every morphotype within every haplotype, we compared gross colony morphology using in situ and ex situ photographs. We also examined polyp morphology using light microscopy, and sclerite morphology using scanning electron microscopy.

We were able to confidently assign species names to most of the Primnoidae. Genus names were assigned to all chrysogorgiids and the remaining primnoids. For the Isididae, species names could be assigned to a haplotype from the subfamily Isidinae. However, no genus names, bar Acanella, were assigned to haplotypes within the subfamily Keratoisidinae due to the large morphological variation present both within and between haplotypes.

We concluded that no species had more than one molecular haplotype but that multiple species may share a single haplotype. Finally, more robust taxonomic characters are needed for use in tandem with genetic characteristics to accurately describe the biodiversity of bamboo corals.

Time-series imagery shows megafauna resilience to turbidity flow in submarine Kaikōura Canyon (Aotearoa/New Zealand)

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A 7.8 (Mw) earthquake triggered a large turbidity flow in Kaikōura Canyon in 2016. This event provides a unique opportunity to study the immediate and medium-term influence of large-scale disturbances on structuring benthic communities in canyons. Photographic transects showing mega-epibenthic fauna and lebensspuren (feeding and other life traces on the seafloor) were collected using a towed camera at five sites in the head of the canyon 10 weeks, 10 months, and 4 years after the event were compared to the same transects collected 10 years before. This analysis revealed that immediately after the turbidity flow there was little evidence of a living mega-epibenthic community, although chemosynthetic habitats briefly developed. Changes in the behaviour of fish, primarily Macrouridae, were also observed. Four years after the turbidity flow event, the visual surveys indicate that the benthic community has progressed to a later stage of recovery, being somewhat similar in structure to that observed before the event. These results, along with a similar time-series of bathymetric and macro-infauna data from sediment cores, form the basis of a wider project that aims to build models predicting rates of benthic community recovery from large disturbances in the deep sea. These models will contribute, not only to a better understanding of the influence of natural disturbances from turbidity flows in canyons and the deep sea but can also be used to help understand the impact of anthropogenic disturbance such as seabed mining.

3D Classification of Cold-Water Coral Reefs in the Porcupine Bank Canyon: A Comparison of Classification Techniques for 3D Reconstructions of Cold-Water Coral Reefs and Seabed

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Cold-water corals (CWC) reefs and submarine canyons are complex structural habitats that are considered key components of deep-sea ecosystems. As three-dimensional structural habitats, there is a need for robust and accessible technologies to enable more accurate reef assessments. The use of Remotely Operated Vehicles (ROV) combined with Structure-from-Motion (SfM) photogrammetry represent an effective and non-destructive methodology that yields high-resolution reconstructions of deep-sea environments such as cold-water coral habitats and submarine canyons. The increase of data derived from SfM mapping has led to the necessity for new tools and techniques to aid time-effective and high-quality analysis of large areas.

In this study, three classification workflows [Multiscale Geometrical Classification (MGC), Colour and Geometrical Classification (CGC) and Object-Based Image Classification (OBIA)] were applied to photogrammetric reconstructions of CWC habitats. In total, six-point clouds, orthomosaics, and digital elevation models, generated from structure-from-motion photogrammetry, are used to evaluate each classification workflow. For the first time, the techniques were applied to the CWC reefs in the Porcupine Bank Canyon (PBC), located approximately 300 km southwest of Ireland. We analysed the classification accuracy results, overall performance and the potential loss of information when using 2D and 3D data.

Our results show that 3D Multiscale Geometrical Classification outperforms the Colour and Geometrical Classification method. However, each method has advantages for specific applications pertinent to the wider marine scientific community. Results suggest that SfM can contribute to more precise structural analysis of CWC habitats while also providing grounds for temporal and volumetric change detection in CWC reefs. Furthermore, advancing from commonly employed 2D image analysis techniques to 3D photogrammetry classification methods is advantageous and may provide a more realistic representation of cold-water coral habitats.

Temporal Variability of Cold-water Coral Habitats from the Porcupine Bank Canyon, NE Atlantic

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7. iCRAG (Irish Centre for Research in Applied Geosciences).

The Porcupine Bank Canyon, NE Atlantic, is the largest submarine canyon occupying the Irish Margin. Certain characteristics of the canyon (strong bottom currents, intertidal mixing, food availability) provide an ideal environment for Cold-water corals (CWCs). These organisms trap current-suspended particles from their environment, which become deposited in and around the coral framework. This results in the growth of topographic features called CWC mounds, which contain a record of paleoenvironmental change through time. Here, we present a project within the MMMonkey_Pro (**www.marinegeology.ucc.ie**) research programme, which focuses on the temporal development of CWC habitats in submarine canyons.

ROV-mounted vibrocore samples have been retrieved from a range of CWC habitat types within the Porcupine Bank Canyon (PBC), NE Atlantic. These cores have been scanned using computed-tomography (CT) creating comprehensive imagery of the internal architecture of the CWCs, as representative of reef development stages. Variables such as matrix:coral ratio, coral-fragmentation, coral-fragment orientation and size (Titschack et al., 2015), allow CT-derived facies types to be defined. An off-mound core revealed a fine-scale record of ice-rafted debris (IRD), giving an insight into ice-sheet instability through Marine Isotopic Stages 1-3. The relative abundance of the Neogloboquadrina pachyderma sinistral has been used to identify periods of glacial/interglacial conditions, and further constrain geochronology. $\delta^{18}O$ analysis of Globerigina bulloides and N. pachyderma sinistral have been used determine absolute surface and subsurface temperatures. $\delta^{13}C$ values recorded in planktonic and benthic foraminiferal calcareous tests have revealed paleocirculation patterns in the canyon. It was shown that the melting of nearby grounded icebergs intensify bottom currents, triggering slope failure in the canyon, thereby initiating the decent of CWC debris into the continental abyss. Evidence shows that a decoupling of surface and bottom waters is taking place. Optimal growth conditions for CWCs through the Late Pleistocene to mid-Holocene have been determined.

This unique multidisciplinary ensemble approach, has reconstructed regional environmental conditions, uncovering the controls on mound cessation and development related to the CT-identified reef development stages. For the first time, we aim to shed light on what controls the formation of different CWC habitats in the PBC.

Health screening of the reef forming scleractinian cold-water corals *Lophelia pertusa* and *Madrepora oculata* in a remote submarine canyon on the European continental margin, NE Atlantic

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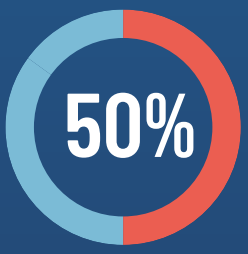
Environmental stressors such as temperature and sedimentation can increase the virulence of pathogens and expedite their ability to cause diseases in deep-sea environments. The present research employed a combination of histology/microscopy and polymerase chain reaction diagnostic techniques to investigate whether haplosporidians, *Vibrio* spp. and other potential pathogens were present in the cold-water scleractinian corals *Lophelia pertusa* and *Madrepora oculata* in the Porcupine Bank Canyon (PBC), NE Atlantic in May 2019. *Haplosporidia* are a globally significant pathogen group for marine invertebrate species. Also, *Vibrio* spp. are common in the environment and most species are problematic pathogens. A total of 75 intact coral polyp tissues were screened for pathogens, particularly since the *Haplosporidia* are not considered to be endemic in corals and their pathogenicity is yet to be determined. No potential pathogen or unidentified cells were observed in the *Madrepora* samples possibly due to the different feeding strategies between the two scleractinian corals. Neither histology nor standard PCR detected haplosporidia in the coral samples, however, other unidentified organisms were observed in the histological samples, including a Rickettsiales-like organisms (RLOs), which occurred at an overall prevalence of 8.0% and at a low infection intensity of 1 - 4. The framework-forming coral, *L. pertusa*, showed a few RLOs infection from the PBC canyon head (2.7%) with more coral infections observed in the south branch of the PBC (5.3%). Similarly, unidentified cells observed in *L. pertusa* tissues from the south branch (4.0%) were more common than those found in the canyon head (1.3%) with an overall prevalence of 5.3%. Also, using Illumina technology, *Vibrio shilonii* was observed in a couple of *L. pertusa* samples in low abundances (0.22%) while no *Vibrio* spp. was detected using a standard PCR technique. Although the route of pathogen infection is unclear, a likely mode of entry could be associated with particulate availability and the feeding strategies of the scleractinian corals. This suggest that this slow growing coral, away from human impacts, invests energy into an enhanced immune function and reduced susceptibility to global pathogens despite a changing ocean environment.

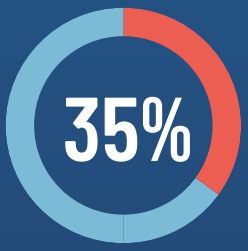
MARINE LITTER IN SUBMARINE CANYONS

5.25 Trillion (240,000 tonnes)

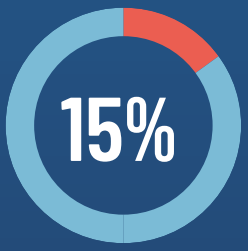
PARTICLES OF PLASTIC
floating on the sea surface



Quickly sinks close to the point of entry



Can travel great distances before eventually sinking



Will remain floating or in the water column

PERSISTENT ORGANIC POLLUTANTS (POPs)

Adsorb onto plastic particles that can be ingested and accumulate in deep-sea organisms

ALIEN INVASIVE SPECIES

Can be transported laterally and vertically by litter, threatening habitats and ecosystems

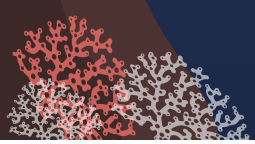
0.9%

Of the **9,477** mapped submarine canyons have been studied for marine litter

Submarine canyons are known as **conduits** for the transport of organic matter, nutrients and sediments from the continental shelf to the deep sea due to hydrodynamic processes such as turbidity currents, density currents and downwelling currents. These processes are also reponsible for the **transport of litter** into the deep sea, making canyons **passive accumulation zones**.

10%

Of litter entering the marine environment are **ghost fishing nets and fishing gears** that continue to pasively entrap organisms



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Morphological characterisation of pockmarks in the surrounding areas of Capbreton canyon

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Capbreton canyon is located in the Cantabrian margin of the SE of the Bay of Biscay (Atlantic Ocean). It runs in an E-W direction parallel to the coastline along 300 km reaching depths of more than 3,000 m.

Within the framework of the European LIFE IP INTEMARES project, this area is being studied for the identification of priority habitats that should be protected and integrated into the Natura 2000 Network. During two oceanographic surveys, bathymetric, backscatter and high-resolution parametric data were acquired, as well as sediment grab samples and video transects of the seabed. A geomorphological characterization of this sector has been carried out. The area includes a section of the main canyon with meandering morphology, where numerous terraces and erosive escarpments are observed. On its southern slope, there are tributary channels perpendicular to the Spanish coast, which intersect the slope and define intertributary platforms with extensive fields of pockmarks. Pockmarks are circular or elliptical seabed depressions related to submarine fluid leaks inside the sedimentary deposits under overpressure.

Around 3000 pockmarks have been mapped with automatic and manual techniques. They are located between 400 and 1000 m deep and have diameters from 30 to 900 m with depths ranging from a few meters to 80 m. Pockmarks can be single or have multiple sinks. In certain sectors there are preferential alignments, which could respond to a tectonic control and a gradation in depth according to areas of fracturing. Connections between these morphologies are also frequent, giving rise to linear incisions or small detachments, suggesting a relationship between pockmarks and areas with unstable slopes. The origin of the pockmarks could be after the formation of these linear incisions, caused by fluid leakage in sediment-filled canyons.

In the seismic profiles acquired, the characteristic reflectors of this type of fluid escape morphologies are observed, as well as paleo-pockmarks or pockmarks inside the sedimentary deposits that have not emerged.

Does offshore meteoric groundwater play a role in submarine canyon formation?

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Offshore meteoric groundwater has been reported at almost 250 sites in global continental margins and has been linked to submarine canyon formation. Groundwater flow can generate excess pore pressures, which lower the effective stress and lead to slope failure. Where it actively discharges at the seafloor, meteoric groundwater is thought to exert a seepage force on sediments, which can cause repeated failure and the formation of submarine canyons by retrogressive slope failure. There is a lack of mechanistic understanding of these geomorphic processes, their rates and their spatio-temporal scales. Such processes are extremely difficult to measure and observe, and their reproduction with numerical models or laboratory simulations has been rare. Precise understanding of how groundwater flow creates seafloor geometries remains elusive.

The objective of this study is to evaluate if, and under which geologic and hydrologic conditions, meteoric groundwater can be a significant geomorphic agent in submarine canyons. We address this problem using an approach that entails a combination of forward stratigraphic modelling for both siliciclastic and carbonate margins, modelling of groundwater flow, and limit equilibrium analyses. We find that offshore meteoric groundwater flow lowers the factor of safety of continental slopes, particularly at sea-level lowstands. Since sea-level has been lower than at present for 80% of the Quaternary, offshore meteoric groundwater should be considered an important factor when reconstructing continental margin evolution.

Where and Why Do Submarine Canyons Remain Connected to the Shore During Sea-level Rise? Insights from Global Topographic Analysis and Bayesian Regression

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The efficiency of sediment routing from land to the ocean depends on the position of submarine canyon heads with regard to terrestrial sediment sources. We aim to identify the main controls on whether a submarine canyon head remains connected to terrestrial sediment input during Holocene sea-level rise. Globally, we identified 798 canyon heads that are currently located at the 120m-depth contour (the Last Glacial Maximum shoreline) and 183 canyon heads that are connected to the shore (defined here as being located no more than 6 km from the coast – potentially tapping into longshore sediment transport) during present-day highstand. Regional hotspots of shore-connected canyons are the Mediterranean active margin and the Pacific coast of Central and South America. We used 34 terrestrial and marine predictor variables to predict shore-connected canyon occurrence using Bayesian penalized regression. Our analysis shows that steep and narrow shelves facilitate canyon-head connectivity to the shore. Moreover, shore-connected canyons occur preferentially along active margins characterized by resistant bedrock and high river-water discharge.

Formation of giant deep-water canyons in offshore northern Tanzania as a result of Neogene tectonics

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The northern margin of Tanzania, facing the Indian Ocean, is dissected by the three large islands of Mafia, Zanzibar, and Pemba, and the troughs that separate them from the mainland. Although a relation between the formation of the islands and the tectonics of the East African Rift System (EARS) has been proposed, a quantification of the timing of the uplift and the effect of seafloor deformation on the deep-water sediment routing system is lacking.

In this study, we investigate the Oligocene to recent stratigraphy offshore the islands of Zanzibar and Pemba using 2D seismic reflection profiles and exploration wells with the goal of reconstructing changes in canyons/channels network through time and date the subaerial exposure of the islands.

In detail, we used the changes in the submarine drainage network as a tape recorder of the different tectonic events. We discovered a decrease in the number of slope channels during the middle-upper Miocene and the upper Miocene to lower Pliocene offshore Pemba and Zanzibar islands, respectively, that we interpreted as a result of the uplift of the Island. The estimated timing indicates a potential relation with the EARS tectonics, but the lack of deep seismic profiles prevents a full understand of the tectonic drivers. The deformation of the seafloor leading to the subaerial exposure of the islands promoted the formation of two newly discovered giant canyons, characterized by a modern width of c. 30 km and 8 km, and depth of c. 485 m and 260 m, in a water depth of 2200 m. These canyons represent the main conduit of sediments for this sector of the western Indian Ocean during the last 20 Myr and likely feed a submarine fan in the Somalia abyssal plain. Supported by these new results, we propose a new alternative model for the evolution of the Pemba and Zanzibar islands, highlighting the evolution of channel pathways and canyons from the Oligocene to present day.

Increased frequency of out-of-channel sediment gravity flows are coincident with Late Pleistocene falling sea-level offshore Morro Bay, California

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Stanford University

A series of waveform-like bathymetric features with wavelengths of ~400–500 m and amplitudes of ~50 m occur within a ~1.5 km2 zone offshore Morro Bay, California (~750–880 mwd) that is adjacent to a prominent submarine channel bend. The presence of these features may provide clues as to how sediment is mobilized across the continental slope. Furthermore, studying these features will provide insight into the geohazard risk of submarine gravity flows for offshore floating wind farm developments proposed in this area. To study the origins of this waveform field, a series of autonomous underwater vehicle (AUV) high-resolution CHIRP bathymetric surveys and a suite of 11 sediment cores (~1–7.0 m penetration) were collected across this region. Cores penetrating the waveforms preserve a high abundance of sand-rich sediment gravity flow deposits. We present 25 new radiocarbon ages obtained from planktonic foraminifera that were collected from mud directly below sand horizons. Age data provide maximum depositional ages of sedimentation events that constrain the timing and event frequency of out-of-channel sediment gravity flows. Across all sediment cores, 14 Holocene sand horizons were identified while 119 sand deposits were dated to be Pleistocene in age (ca. 12–40 Ka). An approximate order of magnitude increase in sand-horizon frequency density from ca. 20–22 Ka to ca. 27 Ka from sediment cores penetrating the waveform suggests that out-of-channel sediment gravity flows were more frequent in the Late Pleistocene. This suggests that the frequency of sediment gravity flows was greater during the Late Pleistocene and diminished significantly by the Holocene. Moreover, approximately 69% of all noted sand intervals range between maximum depositional ages of ca. 25–18 Ka, which corresponds to the terminus of the Late Pleistocene's falling stage sea-level into the Last Glacial Maximum (ca. 18 Ka). These observations provide a high-resolution example of a substantial increase in sedimentation rate across an unincised portion of the continental slope coincident with a transition from falling stage to lowstand sea-levels. This work provides a first-hand assessment of the geohazard potential of submarine gravity flows offshore Morro Bay, California.

Guayanilla Canyon, Offshore Southwest Puerto Rico: An Earthquake Created Canyon System?

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Guayanilla Canyon and adjacent channels form the largest canyon system on the southern margin of Puerto Rico covering an area of approximately 1,300 km2, between water depths of ~ 10 and 3,150 m. Beginning with a M6.4 earthquake on 7 January 2020, the head of Guayanilla Canyon has been the focal point of intense low-magnitude seismic activity that has been punctuated by sporadic higher magnitude (M4-5) earthquakes and localized crustal subsidence. The canyon system indents the shallow-reef topped insular shelf by as much as 10 km. Mean discharge from the largest terrestrial river draining into Guyanilla Bay, 1.2 km north of the canyon head, is less than 0.2 m/s^2 and no clear drainage channel connects the bay to the canyon.

Abrupt meanders, cut-off channels, and linear ridges that fall along several prominent lineations crossing the canyon systems are observed on high-resolution bathymetry. Two of these lineaments are aligned with normal faults bounding a 100s-of-meters deep buried half graben on the shelf east of the current seismic activity. Given the extremely low terrestrial input to the canyon system, the distribution of seismicity, and the presence of recently imaged faults in the sub-surface, we hypothesize that the canyon has evolved over time via insular shelf and canyon wall collapse induced by earthquake shaking. The unique morphological features in the region of seismicity suggest that a long history of seismic activity, fault displacement and crustal subsidence are capable of forming and modifying near-shore submarine canyons in the absence of terrestrial input.

IMPACTS OF LITTER IN SUBMARINE CANYONS

Once an item of litter enters a submarine canyon, the rugged terrain makes it difficult for it to leave. Rocks and biogenic structures aggregate and snag litter, enabling the persistence of litter in these habitats and ecosystems.

MARINE LITTER INTERACTIONS

- Death
- Ghost fishing
- Smothering
- Necrosis
- Covering
- Abrasion
- Breakage
- Entanglement
- Encrustment
- Colonisation
- Epibiosis
- Refugia

When litter comes into contact with a deep-sea organism such as a cold-water coral, there can be severe impacts from mechanical damage, such as suffocation, hindering the ability to feed, breakages and even **death**. When they die and turn to rubble the **litter gets released** and is **free to repeat the cycle** on other organisms.

521,000 Items/km²

Recorded in the Messina Canyon, Sicily, the highest abundance of litter recorded in any submarine canyon to date

INCISE
INTERNATIONAL NETWORK FOR SUBMARINE CANYON INVESTIGATION AND SCIENTIFIC EXCHANGE

UNIVERSITY OF GIBRALTAR

National Oceanography Centre

UNIVERSITY OF PLYMOUTH

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Organic carbon transfer in submarine canyon and deep-sea dispersal systems around Aotearoa New Zealand

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The submerged continental mass of Zealandia is dissected by numerous submarine canyons and channels that transfer sediment and associated organic matter from the coast to the deep-sea. Sediment discharge from Aotearoa New Zealand rivers accounts for ~3% of sediment delivered to the ocean across Oceania, much of which is then captured by deep-sea dispersal systems that punctuate the continental margin. Episodic geological events also contribute to this sediment supply, with the most recent 2016 Mw7.8 Kaikōura Earthquake leading to a canyon-flushing event that excavated ~850 metric megatons (Mt) of sediment out of the Kaikōura Canyon on the northeastern coast of the South Island/Te Waipounamu.

This event also transferred ~7 Mt of organic carbon (OC) to the deep ocean, equivalent to over twice the annual terrestrial particulate OC flux from New Zealand rivers. Using bulk and fatty acid-specific stable isotope analyses, pre-earthquake sediments in the steep, highly incised Kaikōura Canyon were dominantly terrigenous (~40-50%) in the upper parts of the canyon but diminished rapidly down-canyon to values of ~15% at 1500 m water depth, just ~25-30 km off the coast. Similar analyses of post-earthquake samples, together with DNA markers and ramped pyrolysis methods, demonstrate the effect of the canyon-flushing event in distributing terrigenous organic material along the Hikurangi Channel, which is connected to the Kaikōura Canyon and is the main deep-sea sediment conduit along the east coast North Island/Te Ika a Māui.

Conversely on the opposite, west coast of the South Island/Te Waipounamu, sediment OC content in the Hokitika Canyon showed that the terrigenous influence from high-sediment discharge rivers extends almost 200 km offshore to water depths of ~2000 m. Here, terrigenous OC content was 70-80% along most of the length of this sinuous, lower gradient canyon system. These two contrasting canyon systems (Hokitika and Kaikōura) potentially represent different endmembers in terms of sediment and OC delivery to the deep ocean, driven by variations in riverine sediment supply, shelf oceanography and geological processes.

Whittard Canyon as pathway and sink for organic carbon

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Submarine canyons provide effective connections between the productive shelf waters and the nutrient poor deep sea, playing an important role in lateral transport of organic carbon. Moored observatories were deployed and sediment samples were collected in the eastern most branch of the Whittard Canyon (Bay of Biscay) to determine which processes affect organic matter dispersal and deposition. Distinct and permanent nepheloid layers were observed between 1200 and 2500m water depth, which are related to resuspension of (organic) matter by tidal currents interacting with the sloping topography. Long term (>12 months) measurements showed that significant amounts of particulate matter were transported by intermittent gravity flows some of which were related to major storms, resulting in the transport of large volumes of matter as shown by elevated mass and organic carbon fluxes. Some events in winter were characterized by peaks in fluorescence, which indicates the supply of relatively fresh organic matter to 3000 m water depth, likely providing an important food supply mechanism to the deep-sea faunal communities.

Analysis of surface sediments showed that the head of the canyon is characterized by low organic matter contents, as are the slopes of the canyon, while the deepest part (>2000 m water depth) of the canyon is dominated by marine derived material, containing high, but aged organic matter. A depo center was found at 2100 m water depth, showing extremely high sedimentation rates up to 11.6 cm per year. Our data, when compared to other submarine canyons in the North Atlantic, shows that Whittard Canyon is an active system being a pathway as well as sink for organic matter, emphasizing the important role of submarine canyons in the global marine carbon cycle.

Tracing particulate organic matter pathways in deep-sea ecosystems: Food supply and partitioning in Whittard canyon walls cohabitated by *Acesta excavata* (Bivalvia: Limidae) and cold water corals (Scleractinia)

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Particulate Organic Matter (POM), *Acesta excavata* and Scleractinian cold water corals (CWCs) were collected during two surveys in June 2014 and August-September 2015 from several depths and branches of the Whittard Canyon System.

Elemental (OC, N), bulk isotopic (δ13C, δ15N), and lipid analysis is presented to characterise the nutritional quality and quantity of POM and trace the organic matter signal to biological tissues to understand trophic dynamics and resource partitioning between overlapping filter feeding phyla in vulnerable deep-sea ecosystems. This study focusses upon two novel deep-sea ecosystems; an *A. excavata* dominated canyon wall with a strong association to CWC *Madrepora oculata* detected near the Western-Middle Branch between 633 to 762 m (Johnson et al., 2013), and a CWC *Lophelia pertusa* dominated canyon wall with occurrences of *A. excavata* in the Eastern Branch at ~ 1350 m (Huvenne et al., 2011). POM from intermediate and benthic nepheloid layers (INLs and BNLs) have been identified as potential food sources, respectively (Huvenne et al., 2011; Wilson et al., 2015). BNLs in proximity to the Acesta wall have been linked to trawl-fishing activities (Daly et al., 2018).

Bulk isotopes and dietary lipids of *A. excavata* and CWCs are significantly different to POM across both surveys. As tissue signals provide a broader temporal insight into diet, their main food source may not have been sampled during either cruise. Alternatively, CWCs may be capable of N2 fixation and internal cycling (Middelburg et al., 2015). Emerging Bivalvia and Scleractinia research suggests that *A. excavata* and CWCs may be capable of trophic upgrading (Kabeya et al., 2018).

Does the presence of nepheloid layers in the most Eastern Branch of Whittard Canyon influence the bacterial community composition and abundance?

Sofia Ledin, Gerard Duineveld, Marc Lavaleye, Furu Mienis

NIOZ Royal Netherlands Institute of Sea Research

Submarine canyons are regarded as major conduits for particle and organic matter transport from the continental shelf to the food deprived deep sea. The heterogeneous topography in canyon systems interacts with the hydrography, resulting in the resuspension of (organic) matter generating distinctive nepheloid layers characterised by a higher particle density than in clear waters. In the most eastern branch of Whittard Canyon nepheloid layers were observed between 1200 and 2500 m water depth.

We hypothesis that a higher amount of organic matter in these nepheloid layers will increase the microbial activity, resulting in a difference in bacterial community composition and abundance in and out of nepheloid layers. To investigate the microbial community composition and abundance the most eastern branch of Whittard Canyon (Celtic Margin, NE Atlantic) was visited during cruises in 2017, 2018 and 2019 with R/V Pelagia. Water samples, collected with the CTD/Rosette along the thalweg of the canyon between 700 and 2635 m water depth, were sampled for nutrients, suspended organic matter, bacterial counts, and DNA. Bacterial cell counts were conducted via flowcytometry, showing that bacterial abundance decreases with depth along the canyon.

Overall, the number of cell counts are higher in clear water samples, but preliminary observations from quantification show a higher concentrations of 16s rRNA product in the nepheloid layers. Total genomic DNA was extracted using Qiagen DNeasy® PowerSoil® PRO kit and samples for both 16s and 18s rRNA are currently being sequenced using Illumina MiSeq V3 kit 2x300 for bioinformatic analysis of these microbial communities. Since marine microbes account for the majority of the ocean biomass, microbial communities are fundamental as food source for many species and play an important role in the biogeochemical cycling of carbon, oxygen, nitrogen, and other important elements in the deep sea. By investigating the microbial community in and out of Whittard Canyons nepheloid layers we will obtain a more comprehensive understanding of the microbial community variation in canyons and determine their wider role in the marine food web.

Conference instructions

Support: Please contact Awantha.Dissanayake@unigib.edu.gi for any issues.

FAQS

1. How will the conference run?

The online conference will run as the Zoom webinar function and a parallel meeting function – see Session schedule figure overleaf.

The webinar platform will be the Conference itself where presenters are invited as panellists and the audience will be conference participants.

The parallel meeting function will enable an 'interactive' function akin to that of a face to face conference at coffee breaks. Following each presentation, presenters will dial out of the conference (webinar function) and dial into the breakout rooms (meeting function).

Each conference session will be structured by an initial welcome and house-keeping, followed by first three oral presentations and coffee break, second three oral presentations and a coffee break, followed by the Poster Session - see Session schedule figure overleaf. Participants are free to dial out and join the breakout rooms to converse with presenters regarding their presentations.

NB. Please note, the F2F conference will not be fully replicated so please be patient if trying to ask questions/converse with people in the breakout rooms

2. I paid for registration, how do I join the conference?

Once you register on EventBrite or receive confirmation if you paid by invoice, you will receive two Zoom links a week prior to the conference; one link for the conference, one link for breakout rooms.

3. Can I join the conference and breakout rooms at the same time?

NO. You can only join one function at a time. You will have to dial out of one function and dial into another function using the links provided.

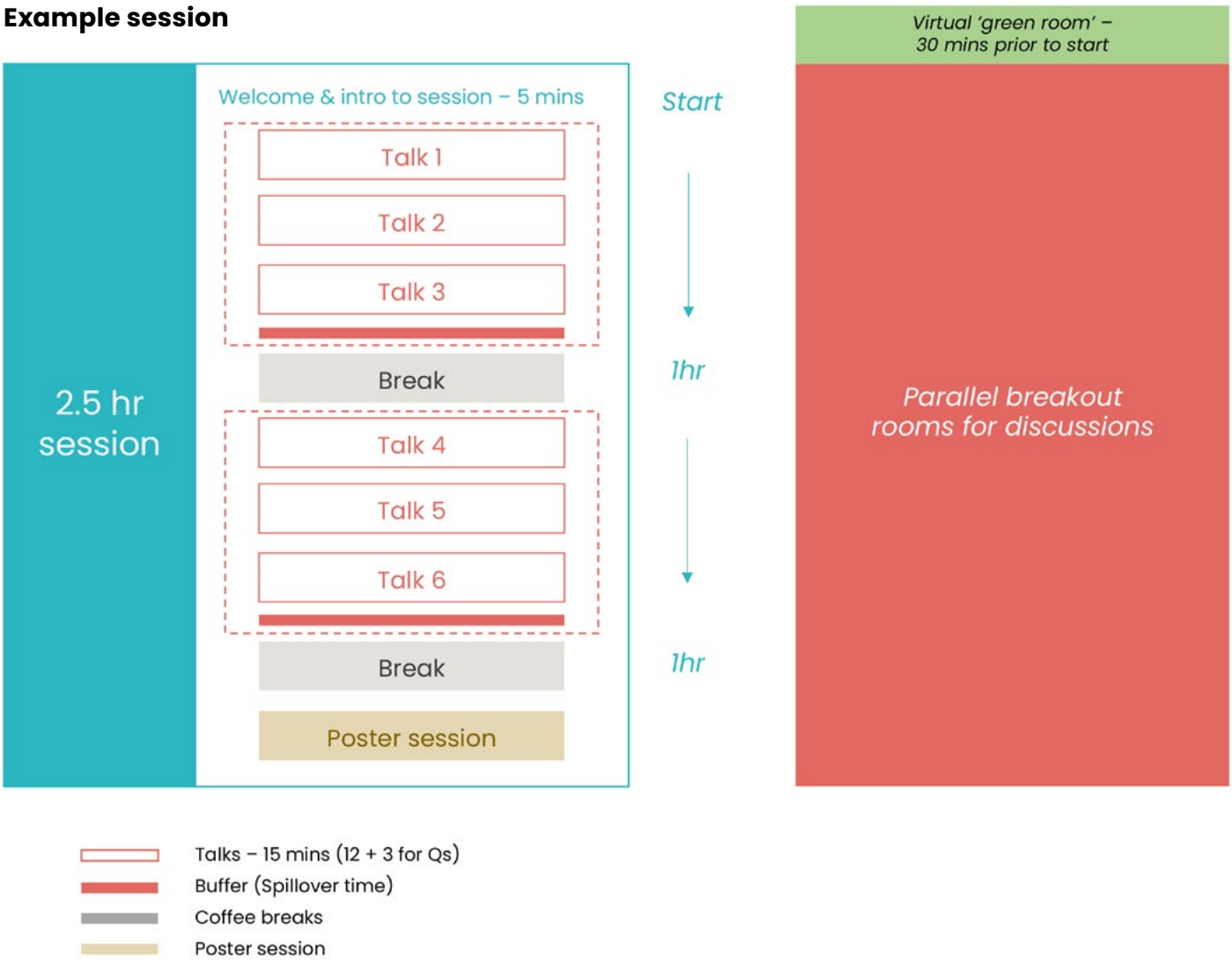
4. How do I ask questions following an oral or poster presentation?

During an oral or poster presentation, the Q&A function will be enabled within the conference to register questions the audience would like to ask. The session chair will read out the questions from the list.

DO NOT ask questions within the 'Chat' function – this function is solely for comments such as '*Great presentation*', '*Really enjoyed your presentation*', etc.

Following each oral or poster presentation the session chair will read out questions received from the Q&A function.

Example session



5. What time zone is the INCISE conference at?

All times are listed in **CEST – Central European Summer TIME**, Gibraltar local time. Please use the following link to work out your local time www.worldtimebuddy.com.

The AM session is at **0900 – 1130 CEST** and primarily geared towards audiences in Asia-Pacific.

The PM session is at **1630 – 1900 CEST** and is primarily geared towards audiences in North, Central and South America. For reference please see time zone comparison below:

Instructions to presenters

Please see below for instructions on your presentation. Due to time constraints (and to prevent Zoom fatigue) we will be strict on timelines to ensure each session runs to time.

Oral presentation

Type: Oral presentation

Format: Live presentation/share screen

Duration: **13 minutes presentation + 2 minutes for questions**

Presenters will be able to dial in to the '*Green Room*' which will be open **30 minutes prior** to the session to allow for presenters to share their screen and test connectivity/audio/video.

Presenters: *Please try to ignore the chat function as comments will flash up on screen whilst you are talking. You will be invited to answer a question directed to you by the Session Chair.*

Poster presentation

Type: Oral presentation – one slide

Format: Live presentation/share screen

Duration: **3 minutes presentation + 2 minutes for questions**

Presenters: *Please try to ignore the chat function as comments will flash up on screen whilst you are talking. You will be invited to answer a question directed to you by the Session Chair.*

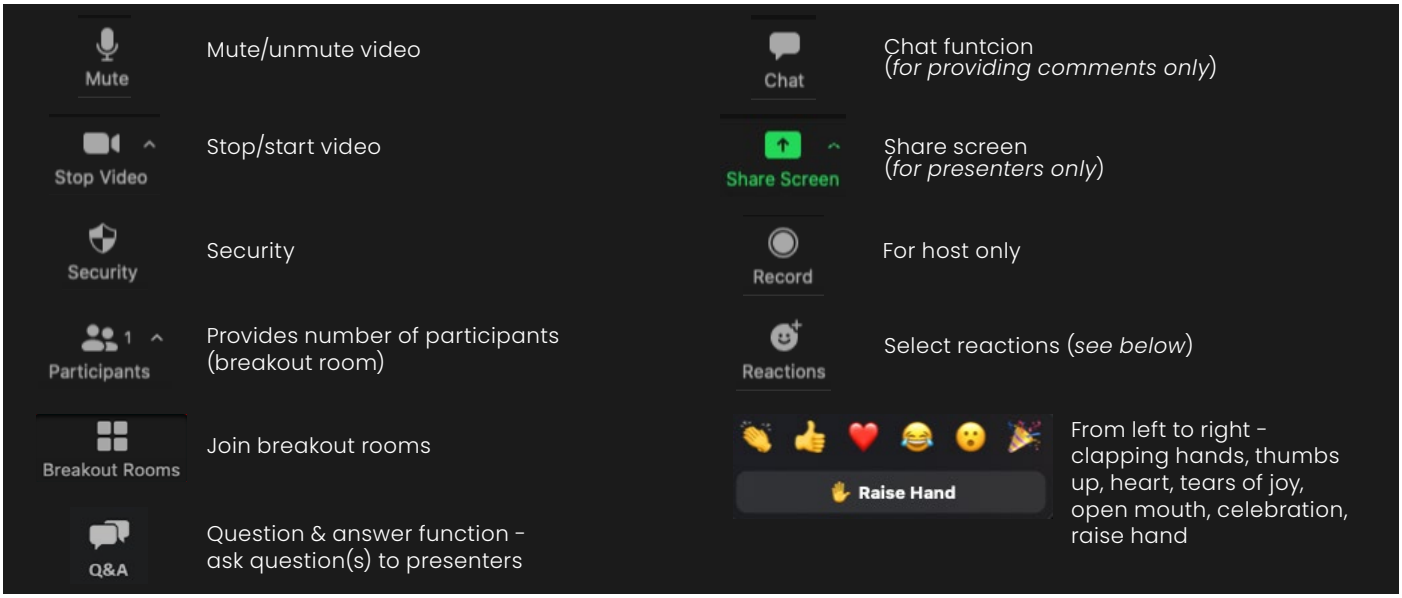
For ease of a smooth conference, please download Zoom, it is free.

Instructions to participants/non-presenters

You will be muted upon joining the conference and camera function disabled.

Please feel free to comment using the chat function and ask questions using the Q&A function. You can leave the conference and join the breakout rooms to meet the presenters and ask questions/converse with other participants.

Summary of Zoom menu bar functions



Description of Zoom menu bar functions

Mute - Audio function will be disabled for participants; presenters will be designated as panellists and have audio and video function enabled.

Start video - Video will not be enabled for participants. Video will be enabled for oral and poster presenters.

Participants - You will be able to see a list of attendees at the conference.

Q&A - Question and Answer function. Session chairs will direct questions received via this function.

Polling - This function will be disabled.

New Share/Pause share - For oral and poster presenters only.

Annotate - For oral and poster presenters only.

Glossary

Breakout rooms - Zoom meeting function

Chat - Chat function to provide comment e.g. *'Great presentation'*, *'Really enjoyed your presentation'*. **DO NOT** ask questions here – they will not be answered.

Conference - Zoom webinar function

F2F - Face 2 face

Q&A - Question and Answer function – method to register questions. The session chair will direct any questions to the relevant presenters.

Session chair - Person chairing each session

INCISE

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5th International Symposium

14th - 18th June 2021