SCOR Working Group Proposal

Title: A FUNCTIONAL TRAIT PERSPECTIVE ON THE BIODIVERSITY OF HYDROTHERMAL VENT COMMUNITIES

Acronym: FDvent

Abstract: Species diversity measures based on taxonomy, and more recently on molecular data, dominate our view of global biodiversity patterns. However, consideration of species functional traits, such as size, feeding ecology and habitat use, can provide insights into biodiversity patterns by representing how communities contribute to ecosystem processes. Moreover response traits, characteristics linked to how species respond to environmental change, have been linked to the processes underpinning community recovery following disturbance. We propose identifying functional traits for the global vent species pool to provide the first quantification of spatial and temporal patterns in functional diversity in this unique ecosystem. We will use expert knowledge and a literature review to identify both effect and response functional traits, and retrieve data for diverse macrofaunal and meiofaunal taxa. Our aim, given that trait-based measures provide a means to directly compare communities with species arising from different evolutionary trajectories, is to test whether vent communities from different biogeographic provinces display functional convergence while accounting for the geological and chemical settings. We will further test for change in functional diversity following the formation of new vents and disturbance events. This knowledge is critical for environmental management, given that hydrothermal vents are presently targeted for mineral resource exploitation by 2017. Our proposed working group will build an open-access traits database and offer a novel perspective on global biodiversity and succession patterns in vent communities. We will advance our understanding of the potential for functional diversity metrics to inform effective management and risk assessment guidelines at vents.

Scientific Background and Rationale

Why Functional Diversity? Most studies of biodiversity patterns and assemblage change focus on species. Even so, while some species may be very similar, others may differ markedly in their morphology, behavior, and ecology, and play different roles in a community and, ultimately, ecosystem function. Therefore functional trait approaches offer a means to distinguish differences in how species interact with their environment and other species (Lefcheck et al. 2015). Functional diversity (FD) metrics integrate the total variation in functional traits across all species within a community, providing an important perspective to diversity that complements patterns gained from taxonomic diversity measures (Faith 1996, Stuart-Smith et al. 2013).

Changes in community processes that are linked to functional traits are, in some cases, more important than changes in the species present, such as when understanding the implications of community responses to disturbance is of interest. Community processes may also be more predictable in comparison to traditional taxonomic approaches (Suding et al. 2008), as well as being a more sensitive measure of community change (Coleman et al. 2015). Therefore, using trait-based methods to characterize community dynamics provides a means to examine functioning-related consequences to community processes following both natural and human-related disturbances.

Functional trait ecology and statistical tools are also rapidly evolving to consider changes in community function driven by local diversity (alpha diversity) and variation of community composition through space (beta diversity). Thus a functional trait perspective will allow us to identify those species that play an important role in maintaining local functional diversity, sites that contribute in exceptional ways to beta diversity, and drivers of significant temporal trends at different spatial scales.

Why Hydrothermal Vent Communities? Functional trait methods have largely been developed using plant assemblages (although functional trait approaches are presently being widely applied) where characteristics that define species in terms of their ecological roles and interactions are direct indicators of ecological process and function. For instance, there is a strong link between leaf traits (e.g., size), plant growth and primary production through photosynthesis. In a similar way, symbiont-hosting invertebrates are dependent on access to hydrothermal vent fluids, which deliver reduced compounds such as hydrogen sulfide or methane, used by microorganisms as an energy source for the synthesis of organic molecules. Animals that host bacterial symbionts have specialized morphological traits including enlarged tissues where bacteria are located, and thus there is a direct relationship between the size and shape of chemosynthetic animals and ecosystem processes, such as primary productivity. Hydrothermal vent ecosystems are therefore particularly compelling conceptually for analysing functional diversity patterns in both time and space. However, a functional trait approach has not yet been attempted in these communities.

The timing and geometry of ancient plate boundaries have shaped the distribution of hydrothermal vent communities which group into distinct biogeographic provinces (e.g., Tunnicliffe & Fowler 1996, Bachraty et al. 2009, Moalic et al. 2011). Vent species therefore differ among vent fields and plates and cannot be compared at a global scale using taxonomic differentiation measures. However, trait-based approaches provide a means to compare communities comprised of different species. Although functionally equivalent species may be present in different vent provinces, it remains an open question whether vent communities have a similar functional composition and structure, although their phylogenetic origins differ. By quantifying global patterns in vent functional diversity we will answer this question and further test whether large-scale differences in physical factors (such as depth) relate to functional diversity patterns (Ramirez-Llodra et al. 2007).

Conservation of hydrothermal vent ecosystems is a growing concern as exploitation of massive sulfide deposits is planned for 2017 in Papua New Guinea and exploration licenses have been issued in both state and high seas vent systems. The strong association of vent ecosystems with the target high-grade ores has focused attention on the risks and the lack of management frameworks to assess potential impacts and devise mitigation (Van Dover 2010, Boschen et al. 2013, Collins et al. 2013). As the International Seabed Authority considers management frameworks for high seas extraction (ISA 2015), our proposed SCOR Working Group (WG) will make considerable progress with a focus on ecosystem function using functional diversity measures to complement taxonomic and molecular approaches.

Functional traits have the potential to offer new insights into how we prioritize, assess risk, and develop conservation and management strategies for these unique ecosystems at local, regional and global scales. We will identify functional traits that are expected to respond to habitat disruption, and test for change in these metrics following formation of new vents, replicated at different sites (e.g., Mid-Atlantic Ridge, East Pacific Rise and Juan de Fuca Ridge) where time-series community data have been collected (e.g., Marcus et al. 2009, Mullineaux et al. 2012, Cuvelier et al. 2014). What we propose is, therefore, a direct analogue of the classical ecological experiment with replication, but one that has been conducted at an appropriate scale for improved global management understanding.

The potential for new ecological understanding gained from analysis of functional diversity at vents to inform global conservation and management policy is great, however a rigorous traits database has yet to be collated for the global vent fauna. We will bridge this gap to build an open-access functional trait database that can be updated as new species and areas of hydrothermal activity are discovered, and can also be extended to include additional chemosynthetic systems such as cold seeps and whale falls.

Terms of Reference

We have assembled an international and interdisciplinary team to:

1. Synthesize species lists for each hydrothermal vent ridge and volcanic arc system by updating and error checking previously collated databases (e.g., Chemosynthetic Ecosystem Science, ChEss: http://chess.myspecies.info) so that we have the most up-to-date species database incorporating newly discovered areas of hydrothermal activity (e.g., Rogers et al. 2012).
2. Identify key functional traits including i) effect traits: traits related to how species influence ecosystem processes, and ii) response traits: traits that we would expect to influence the magnitude, direction and how quickly species respond to environmental change or a disturbance event (Díaz et al. 2013). Given that one of the main and unresolved challenges in the field of functional ecology is the selection of traits that relate to ecological processes and ecosystem functioning (Lefcheck et al. 2015), we will formulate a conceptual framework describing our rationale for inclusion of each functional trait.
3. Use expert knowledge and the literature to parameterize a functional traits database for hydrothermal vent fauna.
4. Apply macroecological analyses to map functional diversity in vent systems and test hypotheses regarding the mechanisms underpinning spatio-temporal patterns in functional diversity, using the best numerical methods to analyze trait-based alpha and beta diversity.
5. Identify functional traits that may have relevance for conservation and management objectives given possible exploitation of deep-sea sulfide deposits and provide guidelines for incorporating functional trait approaches into risk assessment procedures.

Working Plan

Our team includes experts in geochemistry, oceanography, biology, ecology, biogeography, statistical ecological and network modeling, and spans highly experienced senior researchers through to early career researchers. We are thus building international capacity to develop a comprehensive functional traits database and ask ecological questions that are fundamental to building ecological and applied theory. We will achieve our terms of reference though three workshops.

The first workshop "*FDvent: A functional traits database for hydrothermal vent fauna*" will be hosted [early 2016] at the National Oceanography Centre, Southampton, UK. Prior to the workshop, WG members will have produced an updated global species list for vents. We will use the first days of the workshop to identify traits for inclusion in the global database, with the aim of contributing to ongoing efforts to collate functional trait data in a standardized and accessible format (to both humans and computers) and integration with trait information from other taxa (e.g., EMODnet: http://www.emodnet-biology.eu/, Encyclopedia of Life, Traitbank: http://eol.org/info/516, FishBase: www.fishbase.org, Polytraits: (Faulwetter et al. 2014), TRY: http://www.try-db.org).

We will focus on a mixture of effect and response traits that shape ecosystem structure and function, as well as mediating how species respond to environmental changes, such as physiological niche, body mass, generation length, trophic level and reproductive strategy. We will also consider whether species are endemic to vents and their relative dispersal abilities – traits likely to influence species responses to disturbance.

In the second and third days of the workshop we will fill in our traits matrix using the taxonomic literature, to be supplemented as required from museum collections, and the collections of the workshop team. Bringing experts together to represent hydrothermal vent fauna from each ridge system and different taxa will lead to efficient collection of these traits from the literature and allow gaps of knowledge to be filled using expert opinion. Moreover, approaches to missing data have been developed that we can apply, such as the use of imputation methods for ranking of communities on the basis of their functional diversity indices (Taugourdeau et al. 2014). We will further use hierarchical Bayesian analysis to infer values based on those of closely-related species, which allows (1) quantitative data-driven assessment of the lowest level in the taxonomic hierarchy at which a significant proportion of the variation in species-level values is explained and (2) quantification of uncertainty so that values in derived analyses can be weighted to reflect confidence (e.g., Fazayeli et al. 2014) which can be compared to expert estimates.

As a group we will also explicitly consider the sources of error and bias in cross-ecosystem and cross-taxa estimates of traits that can be incorporated in our modeling frameworks (e.g., greater inaccuracy for some taxa or between sampling methods). Defining these issues will then allow us to present solutions, such as modeling sampling variability independently between regions or using machine learning approaches which are not constrained by probabilistic assumptions about the distribution of the response.

The second workshop will be hosted [early 2017] at the University of Victoria, Canada: "*Global patterns in the functional diversity of hydrothermal vent communities*". We will take the functional traits matrix developed in the first workshop to link functional diversity patterns among biogeographic provinces with physical data (e.g., ridge spreading rate, ocean depth, fluid chemistry) to identify patterns, possible drivers and potential processes underpinning the functional diversity of vent communities at large spatial scales. Functional diversity reflects the value and range of traits that influence ecosystem function and thus is not captured in a single measure. We will therefore use community-weighted mean trait values, as well as functional richness, dispersion and redundancy (Mouchet et al. 2010, Laliberté et al. 2014). We will use a variety of approaches including methods to test for trait-environment relationships, e.g., fourth-corner method (Dray and Legendre 2008), generalized and linear mixed effects modeling, and network theory (Moalic et al. 2011, Lindo 2015). We will also extend recently developed tools in community ecology such as local contributions to beta diversity (LCBD indices) to the study of functional trait ecology (Legendre & Gauthier 2014). Our aim is to provide a creative opportunity for our team to explore and model the data using different methods at a range of spatial scales, as well as to brainstorm ways of conceptualizing the data.

The third workshop entitled "*Using community responses to natural disasters and disturbance to guide conservation of hydrothermal vent communities*" will be hosted [early 2018, location to be announced pending the success of co-funding applications to assist associate members with travel costs]. Prior to the workshop our WG will synthesize time-series data from vents (e.g., Marcus et al. 2009, Mullineaux et al. 2012) and analyze trends in the functional diversity of the community. Our aim will be to identify functional traits that are expected to respond to habitat disruption, and test for sensitivity in these functional traits following formation of new vents or disturbance events, replicated at different locations. The workshop will therefore be a venue for our WG to discuss the application of functional traits to inform impact assessments of large-scale exploitation of sulfides and to explore the use of approaches such as temporal beta diversity indices (P. Legendre) and network modeling (S. Kininmonth). We will thus aim to develop a framework to explore how functional traits can inform the management and conservation guidelines for hydrothermal vents and publish our findings (open-access) in an international journal.

Deliverables

Database

- Deliverable 1: Our WG will release our functional traits database at the end of the project including up-to-date and accuracy checked species lists representing the world's vent systems, to be hosted on the InterRidge website (http://vents-data.interridge.org/), and distributed to the Oceanographic Biodiversity Information System (OBIS) database repository and the World Register of Marine Species (WoRMS, T. Horton, proposed associate member, is on the WoRMS steering committee).

Open-access peer-reviewed publications

- Deliverable 2: Our WG will describe the database, our rationale for inclusion or exclusion of particular traits, and a reproducible example for our methods to estimate missing trait data. We will publish these details and the database in a scientific data journal (e.g., Scientific Data) so that the database will be associated with a DOI.
- Deliverable 3: We will accomplish the first macroecological analyses of functional diversity patterns in hydrothermal vent systems, and target our findings for a high-impact, open-access journal.
- Deliverable 4: We will conduct an analysis of functional time-series following catastrophic events and disturbance at hydrothermal vents, and target our findings for a high-impact, open-access journal.
- Deliverable 5: We will publish management and risk assessment guidelines for hydrothermal vent communities based on functional traits for publication and dissemination to policy makers.

Capacity Building

A downloadable, searchable, and freely accessible functional traits database product (FDvent) that will also be published in a static, open-access format (target journal: Scientific Data) will be an important resource. We will ensure compatibility with other database schemas and metadata (e.g., EMODnet, Encyclopedia of Life, and Traitbank). FDvent will provide a basis upon which we can expand in future proposals to include other chemosynthetic communities, such as hydrocarbon seeps and organic falls (e.g., large mammal carcasses, wood). The FDvent database will also be a resource that will allow these unique ecosystems to be included in global analyses comparing different ecosystems to develop ecological theory.

Building FDvent will further allow us to develop proposals to produce more accessible data that is fit for purpose. For instance, Microsoft Research (http://research.microsoft.com/en-us/labs/Cambridge/) offers funding to make biodiversity and functional trait data available in different formats, tailored to a variety of purposes including education, outreach, policy and science.

We will also actively involve early career researchers (full member: Alejandro Estradas, UNAM, Mexico) and invite PhD students to contribute to the working group meetings and to run analyses with the FDvent traits database (Abbie Chapman, NOCS, UK, presently undertaking a PhD co-supervised by A.E. Bates and V. Tunnicliffe, and Rachel Boschen, NIWA, NZ, presently undertaking a PhD co-supervised by WG full member A.A. Rowden). Involving early career researchers will provide important training opportunities and spearhead functional trait ecology in chemosynthetic systems, as well as engaging early career talent in the SCOR process.

Working Group Composition

Full Members (in alphabetical order after the proposed SCOR WG chairs)

Name	Gender	Place of work	Expertise relevant to proposal
1. Amanda Bates (Co-Chair)	Female	University of Southampton, UK	Functional trait ecology, global biodiversity and conservation, hydrothermal vent gastropod biology
2. Verena Tunnicliffe (Co-Chair)	Female	University of Victoria, Canada	Deep-sea biodiversity and conservation, functional traits, Northeastern and western Pacific vent fauna
3. Alejandro Estradas-Romero	Male	Instituto de Geofísica, UNAM, Mexico	Mexican vent fauna, biological oceanography, diatom biology, chemosynthetic microorganisms
4. Andrey Gebruk	Male	P.P. Shirshov Institute of Oceanology, Russia	Deep sea bottom communities, Mid-Atlantic Ridge vents, trophic ecology of hot vent shrimps, functional traits
5. Ana Hilário	Female	University of Aveiro, Portugal	Reproductive ecology and biogeography of deep-sea ecosystems
6. Baban Ingole	Male	CSIR-National Institute of Oceanography, Dona Paula, Goa, India	Environmental impact assessment, conservation and management, Indian Ridge vent fauna
7. Pierre Legendre	Male	Université de Montréal, Canada	Functional diversity statistics, beta diversity indices, numerical ecology
8. Eva Ramirez-Llodra	Female	NIVS, Norway	Census of Marine Life project ChEss coordinator, reproductive ecology
9. Ashley Rowden	Male	NIWA, New Zealand	Biodiversity and conservation, Kermadec Ridge vent fauna
10. Hirome Watanabe	Female	JAMSTEC, Japan	Biogeography and biodiversity, western Pacific and Indian Ocean hydrothermal vents

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1. Stace Beaulieu	Female	WHOI, USA	Biodiversity, biogeography
2. Peter Girguis	Male	Harvard University, USA	Physiology and biochemistry of deep sea microorganisms, relationships between microbes and animals
3. Tammy Horton	Female	NOC, UK	Amphipod taxonomy, functional traits, biogeography
4. Stéphane Hourdez	Male	Station Biologique Roscoff, France	Polychaete taxonomy, biology and ecology
5. Stuart Kininmonth	Male	Stockholm Resilience Centre, Sweden	Bayesian network modeling, global ecology
6. Jozée Sarrazin	Female	IFREMER, France	Biodiversity, impact assessment, Mid-Atlantic and Northeast Pacific Ridge vent fauna
7. Hans Tore Rapp	Male	University of Bergen, Norway	Taxonomy and systematics of marine invertebrates, Arctic Ridge vent fauna
8. Ann Vanreusel	Female	University of Ghent, Belgium	Meiofauna, biodiversity and functioning

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Working Group Contributions

- **Amanda Bates** will co-chair the WG meetings. Amanda did her PhD on the functional traits of gastropod species from the Juan de Fuca Ridge hydrothermal vents. She is a lecturer in macroecology where she works on developing functional trait metrics for conservation applications and global ecology.
- **Verena Tunnicliffe** will co-chair the WG meetings. Verena has been developing understanding of the biogeography of vent systems, community ecology, and species functional traits since their discovery.
- **Alejandro Estradas-Romero** will contribute knowledge of the shallow water vents in the Pacific. He has an interest in the ecology and functioning of microorganisms, phytoplankton ecology and biological oceanography.
- **Andrey Gebruk** will contribute to WG activities as an expert on hydrothermal vent fauna of the Mid-Atlantic Ridge, trophic ecology of hydrothermal vent shrimps and relationships between shallow and deep-water hot vent communities.
- **Ana Hilário** did her PhD on the reproductive ecology of siboglinid tubeworms from hydrothermal vents and cold seeps. Her research is focused in the reproductive ecology and larval dispersal of deep-sea invertebrates, and population connectivity and its implications for biogeography, and spatial planning and management.
- **Baban Ingole** is an expert on Indian Ridge vent fauna, seamount fauna, as well as Environmental Impact Assessment of Deep Sea mineral mining. He further has an interest in the diversity of meio- and macrobenthic species and functional traits for conservation applications.
- **Pierre Legendre** is an expert in numerical ecology, with special emphasis on the variation of communities through space and time (beta diversity). An important component of his research is the development of quantitative methods to analyze multivariate ecological data. He has published papers on functional diversity indices.
- **Eva Ramirez-Llodra** was the Project Manager of the ChEss- Census of Marine Life project (2002-2010) investigating the biogeography of deep-water chemosynthetic ecosystems. She

developed ChEssBase, is co-PI of the international INDEEP network for deep-sea research, and has expertise in biodiversity and reproductive studies of deep-sea ecosystems, including hydrothermal vents.

- **Ashley Rowden** has been developing an understanding of the vent biogeography of the New Zealand region, and its relationship to the vent biogeography of the western Pacific Ocean, through sampling of vent communities on the Kermadec volcanic arc. Ashley is also currently involved in a functional traits-based ecological risk assessment of deep-sea habitats, which includes an assessment of both vent and seep habitats.
- **Hiromi Watanabe** researches biodiversity, biogeography and population connectivity using genetic analyses as well as rearing experiments of embryos and larvae of deep-sea hydrothermal vent faunas in western Pacific and Indian Oceans. She will contribute expertise in reproductive and larval traits of vent species.

Relationship to Other International Programs and SCOR Working Groups

We will build upon the ChEss database (http://chess.myspecies.info) by collating species lists produced since 2010 and error-check the database (proposed full member, E. Ramirez-Llodra designed ChEssBase and co-coordinated ChEss). We will further take advantage of databases that are under development by our WG team (e.g., InterRidge, http://www.interridge.org, by S. Beaulieu).

Our WG will also embrace an open-data philosophy. For instance, WG associate member P. Girguis is presently the chair of DeSSC (Deep Submergence Science Committee, https://www.unols.org/committee/deep-submergence-science-committee-dessc) and he has been working to facilitate international collaborations and “open access” to data and metadata generated during US expeditions. Moreover, Girguis is on the advisory board for the Ocean Genome Legacy (http://www.northeastern.edu/cos/marinescience/ogl/), a non-profit marine research institute and genome bank dedicated to exploring and preserving the threatened biological diversity of the sea. The purpose of OGL’s collection of DNA blueprints (genomes) is to provide secure storage and broad public access to genomic materials, to create a forum for sharing samples, data and ideas, and to serve as a catalyst for research that can help to protect marine ecosystems and improve the human condition. OGL is willing to serve as an open access repository for new samples, and will provide any and all samples for SCOR WG members.

We will contribute understanding on the importance of ecosystem function with respect to deep-sea mining, and thus link to projects such as DOSI, Deep-Ocean Stewardship Initiative (WG members E. Ramirez-Llodra, A.A. Rowden, and V. Tunnicliffe sit on the DOSI advisory board). DOSI seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems (http://www.indeep-project.org/deep-ocean-stewardship-initiative).

We will further take advantage of any opportunties to develop cross-overs between the SCOR Working group on “Seafloor Ecosystem Functions and their Role in Global Process" through Prof. Ingole, who has been invited to attend the group’s first meeting in Naples, Italy (September 2015).

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Appendix

1. Amanda Bates (Co-Chair)

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3. Alejandro Estradas-Romero

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