Food and Agriculture
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Databases and models: new tools for management

The marine environment is under pressure from multiple issues — direct anthropogenic factors (e.g. fishing, oil/gas/mineral exploration and extraction, and ocean waste-disposal events) and indirect factors such as climate change.

In order to protect, manage and conserve the diverse number of ocean habitats and species, and in particular the vulnerable marine ecosystems (VMEs), against these pressures, it is necessary to develop a comprehensive knowledge of where these habitats are, their quantity and quality, and the role they play in the larger ocean ecosystem.

Several tools are increasingly being used to address these knowledge gaps. They include increased data coordination and availability through open-access data agreements and large databases, and marine species distribution models (Vierod, Guinotte and Davies, 2014).

Marine species distribution models

Marine species distribution models (MSDMs) help reduce the knowledge gap by coupling statistical models with information on species biological response to environmental parameters/drivers (e.g. temperature, salinity or depth) (Figure 1). In the deep sea, where

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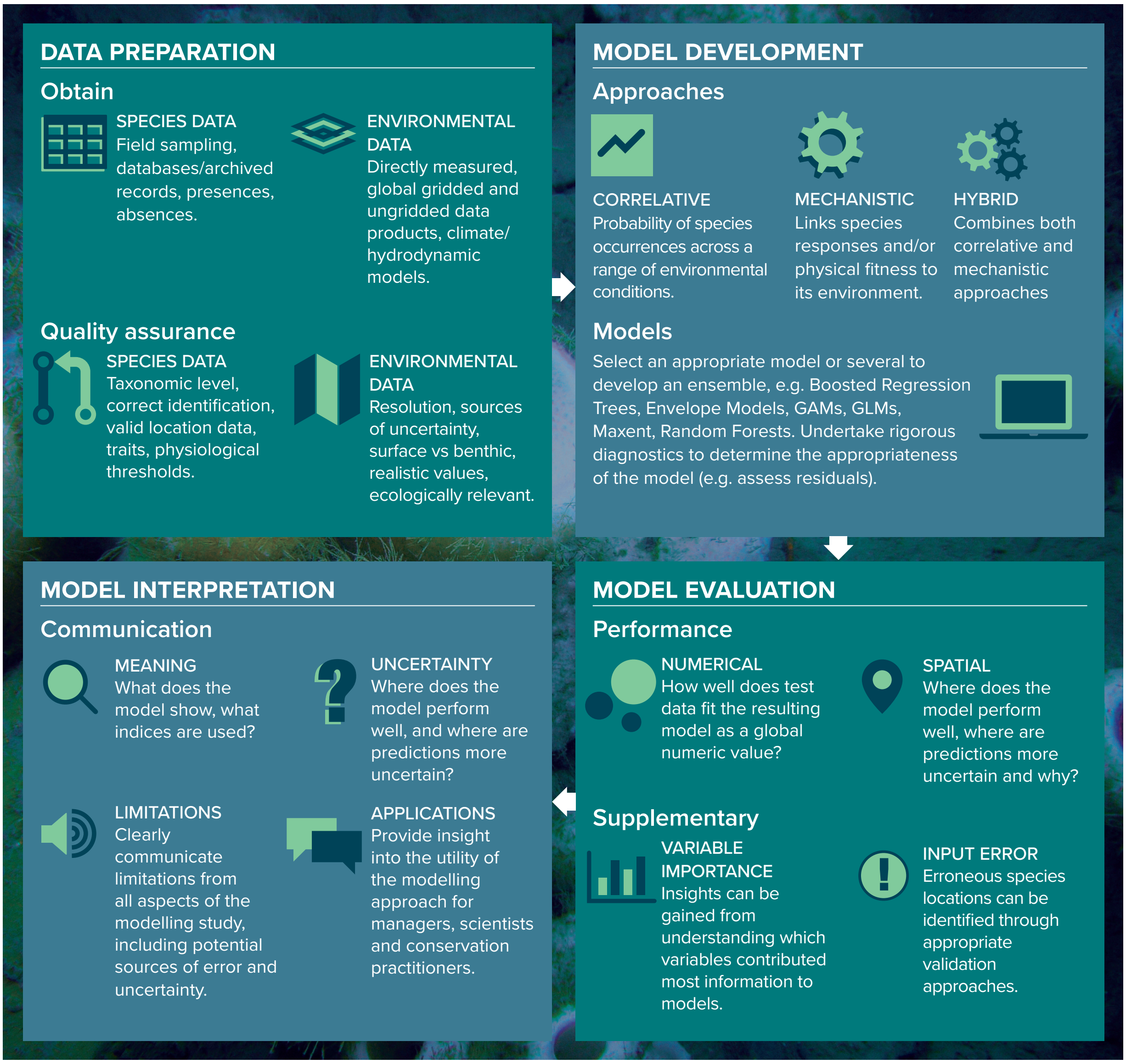
data quantity is missing or low, MSDM methods can be employed by utilizing georeferenced species presence and co-located observations (or extrapolated estimates) of environmental parameters within their locality, and provide outputs that estimate the probability that a species would occupy a certain environmental niche and, by extension, geographical space within the modelled domain.

The majority of MSDM research focuses on predicting the current distribution of a species in a particular area, or on forecasting the distribution of a species in space and/or time (e.g. Davies and Guinotte, 2011). Owing to improvements in oceanographic technologies, which have led to an increase in deep-sea data, and along with developments in MSDM techniques, deep-sea species modelling has increased.

FIGURE 1 Marine species distribution model workflow from data preparation through to model interpretation



Source: Authors' elaboration.

The use of models

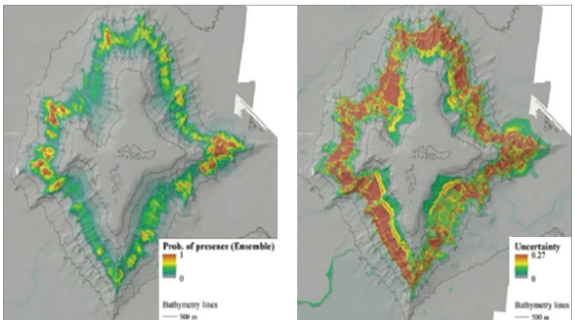
The majority of studies use correlative approaches or generalized additive models with presence–absence, or presence-only records. Recent deep-sea sponge distribution research in the North Atlantic has predicted the current distribution of a variety of species (e.g. *Vazella pourtalesi*, *Geodia barretti* and *Poliopogon amadou*) (Figure 2). Baseline sponge distribution data in the eastern Canadian Arctic were established using species archetype modelling (Box 1). A baseline is imperative for predicting any future changes due to climate changes or anthropogenic factors.

BOX 1 **Technical terms**

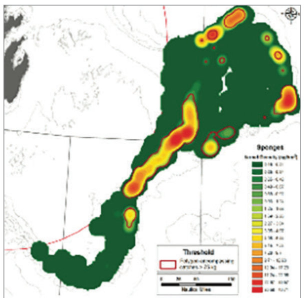
The **species archetype modelling** method groups together species based on like environment responses (known as a species archetype); this is called a cluster. Each cluster is then modelled with a **generalized linear model.** This method strengthens predictions from rare species and simultaneously estimates the probability of a species belonging to its group, and the group's response to the environmental factors (Hui *et al.*, 2013; Leaper *et al.*, 2014).

Kernel density estimates can be used to gather more information from modelled distribution by identifying significantly concentrated areas with high species biomass (Kenchington *et al*. 2009, 2014).

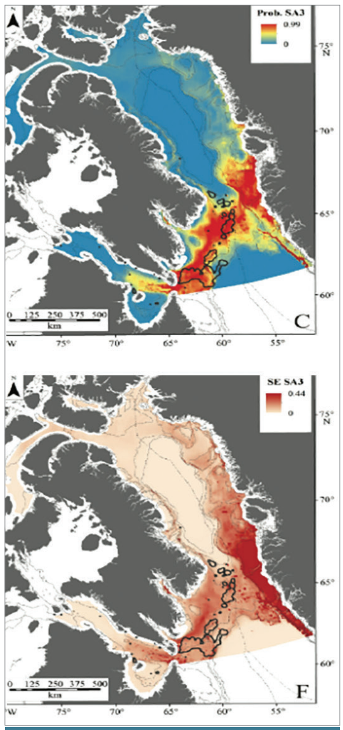
FIGURE 2 **Examples of species distribution models developed for deep-sea sponges**



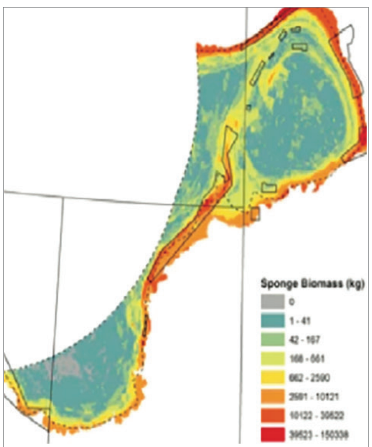
Ramiro-Sánchez *et al.* (2019) Tropic Seamount in Northeast Atlantic. Habitat suitability for sponge *Poliopogon amadou*. Ensemble (GAM, RF, Maxent) with presence-absence records.



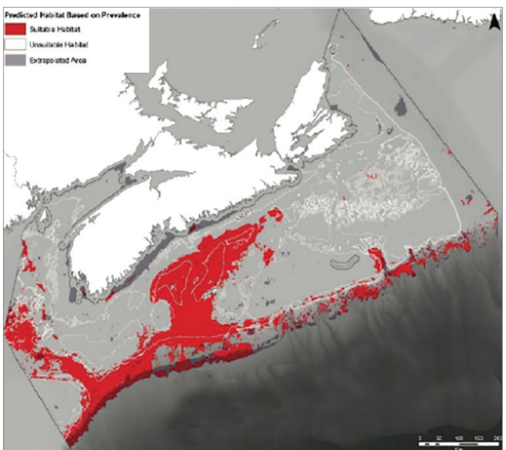
Kenchington *et al.* (2014) Regional – Offshore of Newfoundland and Labrador Biomass model of sponges using kernel density estimation (KDE).



Murillo *et al.* (2018) Regional – Eastern Canadian Arctic Sponges probability of presence and standard error (SA3 – 6 species) predicted with a species archetype modelling approach.



Pham *et al.* (2019) Regional – Flemish Cap Random Forest model utilizing bio-mass data to predict sponge biomass (kg).



Beazley *et al.* (2018) Regional – Scotian Shelf Habitat Suitability for glass sponge's response to climate variability. Random Forest presence-absence model.

Source: Authors' elaboration from publications the references of which are given under each map.

Marine species distribution models have been used for a variety of purposes:

- marine spatial planning (management and conservation issues) (Ramiro-Sánchez *et al.*, 2019);
- marine protected area network planning (Hooker *et al.*, 2011);
- distribution assessment of taxa or living marine resources (Murillo *et al.*, 2018);
- extent assessment of VMEs (Kenchington *et al.*, 2014);
- studying responses to anthropogenic impacts (Pham *et al.*, 2019);
- determining species responses to climate change (Beazley *et al.*, 2018).

QUANTIFYING ORGANISMS

It is also becoming possible – through targeted surveys – to estimate the quantity of organisms in the environment (i.e. their abundance or biomass), particularly at smaller scales (i.e. tens of metres). Data from directed bottom-trawl surveys (Murillo *et al*., 2018), vessel monitoring systems (Pham *et al*., 2019), and drop camera systems (Rooper *et al*., 2018) can all be used to provide biomass or abundance estimates (in kilograms or tonnes per square kilometre of towed area or in numbers per transect imaged). These estimates can be used as inputs in MSDMs to predict the distribution of sponge wet weight continuously over the area of interest, as Pham *et al.* (2019) did in the Flemish Cap to estimate the positive economic impact this sponge accumulation provides. This is an example of scaling up biomass and abundance estimates to gain information on the ecological functionality of the habitat/community, and it provides insight into the potential contributions that deep-sea species make to larger scale processes within the oceans.

SPONGE RESPONSES TO CLIMATE CHANGE

Understanding the responses of species to change is a challenge, particularly in the deep ocean, where species physiology is poorly understood. Marine species distribution models can be used to predict the distribution of species-suitable habitat under projected future climate scenarios (Morato *et al*., 2020), even when the species' physiological requirements are unknown. To estimate future predictions under varying climate projections, a present-day habitat suitability model must be built from a combination of current and historical environmental variables. From there, the species distribution can be projected onto the same spatial area using estimated future environmental variables. Another similar method, applied to *Vazella pourtalesi* by Beazley *et al.* (2018), in assessing whether a species will persist in a differing future climate scenario is to use historical environmental parameters to reconstruct the strength of temporal variability the species has undergone. If the species has shown a robust resistance to strong multi-decadal variability, then this could indicate how the species will respond to future climate variability.

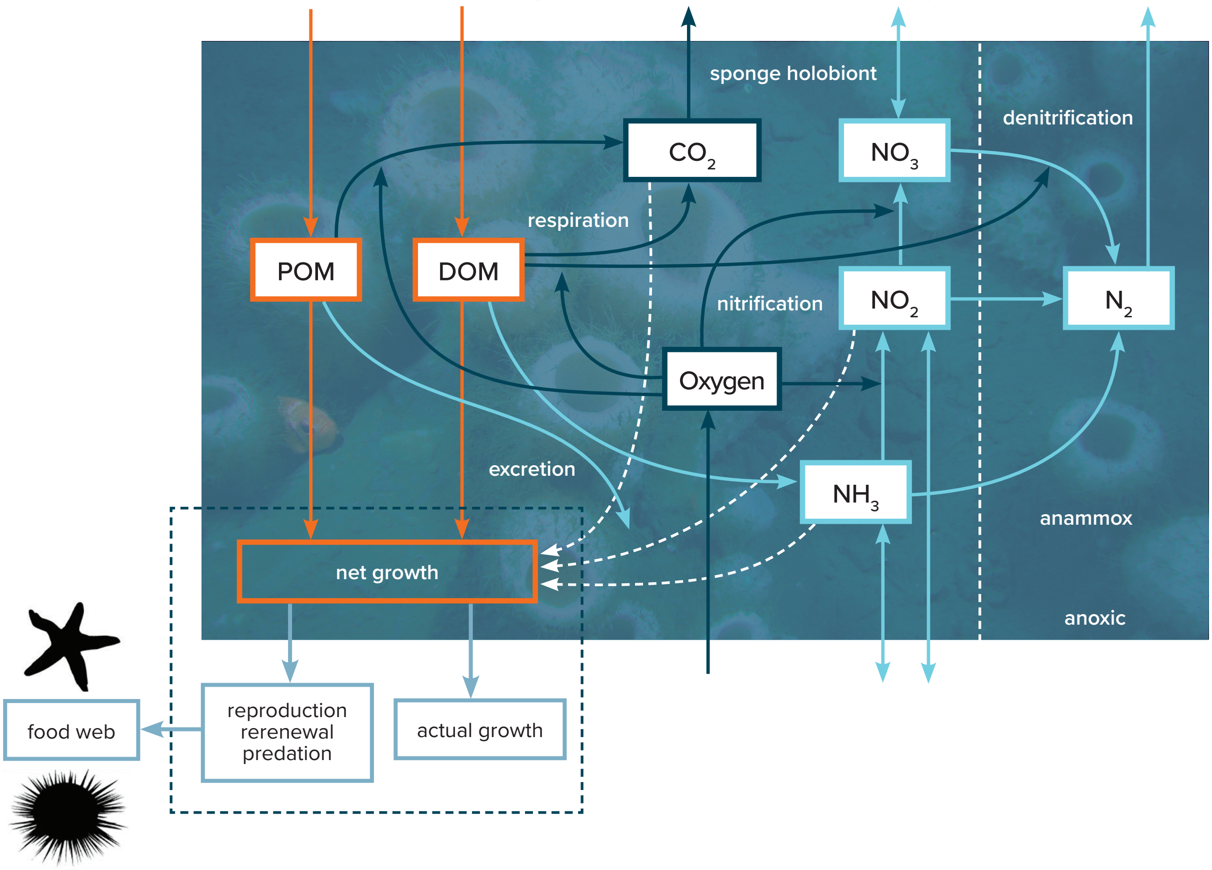
A change in a species distribution may also impact other species dependent on the habitat it provides. This is especially concerning as deep-sea sponge assemblages and reef-forming coral provide numerous ecosystem services (e.g. feeding, breeding grounds, nutrient recycling, and carbon assimilation) (Roberts *et al*., 2009).

Pham *et al.* (2019) estimated the economic value of sponge filtration in the Flemish Cap area by the *Geodia* sponge. It was calculated that the filtration and nitrogen cycling provided by sponges almost doubles the fish catch value for the region. These kinds of estimates of benthic biogeochemical cycling would be less accurate without first utilizing MSDMs in order to predict the current biomass of the species contributing to the biogeochemical cycling process.

Other types of models

There are many other applications of models, not just those that predict the distribution of species. Examples are food-web and biogeochemical cycling models that are able to quantify ecosystem processes. For example, chemical network models have been developed for the deep-sea demosponge *Geodia barretti* from the Barents Sea to couple measured carbon and nitrogen fluxes with internal and unquantified processes, such as biomass production, (de) nitrification, anaerobic ammonium oxidation (anammox) and carbon fixation. *Geodia barretti* selects or retains nitrogen-rich substances, as indicated by the low C:N ratio of sponges. Nutrients are efficiently recycled within the sponges. Most organic nitrogen consumed by a sponge is retained, while the remaining part is released as N_2 and NO_3 (Figure 3). On the other hand, about two-thirds of the organic carbon intake is respired. The retained organic nitrogen and carbon can be used for growth or released as sponge organic matter, which can fuel the food web. From such models, it has been found that starfish and sea urchins feed on sponges. Scaling up to the level of a sponge ground has revealed that the rate of respiration exceeds that of sediment, while nitrogen transforming processes are in a similar range as sediments, indicating that sponge grounds are important for the processing of carbon within deep-sea environments.

FIGURE 3 **A food-web model for a sponge community dominated by *Geodia barretti***



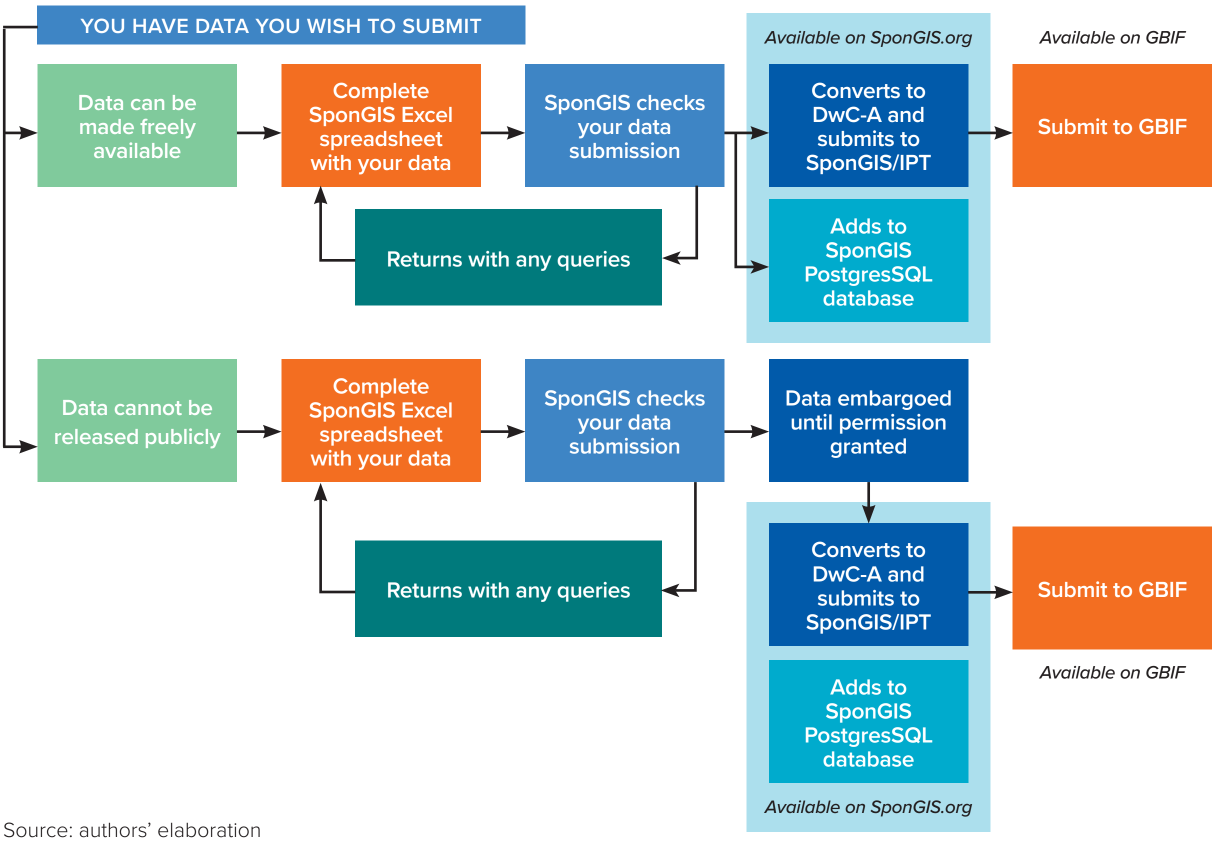
Source: Authors' elaboration.

Databases and data

Increasing the interoperability of, safeguarding of and access to biodiversity (and related) data has been identified as a global priority. This has been largely driven by the need for better understanding of patterns in the face of climate change, species extinctions and, indeed, loss of data due to format changes, archiving on (now) unreadable media, and a lack of adequate long-term storage. Several major projects have increased interoperability, mainly by building a common language, first for the storage of data (for example, defining terms used in storage), and second for the sharing of data in non-proprietary and well-described formats. To address this, SponGIS.org (an acronym for the Sponge Geographical Information System) has been developed, a database designed to capture and curate high-quality data regarding deep-sea sponges.

The SponGIS database has been designed using established data standards, including Darwin and Dublin Core terms, and it adopts the Darwin Core Archive format to store submitted data sets (Figure 4). The Darwin Core has become a common language for the sharing of biodiversity (and related data), and can be used in a flat (single table) or relational (multiple linked tables) database structure (Wieczorek *et al*., 2012). The sharing of data will be facilitated by using the Global Biodiversity Information Facility's Integrated Publishing Toolkit (Robertson *et al*., 2014). While SponGIS adopts some custom terms that are specific for the SponGIS project website, the adoption of international standards, including common terms, is a key step towards fostering data interoperability that can lead to enhanced understanding of biodiversity patterns (Wieczorek *et al*., 2012), including those of deep-sea sponges and deep-sea data in general.

FIGURE 4 **SponGIS data submission process**



Source: authors' elaboration

Conclusions

- Marine species distribution models (MSDMs) are tools for species conservation and management. They provide valuable information on how a species (or a group of species) responds to its environment by where the species distributes itself spatially.
- By utilizing MSDM methods, it is feasible to project how a species may respond to increased climate or anthropogenic pressures.
- Additional types of models (i.e. biogeochemical cycling, and food-web) can provide insight on the species of interest; this type of information can be used to better understand the ecosystem’s processes. Enhanced ecological knowledge is beneficial in the building and interpreting of MSDMs.
- Data are the foundation of species distribution model construction, and the quality and quantity of data used can directly affect the predicting strength and interpretability of the model. Therefore, it is crucial to use the most recent data, to acknowledge and report model uncertainty, and to interpret said models cautiously, keeping the limitations of the data in mind.

References

Beazley L, Wang Z, Kenchington E, Yashayaev, I., Rapp, H.T., Xavier, J.R., Murillo, F.J., Fenton, D. & Fuller, S. 2018. Predicted distribution of the glass sponge *Vazella pourtalesi* on the Scotian Shelf and its persistence in the face of climatic variability. *PLoS One*, 13(10) [online]. [Cited 8 September 2020]. doi:10.1371/journal.pone.0205505.

Davies, A. & Guinotte, J. 2011. Global habitat suitability for framework-forming cold-water corals. *PLoS ONE*, 6 [online]. [Cited 8 September 2020]. doi: 10.1371/journal.pone.0018483

Hooker, S.K., Cañadas, A., Hyrenbach, K.D., Corrigan, C., Polovina, J.J. & Reeves, R.R. 2011. Making protected area networks effective for marine top predators. *Endangered Species Research*, 13: 203–218.

Hui, F.K.C, Warton, D.I., Foster, S.C. & Dunstan, P.K. 2013. To mix or not to mix: comparing the predictive performance of mixture models vs. separate species distribution models. *Ecology*, 94: 1913–1919.

Kenchington, E., Cogswell, A., Lirette, C. & Murillo Perez, F.J. 2009. *The use of density analyses to delineate sponge grounds and other benthic VMEs from trawl survey data*. Ser No N5626. NAFO SCR Doc 09/6. 18 pp.

Kenchington, E., Murillo, F.J., Lirette, C., Sacau, M., Koen-Alonso, M., Kenny, A., Ollerhead, N., Wareham, V. & Beazley, L. 2014. Kernel density surface modelling as a means to identify significant concentrations of vulnerable marine ecosystem indicators. *PLoS ONE*, 10(1) [online]. [Cited 8 September 2020]. doi:10.1371/journal.pone.0117752.

Leaper, R., Dunstan, P.K., Foster, S.D., Barret, N.S. & Edgar, G.J. 2014. Do communities exist? Complex patterns of overlapping marine species distributions. *Ecology*, 95:2016–2025.

Morato, T., González-Irusta, J.-M., Dominguez-Carrió, C., Wei, C.-L., Davies, A., Sweetman, A.K., Taranto, G.H., *et al.* 2020. Climate-induced changes in the suitable habitat of cold-water corals and commercially important deep-sea fishes in the North Atlantic. *Global Change Biology*, 00: 1–21 [online]. [Cited 8 September 2020]. https://doi.org/10.1111/gcb.14996

Murillo, F.J., Kenchington, E., Tompkins, G., Beazley, L., Baker, E., Knudby, A. & Walkusz W. 2018. Sponge assemblages and predicted archetypes in the eastern Canadian Arctic. *Marine Ecology Progress Series*, 597: 115–135 [online]. [Cited 8 September 2020]. https://doi.org/10.3354/meps12589

Pham, C.K., Murillo, F.J., Lirette, C., Maldonado, M., Colaço, A., Ottaviani, D. & Kenchington, E. 2019. Removal of deep-sea sponges by bottom trawling in the Flemish Cap area: conservation, ecology, and economic assessment. *Scientific Reports*, 9: 1–13.

Ramiro-Sánchez, B., González-Irusta, J.M., Henry, L.-A., Cleland, J., Yeo, I., Xavier, J.R., Carreiro-Silva, M., Sampaio, Í., Spearman, J., Victorero, L., Messing, C.G., Kazanidis, G., Roberts, J.M. & Murton, B. 2019. Characterization and mapping of a deep-sea sponge ground on the Tropic Seamount (Northeast Tropical Atlantic): implications for spatial management in the high seas. *Frontiers in Marine Science*, 6: 278 [online]. [Cited 8 September 2020]. doi:10.3389/fmars.2019.00278

Roberts, J.M., Wheeler, A., Freiwald, A. & Cairns, S.D. 2009. *Cold-water corals: the biology and geology of deep-sea coral habitats*. Cambridge, UK, Cambridge University Press.

Robertson, T., Döring, M., Guralnick, R., Bloom, D., Wieczorek, J., Braak, K., Otegui, J., Russell, L. & Desmet, P. 2014 The GBIF Integrated Publishing Toolkit: facilitating the efficient publishing of biodiversity data on the Internet. *PLoS ONE*, 9: e102623 [online]. [Cited 8 September 2020]. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0102623

Rooper, C.N., Wilborn, R., Goddard, P., Williams, K., Towler, R. & Hoff, G.R. 2018. Validation of deep-sea coral and sponge distribution models in the Aleutian Islands, Alaska, *ICES Journal of Marine Science*, 75(1): 199–209 [online]. [Cited 8 September 2020]. https://doi.org/10.1093/icesjms/fsx087

Vierod, A.D.T., Guinotte, J.M. & Davies, A.J. 2014. Predicting the distribution of vulnerable marine ecosystems in the deep sea using presence-background models. *Deep Sea Research Part II: Topical Studies in Oceanography*, 99: 6–18 [online]. [Cited 8 September 2020]. https://doi.org/10.1016/j.dsr2.2013.06.010

Wieczorek, J., Bloom, D., Guralnick, R., Blum, S., Döring, M., Giovanni, R., Robertson, T. & Vieglais, D. 2012. Darwin Core: an evolving community-developed biodiversity data standard. *PLoS ONE*, 7: e29715 [online]. [Cited 8 September 2020]. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0029715

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