Appendix

Template for Submission of Scientific Information

to Describe Ecologically or Biologically Significant Marine Areas

Title/Name of the area:

Crozet Islands abyssal plain EBSA

Presented by (*names, affiliations, title, contact details)*

Dr David Billett

National Oceanography Centre, European Way, Southampton SO14 3ZH, Southampton, UK

Abstract (*in less than 150 words)*

Deep waters (c. 4200m) around the Crozet Islands have localised and isolated seabed communities on sediments lying beneath highly productive waters to the north and east of the Islands. The restricted areas of primary productivity are stimulated by natural iron fertilization from the volcanic islands, in an otherwise low productivity HNLC (High Nutrient Low Chlorophyll) region, characteristic of much of the ocean in the southern hemisphere south of 40°S. Seabed communities under high productivity are radically different from those lying beneath HNLC waters. The most common seabed species at Crozet, the holothurian *Peniagone crozeti*, is superabundant and occurs almost exclusively at the high productivity site. This is highly unusual. Several other new genera and species also occur. Seabed communities under highly productive sites, where they are surrounded by an ocean of low productivity (e.g. HNLC regions), are potentially unique in the southern Indian Ocean and are therefore biologically significant.

Introduction

Natural ocean iron fertilisation, through the addition of iron leached from volcanic islands, has been shown to enhance primary productivity and carbon export into the ocean interior and the deep seabed (Blain et al. 2007; Pollard et al. 2009). Large seasonal pulses of organic matter to the deep-sea floor (Billett et al. 1983) have significant effects on the distributions of benthic species at bathyal and abyssal depths, as well as on the structure of seabed communities in space and time (Smith et al., 2009; Billett et al. 2010; Wolff et al. 2011).

The Southern Ocean is the largest High Nutrient Low Chlorophyll (HNLC) region on Earth. HNLC areas have high concentrations of primary nutrients such as nitrate and phosphate, which should lead to large seasonal phytoplankton blooms in the austral spring, but the blooms do not occur because of low concentrations of other essential elements, notably iron. Within the HNLC expanse, there are hotspots of primary productivity (Fig 1). These occur in areas of natural ocean iron fertilisation, through the entrainment of dissolved iron leached from isolated oceanic islands, such as at the Kerguelen and Crozet Plateaus (Blain et al. 2007; Pollard et al. 2007, 2009). The physical oceanography around Crozet allows concentrations of iron to build up to the north and east of the islands during winter months when low light restricts primary productivity. When solar irradiance increases and stratification of the upper waters starts in the austral spring a seasonal phytoplankton bloom occurs (Fig. 2). To the south of Crozet HNLC conditions persist. SeaWIFs satellite images confirm that the hotspots of primary production stimulated by natural iron fertilization occur consistently from year to year (Fig. 1). Areas under higher primary productivity to the north and east of the Crozet Islands have enhanced export flux of Particulate Organic Carbon (POC) to the deep ocean which has a profound effect on the species that occur there (Wolff et al. 2011).

A recent expedition to the Crozet Islands compared abyssal sediment communities at a depth of c. 4200m under contrasting productivity regimes at two sites; high (+Fe) and low (HNLC) productivity (Fig 3). The two sites were almost identical in their environmental characteristics apart from the productivity of overlying surface waters. The absence of geomorphological and hydrographic barriers between the two sites ensured that there are no constraints on the dispersal of fauna, other than that which might be related to surface water productivity.

The total standing stock of invertebrate megafauna, in terms of biomass and abundance, mirrored the particulate organic carbon (POC) fluxes at the two sites (Wolff et al. 2011). Holothurians were the dominant megafaunal group at both sites accounting for between 70 and 89% of the total wet weight biomass. However, rather than the same species occurring at +Fe and HNLC sites, despite their close proximity, there were striking differences in species composition and dominance (Table 1, Excel Data Table 2 - restricted).

Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.

Location

(Indicate the geographic location of the area/feature. This should include a location map. It should state if the area is within or outside national jurisdiction, or straddling both. It should also state if the area is wholly or partly in an area that is subject to a submission to the Commission on the Limits of the Continental Shelf)

42 to 48ºS and 53 to 60ºE (map appended) (Fig 4).

The area is straddles an Area Beyond National Jurisdiction and within the EEZ and continental shelf extension claim of the Crozet Islands

Feature description of the proposed area

(This should include information about the characteristics of the feature to be proposed, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, and then refer to the data/information that is available to support the proposal and whether models are available in the absence of data. This needs to be supported where possible with maps, models, reference to analysis, or the level of research in the area)

This EBSA relates to seabed sediment communities (c. 4000 to 4500m) under a highly localised high productivity feature in surface waters to the east of the Crozet Islands (Fig 4).

Trawl samples obtained from the Crozet Islands in 2005 indicate that localised high productivity and therefore carbon supply to the seafloor produce highly localised distributions of abyssal fauna, with some common species occurring exclusively in the area (Wolff et al. 2011). The case for an EBSA is based on megafaunal epibenthos, but may apply to other seabed fauna. Of the megafauna, some species were common to the two sites, and occurred in similar abundances, such as the ophiuroids *Ophiura lienosa*, *Ophiura irrorata loveni* and *Amphioplus daleus*, but most megafaunal species showed marked differences (Table 1). Of the elpidiid holothurians *Kolga nana*, *Peniagone willemoesi* and *Peniagone affinis* dominated and occurred almost exclusively at the HNLC site, while closely related, but different, species, *Peniagone crozeti* [39] and *Peniagone challengeri* dominated at the +Fe site. Fauna lying under high productive waters are highly localised in the southern Indian Ocean. Moreover, the species that was most abundant (superabundant), *Peniagone crozeti*, occurred almost exclusively at the +Fe site and was new to science. This is highly unusual at abyssal depths, where many megafaunal species occur throughout a region or even globally (Hansen, 1975).

In terms of ecosystem functioning, the communities are important in carbon cycling and the return of nutrients to the water column and therefore in global nutrient and ocean productivity cycles. Time series studies in high productivity areas have shown that increased fluxes of organic matter to the seabed lead to significant changes in species composition (Billett et al. 2010), radical changes in abundance of over three orders of magnitude (Billett et al. 2001, 2010; Ruhl and Smith 2004; Smith et al. 2009) and therefore large changes in sediment recycling rates. In the latter case normal complete recycling of the sediment surface may be reduced from a period of c. 2.5 years (c. 1000 days) to less than 6 weeks (c. 50 days) (Bett et al. 2001).

Feature condition and future outlook of the proposed area

(Description of the current condition of the area – is this static, declining, improving, what are the particular vulnerabilities? Any planned research/programmes/investigations?)

At present the area is pristine and is likely to remain so (static). There are no vulnerabilities. However, the species in the area may decline of there are changes in surface water productivity through the manipulation of surface productivity in any geoengineering solutions to climate change.

<u>*Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.*</u>

Assessment of the area against CBD EBSA Criteria

(Discuss the area in relation to each of the CBD criteria and relate the best available science. Note that a candidate EBSA may qualify on the basis of one or more of the criteria, and that the boundaries of the EBSA need not be defined with exact precision. And modeling may be used to estimate the presence of EBSA attributes. Please note where there are significant information gaps)

<table>
<tr><td rowspan="2">CBD EBSA Criteria
(Annex I to decision IX/20)</td><td rowspan="2">Description
(Annex I to decision IX/20)</td><td colspan="4">Ranking of criterion relevance
(please mark one column with an X)</td></tr>
<tr><td>Don’t Know</td><td>Low</td><td>Some</td><td>High</td></tr>
<tr><td>Uniqueness or rarity</td><td>Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking
Unique and very abundant species discovered on abyssal seabed (c. 4200m) in areas of high productivity and hence high downward particulate carbon (POC) flux, with highly localized distributions restricted by HNLC conditions and hence low POC flux (Wolff et al. 2011) (Fig 2). It is likely that all depths (200 to > 4500m) to the north and east of the Crozet and Kerguelen plateaus contain unique species. Areas under high productivity are very rare in the southern Indian Ocean. The areas are unique because of their isolation within a vast low productivity HNLC region.</td></tr>
<tr><td>Special importance for life-history stages of species</td><td>Areas that are required for a population to survive and thrive.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking
A comparison with nearby communities under HNLC conditions shows that the benthic organisms lying under high productivity are radically different from those in HNLC regions (Table 1; Excel Data Table 2 - restricted) indicates that increased POC flux to the seafloor is important for the preservation of certain species allowing them to thrive.</td></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td>Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="6">Explanation for ranking

While the communities are highly localized it is not expected that there will be changes in the characteristics of productivity in the region. Indeed if there is an increase in productivity more widely in the southern Indian Ocean, e.g. through geoengineering solutions, the species ranges may increase.</td></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td>Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="6">Explanation for ranking

No major anthropogenic impacts expected. Some evidence of episodic volcanic activity with the potential of impacting large areas of the seabed. Intensity of deep-sea fishing at shallower depths unknown, but have the potential of affecting unknown unique species at depths shallower than 1500m.</td></tr>
<tr><td>Biological productivity</td><td>Area containing species, populations or communities with comparatively higher natural biological productivity.</td><td></td><td></td><td></td><td>X</td></tr>
</table>

<u>*Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.*</u>

Explanation for ranking Higher benthic biomass mirrors known increase in POC flux. Increase in abundance leads to faster turnover of carbon.					
Biological diversity	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				**X**
Explanation for ranking High local species diversity. Different species pools under high and low productivity areas leads to greater regional diversity					
Naturalness	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.				X
Explanation for ranking Pristine					

Sharing experiences and information applying other criteria (Optional)

Other Criteria	**Description**	**Ranking of criterion relevance** (please mark one column with an X)			
		Don't Know	**Low**	**Some**	**High**
Add relevant criteria					
Explanation for ranking					

References

Bett, B. J., M. G. Malzone, B. E. Narayanaswamy & B. D. Wigham (2001). Temporal variability in phytodetritus and megabenthic activity at the seabed in the deep Northeast Atlantic. Progress in Oceanography 50, 349-368.

Billett, D.S.M., Lampitt, R.S., Rice, A.L. & R.F.C. Mantoura (1983). Seasonal sedimentation of phytoplankton to the deep-sea benthos. Nature, London 302, 520-522.

Billett, D.S.M., Bett, B.J., Rice, A.L., Thurston, M.H., Galéron, J., Sibuet, M. & Wolff, G.A. (2001). Long-term change in the megabenthos of the Porcupine Abyssal Plain (NE Atlantic). Progress in Oceanography 50, 325-348

Billett, D.S.M., Bett, B.J., Reid, W.K.D., Boorman, B & Priede, M. (2010). Long-term change in the abyssal NE Atlantic: The 'Amperima Event' revisited. Deep-Sea Research II 57 (15) 1406-1417 doi:10.1016/j.dsr2.2009.02.001

Blain, S. et al. (2007). Effect of natural iron fertilisation on carbon sequestration in the Southern Ocean. Nature 446, 1070-1071.

Cross, I.A., Gebruk, A., Billett, D.S.M. & Rogacheva, A. (2009). *Peniagone crozeti*, a new species of elasipodid holothurian from abyssal depths off the Crozet Isles in the Southern Indian Ocean. Zootaxa 2096, 484-488.

Cross, I.A., Gebruk, A., Billett, D.S.M. & Rogacheva, A. (2012). Rediscovery of the elpidiid holothurian *Peniagone horrifer* (Elasipodida, Holothuroidea, Echinodermata) in the southern Indian Ocean. Marine Biodiversity. DOI 10.1007/s12526-012-0111-x

Hansen, B. (1975). Systematics and biology of the deep-sea holothurians. Part 1 Elasipoda. Galathea Report 13, 1-262.

Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.

Hughes, J.A., Smith, T., Chaillan, F., Bett, B.J., Billett, D.S.M., Boorman, B., Fisher, E.H., Frenz, M. & Wolff, G.A. (2007) Two abyssal sites in the Southern Ocean influenced by different organic matter inputs: Environmental characterization and preliminary observations on the benthic foraminifera. Deep-Sea Research II 54, 2275-2290.

Pollard, R.T. et al (2007). Southern Ocean deep-water carbon export enhanced by natural iron fertilization. Nature 457, 577-581.

Pollard, R.T., Sanders, R., Lucas, M. and Statham , P. (2007). The Crozet natural iron bloom and export experiment (CROZEX). Deep-sea Research II 54, 1905-1914.

Rogacheva, A., Cross, I.A. & Billett, D.S.M. (2009). Psychropotid holothurians (Psychropotidae, Holothuroidea) collected at abyssal depths from around the Crozet Plateau in the Southern Indian Ocean. Zootaxa 2096, 460-478

Rogacheva, A., Cross, I.A. & Billett, D.S.M. (2009). *Gebrukothuria profundus*, a new genus and species of laetmogonid holothurian (Elasipodida, Laetmogonidae) from abyssal depths around the Crozet Plateau in the Southern Indian Ocean. Zootaxa 2096, 479-483.

Ruhl, H.A. and Smith, K.L. (2004). Shifts in deep-sea community structure linked to climate and food supply. Science 305, 513-515

Smith, K.L., Ruhl, H., Bett, B.J., Billett, D.S.M., Lampitt, R.S. & Kaufmann, R.S. (2009). Climate, carbon cycling and deep-ocean ecosystems. Proceedings of the National Academy of Sciences 106 (46), 19211-19218.

Wolff, G.A., Billett, D.S.M., Bett, B.J., Holtvoeth, J., FitzGeorge-Balfour, T., Fisher, E.H., Cross, I., Shannon, R. Salter, I., Boorman, B., King, N.J., Jamieson, A. & Chaillan, F. (2011). The effects of natural iron fertilisation on deep-sea ecology. PLoS One 6 (6) 1-9. e20697 http://dx.plos.org/10.1371/journal.pone.0020697.

Maps and Figures

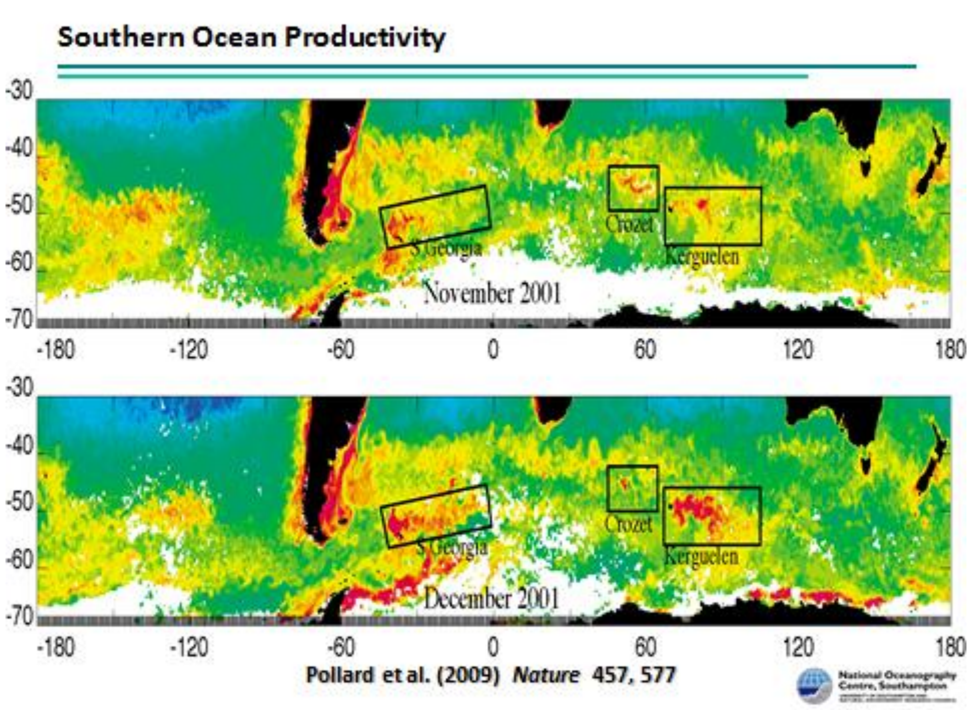

Figure 1. Southern Ocean HNLC region showing localized areas of high productivity in association with some mid ocean islands including Crozet Islands and Kerguelen Island in the southern Indian Ocean.

Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.

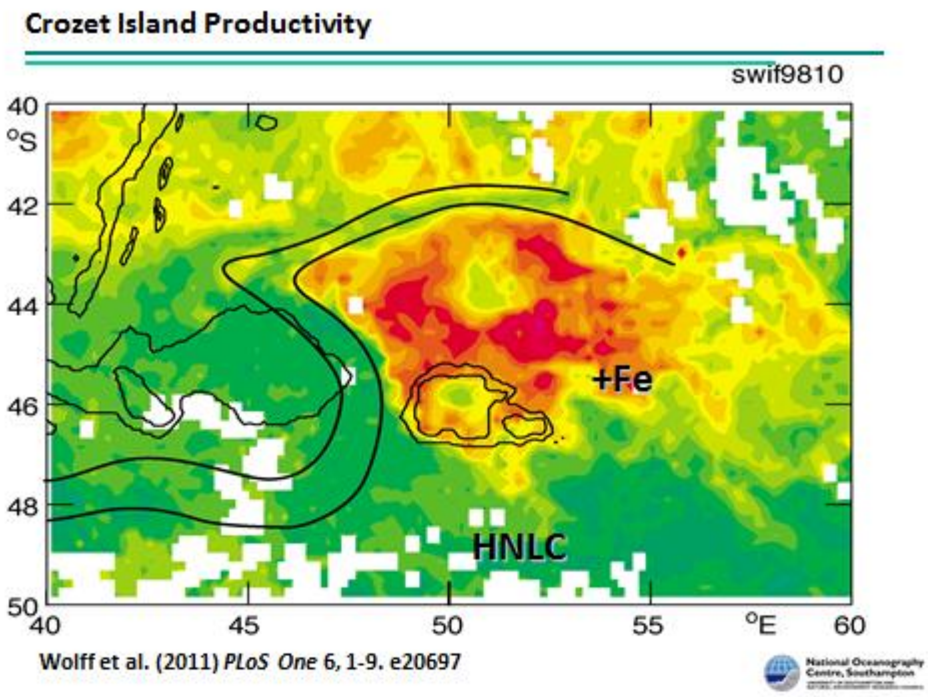

Figure 2. Productivity in the region of Crozet in austral spring and summer months. Showing HNLC and +Fe areas.

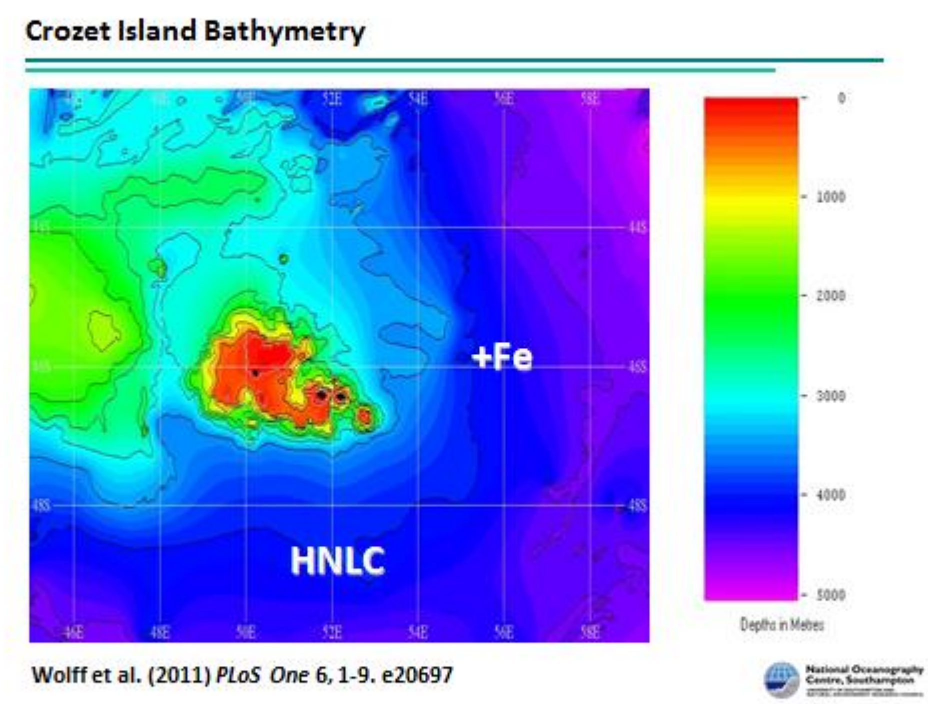

Figure 3. Bathymetry chart of Crozet region sgowing abyssal stations sampled.

Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.

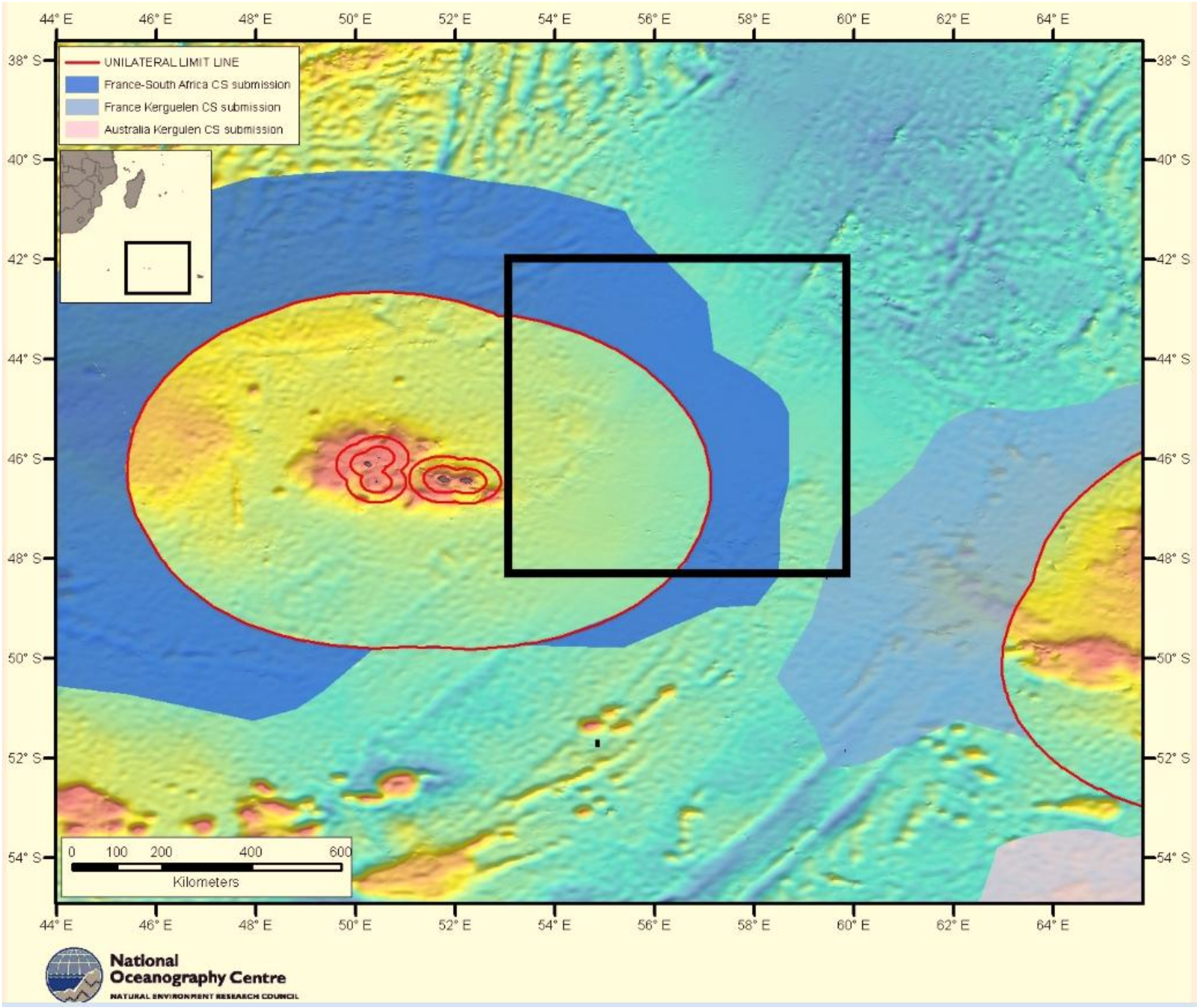

Figure 4. Crozet region with proposed EBSA area marked.

Please note that this template is provided to facilitate information submission on a voluntary basis, only when the information provider finds this template appropriate. If the available information does not fit the format of this template, information can be submitted in another format, in consultation with the Secretariat.

Species Name	Taxon	Density (+Fe) (ind. ha^{-1}) n=4	Biomass (+Fe) (g ha^{-1}) n=4	Rank (+Fe) Abundance/ Biomass	Density (HNLC) (ind. ha^{-1}) n=2	Biomass (HNLC) (g ha^{-1}) n=2	Rank (HNLC) Abundance/ Biomass
Peniagone crozeti	Holothuroidea	259.6	910.5	**1 (3)**	11.1	23.47	
Ophiura lienosa	Ophiuroidea	194.7	53.43	**2**	162.3	64.25	**1**
Amphioplus daleus	Ophiuroidea	128	35.69	**3**	37.9	6.615	**5**
Peniagone challengeri	Holothuroidea	69.2	137.1	**4**	5.6	9.894	
Ophiura irrorata loveni	Ophiuroidea	41.3	38.53	**5**	18.7	17.61	
Kolga nana	Holothuroidea	0	0		17.4	3.276	
Peniagone affinis	Holothuroidea	3.7	29.57		94.6	497.4	**3 (1)**
Peniagone willemoesi	Holothuroidea	1.8	4.544		95.6	134.2	**2 (3)**
Ophiotrema tertium	Ophiuroidea	0.04	$7x10^{-4}$		61.1	7.633	**4**
Psychropotes longicauda	Holothuroidea	12.6	1195	**(1)**	2.5	105	**(5)**
Molpadiodemas aff atlanticus	Holothuroidea	28.3	962.9	**(2)**	0	0	
Molpadiodemas morbillus	Holothuroidea	8.7	460.3	**(4)**	0	0	
Benthodytes sordida	Holothuroidea	5.1	308.7	**(5)**	3.5	131	**(4)**
Styracaster robustus	Asteroidea	6.8	52.11		13.1	230.1	**(2)**

Table 1. The abundance and biomass (wet weight) of the dominant megafaunal invertebrates at abyssal sites around the Crozet Plateau. Shaded boxes indicate significantly different populations in terms of abundance or biomass ($p<0.05$; ANOVA). Rankings (1-5) for the most abundant species and those having the highest biomass (parentheses) are also shown.

Table 2: Please see appendix.

Rights and permissions

(Indicate if there are any known issues with giving permission to share or publish these data and what any conditions of publication might be; provide contact details for a contact person for this issue)

Excel Data Table 2 not yet published – restricted to this EBSA exercise (contact David Billett dsmb@noc.ac