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New data acquisition protocol for benthos bycatch in the French fisheries of the Indian Ocean and the Southern Ocean

Relates to agenda item: 6 Working paper ☒ Info paper ☐

Delegation of French Territory

Abstract

This report provides a presentation of the protocol and first preliminary results

Recommendations

The SC is invited to consider this paper

New data acquisition protocol for benthos bycatch in the French fisheries of the Indian Ocean and the Southern Ocean

Presentation of the protocol and first preliminary results

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Abstract

In 2015, the Muséum national d'Histoire naturelle has started to develop a new data acquisition protocol for benthos bycatch in the French fisheries of the Southern Ocean (statistical areas 58.5.1, 58.6, 58.4.3a, 58.4.4b, 58.4.2) and the Indian Ocean (SIOFA area). ***France proposes this protocol to be adopted by SIOFA for all the fisheries of the area.*** *This protocol aims at producing presence and abundance data of the benthic macro-invertebrates collected by the fishing gears. The main objective is to increase knowledge on the benthic ecosystems impacted by the French fishing activities, in a context marked by the CCAMLR conservation measures for Vulnerable Marine Ecosystems (VME) protection and the Marine Protected Areas (MPA) development and in the short term to decrease this impact. The protocol is based on collecting, weighing and photographic sampling of the benthic macro-invertebrate specimens. A description of the protocol is provided in this document. Preliminary results on quality and quantity of produced data are provided as well some examples of scientific exploitation. The new protocol provided significant results. SIOFA could use part or whole of the protocol to implement in the fisheries scientific monitoring activity.*

Introduction

In 2015, the Muséum national d'Histoire naturelle (MNHN) has started to develop a new data acquisition protocol for benthos bycatch in the French fisheries of the Southern Ocean. This protocol aims to produce presence and abundance data of the benthic macro-invertebrates caught by the fishing gears. It is deployed in all the French fisheries of the Southern Ocean:

- established fisheries in the French Exclusive Economic Zones (EEZ) of Kerguelen (statistical area 58.5.1) and Crozet (statistical area 58.6),
- fish biomass surveys (POKER [5] [6] and PIGE [11] cruises) in the EEZ of Kerguelen,
- exploratory or research fisheries in the CCAMLR areas (presently 58.4.3a, 58.4.4b, 58.4.2).

The protocol is based on:

- sampling of specimens,
- weighing and photographic sampling of the benthos bycatch.

Specimen sampling is a continuation of a former approach [4] [8]. The picture sampling effort is new, and was developed in 2015. The protocol is realized on the commercial fishing vessels by the onboard national scientific observers, with supervision from the MNHN. In the fish biomass surveys, the protocol is conducted by the onboard scientific team. The main objective is to increase knowledge on benthic ecosystems impacted by French fishing activities, in a context marked by the CCAMLR conservation measures [7] [9] for Vulnerable Marine Ecosystems (VME) [2] protection and the Marine Protected Areas development [10]. This objective includes several items:

- inventory of species, after taxonomical identification using the presence data of collected specimens,
- habitat characterization and fishing impact assessment, using abundance data derived from the image dataset.

In this working paper is proposed:

- a description of the protocol,
- first results including quality and amount of data produced.

France proposes this protocol to be adopted by SIOFA for all the fisheries of the area.

Materials and methods

Specimen sampling

Specimen sampling is based on an effort towards conservation of the benthic invertebrates collected by the fishing gears. It aims at producing qualitative data about the presence of the taxa within the different fishery areas, in accordance with the goal of contributing to their inventory.

This part of the protocol is divided in two options:

- opportunistic collection of specimens,
- exhaustive collection of specimens.

Depending on the fishery context, one of the two options is implemented in the observers monitoring work. The opportunistic collection of specimens is implemented in the Toothfish established fisheries of Kerguelen and Crozet, using bottom longlines, and during the fish biomass surveys in the EEZ of Kerguelen, using bottom trawls.

In the case of opportunistic collection, only a part of the collected marine invertebrates sorted and stored by the scientists or scientific observers is preserved. The MNHN can transmit priorities before the cruise or during the cruise, of taxa to be collected depending on the scientific objectives of the team, the national collection increase strategy, and requests from other collaborative teams. In the Toothfish established fisheries, the scientific observer can also take the decision of collecting a specimen, regarding to the rarity the species, or its state of conservation for natural history collections.

In the CCAMLR and SIOFA areas, for exploratory and research fisheries, all the specimens caught on the longlines are collected. In these poorly known areas, any benthic invertebrates presence data needs to be produced. Thus, exhaustive sampling is a unique opportunity to realize an inventory, which is the first condition to build the knowledge background needed for upcoming assessment approaches.

The collected specimens are conserved in alcohol during the cruise with proper packaging and labelling, including date, position and identification of the gear.

At the end of the cruise, the specimens are sent to the MNHN (Paris, France) to be studied and integrated in the national natural history collections. After this process, they are submitted first to taxonomists to be precisely identified, using both molecular and anatomical approaches. The MNHN's taxonomists and experts from the international community are mobilized throught different networks:

- identification workshops organized by the MNHN (Fig.1),
- specimens loans provided by mailing to the experts,
- grants to the experts to come working in the MNHN as invited researchers.

The result of the specimen collection allows a double production:

- a dataset of occurrences based on high quality taxonomic identification,
- an increase of the natural history collections providing comparative material, available to the international scientific community.

Fig.1: flyer of the second identification Antarctic Marine Biodiversity Workshop organized by the MNHN at the Marine Station in Concarneau (France)

Photographic sampling

Photographic sampling has been developed to complement the approach based on the study of the specimens. It aims at producing quantitative data, with abundance recording. The taxonomic identification level is dependent on quality of pictures, training of experts, and external morphological features available. A reduced number of organisms will therefore be identified to species.

The protocol is implemented in:

- established fisheries of the French Exclusive Economic Zones (EEZ) of Kerguelen and Crozet,
- fish biomass surveys, only conducted some years in the EEZ of Kerguelen,
- CCAMLR and SIOFA areas, in addition to the exhaustive collection of specimens according to the availability of the scientific observer, or when exceptional circumstances do not allow the exhaustive collection of specimens.

In fish biomass surveys, the onboard scientific team has to follow the protocol. In this case, all the benthos bycatch is sorted, weighed and photographed.

In established fisheries, the scientific observers record the photographic sampling during the hauling observation. A quarter of each longline is drawn to be fully observed. This was originally designed for monitoring fish bycatch and accidental mortality of birds. For photographic sampling of benthos, all the invertebrates caught on the longline during the hauling observation are collected. If the scientific observer is not positioned in the factory of the vessel during the hauling observation, crew collaboration is needed to collect the organisms.

At the end of the hauling, all the collected organisms are:

- weighted together (Fig.2),
- spread out and photographed together with a scale (Fig.3),
- depending of the observers or the scientist availability:
    - the organisms can be sorted and weighted by phyla,
    - the organisms can be spread out and photographed separately, by colony (Fig.4) or by individual (Fig.5), with a scale.

Photographed organisms are discarded. The weights are recorded in the electronic fishing log. The pictures are stored and identified with file naming rules allowing matching them with the data of the fishing process: date, geographical position, type of gear, part and/or length of the observed line.

If the observer cannot apply the protocol, he also has to record a description and an evaluation of the sampling bias. Typically, three phenomenons can occur:

- a huge amount of caught organisms (Fig.6), making it impossible to remove them all from the longline; in this case, common for example with sea-stars bycatch, a sub-sampling is done,
- destruction of specimens by the machinery of the factory,
- depredation occurrence by killer-whales, making it impossible to the master to slow down the hauling nor to stop it to unhook the specimens.

At the end of the cruise, the data and the pictures are sent to MNHN to be treated and analysed. To treat the pictures a complete specific pipeline of data treatment (Fig.7), with semi-automated process including different components based on various software, has been developed. The pipeline has been developed and tested using the sets of pictures of the benthos bycatch from fish biomass cruises in the EEZ of Kerguelen realized in 2010 (POKER 2 [5]) and 2013 (POKER 3 [5]). The first field of the whole protocol during a scientific cruise has been done during the 2015 PIGE fish biomass survey. The protocol has been also successfully implemented during the POKER 4 survey, which results are still being treated.

Associated to the taxonomic identification of the photographed organisms, the pipeline allows us to extract information about:

- size of the organisms,
- quantity of organisms per taxonomic group.

By crossing this data with the fishing effort data stored in the Pecheker database [1] [3], it is thus possible to produce abundance recordings of the benthic invertebrate bycatch in the fishery areas.

Fig.2: weighing of a set of benthos bycatch specimens collected during the hauling observation of a longline in Kerguelen; picture by fishery observer Hugues Vermande (2015)

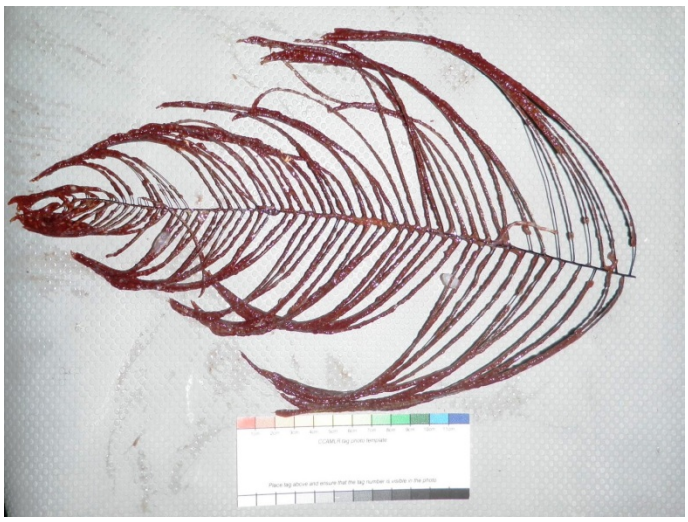

Fig.4: *Antipatharia* coral (*Bathypathes* sp.) photographed separately, longline bycatch from Kerguelen; picture by fishery observer Olivier Guillotin (2015)

Fig.3: bycatch specimens of benthic invertebrates from a station of a trawl survey spread out to be photographed in Kerguelen; picture by scientific team participant Mélyne Hautecoeur (PIGE 2015)

Fig.6: Euryalida brittlestar (*Gorgonocephalus* sp.) photographed separately, longline bycatch from Kerguelen; picture by fishery observer Hugue Vermande (2015)

Fig.6: huge amount of caught benthic invertebrates involving sub-sampling, trawl bycatch from Kerguelen; picture by Mélyne Hautecoeur during biomass survey cruise PIGE (2015)

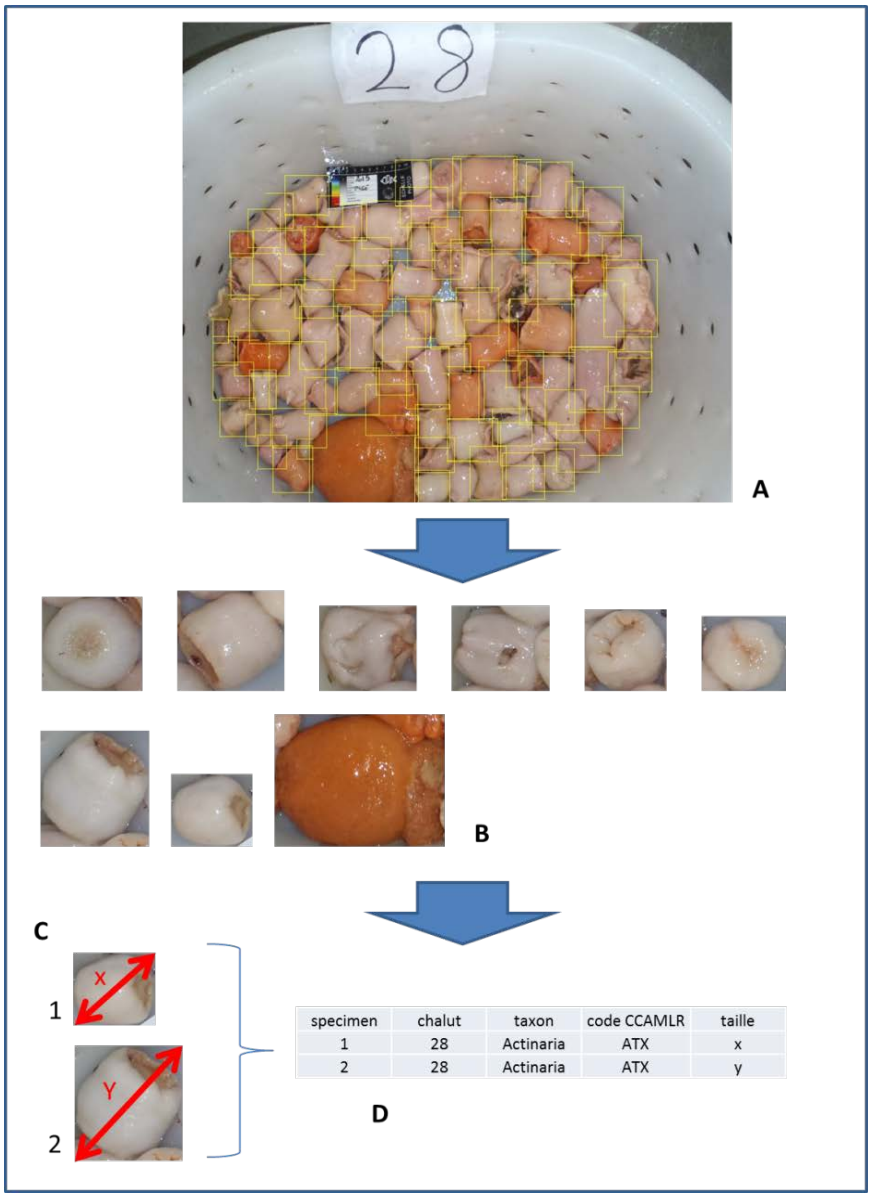

Fig.7: description of the pictures treatment pipeline: count and identification of the organisms (A), extraction of the cropped pictures of each organism (B), measurement (C), storage into a database (D) ready to be extracted for analysis and statistics; raw picture by scientific team participant Mélyne Hautecoeur (PIGE 2015)

Results

Specimen collection

Development of this new protocol is still in progress. Pictures treatment and statistical analysis are underway. Three hundred eighty-nine lots of organisms have been collected, mostly in the area of Kerguelen. The specimens have been partly integrated to the French national natural history collections. They also have been partly identified by the taxonomists of our network of collaborations, in particular during the identification workshops organized by the MNHN.

The quantity of specimens to be obtained is relatively small, but the quality of information based on both anatomy and molecular approaches, is important for inventory.
Furthermore, a series of new species have been discovered. They are being described by the taxonomists, and include new species of corals and crustaceans.

Photographic sampling

The photographic sampling has generated a huge amount of data, both from Kerguelen and Crozet fisheries monitoring, and from the fish biomass surveys in the EEZ of Kerguelen.

On commercial vessels in Kerguelen and Crozet, the protocol allowed to collect 4427 pictures (individuals, colonies or groups of specimens) during the year one of its implementation (from June 2015 to June 2016), mostly in Kerguelen. The sampling effort matches with the fishing effort, which is between 3000 and 6000 longlines each year in Kerguelen and Crozet.

From these pictures, which are still being treated using the pipeline, approximatively 12000 pictures of organisms or colonies with associated data have been obtained. Kerguelen EEZ and Crozet EEZ contributed respectively to approximately 90 % and 10 % of the total number of pictures. These figures correspond to the amount of data which is possible to collect each year using the photographic sampling.

The 2015 PIGE fish biomass survey has been an opportunity for another test restricted to Skiff Banc and the North-East sector of Kerguelen Plateau. Photographic sampling has been applied to 62 stations. Our protocol yielded a total of 7789 pictures of organisms or colonies with associated data

During the development of the pipeline, pictures from the POKER 2 (2011) and POKER 3 (2013) fish biomass surveys have also been treated. These cruises explored the shelf and slope of Kerguelen French EEZ from 100 meters to 1000 meters depth. For the A total of 16174 pictures of organisms or colonies with associated data were derived from analysis of POKER 2 209 stations. POKER 3 yielded 10069 pictures of organisms or colonies with associated data from analysis of pictures sampled from 216 stations.

Thus, the photographic sampling allowed production of a dataset of 46032 pictures of organisms or colonies with associated data, during year one of its implementation.

The dataset covers 9 phyla (Fig.8): *Annelida*, *Arthropoda*, *Brachiopoda*, *Chordata*, *Cnidaria*, *Echinodermata*, *Hemichordata*, *Mollusca* and *Porifera*.

Cnidaria is the most represented phylum with 59.77 % of organisms followed by *Echinodermata* (21.18 %) (Fig.8). 77.2 % of the species or morphotypes recorded are considered VME bioindicators by CCAMLR (Fig.8). In total, 99 taxa, from phylum to species level, have been identified.

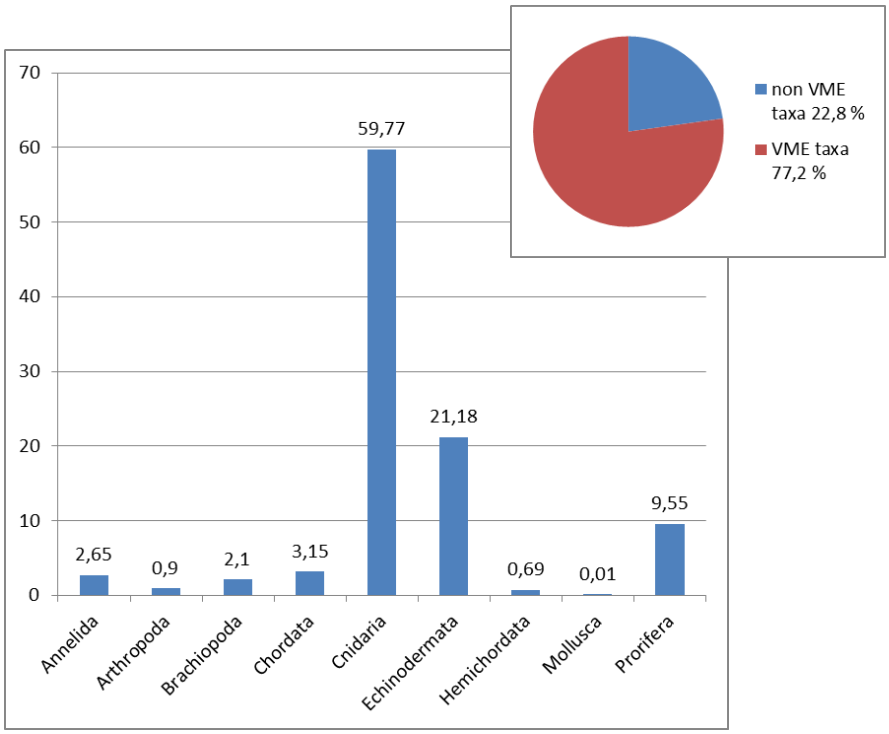

Fig.8: proportion of organisms in each phylum, and proportion of VME and non VME organisms in the picture dataset.

Results derived from this protocol helped produce a number of biodiversity studies aiming at creation of Kerguelen MPA [10] and fishery management [11]. Some examples are mentioned here as an illustration, based on size, presence, and abundance data, both from specimen collection and photographical sampling.

Figure 9 shows size of *Brachiopoda* specimens derived from pictures of benthos bycatch collected during PIGE (2015) as a function of depth. Figure 10 shows the frequency distribution of length of *Brachiopoda* specimens derived from pictures of benthos bycatch collected during PIGE (2015) [11] as a function of depth. Those results were obtained for datamining and for the production of the survey report using an automated treatment process. Similar results at different taxonomic levels of identification were obtained for all the taxa considered to be VME bioindicators by the CCAMLR and caught during the PIGE survey [11]. Due to short deadlines, and to a lack of expertise in *Brachiopoda* species identification, the treatment has been applied to pictures of all *Brachiopoda* pooled together. Despite the low level of taxonomic identification and the use of an automated process designed for data reporting and datamining, the result shows the presence of at least 3 groups that may be interpreted as 3 species of *Brachiopoda* in the study area. Pictures reviewing by a taxonomist specialist of the group allowed later to confirm this result.

Figure 10 shows *Glyphoperidium bursa* habitat distribution prediction in the French EEZ of Kerguelen. The prediction, averaged over each Kerguelen EEZ official statistical squares, was obtained using the Boosted Regression Trees modelling method. Presence data is derived from benthos bycatch data of the fish biomass survey POKER 2 (2009). The specimen collection and the analysis of the pictures were both used to produce the dataset. The environmental data was extracted from available datasets. High prediction values indicate the presence of a suitable habitat, and these are mostly distributed in the North-East sector of the Plateau and the South of the French EEZ.

The creation, in 2016, of the Kerguelen MPA benefited from similar results at different taxonomic levels of identification. In particular, habitat distribution maps were produced for all 22 taxa considered by the CCAMLR to be VME bioindicators [10] and collected during the fish biomass survey POKER 2 [5]. These results helped rank the different EEZ sectors in terms of conservation issues for the benthic habitats and the need of definition of protected areas [10].

Figure 11 shows the distribution of macrobenthos species assemblages in the Skiff Banc and the North-East sector of the Kerguelen Plateau. The clustering results were obtained with a Principal

Component Analysis and Ascending Hierarchical Classification applied to the abundance data of the benthos bycatch of the stations of the fish biomass survey PIGE (2015) [11]. The raw data is from the picture treatment only. For the 62 stations, 7789 organisms and 52 taxa have been identified for this preliminary result based on the photographic sampling. Each cluster is characterized by a typical group of species. Proper statistical tools like the Indval indice allows to reveal bioindicators for each assemblage.

Clustering results highlight convergences and differences in faunal composition of the different sectors of the study area. The stations of cluster 3, present both in the Skiff Banc and the North-East sector of the Plateau, correspond to convergences. Other clusters show spatial structuration of species assemblages, different from the Skiff Banc and the North-East sector of the Plateau, and different within North-East sector. The complete results of this study have also been used to inform policy makers during the creation of the Kerguelen MPA in 2016 [10].

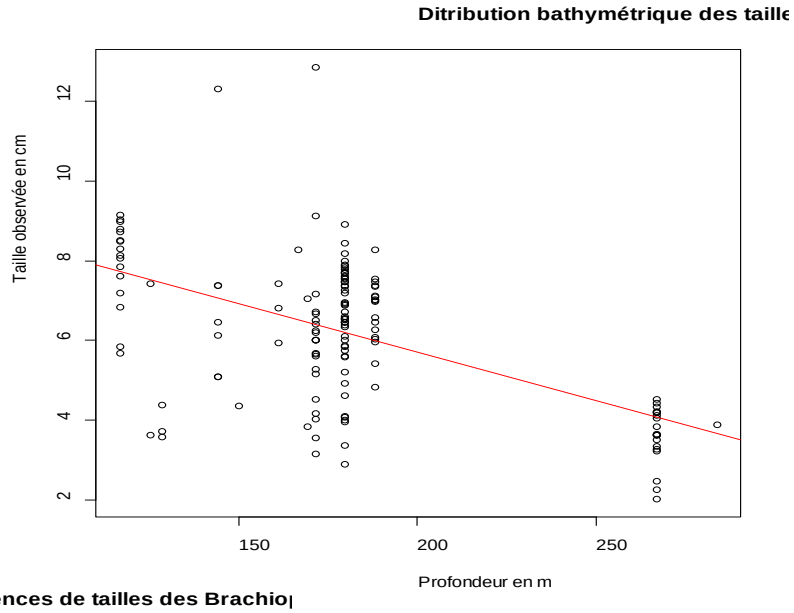

Fig.9: individual size according to the catching depth of the *Brachiopoda* organisms obtained from the treatment of the pictures of the benthos bycatch from the biomass survey cruise PIGE (2015); diameter of the shell given in centimeters, depth given in meters

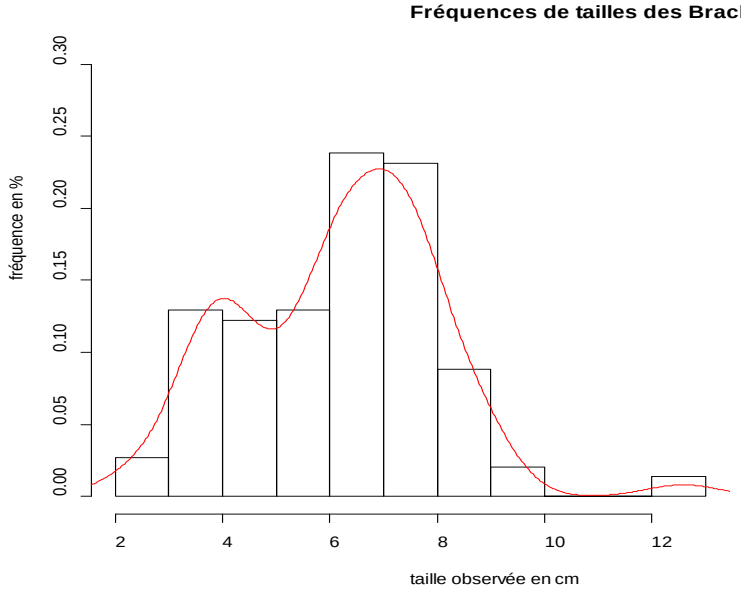

Fig.10: length frequency according to the catching depth of the *Brachiopoda* organisms obtained from the treatment of the pictures of the benthos bycatch from the biomass survey cruise PIGE (2015); diameter of the shell given in centimeters, frequency given in percentages

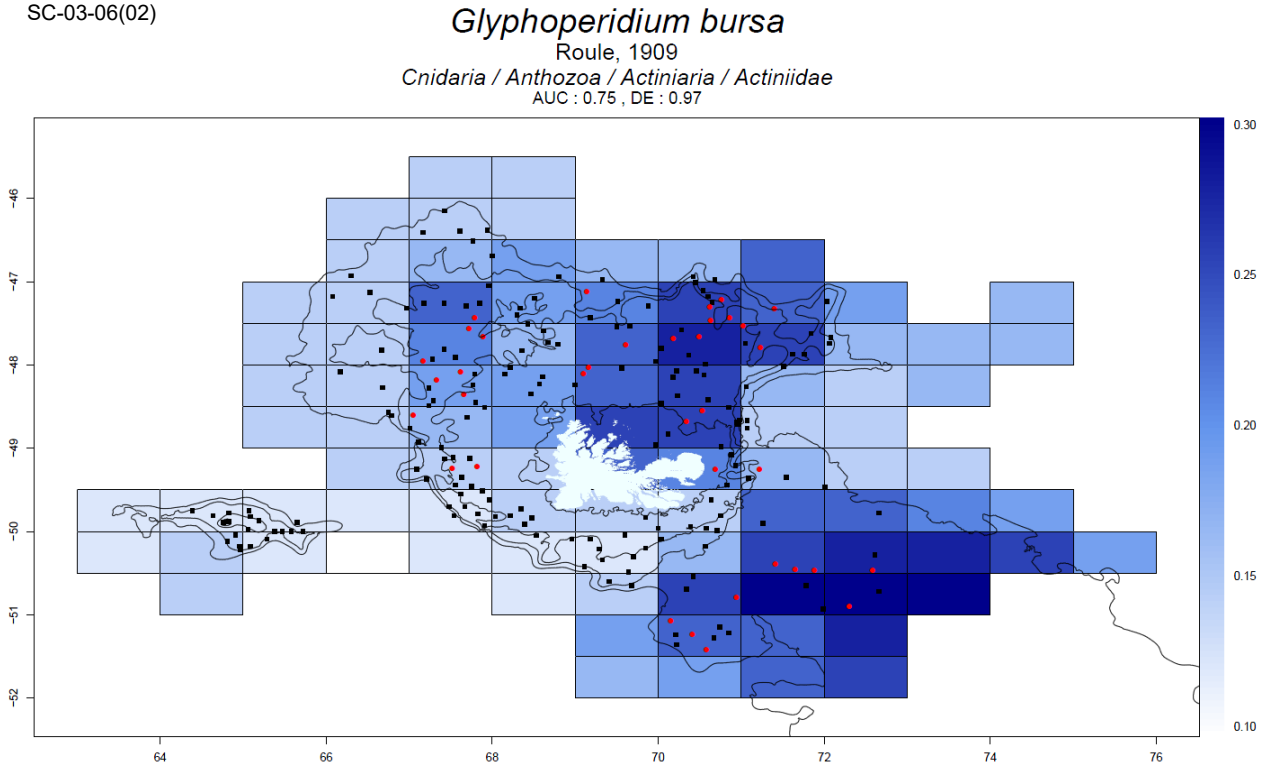

Fig.11: *Glyphoperidium bursa* habitat distribution prediction in the French EEZ of Kerguelen obtained using Boosted Regression Trees modelling method; prediction values are averaged by management areas; black points correspond to absence data and red points to presence data; raw data is from the specimen collection and the analysis of the pictures of the fish biomass survey POKER 2 (2009)

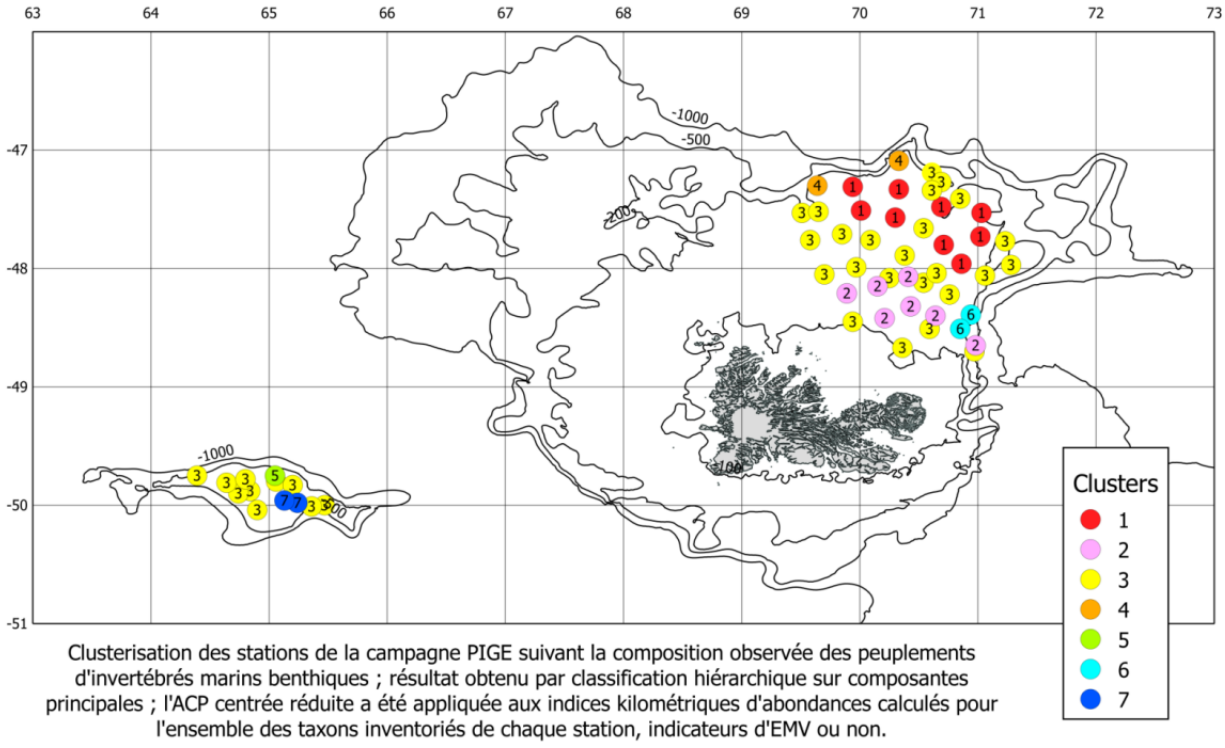

Fig.12: distribution of macrobenthos species assemblages in the Skiff Banc and the North-East sector of the Kerguelen Plateau; clustering results obtained with a Principal Component Analysis and Ascending Hierarchical Classification applied to the benthos bycatch data of the stations of the fish biomass survey PIGE (2015); raw data from picture treatment and analysis only

Discussion

The complementarity of the two approaches within the same protocol allows increasing the data acquisition about the benthos bycatch in the context of the monitoring of the French fisheries of the Southern Ocean.
After two years of testing and development, it is possible to highlight the benefits of this protocol and discuss some of its limits.

Specimen collection

A series of technical constraints constitutes the limit of the specimens collection, preventing the possibility of producing abundance data based on this approach. The main constraint is the high cost of the whole process. Fixing the specimens onboard and organizing their transport at the end of each cruise involves costs that must be added to the funding of the fisheries scientific monitoring. The different treatment steps, starting from the integration into the natural history collections to the identification of the organisms by taxonomists from the international community, also involves important costs.

In addition to that, from collection of the specimens to availability of identification data, a long time is needed to build results. This is mostly due to availability of taxonomists and rarity of experts in some taxa.

However, specimen collection is a fundamental approach to build background knowledge on benthic biodiversity. It allows describing taxa and highlighting their presence in the fishery areas. Proper identification of organisms can only be done using preserved specimens giving access to their anatomical structures and their DNA. The specimens collection must be developed, also to allow development of pictures or video based approaches. Without information produced from specimens and natural history collections where they are housed, it is indeed impossible to build analysis nor interpretations based on pictures or videos observation.

Specimen collection allows increasing invertebrates natural history collections from other poorly sampled areas of the Southern Ocean. The scientific capacity of collecting samples in the Southern Ocean is limited, due to the significant cost of field work in this area. Using the fisheries scientific

monitoring activity to collect specimens could be a significant improvement for benthologists and taxonomists.

Furthermore, commercial vessels can target different areas than the scientific cruises, using different fishing gears. This can allow producing original and complementary data. For example in Kerguelen and Crozet, longlines have collected organisms that scientific expedition had never collected before.

Photographic sampling

Abundance data were produced using photographic sampling. Identification of organisms from pictures was coarser and taxonomic attribution more inclusive than is generally the case with direct observation of organisms. This is the main limit of this approach. Depending on the phylum and the quality of pictures, identification to species level is sometimes possible. However, the more inclusive taxonomic level of identification is generally the family or the genus.

Furthermore, treatment of the pictures is time consuming. Cropping and identifying single organisms from complex pictures is tedious and certainly needs to be at least in part, automated.

However, the photographic sampling seems effective regarding a series of field constraints.

The first constraint is the very short time available for the observers to treat the benthos bycatch. Within all the scientific protocols the national observers have to follow, they can take approximatively 30 minutes per day to work on the benthic invertebrates caught on the gears.

The second constraint is the difficulty to identify the benthic invertebrate taxa. Due to the huge number of taxa within this group and the complexity of their anatomical structures, their identification requires well trained taxonomists and access to laboratory facilities including molecular techniques. On board, observers are often hired according to thier skills in vertebrates identification (fishes, birds and mammals). It is therefore impossible for them to identify precisely all benthic species caught by the fishing gears. As a result, it is impossible to monitor benthos bycatch using field observations recording only (as opposed to collecting, photographing, preserving).

The photographic sampling enables to satisfy these constraints:

- no skills in identification are needed,
- the protocol is not time consuming,
- it allows to transfer the production of the raw data from the field to the laboratory.

Furthermore, and despite the limited level of taxonomic identification, photographic sampling allows statistical and ecological approaches using raw data produced:

- production of huge amount of data allowing statistics,
- abundances recording,
- possibility of extracting organisms size.

Conclusion

The new data acquisition protocol for benthos bycatch in Southern Ocean French fisheries provided significant results, regarding to the amount and the quality of the data produced. The preliminary results show that benthos bycatch survey and VME conservation issues may be taken into account in a near future in the French fisheries management.

The present protocol will improve with the constitution of a reference collection of well identified organisms and a better correlation between these specimens and the photographed ones. A dedicated international collaborative network and development of automated identification tools are obvious avenues that need to be explored.

The main objective of this new protocol is to contribute to the knowledge of marine habitat used by fisheries and to detect any Vulnerable Marine Ecosystems that need to be protected in the future. It also helps policy makers to design marine protected areas. Finally SIOFA could use part or whole of the protocol to implement in the fisheries scientific monitoring activity.

Bibliography

[1] Martin A. & Pruvost P. (2007), Pecheker, relational database for analysis and management of halieutic and biological data from the scientific survey of the TAAF ficheries, Muséum National d'Histoire Naturelle, http://halieutique.mnhn.fr/

[2] CCAMLR. (2009), *CCAMLR VME Taxa Identification Guide,*. Commission for the Conservation of Antarctic Marine Living Resources, Hobart, Tasmania, Australia, 4p. Available at *http://www.ccamlr.org/pu/e/e_pubs/VME_guide.pdf*

[3] Pruvost P., Martin A., Denys G., Causse R. (2009) PECHEKER-SIMPA, a tool for fisheries managment and ecosystem modelling. *In: The Kerguelen Plateau, Marine Ecosystem and Fisheries*, Société Française d'Ichtyologie, 263-270 pp.

[4] Améziane N., Eléaume M., Hemery L., Monniot F., Hemery A., Hautecoeur M. & Dettaï A., (2011). Biodiversity of the benthos off Kerguelen Islands: overview and perspectives. *In*: *The Kerguelen Plateau: marine ecosystems and fisheries*, (Duhamel & Welsford eds.), Société Française d'ichtyologie : 157-167.

[5] Eleaume M., Moreau C., Laffargue P., Hemery L., Hautecoeur M., Gasco N., Martin A., Chai N., Mah C., Améziane N. (2011), Caractérisation et distribution des assemblages benthiques du Plateau de Kerguelen. *In: Poker 2, 2ème campagne d'évaluation de la biomasse de poissons à Kerguelen, Muséum National d'Histoire* Naturelle : 171-179 pp.

[6] Duhamel G., Sinègre R., Hautecoeur M., Chazeau C., Pruvost P., Gasco N., Cascade S., Hoffman M., Aubert J.L., Le Ménager M., Stradal S., Ringelstein J. (2013), *POKER 3, Campagne d'évaluation de la biomasse de poissons à Kerguelen*, Muséum National d'Histoire Naturelle, 264 p.

[7] Conservation Measure 22-07 (2013) Interim measure for bottom fishing activities subject to Conservation Measure 22-06 encountering potential vulnerable marine ecosystems in the Convention Area, Adopted at Meeting CCAMLR-XXXII

[8] Vasset N., Martin A., Pruvost P., Duhamel G., Eléaume M., Améziane N. (2014), *Estimation de la biodiversité pour le domaine 6 (Plateau de Kerguelen) à des fins d'écorégionalisation*, Muséum National d'Histoire Naturelle, Agence des Aires Marines Protégées, Terres Australes et Antarctiques Françaises, 266 pp.

[9] Conservation Measure 22-06 (2015) Bottom fishing in the Convention Area, adopted at Meeting CCAMLR-XXXIV

[10] Koubbi P, Guinet C, Alloncle N, Ameziane N, Azam CS, Baudena A, Bost CA, Causse R, Chazeau C, Coste G, Cotté C, D'Ovidio F, Delord K, Duhamel G, Forget A, Gasco N, Hautecœur M, Lehodey P, Lo Monaco C, Marteau C, Martin A, Mignard C, Pruvost P, Saucède T, Sinegre R, Thellier T, Verdier AG & Weimerskirch H. 2016. Ecoregionalisation of the Kerguelen and Crozet islands oceanic zone. Part I: Introduction and Kerguelen oceanic zone. *CCAMLR Report WG-EMM*- 16/43, 18 june 2016, 32 pp

[11] Martin A., Hautecoeur M., Eléaume M., Améziane N., Duhamel G. (2016), Etude préliminaire des captures accessoires de macrobenthos de la campagne PIGE, Caractérisation des assemblages d'invertébrés benthiques du secteur Nord-Est de Kerguelen et du banc Skiff, et des enjeux de conservation réglementaires associés. *In : Rapport de Campagne PIGE*, UMR BOREA du Muséum National d'Histoire Naturelle, 75-116 pp.