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1 **Seamounts, plateaus and governance issues in the Southwest Indian Ocean, with**
2 **emphasis on fisheries management and marine conservation, using the Walters Shoal as**
3 **a case study for implementing a protection framework**

4
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26

27 **Abstract**

28 There is a growing interest in the management of seamounts of the South Western Indian
29 Ocean (SWIO) both in waters under national jurisdictions and in the Areas Beyond National
30 Jurisdiction (ABNJ). On the one hand, new scientific knowledge has been gathered through
31 various oceanographic cruises during the past decade and, on the other hand, new agreements
32 are under consideration globally to promote conservation and sustainable use of the

33 biodiversity in the ABNJ, where the deep sea ecosystems associated to seamounts are a
34 growing matter of concern. SWIO seamounts have attracted interests from fishing operators
35 since the 1960s, while mining exploration contracts have been recently granted. Seamounts
36 are known to shelter rich, fragile and poorly resilient ecosystems whose important ecological
37 functions that are threatened by various anthropogenic pressures. While many seamounts and
38 shoals are located in national waters, many others fall in the ABNJ with no current legal
39 status *per se*. To ensure conservation of their habitats and biodiversity, it is essential that
40 protection measures are instigated under an internationally-recognized legal and institution
41 framework. In this paper, we review the current state of such a framework relevant to
42 seamounts, with emphasis on fisheries and conservation in the SWIO. We select an
43 emblematic seamount, the Walters Shoal, as a case study to discuss how this site could
44 become a fully-protected space in the ABNJ. Since a large part of the SWIO is under the
45 mandate of the Nairobi Convention (Regional Sea under the auspices of UNEP), guidelines
46 are proposed to spur a dedicated seamount governance in the framework of this Convention.

47

48 *Keywords:* International Law of the Sea, Vulnerable Marine Ecosystems, deep-sea fisheries,
49 deep-sea mining, benthic biodiversity, Saya de Malha Bank, South Indian Ocean Fisheries
50 Agreement, Areas Beyond National Jurisdiction, Amended Nairobi Convention, Marine
51 Protected Areas.

52

53 **1- Introduction**

54 Seamounts are usually described as steep topographic rises of the seabed with an elevation
55 greater than 1000 m (IHO, 2008) and a limited area across the summit (Rogers, 1994; Yesson
56 et al., 2011, Clark et al., 2011). Seamounts in an ecological sense also include knolls and hills
57 rising only a few hundred meters (200-1000 m) above the basal depth (Clark et al, 2007;

58 Rogers 2018). They usually represent active or extinct volcanoes located on underwater
59 plateaus, mid-oceanic rifts or intra-plate hot spots. Estimates of seamount numbers have
60 varied by orders of magnitude, depending on the data resolution and on the extrapolation
61 method used. In the Western Indian Ocean, west of 80°E (FAO area 51), the number of
62 seamounts with an elevation of ≥ 1000 m above the seafloor has been estimated at 2559, of
63 which 820 are located within Exclusive Economic Zones (EEZs) (Yesson et al, 2011). In the
64 South Western Indian Ocean region (SWIO), the seamounts are distributed along the South
65 West Indian Ridge (SWIR, 7700 km from Bouvet Island to Rodriguez triple junction, Sauter
66 & Cannat, 2010), along the Mid-Indian Ridge, on the Mozambique Plateau, on the
67 Madagascar Ridge, a rise which extends over 1100 km south of Madagascar, and in the
68 Mozambique Channel (Courgeon et al., 2016). The submarine plateaus and seamounts of the
69 SWIO originate from a multi-phase history of the Indian Ocean opening and dislocation of the
70 Gondwana supercontinent which began in the early Jurassic (around 180 million years ago). It
71 is noteworthy that the vast majority of seamounts in the SWOI (68%) are located in
72 international waters, beyond national jurisdiction of States (200-nautical miles¹ (M) EEZs)
73 (Kitchingman, 2007, Yesson et al, 2011).

74 Besides the typical seamounts, a characteristic feature of the region is “underwater shoals”
75 that represent submerged shelf areas. Oceanic shoals cover vast shallow areas with depths less
76 than 200 m compared to the limited surface area of seamounts tops. Shoals such as Saya de
77 Malha (8°30’S to 12°S and 59°30’E to 62°30’E) rise to depths of merely 8-15 m below the
78 surface. Saya de Malha is the northern part of the Mascarene Plateau stretching from the north
79 of Mauritius to the Seychelles (Fig. 1).

80 Because of their magmatic origin, seamounts contain mineral resources. A crust of
81 ferromanganese oxide enriched with cobalt, copper, manganese and sulphur has accumulated

¹ M stands for nautical mile, with 1 nautical mile = 1852 m

82 around the oldest reliefs (Wessel, 2007; ISA, 2007). It is estimated that these reserves could
83 exceed those on the continents, but presently the extraction cost remains prohibitive to be
84 economically profitable. However, the situation could change in the coming decades as
85 similar resources on the continents become more and more scarce.

86 Seamounts are also renowned to be particular habitats for a range of rare and fragile
87 species and are thus qualified as biodiversity hotspots (Worm et al., 2003; Morato et al., 2010;
88 Clark et al., 2010). The dominant large fauna on many seamounts is composed of benthic
89 organisms (corals, sponges) which are particularly species-rich and at the origin of high
90 habitat heterogeneity and biodiversity for associated fauna (Buhl-Mortensen et al., 2010).
91 Such species belonging to deep-sea corals and sponges have been designated as indicator
92 species to characterize Vulnerable Marine Ecosystems (VME) because of their sensitivity to
93 bottom fishing impacts (FAO, 2009). Although historical records of benthic-pelagic fauna do
94 exist, from sporadic explorations during the first 60 years of the 20th century, the fauna
95 inhabiting the SWIO seamounts is still poorly known. The lack of knowledge about structure,
96 function and connectivity of seamount ecosystems requires intensive scientific efforts to
97 better assess the threats to seamount resources from fishing and seabed mining (Clark et al.,
98 2012). Seamounts serve as habitat for a large number of VME indicator species (Watling &
99 Auster, 2017), leading these authors to propose that seamounts should be managed as VMEs.
100 The exploitation of fisheries resources associated to seamounts form part of the competence
101 of the Southern Indian Ocean Fisheries Agreement (SIOFA) which regulates some aspects of
102 bottom fishing activities to minimize impacts on the benthic ecosystem and manage deep-sea
103 fisheries.

104 Several seamounts are also marine landmarks for migrating pelagic species at different
105 stages of their life cycle. The Walters Shoal is a foraging destination for Barau's petrel
106 (*Pterodroma barau*) an endemic seabird of Reunion Island that flies here during the breeding

107 season (Pinet et al., 2012). Humpback whales (*Megaptera novaeangliae*) were reported
108 around the Walters Shoal, either by direct sightings (Collette & Parin, 1991; Best et al., 1998),
109 or by satellite tagging (Cerchio et al., 2016; Trudelle et al., 2016). Humpback whales also
110 congregate during winter for breeding along the slopes of the La Perouse seamount, located
111 northwest of Reunion Island (Dulau et al., 2017). Acoustic-based experiments carried out in
112 the Pacific showed that whales can take advantage of enhanced foraging opportunities at
113 seamounts (Johnston et al., 2008).

114 Because of their mineral resources and their biological abundance and richness, seabed
115 mining and bottom trawling put at risk the benthic ecosystem. Mining can cause irreversible
116 destruction of habitats, noise pollution, and contamination by toxic metals, oil and chemicals,
117 with potential biological impacts (reproduction, larval health...). As several exploited species
118 have high longevity with slow growth and late maturity (K-strategy species), their resilience
119 to fishing pressure is very low making their stocks highly vulnerable (Morato and Clark,
120 2007; Clark et al., 2019) and susceptible to become overfished in the absence of appropriate
121 management measures (Clark, 2009). The orange roughy, an often-cited example, has a life
122 span of over 100 years and a maturity around 20 years. Their fisheries worldwide have proven
123 to be non-sustainable (Roberts, 2002; Sissenwine and Mace, 2007; Picher et al., 2010). Whilst
124 this is of great concern, a few seamount fish species and others that aggregate over seamounts
125 (Morato and Clark, 2007) are relatively short-lived and fast-growing, such as the rubyfishes
126 (Emmelichthyidae) or certain lanternfishes (Myctophidae).

127 Although no established deep mining activities occur nowadays (only prospection), the
128 legal protection in the form of a governance framework to regulate possible future
129 exploitation of these features is quasi nonexistent. Ecosystem monitoring would be necessary
130 to ensure that all kinds of possible activities on the seamounts do not jeopardize their
131 ecosystem. Seamounts in ABNJ are of particular matter of concern and form part of ongoing

132 discussions at the international level (<https://www.un.org/bbnj/>). The growing corpus of
133 knowledge that is being acquired on seamounts could help to expand and strengthen the few
134 management actions taken so far by regional organizations, to warrant the conservation of
135 these sensitive and complex ecosystems (Garcia et al., 2013).

136 With this background, the goal of this paper is therefore to integrate scientific information
137 and the current status of the management of natural resources at SWIO seamounts to
138 formulate possible recommendations for the protection of seamount habitats and ecosystems
139 in the ABNJ of the SWIO. We illustrate the various issues and challenges of seamount
140 governance in the ABNJ by using the Walters Shoal, a very shallow seamount (18 m) located
141 at 43°54'E/33°12'S, as a case study, on the basis on advanced ecological knowledge collected
142 on this particular seamount. Eventually we suggest guidelines for an evolution in the legal
143 aspects related to seamounts in the SWIO within the framework of the Amended Nairobi
144 Convention.

145 **2- Current management of seamounts**

146 *2.1 Current principles of marine governance*

147 Whereas a seamount exists as an entity and is so recognized in natural sciences, a
148 seamount has no specific existence *per se* under the United Nations Convention on the Law of
149 the Sea (UNCLOS). A more general legal framework applies to it. The legal status of a
150 seamount depends on its location relative to the different maritime zones that have been
151 established by the UNCLOS. In the Territorial Sea, which extends 12 M from the baseline
152 (coastline), the human activities are governed by the laws and regulations of the coastal state.
153 In the EEZ, extending to a distance of 200 M from the baseline, each coastal state has
154 exclusive rights to exploit natural resources from the water column (e.g. pelagic fish) and
155 from the seabed and subsoil (e.g. oil and gas, minerals, demersal and benthic fish stocks), and
156 to grant access to other nations for exploitation. Beyond the 200 M limit starts the so-called

157 “high seas”, or the ABNJ where no sovereignty can be claimed by any State, with regard to
158 the water column. However, regulation applies to fishing in the ABNJ under the Regional
159 Fisheries Management Organizations (RFMOs) framework.

160 The continental shelf, defined as the seabed and subsoil of the natural prolongation of the
161 coastal state’s land territory under the ocean, is subject to a particular regulation outside the
162 EEZ. When a morphological continuity is scientifically proven from the landmass to the outer
163 edge of the continental margin (beyond the 200 M limit), the coastal state can make a
164 submission to the Commission on the Limits of the Continental Shelf (CLCS) to define the
165 outer limits of its continental shelf beyond 200 M. In most cases, the outer continental shelf is
166 limited to a maximum of 350 M from the coastal baseline but under particular circumstances
167 it can even go beyond. In some cases, topographic features, including seamounts and reefs,
168 are claimed as part of this extension. A recent example shows that such a stake can involve
169 more than a single coastal State. In 2008, Seychelles and Mauritius have agreed to exercise a
170 joint sovereignty of the continental shelf of Saya de Malha, extending beyond the EEZ of the
171 respective two coastal states, which was endorsed by the CLCS in 2011. This extended joint
172 jurisdiction does not concern the water column and the living organisms above the shelf.

173 Outside the extended continental shelf is the “Area” administered by the International
174 Seabed Authority (ISA) which shall organize and control all mineral-related activities
175 concerning the seabed and the subsoil. According to UNCLOS, these mineral resources are
176 recognized as a common heritage of mankind. For the moment, Indian Ocean seamounts like
177 Walters Shoal, Coral Seamount, Middle of What, Atlantis Bank, Fools Flat still belong to the
178 “Area”.

179 *2.2 Management of mineral exploration in the high seas*

180 Among all contracts for exploration managed by ISA, 5 out of the 29 entered into force
181 worldwide are located in the Indian Ocean (1 for polymetallic nodules, 4 for polymetallic

182 sulphides). None of these five contracts concern cobalt-rich ferromanganese crusts (ISA,
183 2019). Middle of What, Atlantis Bank and other seamounts of the SWIR are of potential
184 interest for polymetallic sulphides. For instance, in 2011, the ISA granted a 15-year contract
185 for the exploration of polymetallic sulphides to the China Ocean Mineral Resources Research
186 and Development Association. This contract covers part of the SWIR and consists of 100
187 blocks of 100 km² each, strategically placed along the axial part of the ridge and associated
188 seamounts. It is important to stress that the ISA contracts are, thus far, limited to exploration.
189 The next phase, i.e. the exploitation of marine minerals, may follow, however this remains
190 speculative and is not likely to happen in a near future. Besides mining operations, simpler
191 extractive activities can occur on shallow plateaus, such as the suction dredging of sand and
192 gravel that are most sought-after products for construction work. Nevertheless, issues
193 regarding environmental protection and biodiversity conservation related to extractive
194 purposes beyond national jurisdiction should be considered before any exploitation permit be
195 granted

196 In that perspective, the ISA Mining Code has provisions to protect the marine environment
197 from the harmful effects of mining. Several Regional Environmental Management Plans
198 (REMP) are under development in regions with exploration contracts. These plans aim to
199 conserve areas of the seabed through a network of large no-mining areas called ‘Areas of
200 potential environmental interest’ (APEIs). APEIs are designed by scientists to be
201 representative of the full range of habitats, biodiversity and ecosystem structure and functions
202 to be protected. Thus far, a single REMP is in place worldwide, located in the East Pacific
203 (Clarion-Clipperton Zone) (Lodge et al, 2014). In the absence of spatial planning in the Indian
204 Ocean, a workshop specific to this ocean is planned by the ISA to identify APEIs for a future
205 REMP.

206 *2.3 Deep-sea fisheries management in the Southern Indian Ocean*

207 2.3.1 Outlook on seamount fisheries

208 Deep-sea fishing grounds are in the bathymetric range 200-1200 m. Highly valuable
209 demersal and benthopelagic fish resources have been harvested at seamounts since the 1970s
210 by bottom or midwater trawling, catching a dozen of species in the Indian Ocean, including
211 orange roughy (*Oplostethus atlanticus*), alfonsinos (*Beryx spp*), oreos (*Neocyttus*
212 *rhomboidalis*, *Pseudocyttus maculatus*), cardinalfish (*Epigonus spp*), rubyfish (*Plagiogeneion*
213 *rubiginosus*), southern boarfish (*Pseudopentaceros richardsoni*), rudderfish (*Centrolophus*
214 *niger*), pelagic armourhead (*Pseudopentaceros wheeleri*), Patagonian toothfish (*Dissostichus*
215 *eleginoides*) and bluenose (*Hyperoglyphe antarctica*) (Romanov, 2003; Clark et al., 2007).

216 Soviet vessels started to explore deep-sea fishing grounds in the Southern Indian Ocean in
217 the early 1970s with large stern trawlers. These explorations were supported by research
218 surveys and a strict scientific monitoring, demonstrating that seamount resources are limited
219 and associated to fragile stocks (Romanov, 2003). During the 1980s, the annual catches
220 remained below 4000 t. With the introduction of new operators, catches by non-regulated
221 fisheries increased dramatically during the 1990s reaching a peak of 13140 t in 1999 (FAO
222 2017). Orange roughy dominated the catches during 1998-2006 (range of 2300 to 7500 t)
223 (Fig. 2). After 2010, alfonsinos catches were the highest (1800-4500 t annually), constituting
224 an average 20% of the deep-sea fish catches during 2010-2015 (Fig. 2).

225 Retained by-catch species are also of high value and include several of the species listed
226 earlier. Deep-water demersal sharks (living below 200 m depth) are another matter of
227 concern, as a by-catch of demersal trawl, mid-water trawl, demersal longline and demersal
228 gillnet gears. These sharks have a very low fecundity and have been rated as extremely
229 vulnerable by ecological risk assessment analyses (Lucena-Frédou et al., 2017; Georgeson et
230 al., 2019). In the SWIO, 112 species of such chondrichthyan species have been reported to
231 interact with the deep-sea gears (Ebert 2013, 2014). Seamount fisheries are generally

232 qualified as boom and bust fisheries, thus a swift implementation of management and
233 conservation measures is required.

234 2.3.2 The setting up of a deep-sea fisheries management organization

235 Seamount governance in the Indian Ocean immediately leads to the issue of fishing, and
236 seamount fisheries deserve a close focus. Fishing pelagic species on a seamount never had
237 any specific regulation. In the ABNJ, pelagic resources are accessible to any fishing nation
238 which must comply with the harvest and management rules of the relevant RFMO, and both
239 seamounts and non-seamounts areas are treated the same way. By contrast, specificities were
240 introduced for deep-sea fishing when the SIOFA (<https://www.apsoi.org/>), a FAO Regional
241 Fisheries Management Body, came into force in 2012, creating a competent RFMO for
242 bottom-associated species. SIOFA has currently nine Contracting Parties, Australia, the Cook
243 Islands, the European Union, France (on behalf of its Indian Ocean Territories), Japan, Korea,
244 Mauritius, Seychelles and Thailand. Other states not having yet ratified are Kenya,
245 Madagascar, Mozambique and New Zealand. Comoros is one cooperating non-Contracting
246 Party and Chinese Taipei a Participating fishing entity.

247 The most emblematic initiative relevant to seamounts fisheries in the high seas of the
248 Southern Indian Ocean is a decision taken by private fishing companies to form an association
249 designed to promote responsible fishing and to support effective fisheries management of the
250 species exploited by its members (Shotton, 2006). This initiative was triggered by the lengthy
251 process in establishing the SIOFA (Leroy and Galletti, comm. pers.), and by the worries of
252 some fishing operators that, in the meantime, management issues would remain unaddressed
253 (Shotton, 2006). The Southern Indian Ocean Deepsea Fishers Association (SIODFA) was
254 then created in 2006 by five fishing companies registered in Australia (1), Mauritius (1) and
255 Cook Islands (3). SIODFA members applied to themselves rules concerning a number of
256 seamounts, such as the implementation of 13 voluntary benthic protected areas (BPAs) in the

257 high seas within the SIOFA perimeter, with the expectation that these conservation measures
258 would later remain in the scope of SIOFA for a wider legal dissemination. All SIODFA
259 members have been fishing in the South Indian Ocean since 2000, but some undertook deep-
260 sea fishing as early as 1996.

261 The 13 SIODFA-delimited BPAs comprise a total area of 309150 km² which is less than
262 1% of the SIOFA area. BPAs are designed as localized areas of known value and
263 representative benthic biodiversity where no bottom or midwater trawling would be allowed.
264 Hence, they concern only a depth range where trawling is possible. Strictly speaking, such
265 BPAs only concern deep-sea fisheries and the benthic ecosystems, but neither the water
266 column (meso- and epipelagic fauna) nor the seabed for extractive purposes such as mining
267 and/or oil drilling (although damages would affect pelagic and benthic ecosystems).
268 Nevertheless, when the ISA evaluates the seabed mineral activities, relevant fisheries
269 activities and protected areas do need to be taken into account, thus the BPA status can be
270 helpful in a more holistic approach for the conservation of sensitive areas.

271 2.3.3 Current status of the SIOFA management

272 The SIOFA has adopted 15 binding conservation and management measures (CMM) since
273 2016. So far, SIOFA has mostly focused on the management of orange roughy and alfonsinos
274 stocks inhabiting seamounts among other major fish species (armourhead, bluenose, dogfish,
275 oreos and patagonian toothfish). The downside is that underwater shoals within the SIOFA
276 area of competence, such as Saya de Malha, have been overlooked. A large fraction of the
277 Saya de Malha Bank is in the ABNJ and supports the largest contiguous seagrass beds in the
278 world. For such characteristic, Saya de Malha was considered by UNESCO as a potential
279 candidate to become a Marine World Heritage site, classified as a site with “*Potential*
280 *Outstanding Universal Value*” (Obura et al., 2012). Despite the uniqueness of this underwater
281 shoal, a trawl fishery has been active from 2015 to 2017. Up to 61 Thailand-flagged trawlers

282 were active on an area of 33000 km², performing 4000 trawls per year. The catch declined
283 from 23000 to 10000 t over the first two years collapsing to 2000 t by 2017 (Panjarat &
284 Boonsripum, 2018). Although the two main species caught, lizardfish (*Saurida spp*) and
285 round scad (*Decapterus spp*) are not considered as threatened by the IUCN, the damage
286 created on the benthic ecosystem (corals, sponges, seagrass) is likely to be important and
287 could not be evaluated in a robust manner due to the limited observer coverage rate of 5%.
288 There are ongoing discussions at the SIOFA to define general rules for bottom fishing² in
289 established bottom fishing fisheries, which would apply to the Saya de Malha Bank mixed
290 species fishery. At the 6th Meeting of the Parties in 2019, Mauritius and Seychelles claimed
291 that due to the joint management of Saya de Malha by the two countries, “SIOFA can no
292 longer devise any policy or implement any project in this area”. This statement introduces
293 some confusion with respect to the management of living resources associated to the seabed
294 as the rights conferred by the CLCS and the resulting sovereign rights on the extended
295 continental shelf do not apply to living resources other than sedentary. Difficulties persist in
296 qualifying certain species as sedentary or not, according to UNCLOS Art.77³. Actually,
297 certain species which can be qualified a sedentary or non-sedentary, living slightly above the
298 seabed of the joint management area, fall within the scope of the SIOFA (including certain
299 fish, molluscs and crustaceans).

300 In 2018, SIOFA has established five provisionally designated benthic protected areas
301 (Fig.3) whose Walters Shoal is part of, that are taken from the initial 13 SIODFA BPAs, and
302 is in the process of mapping areas where VME encounters are known to occur on the basis of
303 bottom fishery impact assessments. The binding measure CMM 2019/01 prohibits bottom

² At the SIOFA, the terms ‘bottom fishing’ mean fishing using any gear type likely to come in contact with the seafloor or benthic organisms during the normal course of operations. It includes bottom trawl, mid-water trawl, bottom line and traps or pots.

³ Article 77 of the UNCLOS defines sedentary species as those “which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or subsoil”

304 fishing (with the exclusion of line and trap methods) in the BPAs, and stipulates that scientific
305 observers must be onboard while fishing inside those areas with any other gear. It is therefore
306 with a regional Law of benthic fisheries (under SIOFA) that one must deal with from now on.

307 **3- Towards seamounts as conservation units**

308 The international law in the high seas is dominated by poorly coordinated sectoral regimes
309 (Galletti, 2015). The seamounts are just an illustration of this analysis. The regulation of
310 offshore biological and mineral resources are distinct and separate and the two related
311 economic sectors have been, until now, rather reluctant to any holistic approach regarding
312 seamounts. Recent progress can be acknowledged in the Indian Ocean through the SIOFA
313 management measures, and through the regional environmental management plans that are
314 being developed under the ISA Mining Code, as noted before. Different perspectives are
315 noted between what refers to seamount species on one hand, and to fragile habitats on the
316 other hand. This distinction indicates why conservation units are needed for seamounts.

317 *3.1. The issue of seamount species*

318 The first concern is about the species that live and are incidentally caught at the seamounts,
319 and the environmental rights of the species (status and listing). The question is whether they
320 are legally protected and how. Through the Convention on Migratory Species and its
321 provision for sub-agreements, States along their coasts, in their EEZs and beyond, can decide
322 to protect seamounts and their associated species. In the Convention on International Trade in
323 Endangered Species of Wild Fauna and Flora (CITES) the number of marine species that are
324 protected or trade-managed is minimal. The key taxa of concern on seamounts are the
325 sponges and corals. While the Gorgoniacea *Corallium* spp (red/pink corals) are listed in
326 Appendix III, the other coral species, all present in the SWIO, such as the Antipatharia (black
327 corals), Scleractinia (stony corals), Tubiporidae (organ pipe corals), and Sylasteridae (lace

328 corals), are listed in Appendix II, which includes species of concern. None of the coral species
329 are listed in the Appendix I of the CITES (most endangered species in CITES lists). The
330 status of seamount-associated species has been overlooked so far and needs to be addressed
331 by the CITES.

332 The International IUCN Red List of Threatened Species (www.iucnredlist.org) is another
333 assessment tool, however with no legal value. It helps identifying those species in need of
334 recovery actions. Concerning the SWIO, among 3826 species reported, 335 are deep benthic
335 marine species and 833 are oceanic species. Deep-sea bony fish species, such as orange
336 roughy, alfonsinos, bioluminescent lanternfishes which can occur deeper than 1000 m, as well
337 as deep-water sharks, enter the Red List. Many deep-sea fish assessments are considered as
338 “Data Deficient”. We also note the introduction in the Red List of the first deep-sea
339 hydrothermal vent mollusc, *Chrysomallon squamiferum*, or the Scaly-foot Snail
340 (Endangered), met on three locations restricted to hydrothermal vents on deep-ocean ridges in
341 the Indian Ocean, at depths of up to 2,900 m (Sigwart et al, 2019). In addition, most
342 seamount- associated species have a commercial status in fisheries: target, by-catch, or
343 discard.

344 *3.2. The issue of seamount habitats and ecosystems*

345 The VME concept introduced by FAO in 2009 refers to a functional or structural traits
346 based on various criteria (rarity, functional significance, fragility, life history traits of
347 component species, structural complexity of the site). Therefore, RFMOs and fishing states
348 have taken initiatives to mitigate significant adverse impacts of fishing on VMEs. In 2019,
349 SIOFA has adopted a list of VME taxa for its area of competence, a first step towards
350 establishing binding management procedures regarding VMEs. This list includes nine orders
351 among the Cnidaria, two classes of Porifera, Ascidiacea, Bryozoans, Brachiopoda,
352 Pterobranchia, Serpulidae, Xenophyophora, Bathylasmatidae, Stalked crinoids, Euryalida and

353 Cidaroida. The next step is the application of a common VME encounter protocol when VME
354 thresholds are reached. Presently, there are no agreed and unified threshold levels and move-
355 on rules (requiring vessels to stop fishing in the impacted area) at the SIOFA, as each flag is
356 applying its own criteria or those existing at the Commission for the Conservation of
357 Antarctic Marine Living Resources (CCAMLR). Moreover, units used to quantify the VME
358 taxa caught are not homogeneous, either expressed in kg or liters. There are also
359 disagreements between flag states at SIOFA on setting up a regulation concerning all gears.
360 The SIOFA Scientific Committee (SC) has recommended that, whatever the gear, bottom
361 fishing should be considered as degrading the scientific and biodiversity value of the area,
362 although bottom fishing gears have different levels of impact. Trawl fishing is closed in the
363 interim BPAs, however detailed observations on the impact of non-trawl gears is lacking for
364 several flag states. All VME data should be reported, not just triggers of VME encounters.
365 Such obligation does not exist yet at SIOFA.

366 High-resolution bathymetric mapping and habitat delineation are essential to define
367 science-based regulations. Several flag states have conducted such studies in the framework
368 of bottom fishery impact assessments. Following Last et al (2010) the SIOFA area was
369 classified into six bathomes (“ecologically meaningful depth ranges within fishable depths”)
370 defining preferred habitats for various groups of taxa based on depth. In the absence of
371 detailed biological information on the communities present at seamounts, and as a
372 precautionary approach, depth ranges could be used as surrogates for VME fauna.

373 *3.3. How seamounts conservation units might be established?*

374 For such an objective, a legal existence should be given to seamounts, so that specific
375 regulations can be attached to them. The first approach is to progress from merely temporary
376 legal rules towards a definitive and long-term regulation. Interim measures have the
377 advantage of provisional law, allowing some protection while the States and Parties continue

378 to negotiate a more satisfactory agreement (Galletti, 2004). However, interim measures can be
379 challenged at each annual meeting by the most uncooperative States or Parties. Business-as-
380 usual scenarios can sometimes be preferred by some flag states. The role of the scientific
381 advice here is key to propose science-based rules, aiming at conservation of fragile
382 ecosystems; this is what the SIOFA SC is committed to, as indicated earlier.

383 The second approach is to establish Marine Protected Areas (MPAs) around seamounts of
384 particular scientific and bioregional interest. Such a management measure can be
385 implemented by a single State, when a seamount is present in its waters, or by RFMOs for
386 seamounts located in the ABNJ. However, the latter is quite unusual. It was achieved by the
387 Oslo-Paris (OSPAR) Commission with OSPAR MPAs in the North-East Atlantic. In the
388 SWIO, the five provisional BPAs adopted by SIOFA might end up as a permanent measure.
389 Such process initiated by SIOFA goes over the traditional role of RFMOs to assess stocks and
390 manage fisheries. The BPAs represent one type of marine spatial protection, which, though
391 partial, introduces new measures restricting access to the fishing fleets as limiting catches or
392 footprint, imposing a move-on rule to another site in case of encounter with a VME,
393 obligation to undertake bottom fishing impact assessments and to submit a management plan.
394 This set of measures forms the embryo of an MPA regulation. However the transfer of such
395 seamount status into a fully protected space is not achieved so far, while this could be set as a
396 medium-term objective for the most sensitive sites. The current situation is that there are
397 many gaps in the existing framework for the protection of biodiversity in ABNJ, as reviewed
398 by Wright et al (2018), including the absence of a global framework to establish any type of
399 MPAs in ABNJ.

400 A comprehensive protection of fragile ecosystems would be reached by including
401 regulation on deep-sea mining to the fishing regulation, i.e. banning extractive activities and
402 declaring no-take areas for the concerned seamounts. A full protection status in the ABNJ

403 would in theory become possible thanks to the reform initiated under UNCLOS. Since 2006,
404 discussions convened under the United Nations General Assembly aim to elaborate an
405 “international legally binding instrument” (ILBI) for the conservation and sustainable use of
406 marine biodiversity in areas beyond national jurisdiction (BBNJ process). The spirit of this
407 instrument is presently based on four elements. Two of them, area-based management tools
408 (ABMTs) including MPAs, and environmental impact assessments (EIAs) are of particular
409 relevance for seamounts in ABNJ. The ILBI is expected to include provisions to establish
410 integral ABNJ MPAs, which constitute a drastic evolution in both the Law of the Sea and the
411 form of ocean governance. It would enable new MPAs to incorporate all biotic and abiotic
412 components, unlike most of marine sanctuaries that are limited to certain species, such as
413 those banning whaling and reducing threats to whales (Sorby, 2018), benthic protected areas
414 (noted earlier) or pelagic MPAs. This future legal instrument relevant to the UNCLOS opens
415 up unprecedented possibilities for bilateral or regional cooperation in identification, design
416 and management of sites from high-resolution mapping. Yet, these possibilities will remain
417 pure theory if not connected to documented and scientifically supported cases of seamounts,
418 alongside diplomatic actions and financial resources allocated to this aim. Nevertheless, a
419 number of issues still need to be resolved within the ILBI with relevance to seamounts, *inter*
420 *alia*: a more clear definition of the sedentary species (still open to controversy) especially the
421 fact that such status is disconnected from the concept of biodiversity, the possibility to
422 develop area-based measures (ABMTs) in the water column in support of environmental
423 protection of the shelf (or seamount) biodiversity, and the articulation of the new regulation
424 with existing regional and global organizations (Mossop, 2017). In the following section, we
425 shall connect these reflections with a practical case, the Walters Shoal, and discuss whether it
426 could be a candidate for a fully protected seamount.

427 **4- The Walters Shoal: an ABNJ seamount case-study in the SWIO**

428 The Walters shoal is one emblematic seamount among the other isolated sites where issues
429 of maintaining a natural and shared heritage arise. The environmental characteristics and
430 isolation of this site are reviewed to discuss the value of classifying it as an ILBI-type integral
431 MPA.

432 *4.1 Environmental setting*

433 The Walters Shoal (43°54' E/33°12' S) is an isolated seamount located on the Madagascar
434 Ridge, 855 km South of Madagascar, 1300 km East of the South African coast, 1760 km from
435 Reunion Island (France), 1600 km from Crozet (France), and 1600 km from Prince Edwards
436 Islands (South Africa). The Madagascar Ridge extends southwards from the Madagascar
437 landmass. No obvious magnetic anomalies, which would have supported an oceanic origin,
438 have been found along this plateau. Some models of the Indian Ocean basin evolution
439 consider that the Madagascar Ridge to be partly continental (Reeves, 2014). These
440 considerations on geological continuity of the seabed with the adjacent landmasses have
441 considerable implications in the allocation of the “Extended Continental Shelf” to coastal
442 States under the UNCLOS.

443 Discovered in 1962 by the South African vessel Natal, the Walters Shoal is one of the most
444 emblematic and atypical seamount in the SWIO, located in the ABNJ at the confluence of the
445 Sub-tropical and the Sub-Antarctic waters. The seafloor mapping performed during the
446 MD208-Walters Shoal cruise in 2017 (DOI: 10.17600/17002700) reveals a complex
447 submarine morphology which is different from other seamounts previously described in the
448 region (Courgeon et al., 2016, 2017) (Fig. 4). The base of the edifice lies on the Madagascar
449 Ridge at about 600 m depth and the flat top is located at around an average depth of 18 m.
450 Previous investigation showed a caldera-like shape of the summit, with depth of the order
451 ~50m in the middle part of the peak (*RV Marion Dufresne* cruises in 1973 and 1976,
452 unpublished data). Rocks collected at the vicinity and along the flanks of the seamount are

453 diverse. Cold-water carbonates such as algal and rhodolithes (coralline algae) are abundant
454 especially on top of the seamount but also on submerged terraces. Volcanic glass and basalt
455 fragments collected in some samples confirm that the seamount has formed by volcanic
456 extrusion on the seafloor.

457 The Walters Shoal benthic fauna has been subject to dedicated cruises. In 1964, the *RV*
458 '*Anton Bruun*' discovered several new species of marine invertebrates such as the crinoid
459 *Comanthus wahlbergi tenuibrachia* Clark, 1972 and crustaceans *Jaeropsis waltervadi*
460 Kensley, 1975 and *Alpheus waltervadi* Kensley, 1969. In 1988, the Soviet Oceanographic
461 Vessel '*Vityaz*' carried out the most extensive exploration of this seamount to date, both in
462 the summit area and on the slopes as deep as 2050 meters. It provided the most
463 comprehensive list of fish species including eight endemic species (Collette and Parin 1991;
464 Parin et al. 1993). Despite these surveys, the annelid *Synelmis britayevi* Salazar-Vallejo, 2003
465 and the lobster *Palinurus barbarae* Groeneveld, Griffiths & Van Dalsen, 2006 were only
466 recently discovered as new for science. The most recent inventory of the benthic fauna and
467 flora was performed by the Museum National d'Histoire Naturelle (MNHN, France) in the
468 context of the Tropical Deep Sea Benthos program
469 (<https://expeditions.mnhn.fr/program/tropicaldeep-seabenthos>) during the MD208 cruise. So
470 far, the total number of species identified there is around 250 including a majority of small
471 invertebrates (mollusks, crustaceans), 20 fish species and more than 60 species of algae. New
472 species of Asterids from this cruise have been recently published (Mah, 2018) suggesting that
473 the ongoing taxonomic studies could reveal new endemic species and benthic assemblages.

474 Nevertheless, in comparison to tropical seamounts, the Walters Shoal fauna (and flora)
475 remains indeed unquestionably poor, mostly composed of small, endemic and new species.
476 The ecological facies of the Walters Shoal with a coralligenous top (Fig. 5) and the great
477 diversity of habitats along the slopes is a truly remarkable environment. At its 4th session, the

478 SIOFA SC has recognized this seamount as an area of bioregional significance (SIOFA,
479 2019). The physical and biological setting of the Walters Shoal render this site a unique
480 "biogeographic feature" in the SWIO with should be preserved from both mineral extractive
481 and fishing activities.

482 *4.2 Regional connectivity and local retention*

483 The connectivity within the SWIO has been investigated by Lagrangian modelling where
484 larvae released at different sites act only as passive drifters (Crochelet et al., this issue). This
485 study concludes that Walters Shoal is weakly connected to the seamounts, plateaus and
486 coastal ecosystems located north of 26°S, or to the Mozambique Channel and the East African
487 coast, even after 4 months of drift (<0.1% of 'artificial' larvae released at sites and reaching
488 destination). By contrast, the model represents a high local retention at Walters Shoal, which
489 is ranked first (12% of released larvae staying on site) among all seamounts of the SWIO
490 region (Crochelet et al., this issue).

491 In line with connectivity, the matter of seamount-related endemism (at the scale of a chain
492 of seamounts, between seamounts separated by oceanic basins and with inshore areas) has
493 become a major research area in the context of conservation of fragile and iconic species. For
494 some authors seamounts harbor isolated benthic species, promoting endemism (Richer de
495 Forges et al., 2000; Gjerde & Breide, 2003). Nevertheless, this is not a compelling evidence
496 everywhere as contrasted situations have been reported (Gofas, 2000; Dijkstra & Gofas, 2004)
497 and studies including adjacent continental margin fauna showed evidences of faunal
498 exchanges (Samadi et al., 2006; Hall-Spencer et al., 2007; Thoma et al., 2009). Endemism is
499 deeply related to life-history traits, also to the ocean circulation pattern, however the paradigm
500 that endemism is particular high at seamounts is challenged (Rowden et al, 2010). In the case
501 of the Walters Shoal, we can note a good agreement between the high local retention rate

502 estimated by the Lagrangian model and the relatively high number of endemic species being
503 discovered at that seamount.

504 *4.3 Discussion on a possible integral MPA for the Walters Shoal*

505 The scientific knowledge acquired on Walters Shoal's ecosystem has led to its recognition
506 as a seamount of bioregional importance against a set of criteria, including VMEs (SIOFA,
507 2019). The Walters Shoal is located in the ABNJ but this status may change alongside a
508 submission made by Madagascar to the CLCS defining the outer limits of its continental
509 shelf.

510 4.3.1 Possible perimeters for a Walters Shoal's integral MPA

511 The delineation of MPA perimeters is generally based on scientific elements, biological or
512 geological. However, the rules of the International Law of the Sea are of key importance
513 especially for the legal layout, the delineation methodology, including the rights of the nearest
514 States concerned by an issue of continental shelf extension (France, Madagascar,
515 Mozambique and South Africa for the SWIO). In many instances, the knowledge of
516 biological properties of a site is not considered whilst boundaries are set quasi exclusively on
517 the basis of the geomorphological profile. Under UNCLOS, as well as in the customary
518 international law (for States that have not ratified UNCLOS), the determination of the legal
519 extent of conservation units requires (i) knowledge of the geophysical characteristics of the
520 seabed and subsoil; (ii) the use of "formulas" based on the position of the foot of continental
521 slope or the sediment thickness; and (iii) the selection of delineation constraints (inter alia 350
522 M from coastline, or 100 M from the 2500 m isobath). These considerations lead us to
523 conduct an exercise of perimeter delineation for a Walters Shoal's MPA where both the
524 benthic habitat and the superjacent water column would be regulated (as this seamount is also
525 a landmark for large marine mammals, as reported in the introduction). There is sufficient
526 scientific information produced by the MD208 cruise to claim that depth ranges larger than

527 the current SIOFA “Walters Shoal BPA” have ecological peculiarities. The 200-500 m fauna
528 does not share any species with the upper plateau while the 600-1000 m and 1500-2000 m
529 sections are different from each other and have no analog in the upper layers (Bouchet and
530 Corbari, comm. pers). A conservation effort directed on a single stratum (like the SIOFA
531 BPA) would not be sufficient here. Four possible perimeters around the Walters Shoal ranked
532 by decreasing size (Fig. 6) are proposed and briefly discussed:

- 533 • An area demarcated by the 2500 m isobath (309700 km²) because this specific depth
534 contour could become a legal key element for the delineation between a Madagascar’s
535 extended continental shelf and an ABNJ Walters Shoal MPA. This isobath also
536 represents a wider geomorphologic entity where the Walters Shoal is located;
- 537 • An area demarcated by the 2000 m isobath (165200 km²) with its northern boundary
538 being tangential to the legal theoretical 350 M limit. Such depth includes ecological
539 features that are of insular (0-1500 m) and deep marine (>1500 m) nature. It is also
540 useful to include depth ranges that can be compared with other sites to understand the
541 effects of connectivity and benthic settlement. For instance, the presence of the bonus
542 *Thalassocyon gastropod* was reported by Bouchet (comm. pers) at 2000 m on the
543 slopes of Walters Shoal, while this species was described and known until now only in
544 South Africa.
- 545 • An area centered in the Walters Shoal and demarcated by the 1000 m isobath (102000
546 km²), also including four smaller seamounts located in the close vicinity (west and
547 southwest) of the Madagascar Ridge. This area matches the patch of higher density of
548 retention of passive larvae (Crochelet et al, this issue) which could suggest a strong
549 homogeneity in fauna between the Walters Shoal and these neighboring seamounts.
- 550 • The Walters Shoal summit (33°12’S / 43°54’E) and its slope, a minimal conservation
551 area of 3100 km² (for comparison, the SIOFA Walters Shoal BPA has an area of 3443

552 km²). This perimeter can be considered quite small, but in terms of ecological facies,
553 an isolated seamount summit with coralligenous habitat is a remarkable environment.
554 For these reasons, the top of Walters Shoal remains a unique biogeographic entity
555 (FFEM, 2019)

556 These four areas represent respectively 9.6, 5.1, 3.2 and 0.1 times the size of the five
557 existing interim BPAs adopted by the SIOFA. The reasoning based on isobaths and depth
558 ranges to define conservation units is supported by the bathymetric surrogacy of VME taxa, as
559 previously mentioned (see section 3.2) after Last et al (2010).

560 4.3.2 The Walters Shoal in the perspective of an extended Madagascar's continental shelf

561 Madagascar has made a submission in April 2011. The new seabed under its jurisdiction
562 would then reach a distance of almost 900 M south of the country's landmass (Fig. 7).
563 Whether or not the Walters Shoal will eventually be part of the Madagascar's continental
564 shelf will depend on the scientific and technical data supplied by Madagascar in support of its
565 claim on geological continuity, and the scientific acceptance by the CLCS. The fate of
566 Walters Shoal is therefore uncertain, as it may either remain in the ABNJ or fall under
567 Madagascar sovereign rights. Whatever the outcome, it is essential that a full conservation of
568 this site is warranted. The search for an ambitious and coherent perimeter for a Walters Shoal
569 MPA will then have to go through a zoning exercise, therefore through bilateral or
570 multilateral cooperation agreements to manage, enhance, and finance an area where biological
571 monitoring could be accepted as a new priority.

572 **5- Proposed guidelines in a Nairobi Convention framework**

573 The access to seamounts of regional or global importance in the SWIO and to the
574 protection of their ecosystems and resources were among the concerns raised to the attention
575 of the Nairobi Convention. Its area of competence covers the EEZs of 10 States (Comoros,
576 France, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, Tanzania and the

577 Republic of South Africa). During the PRECop 9 (Galletti et al., 2018) and COP 9 of the
578 Nairobi Convention in August 2018. The goal was to arouse the interest of the Contracting
579 States for public decisions addressing shared issues, including the deep-environment, to
580 ensure a sustainable use of natural resources, in line with UN SDG14.

581 It is worth recalling the principles leading to consider a maritime governance of seamounts
582 ecosystems within the amended Nairobi Convention for the Protection, Management and
583 Development of the Marine and Coastal Environment of the Western Indian Ocean. Through
584 one of its protocols, related to Integrated Coastal Zone Management (under negotiation), this
585 would allow *inter alia* that sites localized between EEZs, or even between EEZs and ABNJ
586 (therefore outside the current area of competence of the amended Nairobi Convention) might
587 be treated together under the criteria of ecological (and to some extent, economical)
588 connectivity. In order to ensure the sustainability of the coastal and offshore fisheries in the
589 region (Popova et al., 2019), the biodiversity of seamounts, even those in the ABNJ, should
590 ideally be protected. For those seamounts, an extended mandate of the Nairobi Convention
591 could be conceivable since the governance of the Nairobi Convention is evolving. For
592 instance, the decision CP9/7 (2018 - UNEP/EAF/CP.9/3) explicitly requests Contracting
593 Parties, and other partners, to support projects for the conservation and sustainable
594 exploitation of seamount and hydrothermal vent ecosystems of the SWIO in ABNJ and to
595 collaborate in the management of activities in their adjacent waters with the IUCN.

596 The Nairobi Convention is promoting an agreement on a *Regional ocean governance*
597 *strategy for the WIO region* to guide States in their development agenda and to develop a
598 partnership approach for implementing SDG14. Seamounts must be part of this strategy. The
599 framework of the preparatory meetings for the Nairobi Convention biennial meetings (CoP)
600 and the Convention work plan 2018-2022, provide a new adequate framework for the
601 acquisition of multidisciplinary knowledge that is essential in the multilateral public decision-

602 making process relevant to seamounts protection. However we recognize the long road
603 between the science-based evidence and the adoption of exclusionary decisions, as in the case
604 of MPAs.

605 The Nairobi Convention work plan should then:

606 1. Promote marine spatial planning studies in order to compile an inventory of the
607 existing and planned at-sea activities in the whole SWIO region, in both areas under
608 national jurisdiction and international waters;

609 2. Encourage historical data rescue activities on seamounts of the SWIO in order to set
610 up a knowledge base on the marine natural heritage, its potential and its vulnerability;

611 3. Develop multidisciplinary capacities in the administration of the riparian states in
612 order to design harmonized management plans dedicated to seamounts conservation in
613 EEZ and their adjacent waters where distant and/or connected seamounts are located;

614 4. Examine the issue of extending its geographical competence beyond national
615 jurisdiction as a consequence of different types of connectivity (economic,
616 ecological...) between seamounts located in international waters and coastal zones,
617 which will require new type of partnership with non-member States;

618 5. Draw the attention of the States on the situation of seamounts included on the legal
619 continental shelf of a coastal State whereby pelagic resources fall within the
620 jurisdiction of RFMOs while living benthic, demersal and mineral resources come
621 under the jurisdiction of the coastal state that exercise certain rights on the continental
622 shelf. Therefore, it is proposed that the Nairobi Convention facilitates the
623 implementation of harmonized conservation/exploitation policies of those entities;

624 6. Account for new measures from RFMOs, in particular the five SIOFA seamount
625 BPAs in ABNJ waters (Walters Shoal, Coral, Middle of What, Atlantis Bank, Fools

626 Flat), with ban of bottom trawl fishing and mandatory boarding of observers for all
627 other gears, pending a final management plan by SIOFA in 2019;

628 7. Support the States to engage any form of partial or total network protection of areas
629 of scientific and bioregional importance that is partially documented by the Large
630 Marine Ecosystems (LME), the EBSA process, or the oceanographic cruises, but
631 which presently remains without any legal protection;

632 8. Capitalize on opportunities provided in the ILBI to enable convergence of the
633 Indian Ocean States on 5 themes: i) spatial management and MPAs in international
634 waters; ii) marine technology transfer; iii) sharing advantages of the genetic diversity;
635 iv) combating IUU fishing and v) environmental impact assessments.

636 These guidelines are rather generic in terms of regional management. However, due to the
637 focus made in this paper on the governance in the SWIO, they are clearly directed to the
638 Nairobi Convention as a contribution to new objectives being reshaped in the perspective of
639 an extended mandate of this organisation. If they were acknowledged and implemented by the
640 sole members States of the Nairobi Convention, these guidelines would represent a significant
641 progress from the present situation.

642 **6- Conclusion**

643 In a blue economy perspective, seamounts are anything but anecdotal for the wealth of
644 Indian Ocean nations. Several of them form refuges with remarkable species richness.
645 Through connectivity by the ocean circulation, overfishing and loss of biodiversity on
646 seamounts and shoals can negatively affect fisheries, livelihoods and ecosystem services
647 along the coastlines. For a while, the seamounts have been utilized as a source of profit, often
648 in an unsustainable manner. Therefore, more stringent measures need to be established around
649 those particular spaces and towards the design of marine protected areas or any other kind of
650 conservation unit.

651 Although establishing an MPA around an isolated seamount would be a significant step
652 forward, this might not be sufficient to ensure an efficient protection of sensitive ecosystems
653 and sustain their ecological functions. It is therefore highly desirable to identify the seamounts
654 to be protected and create a legal networks of seamounts-MPAs by connecting them through
655 corridors (Galletti, 2014). Seamounts networks should be embedded into the legal zoning of
656 area-based management tools (ABMTs), including MPAs in ABNJ that the ILBI would
657 render possible.

658 We have attempted to document the possible establishment of a fully protected MPA
659 centered on the Walters Shoal, with different possible perimeters, on the basis of scientific
660 evidence of its biological uniqueness and possible new legal framework that could be
661 implemented under UNCLOS and in a regional seas organization under UNEP, the Nairobi
662 Convention. This can be viewed as an anticipation exercise as the legal and international
663 framework in the ABNJ is still lacking, more exactly not yet available (at the time of writing)
664 as 2020 should be the year when ILBI is completed. However we are convinced that our
665 arguments, in complement to other ongoing studies and discussions, can contribute to a
666 gradual evolution towards more conservation units established in the medium term in the
667 waters under national jurisdiction as well in ABNJ of the SWIO.

668 **Disclaimer**

669 This article is a research paper. The views expressed by the authors do not necessarily reflect
670 those of their affiliated institutions. The designations employed do not imply the expression of
671 any opinion whatsoever on the part of affiliated institutions concerning the legal status of any
672 country, territory, or area or of its authorities, or concerning the delimitation of its frontiers or
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682

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Fig. 2- Deep-sea fishes catches in the Southern Indian Ocean (source: FAO 2017 FishStat)

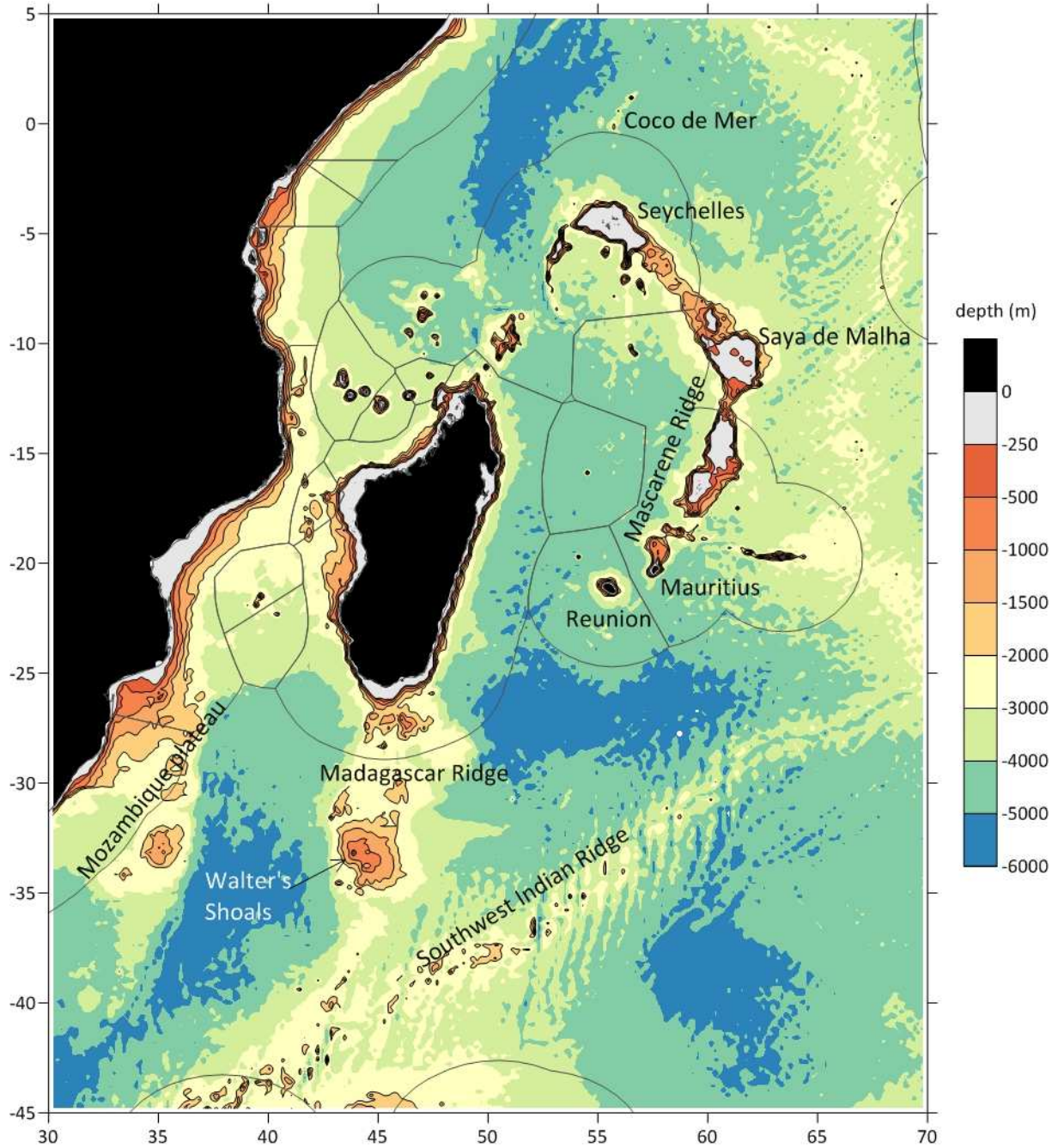
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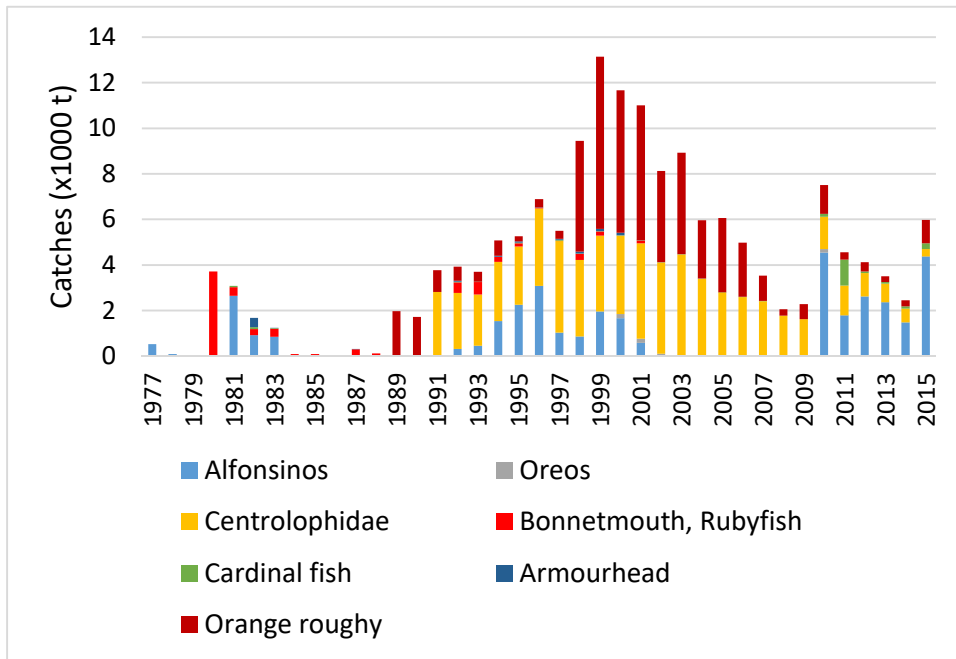
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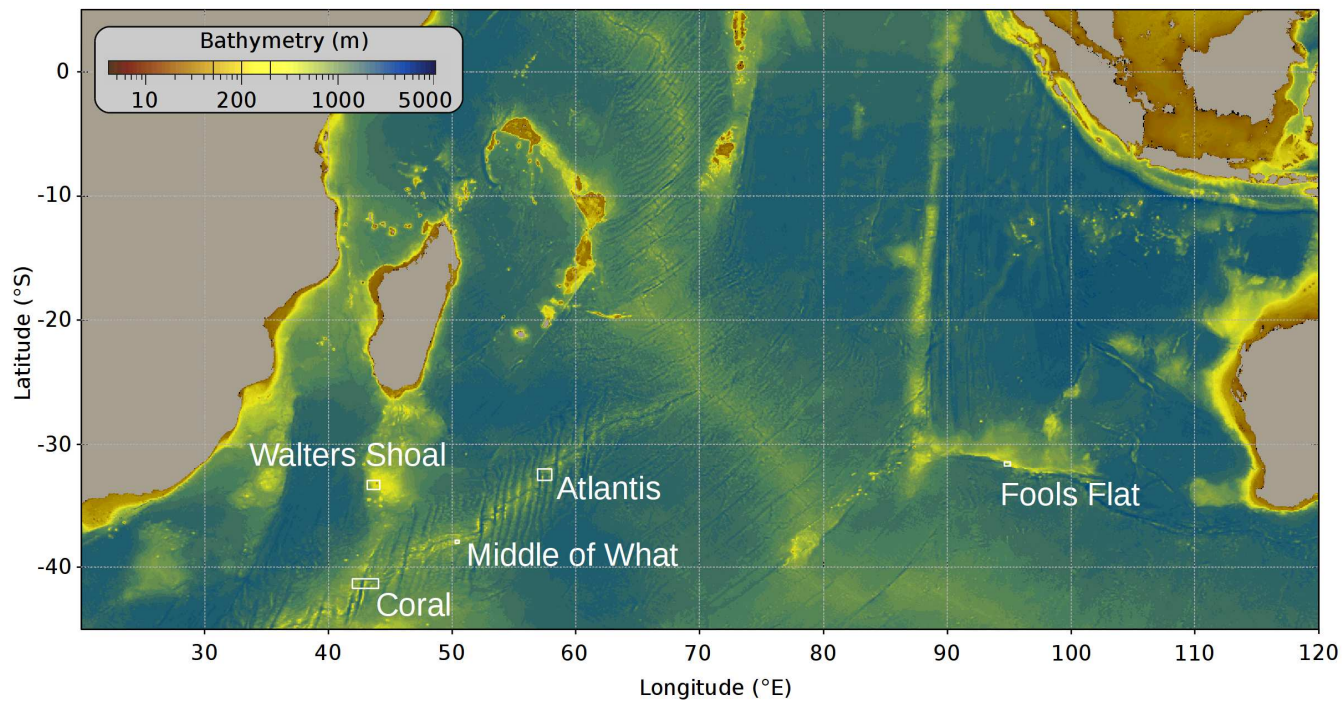
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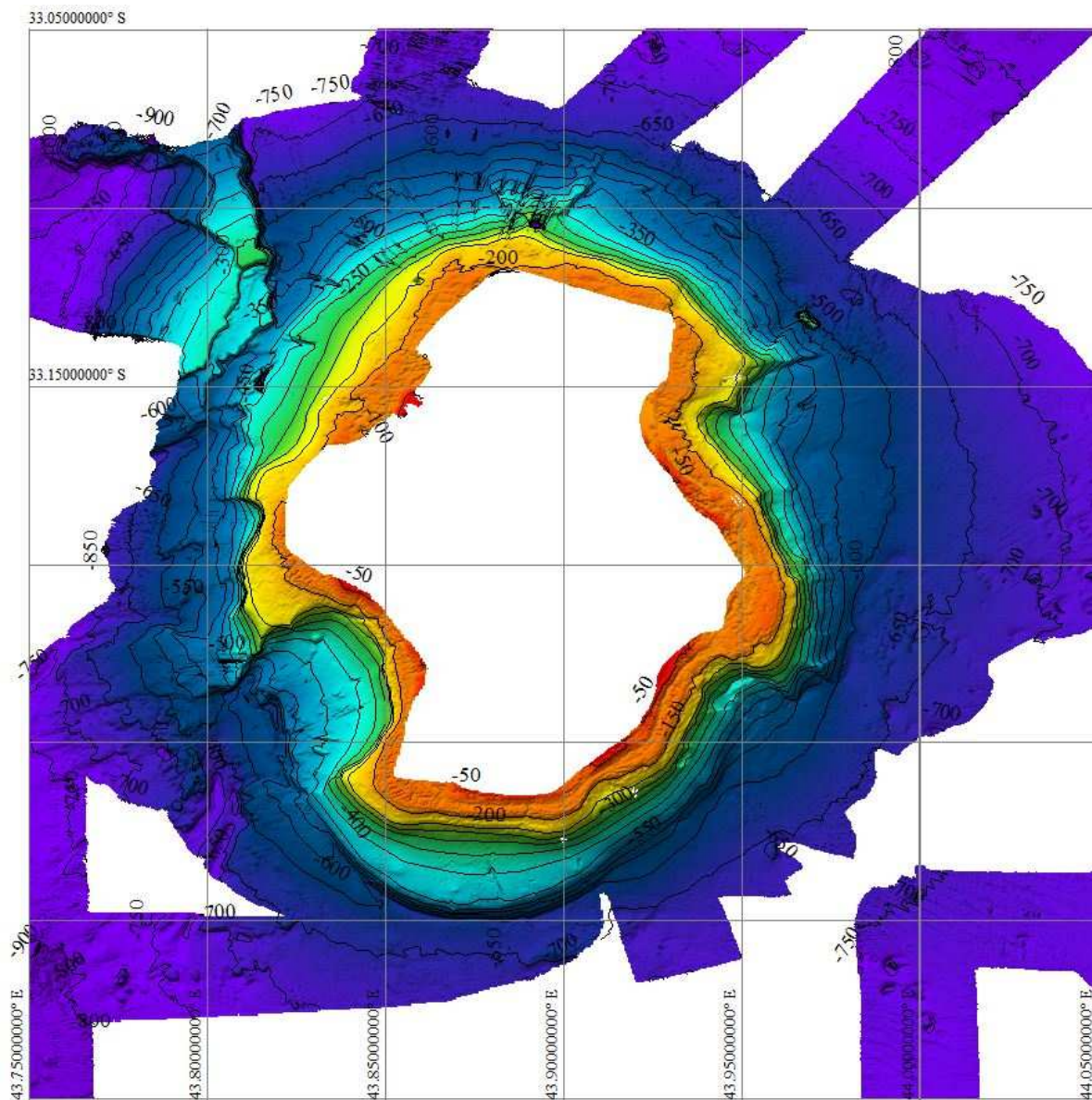
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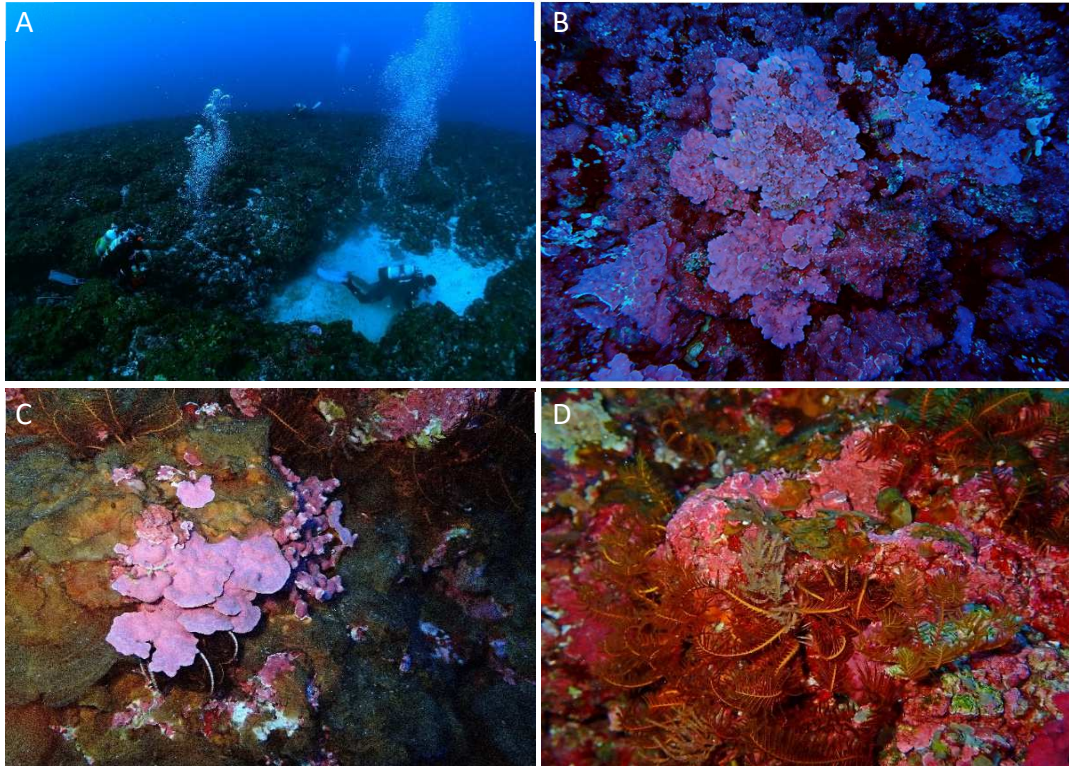
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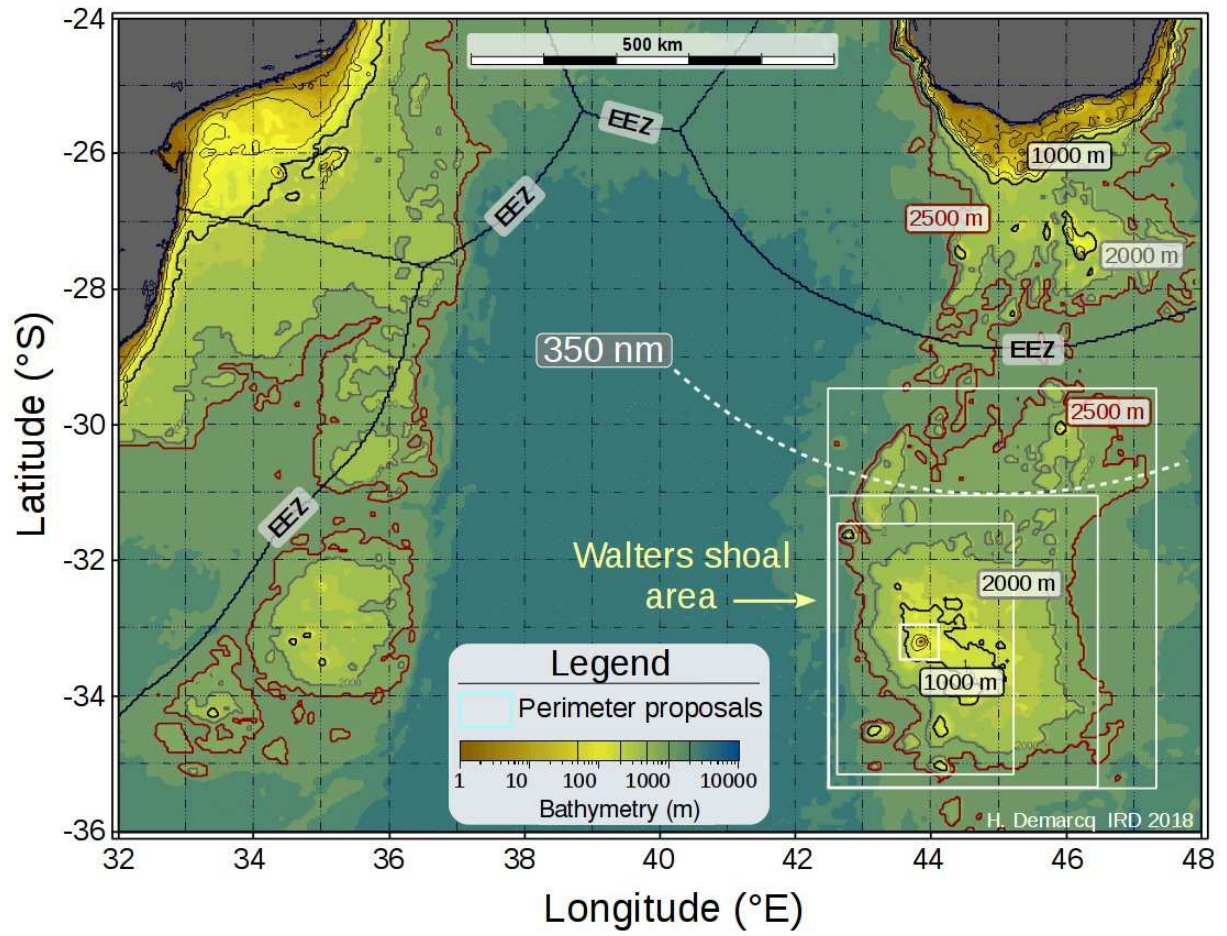
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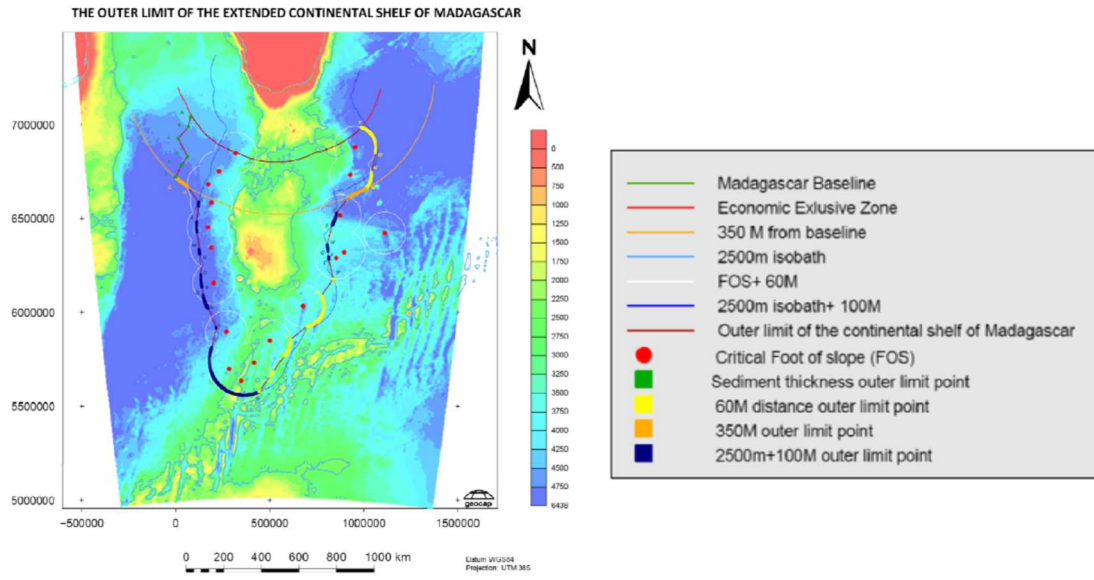
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Figure 6

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Figure 7