Lost fishing gear and litter at Gorringe Bank (NE Atlantic)

Rui P. Vieira[a,b], Isabel P. Raposo[c], Paula Sobral[c], Jorge M.S. Gonçalves[d], Katherine L.C. Bell[e], Marina R. Cunha[a]

[a] Departamento de Biologia & CESAM, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

[b] Graduate School of the National Oceanography Centre Southampton, University of Southampton, Waterfront Campus, European Way, Southampton, SO14 3 ZH, UK

[c] IMAR – Instituto do Mar, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal

[d] CCMAR — Centre of Marine Sciences, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

[e] Ocean Exploration Trust, URI Narragansett Bay Campus, South Ferry Road, Narragansett, RI 02882, USA

Abstract

Studies concerning marine litter have received great attention over the last several years by the scientific community mainly due to their ecological and economic impacts in marine ecosystems, from coastal waters to the deep ocean seafloor. The distribution, type and abundance of marine litter in Ormonde and Gettysburg, the two seamounts of Gorringe Bank, was analysed from photo and video imagery obtained during ROV-based surveys carried out at 60-3015 m depths during the E/V *Nautilus* cruise NA017. Located approximately 125 nm southwest of Portugal, Gorringe Bank lays at the crossroad between the Atlantic and the Mediterranean and is therefore characterized by an intense maritime traffic and fishing activities. The high frequency of lost or discarded fishing gear, such as cables, longlines and nets, observed on Gorringe Bank suggests an origin mostly from fishing activities, with a clear turnover in the type of litter (mostly metal, glass and to a much lesser extent, plastic) with increasing depth. Litter was more abundant at the summit of Gorringe Bank (ca. 4 items.km^{-1}), decreasing to less than 1 item.km^{-1} at the flanks and to ca. 2 items.km^{-1} at greater depths. Nevertheless, litter abundance appeared to be lower than in continental margin areas. The results presented herein are a contribution to support further actions for the conservation of vulnerable habitats on Gorringe Bank so that they can continue contributing to fisheries productivity in the surrounding region.

Keywords

Marine litter; Fisheries; impacts; Gorringe Bank; NE Atlantic; seamounts.

Introduction

Seamounts are prominent structures globally distributed across the ocean basins rising from bathyal depths to a few tens of meters below the sea surface (Clark et al., 2010; Wessel et al., 2010). In the northeastern Atlantic, several seamounts are irregularly spread over 700 km from the SW Iberia to the Madeira archipelago (Abecasis et al., 2009; Morato et al., 2013). The Gettysburg and Ormonde seamounts, forming Gorringe Bank, are the most outstanding of these features at a close distance from Portuguese mainland (Karson et al., 2012).

Gorringe Bank harbours large areas with rocky outcrops that support vulnerable habitats such as coral gardens and sponge aggregations (Xavier and van Soest, 2007; Karson et al., 2012), and at shallower depths also coralligenous algae and kelp beds (OCEANA, 2005). Earlier surveys on Gorringe Bank, conducted by SCUBA divers and with ROVs in photic zone, provided a comprehensive study of the fish communities in shallower depths (e.g. Gonçalves et al., 2004; OCEANA, 2005; Abecasis et al., 2009) but very little is known on the benthic biodiversity at greater depths.

Seamounts are particularly exposed to human activities owing to their role for world fisheries (Pitcher et al., 2010). Threats, such as overfishing, habitat loss, and litter disposal have been already documented on some seamounts (Clark et al., 2010; Pitcher et al., 2010; Wienberg et al., 2013). Recently, Pham et al. (2013) provided the first study on marine litter on seamounts, and reported a significant amount of lost fishing gear on the summit and slopes of Condor Seamount suggesting a fisheries-related origin of lost or dumped materials.

Perceptions on distribution and abundance of marine litter have increased over the last few years (Ramirez-Llodra et al., 2011). Although some studies have been conducted from shores to deeper regions of continental margins, the effects of debris on marine communities and its habitats remain poorly known (Keller et al., 2010; Miyake et al., 2011; Mordecai et al., 2011; Ramirez-Llodra et al., 2011; Wei et al., 2012). Marine debris may enter directly into the oceans through a wide variety of maritime human activities including disposal (e.g. clinker, sewage, chemical products or radioactive materials) and exploitation of natural resources (e.g. lost fishing gears, oil and gas, mining, pipelines) (Kidd and Huggett, 1981; UNEP, 2009; Ramirez-Llodra et al., 2011). Moreover, any debris discarded, disposed, or abandoned at the coast or even far inland can potentially become marine debris. In fact, terrestrial human activities are the main source of marine debris worldwide and are responsible for 70-80% of all debris that end up in the ocean (Bowmer and Kershaw, 2010) dragged by the wind, rain, and tides or transported by rivers (Barnes et al., 2009).

Anthropogenic debris has been accumulating in marine environments from heavily populated coastlines to remote shorelines in high latitudes, floating on the surface or sunk at the bottom of the ocean (Barnes et al., 2005). Factors such as coastline morphology and hydrodynamics determine the extremely irregular distribution of marine debris throughout the oceans. However, it is recognized that marine debris distribution patterns along the seabed are influenced by human activities such as fishing activities, urban development, tourism, and maritime traffic (Micheli et al., 2013; Ramirez-Llodra et al., 2013).

Here we provide an analysis of the abundance, type and distribution of litter on Gettysburg and Ormonde seamounts documented during ROV video transects conducted at bathyal depths on Gorringe Bank.

Material and methods

Survey area - Gorringe Bank

Gorringe Bank is a ridge with a northeast-southwest direction that extends from southern Portugal, approximately 125 nautical miles off Cape St. Vicente (Figure 1). It is formed by Gettysburg and Ormonde seamounts and covers an area of about 9500 km^2. Gettysburg (36º33'N, 11º34'W) and Ormonde (36º42'N, 11º09'W) peaks rise up to less than 50 meters below the sea surface, while the bases of these seamounts are rooted in the Horseshoe Abyssal Plain at depths of more than 5000 meters. Gorringe Bank sits on the Eurasian-African plate boundary and has been the site of intense geologic activity (Tortella et al., 1997).

Video survey

From 8 to 19 October 2011, E/V *Nautilus* revisited the Gorringe Bank. The main objective of the cruise was to document unexplored geological features of the Gorringe Bank (Karson et al. 2012), but the ROV surveys also provided relevant information on the benthic assemblages and human impacts on the seafloor. Three dives were conducted on the Gettysburg Seamount, one on the SE flank (H1201) and two on the NW flank (H1202 and H1203); and a fourth dive was conducted on the southern flank of the Ormonde Seamount (H1204) (Table 1; Figure 2).

The dives were performed by the ROVs *Hercules* and *Argus*, a two-body vehicle system, that uses a state-of-the-art navigation system in tandem with ultra-short baseline positioning and its equipped with a high-definition video system, a high-resolution stereo still camera system and a Seabird Fastcat conductivity-temperature-depth (CTD). *Hercules* was always deployed with the deep-towed system *Argus* that floats several meters above the seafloor providing a bird's-eye view of *Hercules* on the seafloor (Bell et al., 2012).

Annotations from video footage and photos provided the data on the type and distribution of marine litter. The observations were checked thoroughly to avoid double counting (video and photo) and each fragment was counted as one item; long but continuous fishing lines were counted as one item. Litter items were categorized as fishing gear (e.g. longlines, nets and cables), glass, metal, plastic. The category "Others" includes pottery, rubber, wood and unidentified or complex items.

For the estimates on litter abundance (number of items per linear km) the following bathymetric ranges were considered: 0-125 m, 125-500 m, 500-1000 m, 1000-2000 m, and 2000-4000 m (see Supplementary material). The area of the seafloor covered by each dive varied, but was often greater at shallower depths. Therefore, in order to obtain more accurate estimates on the density of litter, the bathymetric ranges considered here were progressively wider at greater depths.

Results

A collection of 4832 photographs of the seafloor was taken and 124 hours of video recorded. The bathymetric range of dives was between 60 to 3015 m along a distance totalling 80.6 km (Table 1).

A total of 91 litter items were found in the photos and video analysed from Gorringe Bank (Table 2). Marine litter composition suggested an origin mostly from maritime activities. In fact, lost or discarded fishing gear (hereafter designated as lost fishing gear) accounted for most of the observed items (56%), whilst other frequent types of litter included dumped glass bottles (15%), metal (e.g. ship artefacts, tins, cans) and plastics (10% each). Observed items of litter also included processed wood, rubber, pottery and, even, a chair at 2340 m water depth (Figure 3).

The spatial distribution of the different types of litter (Figures 2, 4 and 5) shows that lost fishing gear (FG) was observed mostly on the summit and upper flank (approx. 500 m) of Gettysburg and Ormonde seamounts although some items were also found at greater depths. Figure 4 illustrates the turnover in the type of litter with increasing depth: lost fishing gear that prevails at shallower depths (0-500 m) is gradually replaced by heavier items such as glass bottles (G) and then metal (M) at greater depths. Glass bottles, the second most common debris found in the Gorringe Bank, were particularly concentrated in the gentle southern slope of the Ormonde Seamount (500-1000 m, Figures 2 and 5) in the vicinity of fished areas, while plastics (P) were predominantly detected on the SE slope of Gettysburg Seamount. Metal items were scattered around the two seamounts at depths between 1300 and 2950 m (Figures 2 and 5).

The highest densities of litter were observed during the dives at the Ormonde Seamount (Figure 5). Overall, litter was more abundant at the summit of the seamounts (ca. 4 items.km^{-1}, mostly fishing gear, at 125-250 m depth), decreasing to less than 1 item.km^{-1} at 500-1000 m and then increasing again to ca. 2 items.km^{-1} at greater depths (Figure 5).

Discussion

Type, abundance and distribution of litter

Studies concerning marine litter have received great attention over the last several years by the scientific community mainly due to their ecological and economic impacts. These studies are mostly focused on the coastal areas and, to a lesser extent, also on deeper areas along the continental margins.

Terrestrial activities are often identified as the main source of the plastic materials and glass that form most of the litter frequently observed in marine ecosystems along the continental margins. This has been observed for instance in the Greek gulfs (Koutsodendris et al., 2008), but also in several submarine canyons, some located near heavily populated and industrialized regions such as the Gulf of Lions canyons (Galgani et al., 1996), Lisbon and Setúbal canyons in the NE Atlantic (Mordecai et al., 2011), the Blanes Canyon in the Mediterranean Sea (Ramirez-Llodra et al., 2013), and the Monterey Canyon, off central California, USA (Schlining et al., 2013). Gorringe Bank is located at the crossroads of important corridors of maritime traffic (from and to various Atlantic and Mediterranean regions) and is also open for fishing activities (CNADS, 2001), which may explain the diverse array of litter items reported herein.

The predominant maritime origin of litter on the Gorringe Bank is consistent with the results obtained by Pham et al. (2013) on the Condor Seamount where lost fishing gear dominates the litter accounting for 73% of the debris found near the summit (185-265 m depth). Other types of litter such as glass and plastics are also found on the slopes of seamounts (Pham et al., 2013). On Gorringe Bank, glass (mostly bottles) was found in the vicinity of the fishing areas suggesting that this material may have been locally disposed. Yet, the origin of plastics is more difficult to determine as these materials can easily drift over long distances from either terrestrial (Watters et al., 2010) or maritime sources. In certain cases, such as in submarine canyons, the interaction between topography and oceanographic conditions is likely to favour long-term litter deposition (Schlining et al., 2013). Gorringe Bank is an obstacle to the Mediterranean Outflow Water (Mason et al., 2006) and the seamount topography offers favourable conditions for the incidence of meddies (Serra and Ambar, 2002;

Peliz et al., 2005; Aguiar et al., 2013). Such conditions may contribute to the retention and deposition of plastics as suggested by the predominance of these materials on the SE flank of the Gettysburg seamount.

Previous studies have shown the influence of terrestrial inputs on the accumulation of marine litter in coastal areas as well as the relationship between the distribution and type of litter and the distance to the coast or the depth gradient (e.g. Galgani et al., 1995; Katsanevakis and Katsarou, 2004; Lee et al., 2006; Watters et al., 2010; Pham et al., 2013; Ramirez-Llodra et al., 2013). However, quantitative studies on marine litter are scarce and comparisons of densities from different areas are hindered by differences in sampling methodologies (Watters et al., 2010; Mordecai et al., 2011; Ramirez-Llodra et al., 2013). According to Galgani et al. (2000) marine debris on seabed may range from 0 to 101000 items per km^{-2} in European seas but their abundance may decrease with distance from the shore and/or towards deeper waters (e.g. Greek gulfs; Koutsodendris et al. 2008). The abundance of litter in seamounts is expected to be lower: on Condor Seamount summit overall litter density was estimated as 1439 items.km^{-2} or 0.3 items.100 m^{-1} (3 items.km^{-1}) (Pham et al., 2013) while on Gorringe Bank at comparable depths it was 4 items.km^{-1}. This density is high considering the remoteness of these oceanic features but in both cases litter is mainly composed of lost fishing gear suggesting a high fishing pressure on these seamounts.

The impact of fisheries

Lost fishing gear is consistently the main component of marine litter in areas impacted by fishing activities, either off California (Moore and Allen, 2000), or in the East China Sea (Lee et al., 2006), the Celtic Sea (Galgani et al., 2000), at the upper slopes of the Blanes Canyon in the Mediterranean Sea (Ramirez-Llodra et al., 2013), and of the Nazaré Canyon off Portugal (Mordecai et al. 2011). The economic value of fish stocks on seamounts is high and the pressure over these oceanic features increases with their proximity to fishing harbours (Ressurreição and Giacomello, 2013).

In terms of deep-sea fisheries, bottom trawling has much more severe impacts on the integrity of the seafloor and their biological assemblages (Puig et al., 2012) than drifting vertical longline fishery. However, according to information retrieved from experienced fisherman, the impacts of the latter on the Gorringe Bank may extend down to 2000 m depth while the exact depth range to which trawling is done is unknown. The effects of lost fishing gear on the benthic ecosystems are direct and immediate (e.g. damaging corals and other erect biogenic structures, removing non-target species trough by-catch), persisting over time (e.g. ghost-fishing, hitch-hiking and alien invasions) (Erzini et al., 1997; Borges et al. 2001; Gilman et al., 2006, 2008; Gregory, 2009; Sampaio et al., 2012). Long-term impacts of lost fishing gear on marine ecosystems remain poorly understood but it is known that even when the original materials are degraded they may be detrimental to some organisms (e.g. cluttering of filter-feeder structures by microplastics) and they can also be transported to other areas as reported by Watters et al. (2010) who found fishing monofilaments as the main debris on deep seafloor areas off California (USA).

The high frequency of lost or discarded fishing gear, such as cables, longlines and nets observed on Gorringe Bank ranks fishing activities as the main source of litter and suggests a high fishing pressure on these seamounts. Commercial fisheries operated by fishing vessels from the mainland and from the Madeira Islands are allowed over all the seamounts to the south of Portugal including Gorringe Bank

(OCEANA, 2005). Longlines are commonly used by the Portuguese fishery fleets (Erzini et al., 1999, 2001) to catch on large number of different species in a wide depth range from shallow to deep waters (Menezes et al., 2009). Data provided by the Portuguese Directorate of Marine Resources (DGRM) shows an intense longline fishery activity in recent years in five geographic areas over and around Gorringe Bank (Table 3 and Figure 1). Although there are no data available on previous years, the analysis of the Table 3 reveals that the highest fishing pressure occurred in 2010 (257 days of fishing and 31 vessels), especially in the area 2D8 located over the summit of the two seamounts (89 days and 8 vessels). In 2011, the total fishing effort in the region was greatly decreased in number of vessels (77% of the previous year) and mainly in number of fishing days (43% of the previous year), but most vessels (12 out of 23) focused their activity on area 2D8 and the pressure over this area was maintained (83 days of fishing). In 2012, the fishing activity in the region was practically abandoned. Considering that the average catch ($kg.d^{-1}$) maintained similar values between 2010 and 2011 (with the exception of area 1D8) this trend may be related with the economic downturn in Portugal; the conjunction of rising costs associated to fishery operations (increasing prices of fuel), especially at greater distances from the mainland harbours, and decreasing market value of the fish landed resulted in unprofitable cost/benefit ratios.

The catch composition on Gorringe Bank is diverse and accounts for a total of 61 species, both pelagic and benthopelagic (Figure 6, based on landings on mainland Portugal). The prevalent catch is *Conger conger*, *Phycis phycis*, *Polyprion americanus* and *Muraena helena* (Figure 7) and other species typically associated with rocky outcrops where the risk of losing or damaging the fishing gear is highest.

Final remarks

Accumulating proof of the human impact on the deep sea confirms the significant threat to its biodiversity and requires serious and urgent action (Morato et al., 2010; Ramirez-Llodra et al., 2011; Levin and Sibuet, 2012; Norse et al., 2012; Micheli et al., 2013). Information on distribution and type of litter is a powerful tool to increase societal and scientific awareness regarding the degradation of even the most remote marine ecosystems (Ruhl et al., 2011). It also provides important evidence on the anthropogenic pressures operating in these ecosystems and is therefore essential for their effective management (MSFD, 2008).

Until now, the abundance and diversity of litter on Gorringe Bank remained unseen, a silent record of long-lasting impacts from intense maritime traffic and commercial fisheries. Owing to the high value of the fisheries at these seamounts one can expect that, in the absence of further protective legislation, the improvement of the economic circumstances will resume the fishing pressure and subsequent degradation of the natural habitats on Gorringe Bank.

The large areas with rocky outcrops on Ormonde and Gettysburg seamounts support vulnerable habitats such as coral gardens and sponge aggregations at bathyal depths and coralligenous algae and kelp beds at the summit; the highly diverse and productive benthic assemblages provide habitat for feeding and reproduction not only for commercially important fish and crustaceans, but also for other species including turtles and seabirds (Gonçalves et al., 2004; OCEANA, 2005; Xavier and van Soest, 2007; Abecasis et al., 2009; Hilário and Cunha, 2013).

Because of these characteristics, Gorringe Bank was used by the World Wildlife Fund as a showcase example and it was subsequently nominated by Portugal for the OSPAR set of Marine Protected Areas (http://www.ngo.grida.no/wwfneap/Projects/MPAmap.htm). The results presented herein are a contribution to support further actions for the conservation of vulnerable habitats on Gorringe Bank. Protection of these seamounts is expected to maintain healthy ecosystems locally so they can continue contributing to fisheries productivity in the surrounding region.

Acknowledgments

Authors are grateful to the scientific and technical parties on board E/V *Nautilus*, Expedition NA017. We would like to thank to Professor Teresa Calvão from the Department of Environmental Sciences and Engineering (FCT-UNL) for assistance in marine debris mapping, to Ana Hilário for the useful comments and to Luis Bentes for the help with the Figure 1. Special thanks to ADAPI - Associação de Armadores de Pescas Industriais, to Mr. Jerónimo Rato (Associação de Armadores da Pesca Local, Costeira e do Largo do Oeste) and to DGRM for the valuable information provided. This research used images and data provided by the Nautilus Exploration Program. Rui Pedro Vieira is currently supported by the doctoral grant from the Portuguese Science Foundation (SFRH/BD/84030/2012). This work was partially supported by European Funds through COMPETE and by National Funds through the Portuguese Science Foundation (FCT) within project PEst-C/MAR/LA0017/2013.

References

Abecasis, D., Cardigos, F., Almada, F., Gonçalves, J.M.S., 2009. New records on the ichthyofauna of the Gorringe seamount (Northeastern Atlantic). Marine Biology Research 5, 605–611.

Aguiar, A.C.B., Peliz, A., Carton, X., 2013. A census of Meddies in a long-term high-resolution simulation. Progress in Oceanography 116, 80–94. http://dx.doi.org/10.1016/j.pocean.2013.06.016

Barnes, D.K.A., Milner, P., 2005. Drifting plastic and its consequences for sessile organism dispersal in the Atlantic Ocean. Marine Biology 146, 815–825. DOI: 10.1007/s00227-004-1474-8

Barnes, D.K.A., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B 364, 1985–1998. DOI: 10.1098/rstb.2008.0205

Bell, K.L.C., K. Elliott, C. Martinez, and S.A. Fuller, eds. 2012. New Frontiers in Ocean Exploration: The *E/V* Nautilus and NOAA Ship Okeanos Explorer 2011 Field Season. Oceanography 25 (1), supplement, 68 pp. http://dx.doi.org/10.5670/oceanog.2011.supplement.01.

Borges, T.C., Erzini, K., Bentes, L., Costa, M.E., Gonçalves, J.M.S., Lino, P.G., Pais, C., Ribeiro. J., 2001. By-Catch and discard practices in five Algarve (southern Portugal) métiers. Journal of Applied Ichthyology 17, 104–114. DOI: 10.1111/j.1439-0426.2001.00283.x

Bowmer, T., Kershaw, P., 2010. Proceedings of the GESAMP International Workshop on Microplastic particles as a vector in transporting persistent, bioaccumulating and toxic substances in the oceans. Reports & studies n.82. UNESCO-IOC, Paris.

Clark, M.R., Rowden, A.A., Schlacher, T., Williams, A., Consalvey, M., Stocks, K.I., Rogers, A.D., O'Hara, T.D., White, M., Shank, T.M., Hall-Spencer, J.M., 2010. The Ecology of Seamounts: Structure, Function, and Human Impacts. Annual Review of Marine Science 2, 253–278. DOI: 10.1146/annurev-marine-120308-081109

CNADS, 2001. Reflexão sobre o Desenvolvimento Sustentável da Zona Costeira. Conselho Nacional do Ambiente e do Desenvolvimento Sustentável, Lisboa. http://www.cnads.pt/index.php?option=com_docman&task=doc_download&gid=22&Itemid=84

Erzini, K., Monteiro, C.C., Ribeiro, J., Santos, M.N., Gaspar, M., Monteiro, P., Borges, T.C., 1997. An experimental study of gill net and trammel net "ghost fishing" in the Algarve (southern Portugal). Marine Ecology Progress Series 158, 257–265

Erzini, K., Gonçalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., 1999. Catch composition, catch rates and size selectivity of three longline métiers in the Algarve (southern Portugal). Boletin Instituto Español de Oceanografia 15 (1–4), 313–323.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., 2001. The hake deepwater semi-pelagic (“pedra-bola”) longline fishery in the Algarve (Southern Portugal). Fisheries Research 51 (2–3), 327–336. http://dx.doi.org/10.1016/S0165-7836(01)00256-9

EU-MSDF. DIRECTIVE 2008/56/EC of the European Parliament and of the Council, establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, 17 June 2008. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF.

Galgani, F., Burgeot, T., Bocquene, G., Vincent, F., Leaute, J.P., Labastie, J., Forest, A., Guichet, R., 1995. Distribution and abundance of debris on the continental shelf on the Bay of Biscay and in Seine Bay. Marine Pollution Bulletin 30 (1), 58–62.

Galgani, F., Souplet, A., Cadiou, Y., 1996. Accumulation of debris on the deep sea floor off the French Mediterranean coast. Marine Ecology Progress Series 142, 225–234. DOI: 10.3354/meps142225.

Galgani, F., Leauteb, J.P., Moguedet, P., Souplet, A., Verind, Y., Carpentierd, A., Goraguere, H., Latrouitee, D., Andralf, B., Cadioua, Y., Maheg, J.C., Poulard, J.C., Nerisson, P., 2000. Litter on the sea floor along European Coasts. Marine Pollution Bulletin 40 (6), 516–527.

Gilman, E., Brothers, N., McPherson, G., Dalzell, P., 2006. Review of cetacean interactions with longline gear. Journal of Cetacean Research and Management 8 (2), 215-223.

Gilman, E., Clarke, S., Brothers, N., Alfaro-Shigueto, J., Mandelman, J., Mangel, J., Peterson, S., Piovano, S., Thomson, N., Dalzell, P., Donoso, M., Goren, M., Werner, T., 2008. Shark interactions in pelagic longline fisheries. Marine Policy 32, 1–18. DOI: 10.1016/j.marpol.2007.05.001

Gonçalves, J.M.S., Bispo, J., Silva, J., 2004. Underwater survey of ichthyofauna of eastern Atlantic seamounts: Gettysburg and Ormonde (Gorringe Bank). Archive of Fishery and Marine Research 51 (1–3), 233–240.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society B 364, 2013–2025. DOI: 10.1098/rstb.2008.0265

Hilário, A., Cunha, M.R., 2013. Notes on a mating event of the deep-sea crab *Chaecon affinis* in the Gorringe Bank (NE Atlantic). Deep-Sea Research II: Topical Studies in Oceanography 92, 58–62. http://dx.doi.org/10.1016/j.dsr2.2013.01.021

IOC, IHO and BODC, 2003. "Centenary Edition of the GEBCO Digital Atlas", published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organization as part of the General Bathymetric Chart of the Oceans; British Oceanographic Data Centre, Liverpool.

Karson, J.A., Bell, K.L.C., Nanfito, A., Joyce, D., Cunha, M.R., Cristobo, J., Manjon, E., 2012. In search of serpentinization on Gorringe Bank. Oceanography 25, 38–39.

Katsanevakis, S., Katsarou, A., 2004. Influences on the distribution of marine debris on the seafloor of swallow coastal areas in Greece (Eastern Mediterranean). Water, Air, and Soil Pollution 159, 325–337.

Keller, A.A., Fruh, E.L., Johnson, M.M., Simon, V., McGourty, C., 2010. Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US West Coast. Marine Pollution Bulletin 60, 692–700. http://dx.doi.org/10.1016/j.marpolbul.2009.12.006

Kidd, R.B., Huggett, Q.J., 1981. Rock debris on abyssal plains in the northeast atlantic - a comparison of epibenthic sledge hauls and photographic surveys. Oceanologica Acta 4 (1), 99–104.

Koutsodendris, A., Papatheodorou, G., Kougiourouki, O., Georgiadis, M., 2008. Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. Estuarine, Coastal and Shelf Science 77, 501–512. http://dx.doi.org/10.1016/j.ecss.2007.10.011

Lee, D.-I., Cho, H.-S., Jeong, S.-B., 2006. Distribution characteristics of marine litter on the sea bed of the East China Sea and the South Sea of Korea. Estuarine, Coastal and Shelf Science 70, 187–194. DOI: 10.1016/j.ecss.2006.06.003

Levin, L.A., Sibuet, M., 2012. Understanding Continental Margin Biodiversity: A New Imperative. Annual Review of Marine Science 4, 79–112. DOI:10.1146/annurev-marine-120709-142714

Mason, E., Coombs, S., Oliveira, P., 2006. An overview of the literature concerning the oceanography of the eastern North Atlantic region (No. 33). IPIMAR, Lisboa.

Menezes, G.M., Rosa, A., Melo, O., Pinho, M.R., 2009. Demersal fish assemblages off the Seine and Sedlo Seamounts (Northeast Atlantic). Deep-Sea Research II: Topical Studies in Oceanography 56, 2683–2704. DOI:10.1016/j.dsr2.2008.12.028

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A.A., 2013. Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. PLoS ONE 8 (12): e79889. DOI: 10.1371/journal.pone.0079889

Miyake, H., Shibata, H., Furushima, Y., 2011. Deep-sea litter study using deep-sea observation tools. In: Omori, K., Guo, X., Yoshie, N., Fujii, N., Handoh, I.C., Isobe, A., Tanabe, S. (Eds.). Interdisciplinary Studies on Environmental Chemistry - Marine Environmental Modeling and Analysis, pp 261-269.

Moore, S.L., Allen, M.J., 2000. Distribution of anthropogenic and natural debris on the mainland shelf of the Southern California Bight. Marine Pollution Bulletin 40, 83–88. http://dx.doi.org/10.1016/S0025-326X(99)00175-7

Morato, T., Pitcher, T.J., Clark, M.R., Menezes, G., Tempera, F., Porteiro, F., Giacomello, E., Santos, R.S., 2010. Can we protect seamounts for research? A call for conservation. Oceanography 23 (1), 190–199.

Morato, T., Kvile, K.Ø., Taranto, G.H., Tempera, F., Narayanaswamy, B.E., Hebbeln, D., Menezes, G.M., Wienberg, C., Santos, R.S., Pitcher, T.J., 2013. Seamount physiography and biology in the north-east Atlantic and Mediterranean Sea. Biogeosciences 10, 3039–3054. DOI: 10.5194/bg-10-3039-2013.

Mordecai, G., Tyler, P.A., Masson, D.G., Huvenne, V.A.I., 2011. Litter in submarine canyons off the west coast of Portugal. Deep-Sea Research II: Topical Studies in Oceanography 58, 2489–2496. DOI: 10.1016/j.dsr2.2011.08.009

Norse, E.A., Brooke, S., Cheung, W.W.L., Clark, M.R., Ekeland, I., Froese, R., Gjerde, K.M., Haedrich, R.L., Heppell, S.S., Morato, T., Morgan, L.E., Pauly, D., Sumaila, R., Watson, R., 2012. Sustainability of deep-sea fisheries. Marine Policy 36, 307–320. DOI: 10.1016/j.marpol.2011.06.008

OCEANA (2005). The Seamounts of the Gorringe Bank. Available at www.oceeana.org (accessed December 2013).

Peliz, A., Dubert, J., Santos, A., Oliveira, P., Le Cann, B., 2005. Winter upper ocean circulation in the Western Iberian Basin – Fronts, Eddies and Poleward Flows: an overview. Deep Sea Research Part I: Oceanographic Research Papers 52, 621–646. http://dx.doi.org/10.1016/j.dsr.2004.11.005

Pham, C.K., Gomes-Pereira, J.N., Isidro, E.J., Santos, R.S., Morato, T., 2013. Abundance of litter on Condor seamount (Azores, Portugal, Northeast Atlantic) Deep-Sea Research II: Topical Studies in Oceanography 98, 204–208. http://dx.doi.org/10.1016/j.dsr2.2013.01.011

Pitcher, T.J., Clark, M.R., Morato, T., Watson, R., 2010. Seamount fisheries: Do they have future? Oceanography 23 (1), 134-144.

Puig, P., Canals, M., Company, J.B., Martin, J., Amblas, D., Lastras, G., Palanques, A., Calafat, A., 2012. Ploughing the deep sea floor. Nature 489, 286–289. DOI: 10.1038/nature11410

Ramirez-Llodra, E., Tyler, P.A., Baker, M.C., Bergstad, O.A., Clark, M.R., Escobar, E., Levin, L.A., Menot, L., Rowden, A.A., Smith, C.R., Van Dover, C.L., 2011. Man and the last great wilderness: human impact on the Deep Sea. PloS One 6 (8), e22588. DOI: 10.1371/journal.pone.0022588

Ramirez-Llodra, E., De Mol, B., Company, J.B., Coll, M., Sardà, F., 2013. Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea. Progress in Oceanography 118, 273–287. http://dx.doi.org/10.1016/j.pocean.2013.07.027

Ressurreição, A., Giacomello, E., 2013. Quantifying the direct use value of Condor seamount. Deep-Sea Research II: Topical Studies in Oceanography 98, 209–217. http://dx.doi.org/10.1016/j.dsr2.2013.08.005

Sampaio, I., Braga-Henriques, A., Pham, C., Ocaña, O, Matos, V., Morato, T., Porteiro, F.M., 2012. Cold-water corals landed by bottom longline fisheries in the Azores (north-eastern Atlantic). Journal of the Marine Biological Association of the United Kingdom 92, 1547–1555. DOI: 10.1017/S0025315412000045.

Schlining, K., von Thun, S., Kuhnz, L., Schlining, B., Lundsten, L., Stout, N.J., Chaney, L., Connor, J., 2013. Debris in the deep: Using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA. Deep Sea Research Part I: Oceanographic Research Papers 79, 96–105. http://dx.doi.org/10.1016/j.dsr.2013.05.006

Serra, N., Ambar, I., 2002. Eddy generation in the Mediterranean Undercurrent. Deep-Sea Research II: Topical Studies in Oceanography 49, 4225–4243. http://dx.doi.org/10.1016/S0967-0645(02)00152-2

Tortella, D., Torne, M., Pérez-Estaún, A., 1997. Geodynamic Evolution of the Eastern Segment of the Azores-Gibraltar Zone: The Gorringe Bank and the Gulf of Cadiz Region. Marine Geophysical Researches 19, 211–230.

UNEP, 2009. Marine Litter: A Global Challenge. UNEP, Nairobi, 232 pp.

Watters, D.L., Yoklavich, M.M., Love, M.S., Schroeder, D.M., 2010. Assessing marine debris in deep seafloor habitats off California. Marine Pollution Bulletin 60, 131–138.

Wei, C.-L., Rowe, G.T., Nunnally, C.C., Wicksten, M.K., 2012. Anthropogenic ‘‘Litter’’ and macrophyte detritus in the deep Northern Gulf of Mexico. Marine Pollution Bulletin 64, 966–973. DOI: 10.1016/j.marpolbul.2012.02.015

Wessel, P., Sandwell, D.T., Kim, S.-S., 2010. The Global Seamount Census Oceanography 23 (1), 24–33. http://dx.doi.org/10.5670/oceanog.2010.60.

Wienberg, C., Wintersteller, P., Beuck, L., Hebbeln, D., 2013. Coral Patch seamount (NE Atlantic) – a sedimentological and megafaunal reconnaissance based on video and hydroacoustic surveys. Biogeosciences 10, 3421–3443. DOI: 10.5194/bg-10-3421-2013.

Xavier, J., van Soest, R., 2007. Demosponge fauna of Ormonde and Gettysburg Seamounts (Gorringe Bank, north-east Atlantic): diversity and zoogeographical affinities. Journal of the Marine Biological Association of the United Kingdom 87, 1643–1653. DOI: 10.1017/S0025315407058584

Figure 1. Location of Gorringe Bank. Rectangles mark different subdivision areas for assessment of fishing effort in the region (see also Table 3). Background bathymetric contour lines from http://www.gebco.net (The GEBCO_08 Grid, version 20100927).

Figure 2. ROV transects conducted on Gorringe Bank. Litter items are indicated with different symbols. O (other); P (plastic); M (metal); G (glass); FG (fishing gear). Background bathymetric contour lines from http://www.gebco.net (The GEBCO_08 Grid, version 20100927). Black lines represent ROV on bottom, while white lines symbolize off bottom transit movements.

Figure 3. Examples of litter found in the Gorringe Bank. a) Fishing net; b) cable; c) lost fishing gear; d) part of fishing gear colonized by benthic fauna; e) dumped chair; f) glass bottle.

Figure 4. Bathymetric turnover of the types of litter.

Figure 5. Density of litter items at different bathymetric ranges in the SE (dive #1) and NW (dive #2 and #3) flanks of Gettysburg, the S flank of Ormonde (dive #4) and the overview of all pooled data. O (other); P (plastic); M (metal); G (glass); FG (fishing gear).

Figure 6. Trend in the benthopelagic (a) and pelagic (b) catches from 2010 to 2012 based on landings on mainland Portugal (data provided by DGRM).

Figure 7. Images of fishes observed in the Gorringe Bank. a) *Conger conger*, at 145 m; b) *Phycis* sp., at 115 m; c) *Polyprion americanus*, at 550 m; d) *Muraena helena*, at 144 m.

Table 1

Table 1. Metadata of the ROV dives on Gettysburg and Ormonde Seamounts (data from ROV).

Location	Dive	Distance (km)		Date	Time	Depth (m)	Latitude	Longitude
SE Gettysburg	#1	10.5	on bottom	2011.10.10	00:00	3015	36º25.01'N	11º20.05'W
			off bottom	2011.10.10	17:27	1500	36º26.78'N	11º22.02'W
NW Gettysburg	#2	25.1	on bottom	2011.10.13	17:21	2326	36º40.02'N	11º37.99'W
			off bottom	2011.10.15	07:02	60	36º33.13'N	11º34.59'W
NW Gettysburg	#3	11.3	on bottom	2011.10.15	12:42	1503	36º35.01'N	11º39.99'W
			off bottom	2011.10.16	13:11	110	36º32.94'N	11º35.03'W
S Ormonde	#4	33.7	on bottom	2011.10.16	20:25	2255	36º37.32'N	11º01.38'W
			off bottom	2011.10.18	16:30	125	36º41.29' N	11º08.23'W

Table 2

Table 2. Types of debris found in Gettysburg and Ormonde seamounts. N. number of observed items.

Type of debris	Examples	Seamount	Depth (m)	N	%
Fishing gear	Cables, lines, net, shackle	Gettysburg, Ormonde	114-3014	51	56.0
Glass	Bottles, glass window	Gettysburg, Ormonde	151-2196	14	15.4
Plastic	Bottles, bags	Gettysburg, Ormonde	387-2944	9	9.9
Metal	Beverage can, tin can, shelf	Gettysburg, Ormonde	1283-2958	9	9.9
Rubber	Fragment	Gettysburg	920	1	1.1
Processed wood	Fragment	Gettysburg	386	1	1.1
Pottery	Fragment	Ormonde	730	1	1.1
Other	Chair, others	Gettysburg, Ormonde	166-2942	5	5.5

Table 3

Table 3. Descriptors of fishing activities in the Gorringe Bank by area (as shown in Figure 1), between 2010 and 2012 (data provided by DGRM and ADAPI (Associação dos Armadores das Pescas Industriais).

	2010						2011						2012					
Area	**1D8**	**2D8**	**1D9**	**2D9**	**3D9**	**Total**	**1D8**	**2D8**	**1D9**	**2D9**	**3D9**	**Total**	**1D8**	**2D8**	**1D9**	**2D9**	**3D9**	**Total**
No. of vessels	5	**8**	4	7	7	31	4	**12**	3	2	2	23	0	0	0	1	0	1
No. of fishing days	63	**89**	7	57	41	257	13	**83**	9	2	3	110	0	0	0	2	0	2
Biomass (kg)	44841	**78460**	4675	51498	46107	225581	6347	**57331**	5940	1830	3688	75136	0	0	0	610	0	610
Catch ($kg.d^{-1}$)	712	**882**	668	903	1125	877.7	488	**691**	660	915	1229	683.1						305.0
Fuel (€/ton)						476						622						681

Figure 1
Click here to download high resolution image

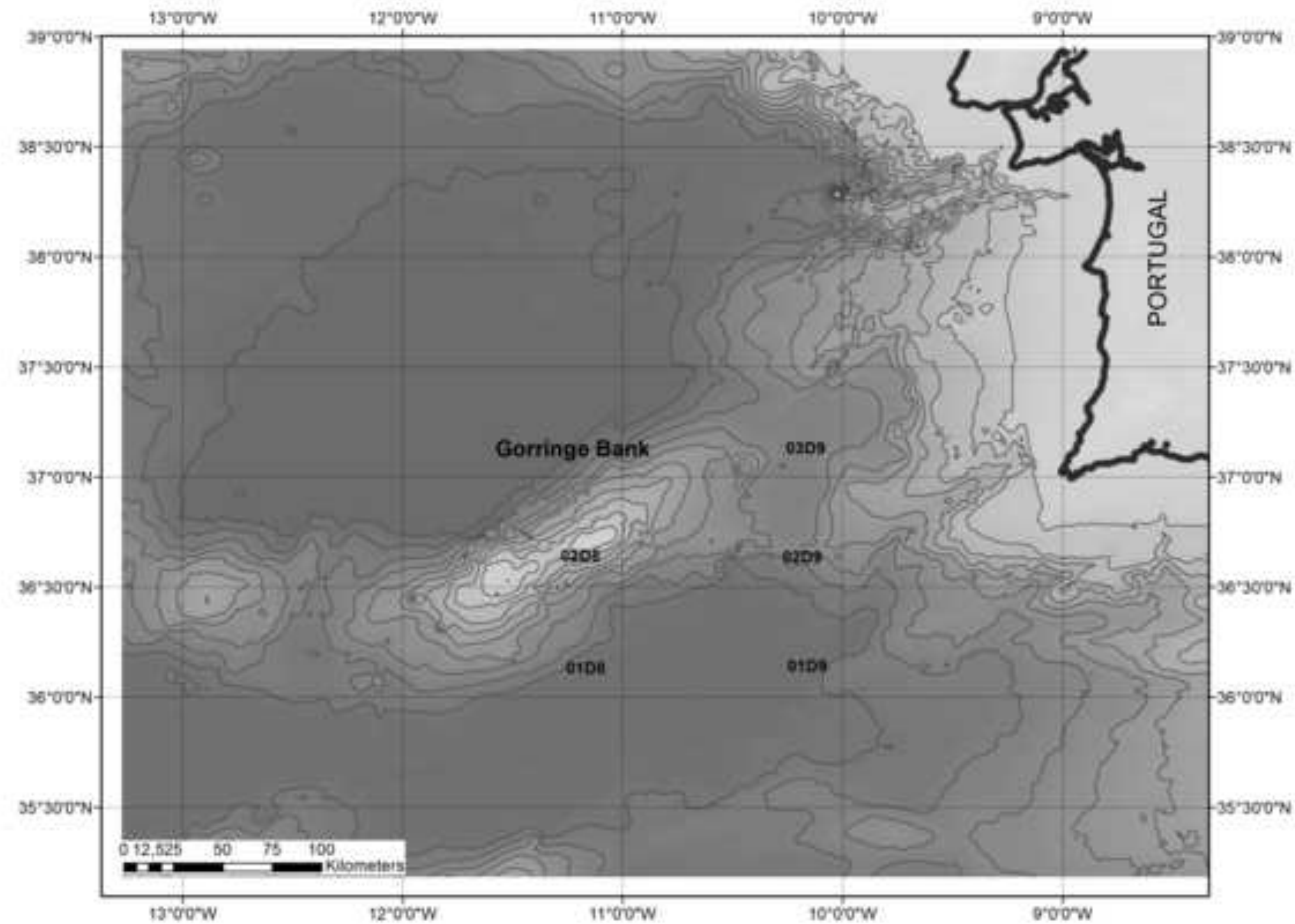

Figure 2
Click here to download high resolution image

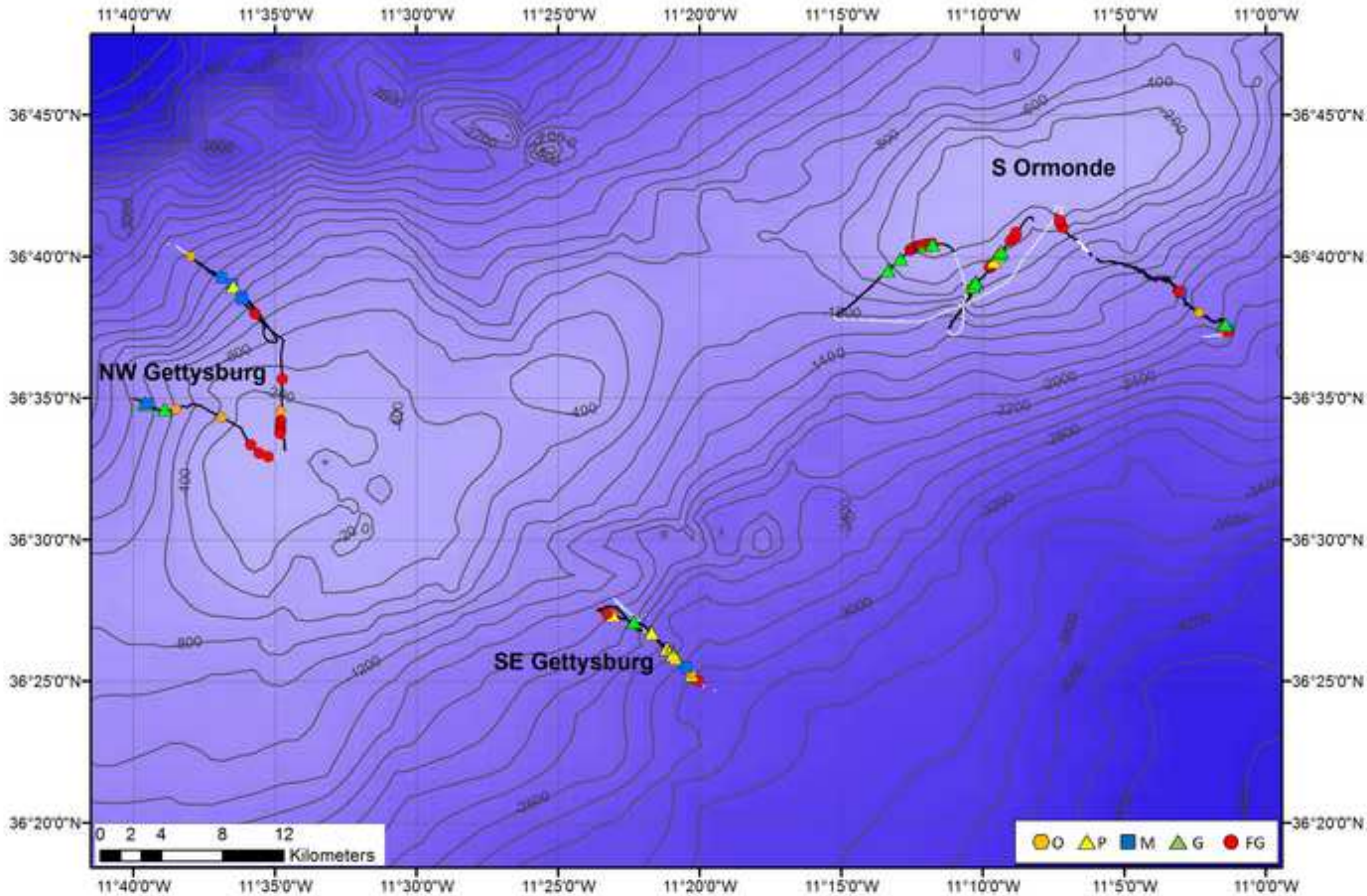

Figure 3
Click here to download high resolution image

Figure 4
Click here to download high resolution image

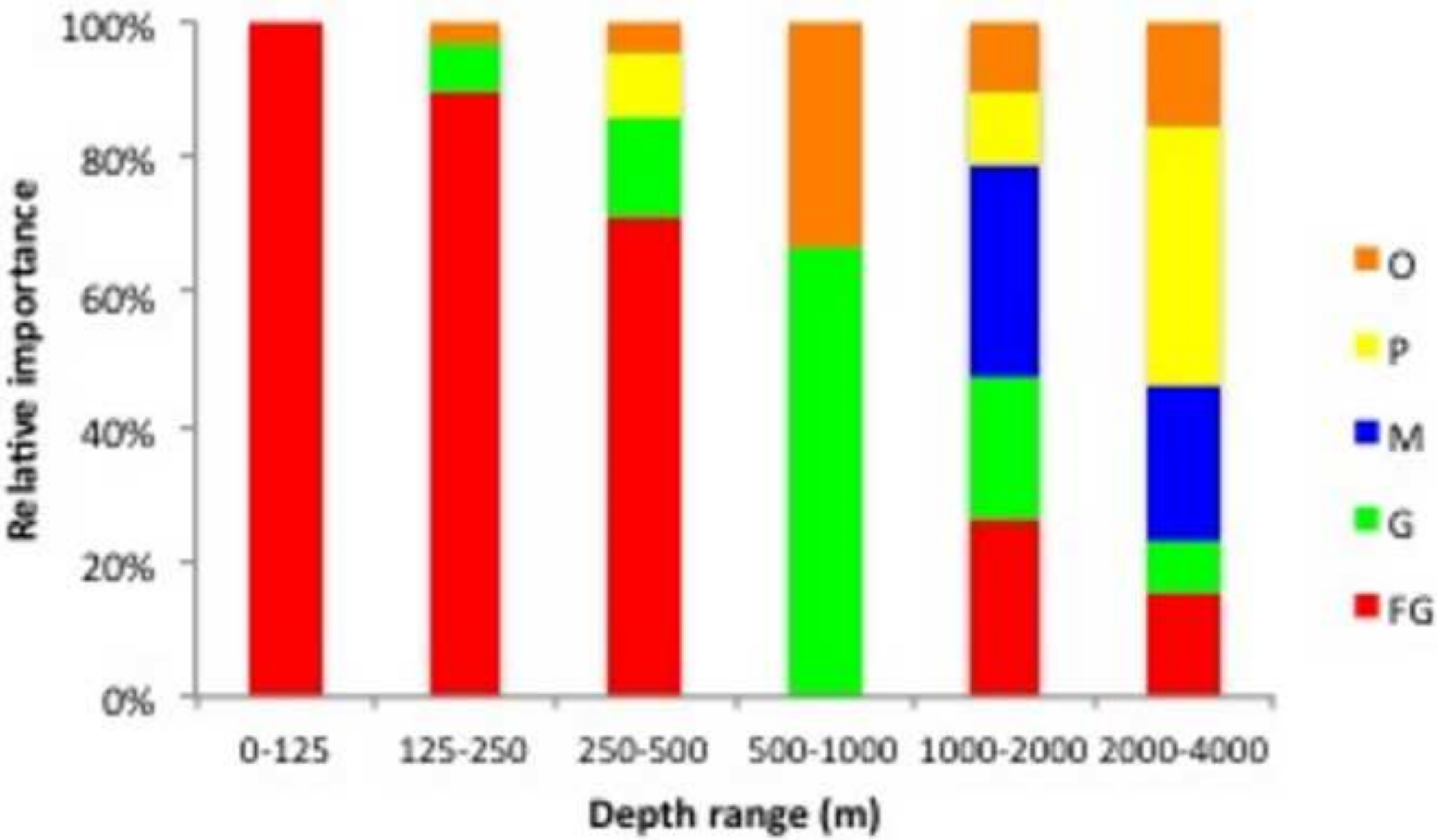

Figure 5
Click here to download high resolution image

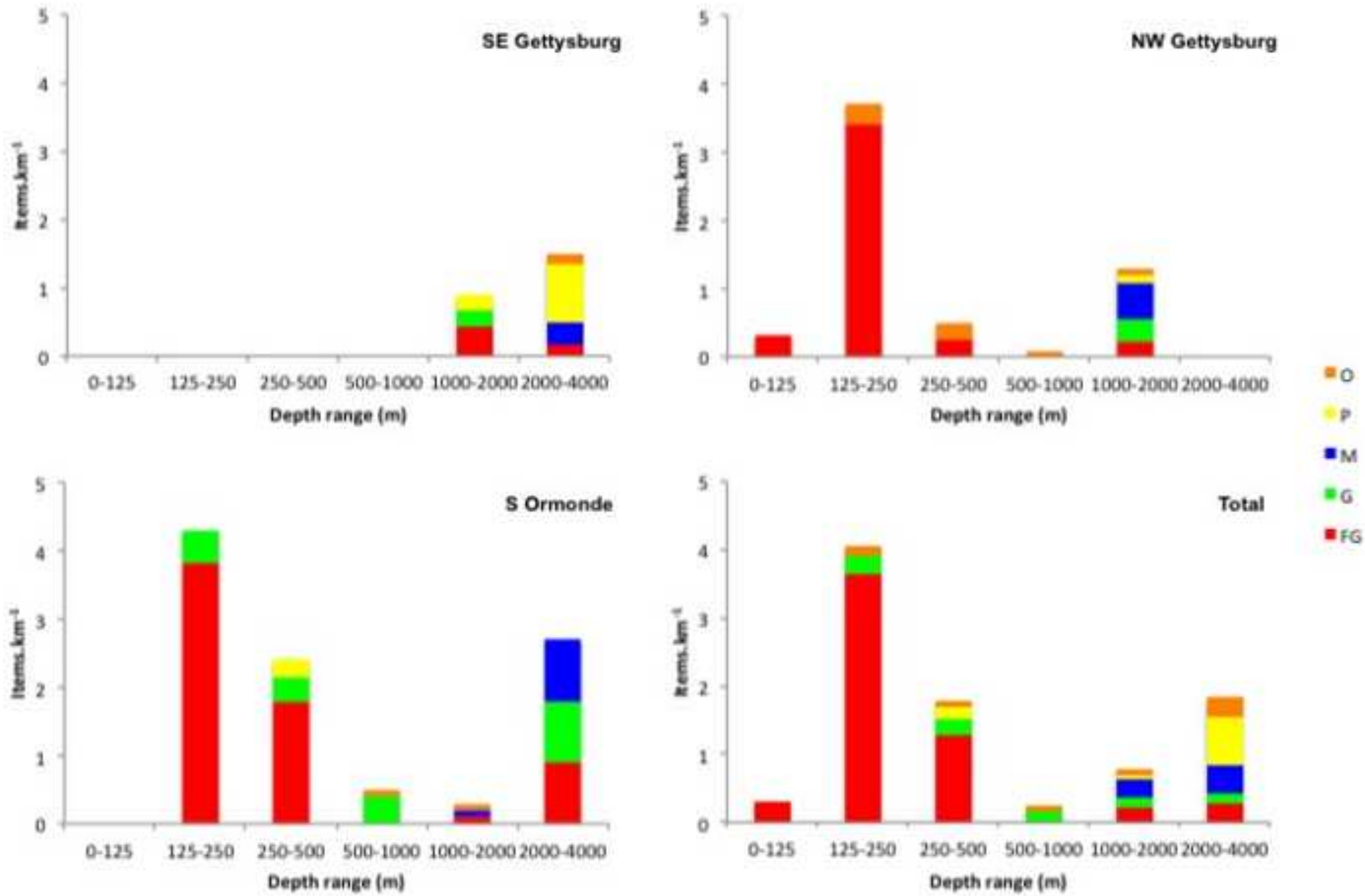

Figure 6
Click here to download high resolution image

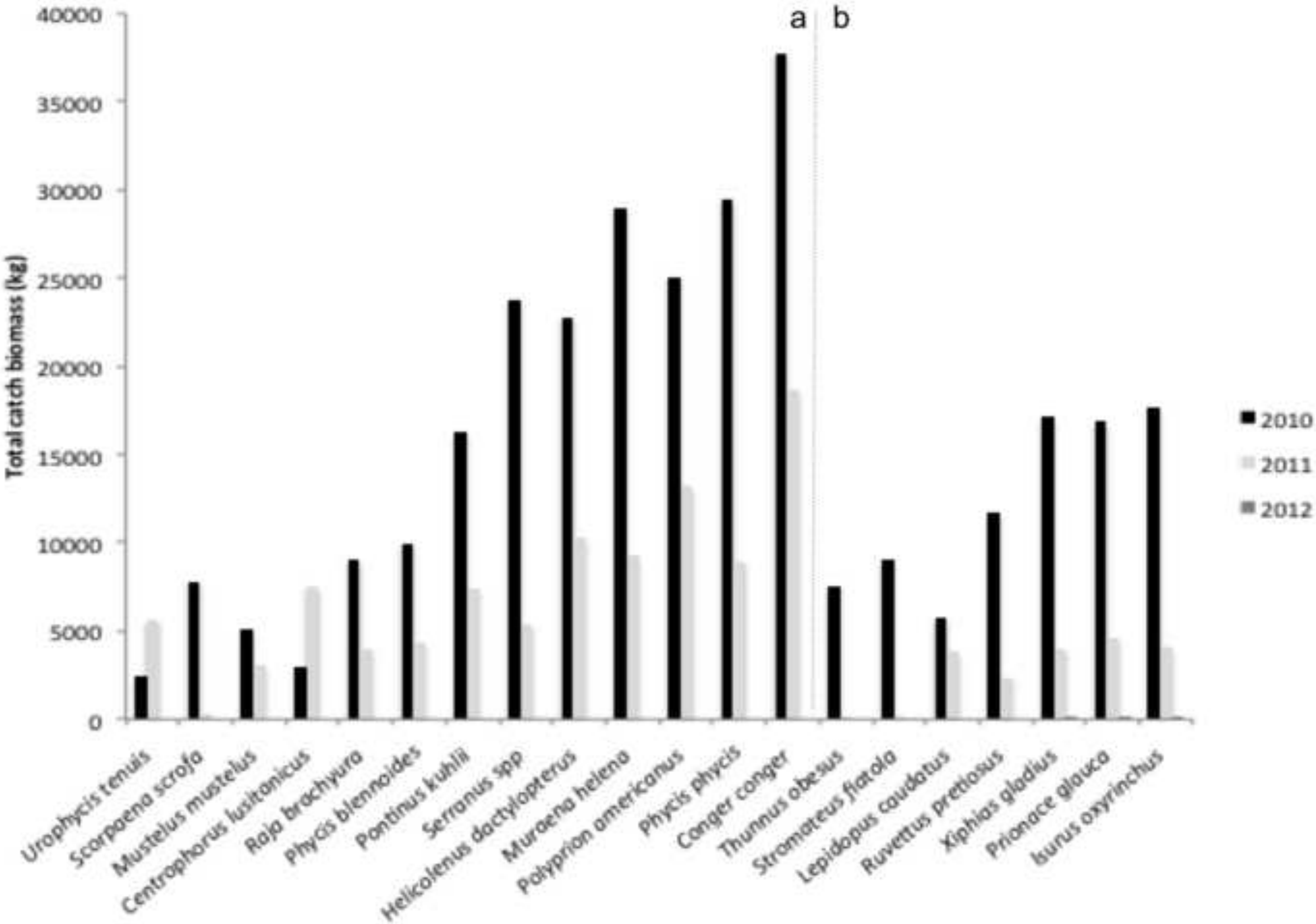

Figure 7
Click here to download high resolution image