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SOUTHERN INDIAN OCEAN REGIONAL WORKSHOP
TO FACILITATE THE DESCRIPTION OF
ECOLOGICALLY OR BIOLOGICALLY
SIGNIFICANT MARINE AREAS
Flic en Flac, Mauritius, 31 July to 3 August 2012

DATA TO INFORM THE CBD SOUTHERN INDIAN OCEAN REGIONAL WORKSHOP TO FACILITATE THE DESCRIPTION OF ECOLOGICALLY OR BIOLOGICALLY SIGNIFICANT MARINE AREAS

Note by the Executive Secretary

1. The Executive Secretary is circulating herewith a background document on data to inform the CBD Southern Indian Ocean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas. The information document was prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), with financial support from the Government of Australia, in support of the Secretariat of the Convention on Biological Diversity in its scientific and technical preparation for the above-mentioned regional workshop.

2. The document is circulated in the form and language in which it was received by the Secretariat of the Convention on Biological Diversity.

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National Research
FLAGSHIPS
Wealth from Oceans

CSIRO

Data to inform the CBD Southern Indian Ocean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas

Piers Dunstan and Mike Fuller

July 14, 2012
Prepared for: the Secretariat of the Convention on Biodiversity (SCBD)

www.csiro.au

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1 Background

CSIRO, in conjunction with international partners, has identify and mapped a large number of data sets and analyses for consideration by the Southern Indian Ocean Regional Workshop to facilitate the description of Ecologically or Biologically Significant Marine Areas (EBSAs). The data sets obtained cover both biological and physical data sets. The data is intended to be used by the expert regional workshop convened by SCBD to aid in identifying EBSAs through application of scientific criteria in annex I of decision IX/20 as well as other relevant compatible and complementary nationally and intergovernmentally agreed scientific criteria. Each data set may be used to meet one or more of the EBSA criteria. Printed maps will also be available for annotation at the workshop. The data collected will be made available for download at the Australian Ocean Data Network Portal http://portal.aodn.org.au/webportal/ can can be found by searching for the key word ”EBSA”. The layers are available as shape files and geotiffs.

2 GOODS Biogeography

A new biogeographic classification of the worlds oceans has been developed which includes pelagic waters subdivided into 30 provinces as well as benthic areas subdivided into three large depth zones consisting of 38 provinces (14 bathyal, 14 abyssal and 10 hadal). In addition, 10 hydrothermal vent provinces have been delineated. This classification has been produced by a multidisciplinary scientific expert group, who started this task at the workshop in Mexico City in January 2007. It represents the first attempt at comprehensively classifying the open ocean and deep seafloor into distinct biogeographic regions. The biogeographic classification classifies specific ocean regions using environmental features and to the extent data are available their species composition. This represents a combined physiognomic and taxonomic approach. Generalised environmental characteristics of the benthic and pelagic environments (structural features of habitat, ecological function and processes as well as physical features such as water characteristics and seabed topography) are used to select relatively homogeneous regions with respect to habitat and associated biological community characteristics. These are refined with direct knowledge or inferred understanding of the patterns of species and communities, driven by processes of dispersal, isolation and evolution; ensuring that biological uniqueness found in distinct basins and water bodies is also captured in the classification. This work is hypothesis-driven and still preliminary, and will thus require further refinement and peer review in the future. However, in its present format it provides a basis for discussions that can assist policy development and implementation in the context of the Convention on Biological Diversity and other fora.

Global Open Oceans and Deep Seabed (GOODS) biogeographic classification (http://ioc-unesco.org/index.php?option=com_content&task=view&id=146&Itemid=76)

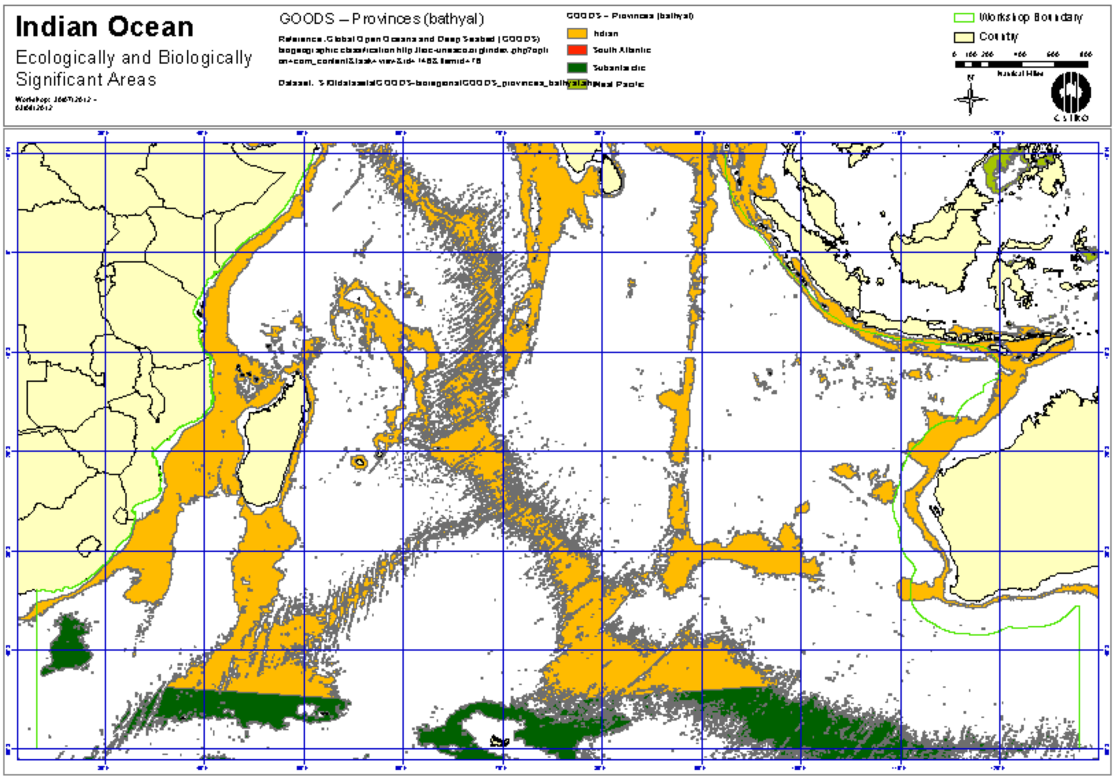

Figure 2.1: GOODS Bathyl Bioregions

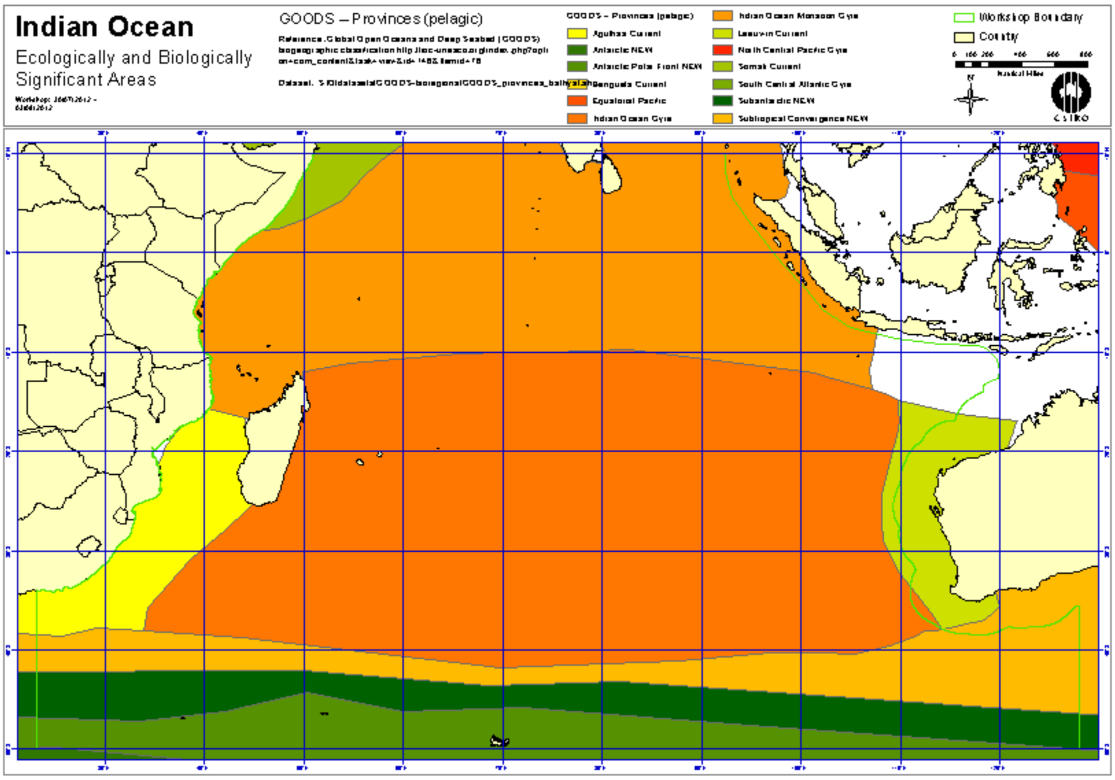

Figure 2.2: GOODS Pelagic Bioregions

3 Biological Data

3.1 Important Bird Areas

The Important Bird Areas (IBAs) programme of BirdLife International seeks to identify, document and conserve sites that are critical for the long-term viability of bird populations. The programme began in the 1980s and the process of site inventory is very well advanced in the terrestrial environment, with more than 10,000 sites already identified around the world. Conservation actions are underway at many of these sites, many now benefiting from enhanced protection status. Following the success of the IBA approach in the terrestrial and freshwater environment, BirdLife is now adapting and extending the programme to the oceans. BirdLife International (2009) found that there is considerable overlap and congruence between the criteria used to identify marine IBAs and those adopted by the CBD to identify EBSAs. This is particularly so for criteria relating to vulnerability and irreplaceability. BirdLife International manages the Global Procellariiform Tracking Database (www.seabirdtracking.org) a unique collaboration between many of the worlds seabird tracking scientists. The relevant data were made available to run an IBA analysis for this region, and the resulting sites are included on the map. Three types of tracking device are available; Platform Transmitter Transponders (PTT), Global Positioning Systems (GPS) and Geolocators (GLS). Location estimates derived from each of these systems have different accuracies, GPS data being accurate to meters, PTT to within 50km and GLS data being the most erroneous, with a mean error of 186km. PTT and GPS data were combined and analysed together because erroneous fixes were within the large-scale foraging movements being investigated. However, Because GLS data include much more error (and also only provides two fixes per day) they are treated separately, and only used directly for triggering sites as IBA during non-breeding migrations, when the birds movements were much larger than (and therefore distinguishable from) the erroneous locations.

BirdLife International maintains an online database (http://seabird.wikispaces.com/) of seabird ecology and foraging ranges, as a basis for identifying key foraging areas around breeding sites that qualify as IBAs. The majority of congregatory seabirds are central place foragers during the breeding season returning to their breeding colony regularly to share incubation duties or feed chicks. These species, many of which forage in association with pelagic fish schools, radiate from colonies with individual and inter-trip variation in the distance travelled from the colony. Identifying foraging areas up to the maximum foraging range recorded would be a poor representation of the foraging area for the majority of birds, since these extremes apply to only a small percentage of birds. The approach adopted here was to define sites based on their importance to a greater proportion of the colony, and this was done by selecting the maximum range to which IBA threshold numbers of a trigger species travelled.

BirdLife International (2010). Marine Important Bird Areas toolkit: standardised techniques for identifying priority sites for the conservation of seabirds at sea. BirdLife International, Cambridge UK. Version 1.2: February 2011 http://www.birdlife.org/eu/pdfs/Marinetoolkitnew.pdf

BirdLife International (2009). Designing networks of marine protected areas: exploring the linkages between Important Bird Areas and ecologically or biologically significant marine areas. Cambridge, UK: BirdLife International. http://www.cbd.int/doc/meetings/mar/ewbcsima-01/other/ewbcsima-01-birdlife-02-en.pdf

O'Brien, M., and Waugh, S.M. 2010. Important Bird Areas in the Pacific 2010. Unpublished report to BirdLife International. http://www.sprep.org/publication/pub_detail.asp?id=857

Ramrez I., P. Geraldes, A. Meirinho, P. Amorim & V. Paiva (2008). reas Marinhas Importantes para as Aves em Portugal. Projecto LIFE04NAT/PT/000213 - Sociedade Portuguesa Para o Estudo das Aves. Lisboa

Arcos, J.M., J. Bcares, B. Rodrguez y A. Ruiz. 2009. reas Importantes para la Conservacin de las Aves marinas en Espaa. LIFE04NAT/ES/000049-Sociedad Espaola de Ornitologa (SEO/BirdLife). Madrid.

3.2 Catches of Commercial Pelagic Species

Indian Ocean Tuna Commission

Data from the Indian Ocean Tuna Commission (IOTC) lists catch in weight (purse seine) and/or numbers of fish (longline) of tuna and tuna-like species, preferably raised to the total nominal catch and fishing effort by month, species and gear. The maximum spatial aggregation should be by 1x1 grid area for purse seine and 5x5 grid area for longline.These data, are considered to be in the public domain, provided that the catch of no individual vessel can be identified within a time/area stratum. In cases when an individual vessel can be identified, the data are aggregated prior to release by time, area or flag to preclude such identification, and will then be in the public domain.

The data provided here show the total catch over the years 2001-2010 and 1991-2001 for each of the 1x1 and 5x5 grid areas for tuna species, marlin species and other species for long line and for tuna species for purse seine.

http://www.iotc.org/English/data/databases.php

3.2.1 Long Line - Tuna

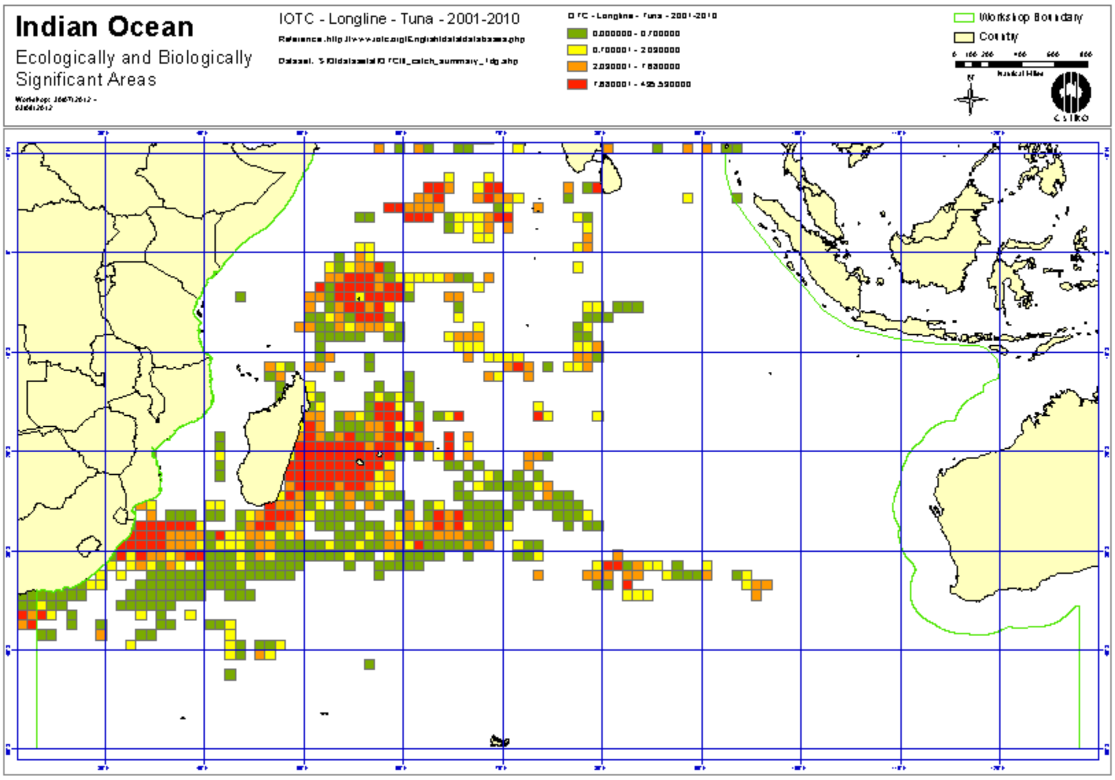

Figure 3.1: Total Long Line Tuna Catch, 2001 - 2010

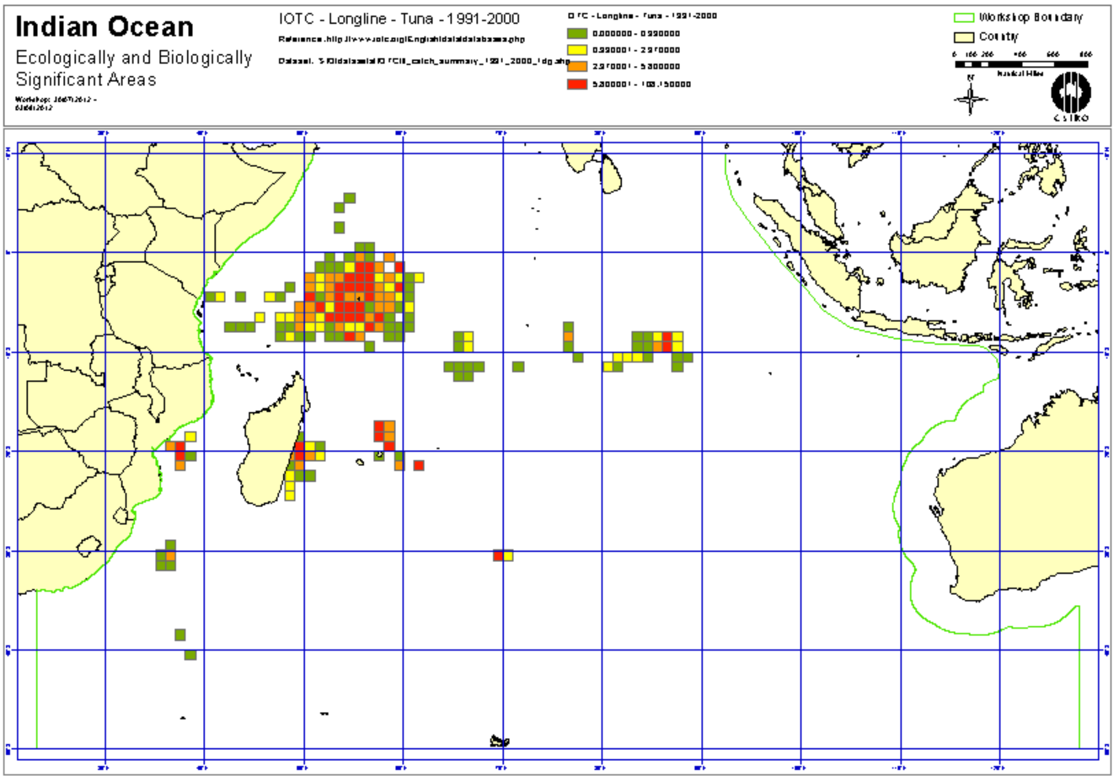

Figure 3.2: Total Long Line Tuna Catch, 1999 - 2000

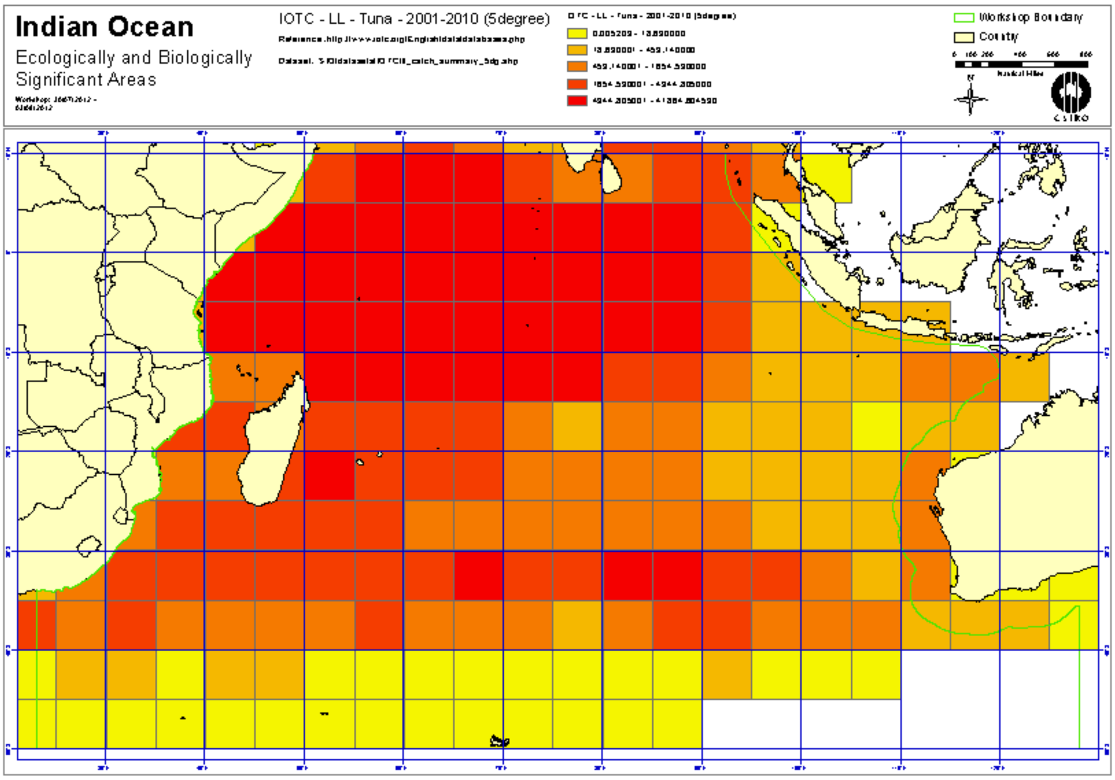

Figure 3.3: Total Long Line Tuna Catch, 2001 - 2010, 5^o grid

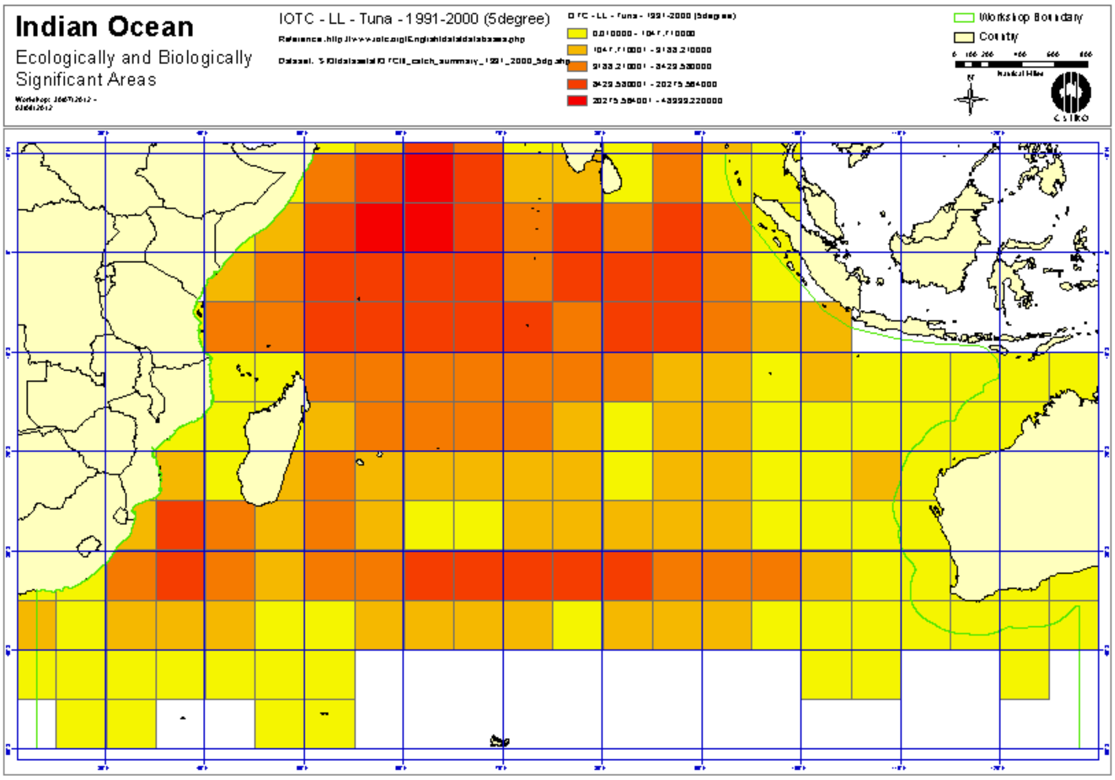

Figure 3.4: Total Long Line Tuna Catch, 1999 - 2000, 5^o grid

3.2.2 Long Line - Marlin

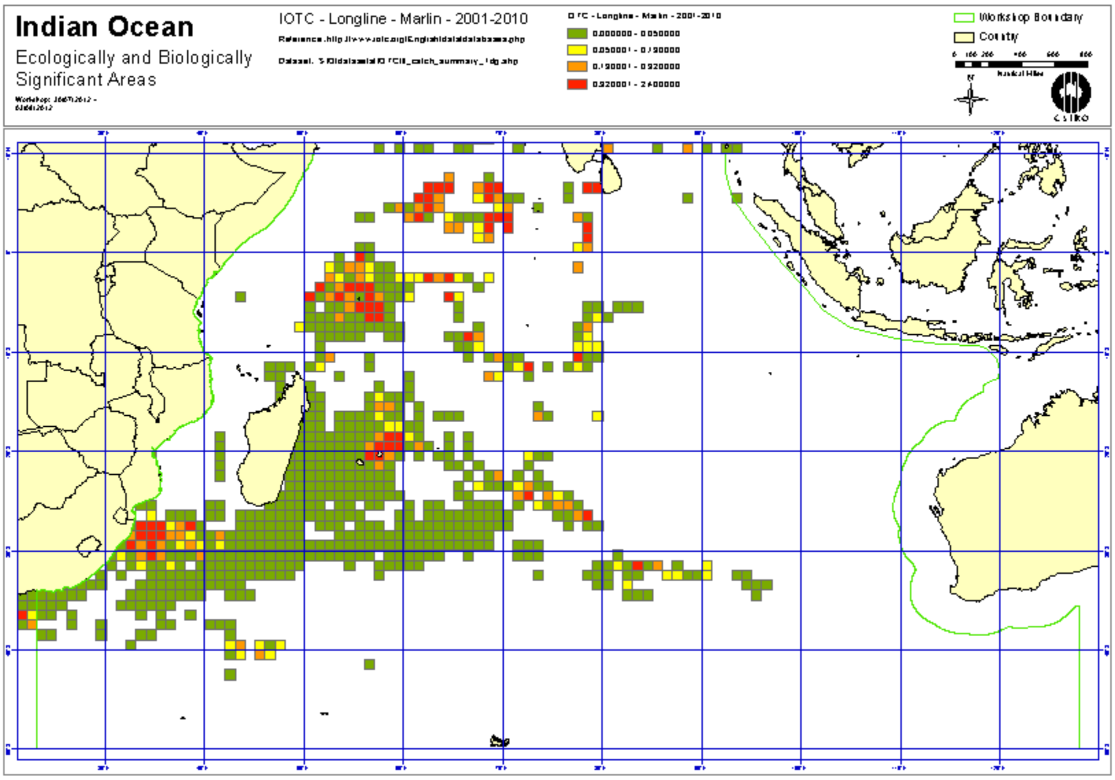

Figure 3.5: Total Long Line Marlin Catch, 2001 - 2010

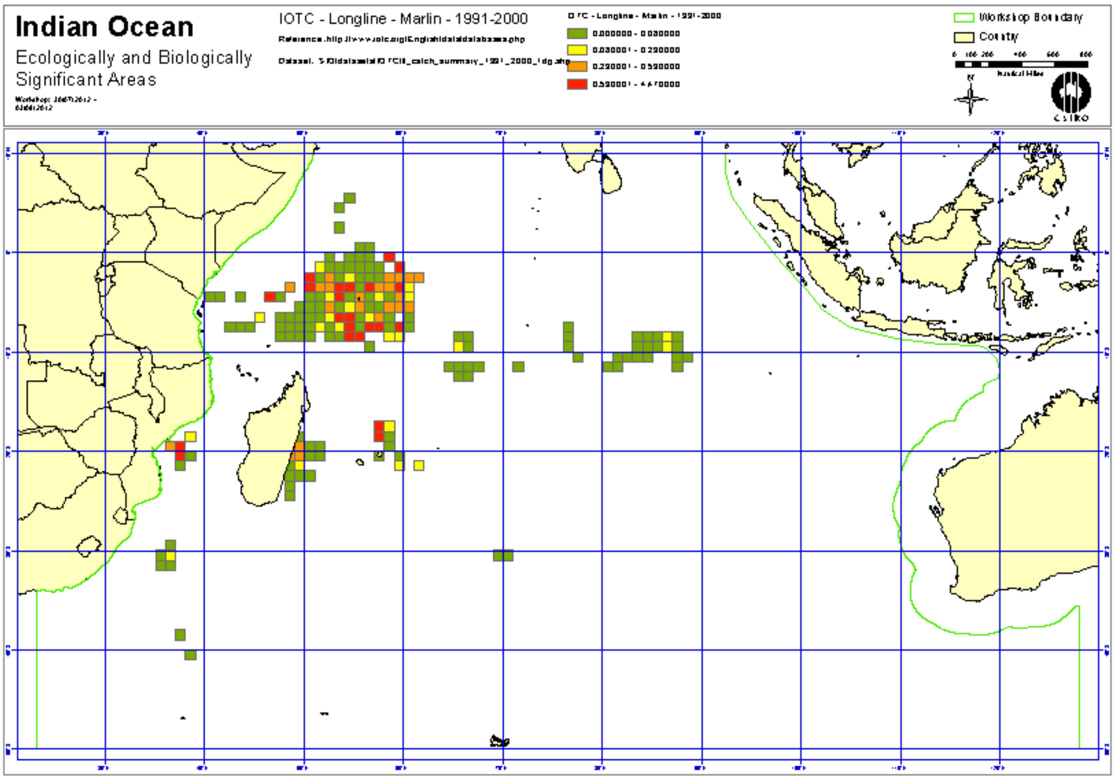

Figure 3.6: Total Long Line Marlin Catch, 1999 - 2000

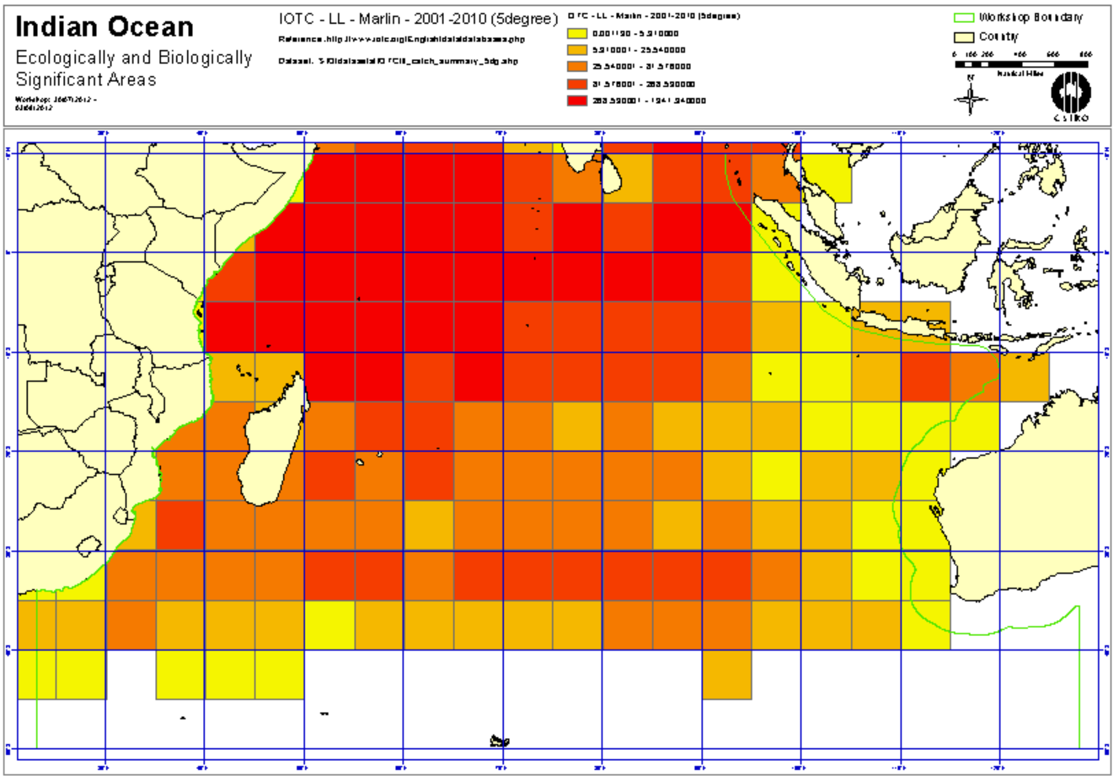

Figure 3.7: Total Long Line Marlin Catch, 2001 - 2010, 5^o grid

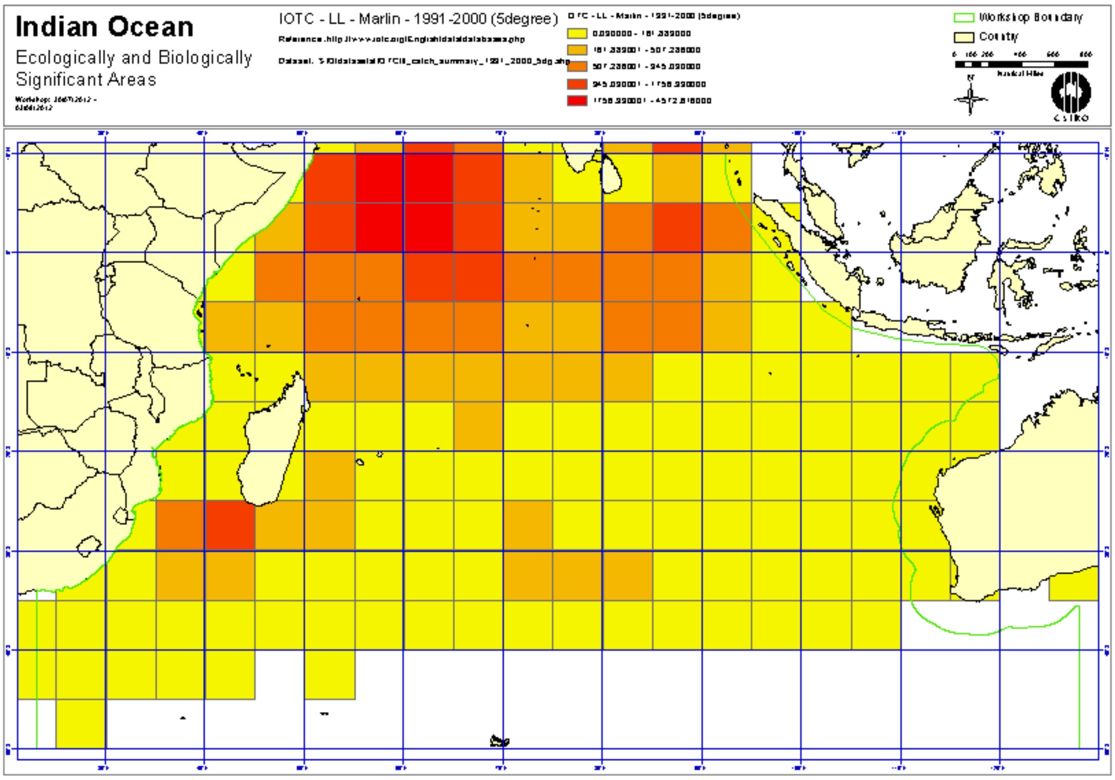

Figure 3.8: Total Long Line Marlin Catch, 1999 - 2000, 5^o grid

3.2.3 Long Line - Other

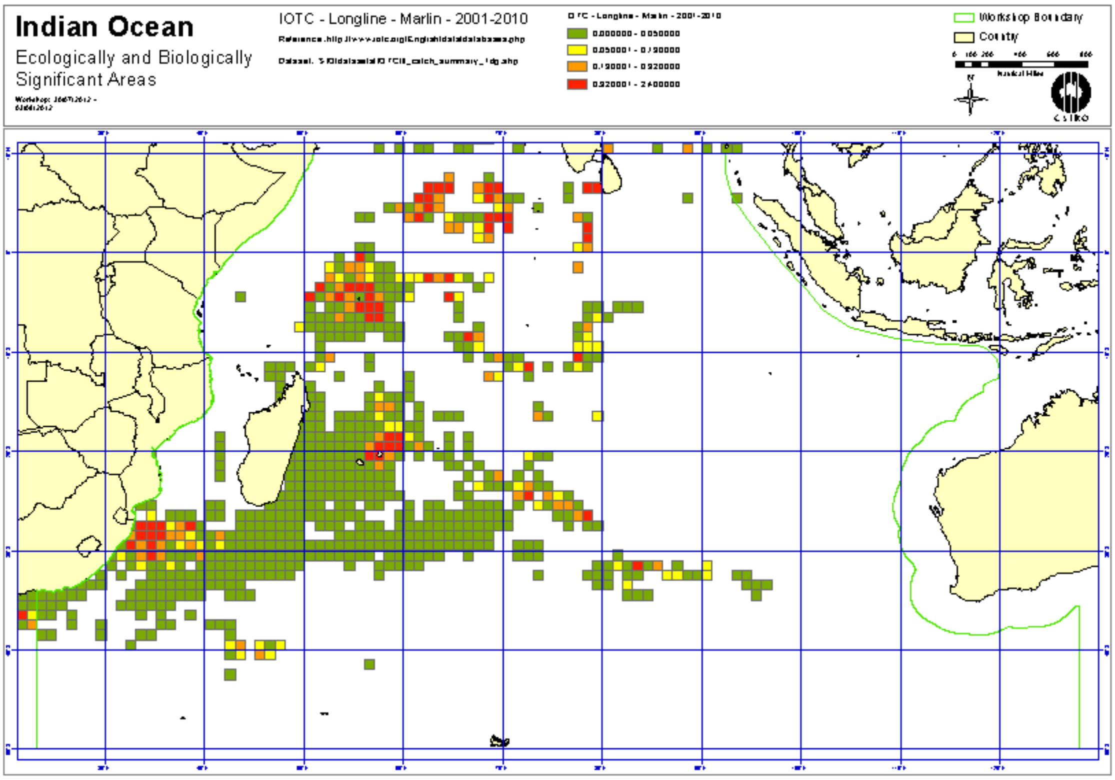

Figure 3.9: Total Long Line Catch other species, 2001 - 2010

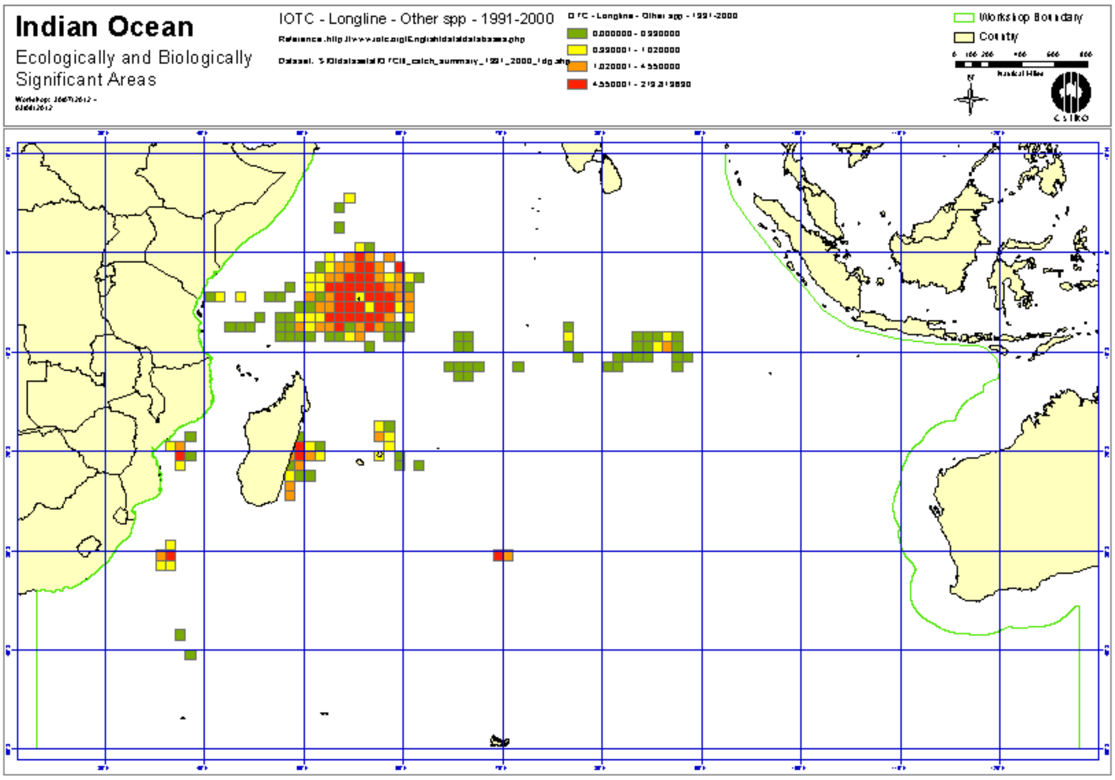

Figure 3.10: Total Long Line Catch other species, 1999 - 2000

3.2.4 Purse Seine - Tuna

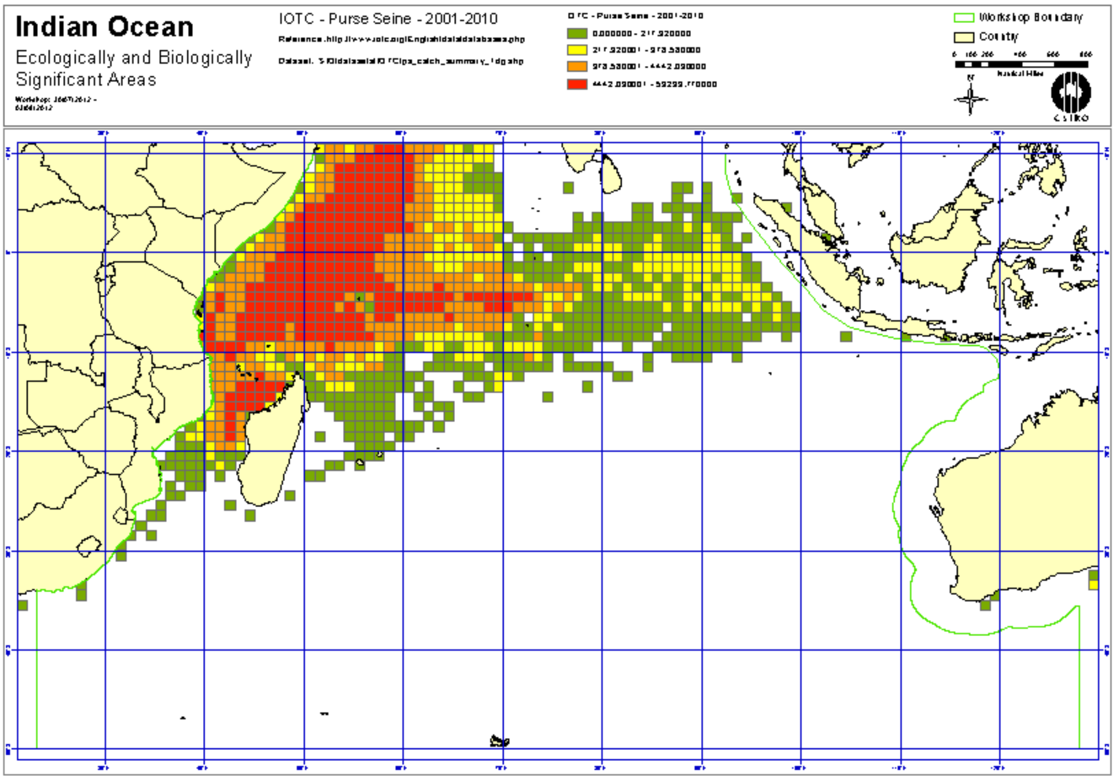

Figure 3.11: Total Purse Seine Tuna Catch,

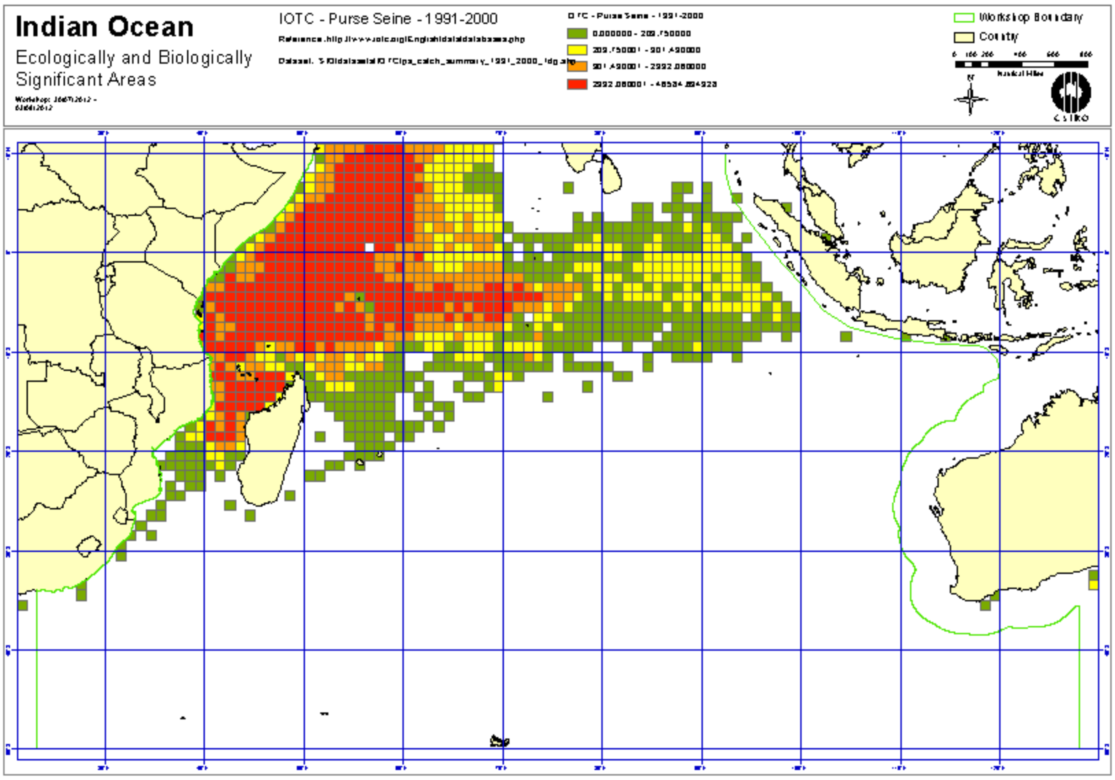

Figure 3.12: Total Purse Seine Tuna Catch,

3.3 Habitat preferences of juvenile SBT across their range

Juvenile southern bluefin tuna (SBT) range widely between the major juvenile summer grounds in the Great Australia Bight (GAB) and wintering areas in the southern ocean. The extent of these movements and the behaviours of SBT in different regions may be related to environmental conditions, as has been demonstrated for this species at other life stages (e.g. Patterson et al. 2009; Bestley et al. 2010; Fujioka et al. 2010; Fujioka et al. in press). Ocean conditions may directly influence distribution and behaviour, may act indirectly through influences on prey, or through a combination of the two. In the absence of information on prey distribution, only the influence of environmental conditions alone can be determined, but we note the exact mechanism may remain elusive. In summer the Habitat preference maps, described by a combination of SST and chl a,show that in most years, the GAB is the most preferred summer location in the southern oceans. There is a high preference habitat band across the Indian Ocean (IO), although extension of this habitat all the way to South Africa has been reduced in recent years. In winter the highest preferences are in the central IO, but there is also an area of high preference in the GAB in both periods.In the Tasman Sea, the band of high preference is almost entirely absent in the recent period, and there is no connecting band of high preference between the GAB and the Tasman Sea.

Basson, M., Hobday, A.J., Eveson, J.P., Patterson, T.A. (2012) Spatial Interactions Among Juvenile Southern Bluefin Tuna at the Global Scale: A Large Scale Archival Tag Experiment. FRDC Report 2003/002.

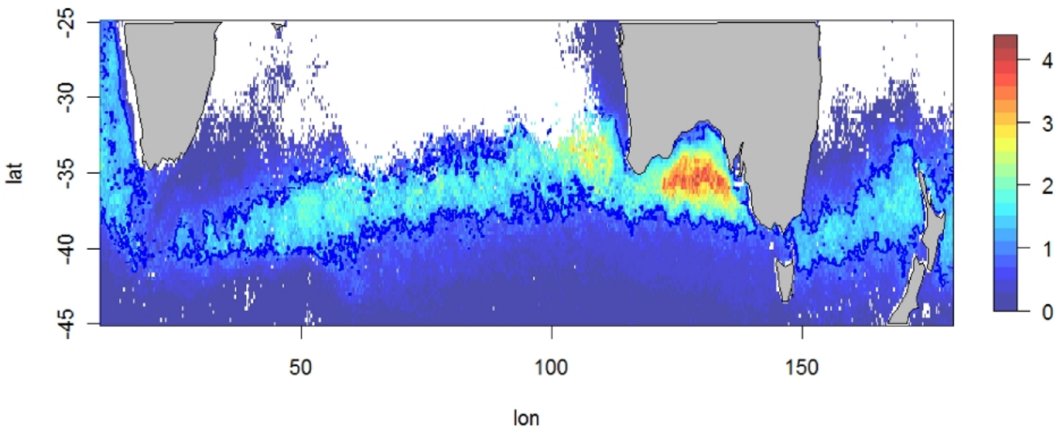

Figure 3.13: Preference maps for SBT in the resident state, based on preferences in summer in southern Australia (110-145oE, Jan-May, 2004-06) for combinations of SST and log(chl a), projected over oceanographic conditions in the whole of the Indian Ocean. A contour at preference =1 is shown in blue. White areas reflect missing oceanographic data or covariate values outside those of the preference curve. Values above 1.0 indicate preferred areas.

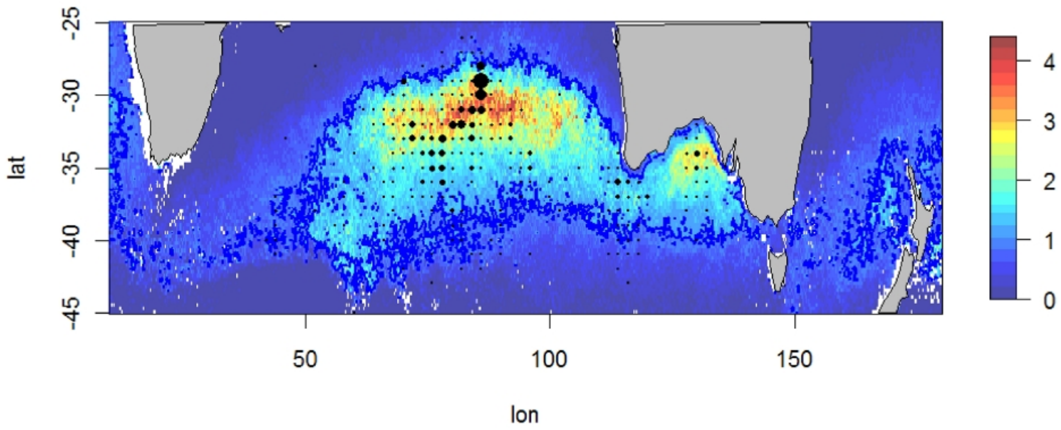

Figure 3.14: Preference map for SBT in the resident state, based on preferences in winter in the IO (40-115oE, August-November) for combinations of SST and log(chl a), projected over oceanographic conditions in the whole of the Indian Ocean and in 2004-06. A contour at preference =1 is shown in blue. White areas reflect missing oceanographic data or covariate values outside those of the preference curve. Black dots show relative levels of residency in each (2^olon x 1^olat) grid square. Values above 1.0 indicate preferred areas.

3.4 Patterns of Green Turtle Movements

The green turtle Chelonia mydas is classified as endangered because of global declines over the past few centuries due to human exploitation and habitat destruction, particularly the loss of nesting areas. The SW Indian Ocean is an important nesting and feeding ground for green turtles. Over the past few centuries, over-exploitation and destruction of nesting and foraging sites have resulted in the decrease and local extinction of some populations. In this region, nesting sites are scattered over many small islands, as well as along the coasts of Madagascar and east Africa. Many sites are poorly documented and/or lack long term data for population assessment because they are difficult to access. A key issue in the conservation of green turtles is the time lag at which the impact of conservation measures may be detected, due to the slow demography of the species; this reinforces the case for collecting long-term data on sea turtles, as well as data on other life stages of each species, since reproductive females represent only one component of the population. More emphasis is needed on protecting sea turtles at their feeding grounds and on pelagic stages at sea in order to complement protection at nesting sites.

Lauret-Stepler et. al. (2007) Reproductive seasonality and trend of Chelonia mydas in the SW Indian Ocean: a 20 yr study based on track counts. ENDANGERED SPECIES RESEARCH 3:217227

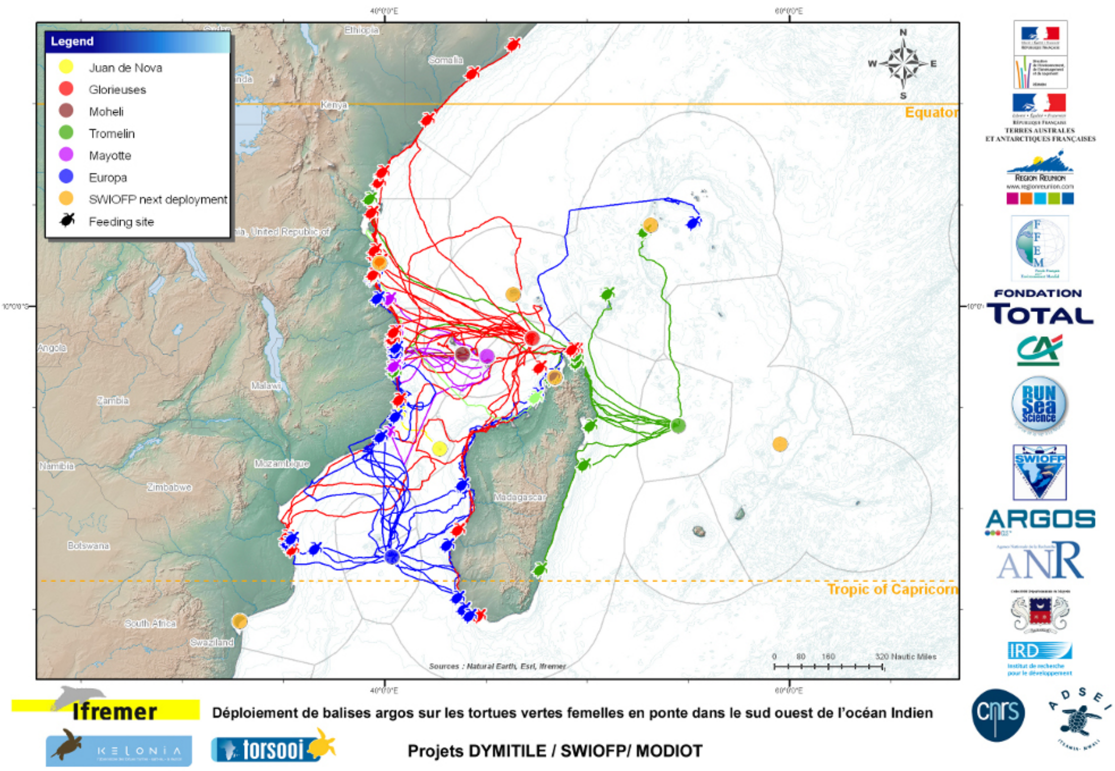

Figure 3.15: Turtle Movements

3.5 IOSEA Turtle feeding and nesting sites

The Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia puts in place a framework through which States of the Indian Ocean and South-East Asian region, as well as other concerned States, can work together to conserve and replenish depleted marine turtle populations for which they share responsibility.

The Memorandum of Understanding applies to the waters and coastal States of the Indian Ocean and South-East Asia and adjacent seas, extending eastwards to the Torres Strait. For implementation purposes, the area is divided into four sub-regions: South-East Asia and Australia, Northern Indian Ocean, Northwestern Indian Ocean, and Western Indian Ocean. The species of marine turtles covered by the MoU are the Loggerhead Caretta caretta, Olive Ridley Lepidochelys olivacea, Green Chelonia mydas, Hawksbill Eretmochelys imbricata, Leatherback Dermochelys coriacea, and Flatback Natator depressus.

This data was downloaded from the IOSEA Marine Turtle - Online Reporting Facility (http://www.ioseaturtles.org/report.php). Data for all species on feeding sites and nesting sites was downloaded and plotted where spatial information was included.

http://www.ioseaturtles.org/index.php

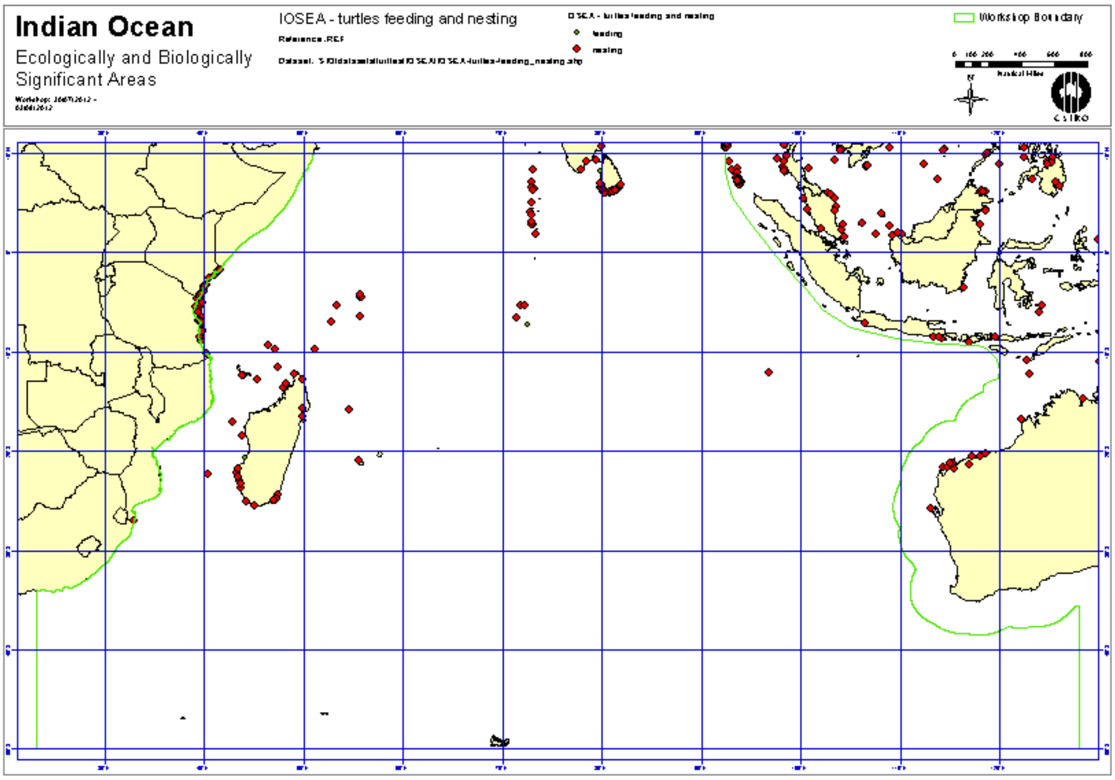

Figure 3.16: Turtle Movements

3.6 Predictions of Deep Sea Corals

Predictive habitat models are increasingly being used by conservationists, researchers and governmental bodies to identify vulnerable ecosystems and species distributions in areas that have not been sampled. However, in the deep sea, several limitations have restricted the widespread utilisation of this approach. These range from issues with the accuracy of species presences, the lack of reliable absence data and the limited spatial resolution of environmental factors known or thought to control deep-sea species distributions. To address these problems, global habitat suitability models have been generated for five species of framework-forming scleractinian corals by taking the best available data and using a novel approach to generate high resolution maps of seafloor conditions. High-resolution global bathymetry was used to resample gridded data from sources such as World Ocean Atlas to produce continuous 30-arc second (,1 km2) global grids for environmental, chemical and physical data of the worlds oceans. The increased area and resolution of the environmental variables resulted in a greater number of coral presence records being incorporated into habitat models and higher accuracy of model predictions. The most important factors in determining cold-water coral habitat suitability were depth, temperature, aragonite saturation state and salinity. Model outputs indicated the majority of suitable coral habitat is likely to occur on the continental shelves and slopes of the Atlantic, South Pacific and Indian Oceans. The North Pacific has very little suitable scleractinian coral habitat. Numerous small scale features (i.e., seamounts), which have not been sampled or identified as having a high probability of supporting cold-water coral habitat were identified in all ocean basins. Field validation of newly identified areas is needed to determine the accuracy of model results, assess the utility of modelling efforts to identify vulnerable marine ecosystems for inclusion in future marine protected areas and reduce coral bycatch by commercial fisheries.

Davies AJ, Guinotte JM (2011) Global Habitat Suitability for Framework-Forming Cold-Water Corals. PLoS ONE 6(4): e18483. doi:10.1371/journal.pone.0018483

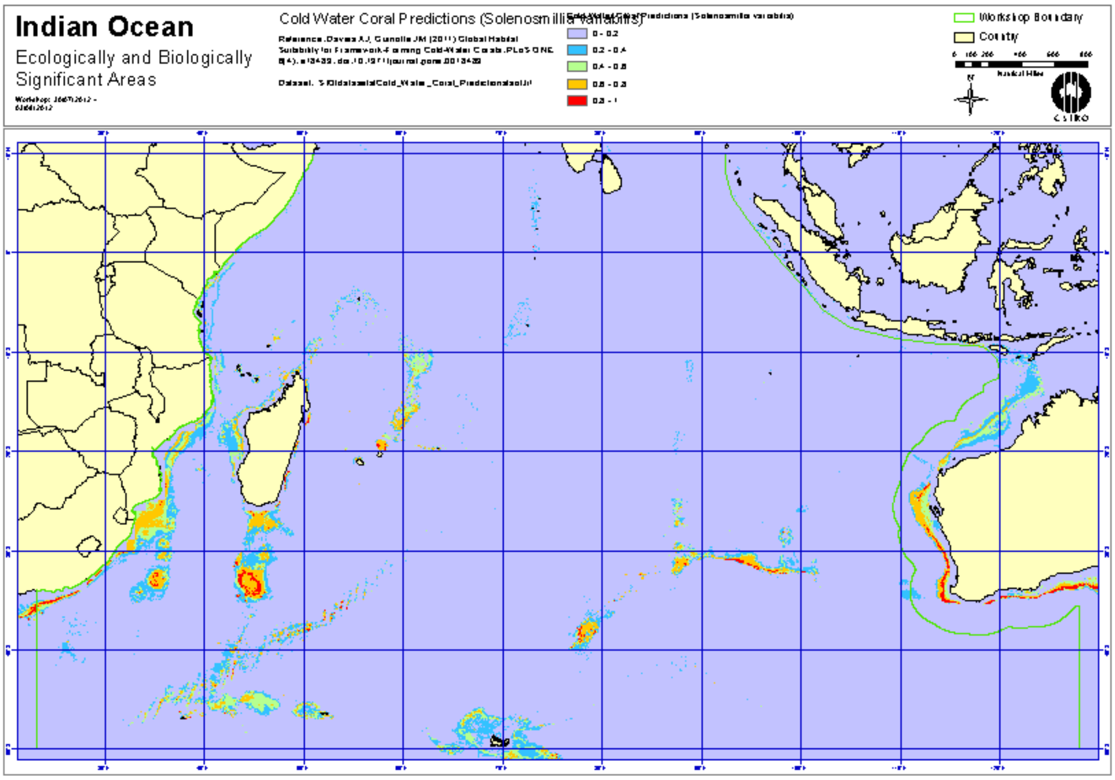

Figure 3.17: Predictions for Solenosmillia variabilis

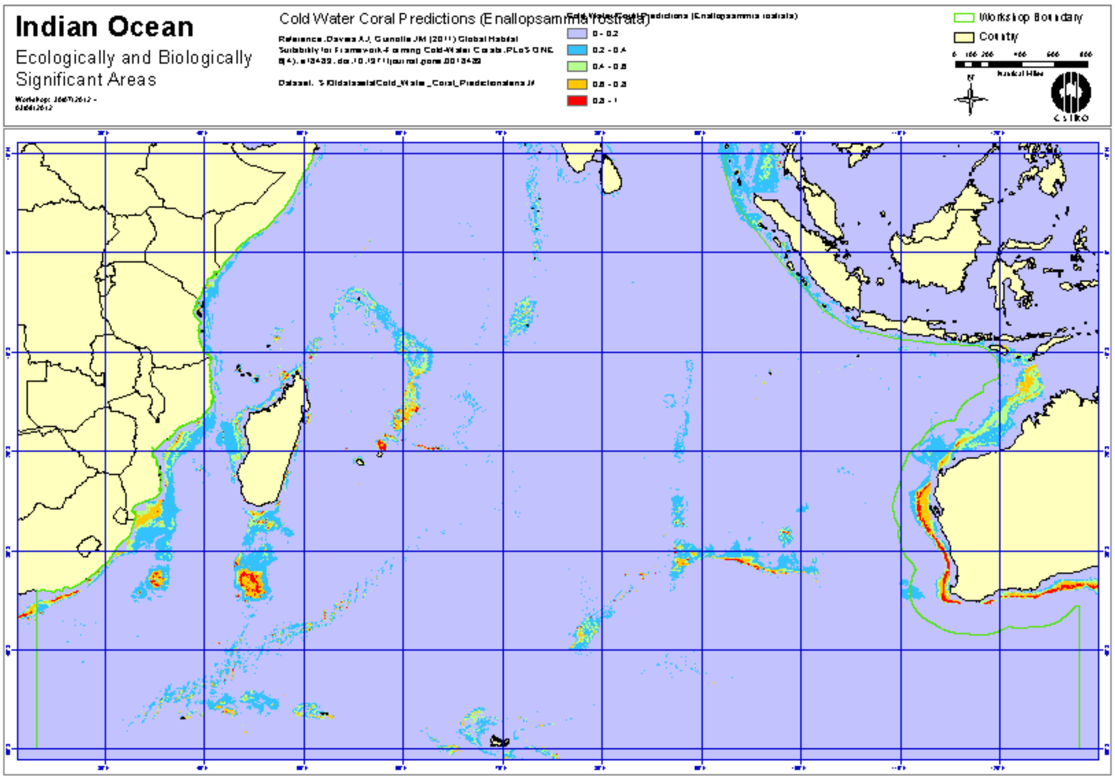

Figure 3.18: Predictions for Enallopsammia rostrata

3.7 OBIS Data

The concept of OBIS was first developed at a conference sponsored by the Census of Marine Life (CoML) in 1997. At the time, a comprehensive system for the retrieval of ocean biological data did not exist. The databases that did exist to distribute ocean biological data failed to ”usefully summarize known distributions and abundance of marine life nor are they organized to encouraged frequent use or intercomparison of datasets” (Grassle 2000). The problems generated by this disenfranchisement of marine data from the frequent user are very serious ones: if scientists cannot efficiently collect and effectively share data about the oceans with each other, how will anyone be able to generate new, comprehensive hypotheses about our oceans? If new findings about the oceans remain localized and hidden from the rest of the marine science community, then the data fails to have an impact on research in the marine science community at large.

Not long after the initial meeting, OBIS was established as a project of the Census of Marine Life to help facilitate global enfranchisement of data within the scientific community. The goal of OBIS was simple: to create ”an online, user-friendly system for absorbing, integrating, and accessing data about life in the oceans” (Grassle 2000). The system would stimulate taxonomic and systematic research and generate new hypotheses concerning: - evolutionary processes - factors related to maintainance of species distributions - roles of marine organisms in marine ecosystem function (Grassle 2000).

For the last decade, the OBIS community has worked tirelessly to make sure that all data contributed to OBIS from hundreds of providers is available to the public through its search interface. In many ways, the OBIS database has become the database that the OBIS community envisioned at its creation.

But OBIS is still evolving: OBIS hopes to become even more user friendly, appealing to both the scientific community and the common internet user. The OBIS community promotes an open access policy and believes that data collected about the oceans should be easily accessible to a diverse set of users.

The data provided here are summaries of OBIS data avaiable. Species Richness and ES(50) data summaries for 1^o grids in the Western South Pacific are provided for all species, deep species($>$100m depth), shallow species ($<$100m depth), all mammals and turtles.

http://www.iobis.org/

3.7.1 All Species

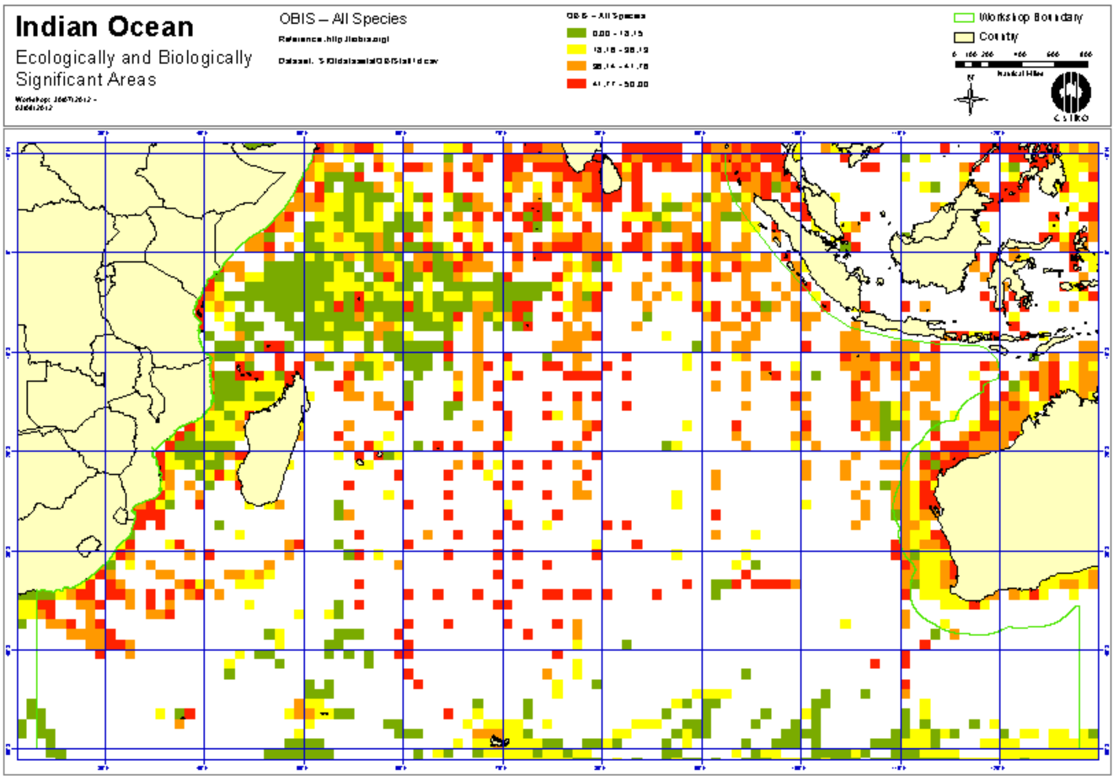

Figure 3.19: OBIS ES(50) for all species

3.7.2 Shallow Species

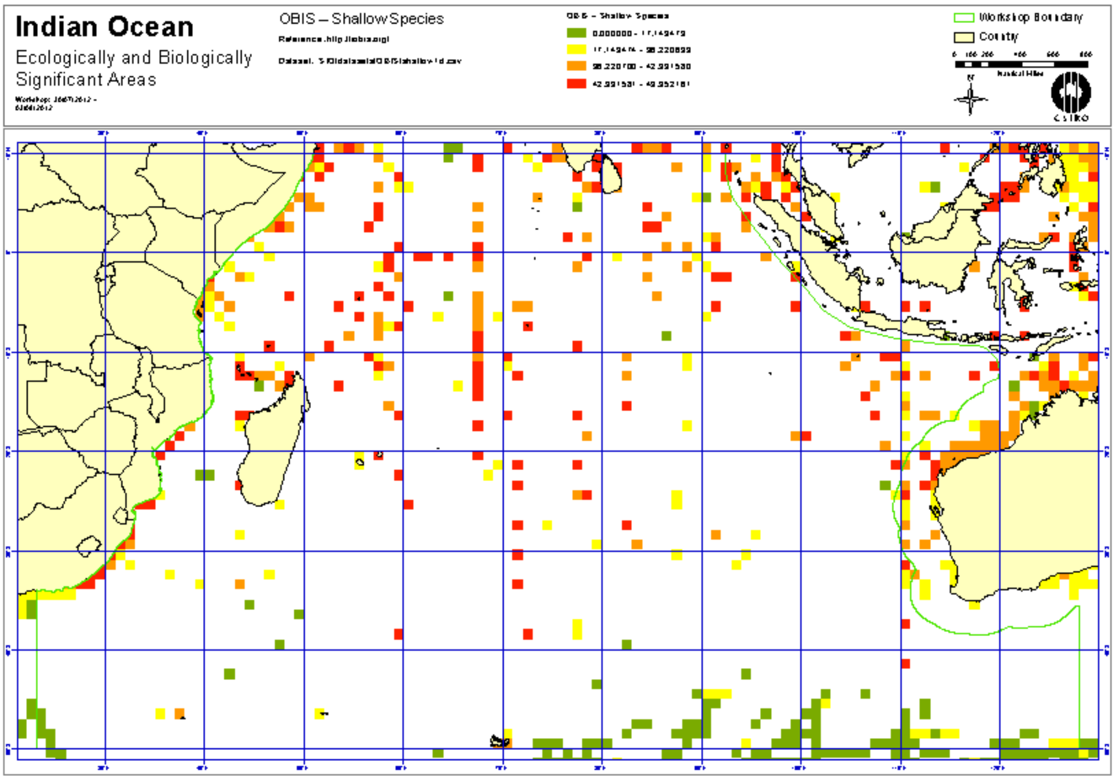

Figure 3.20: OBIS ES(50) for shallow species

3.7.3 Deep Species

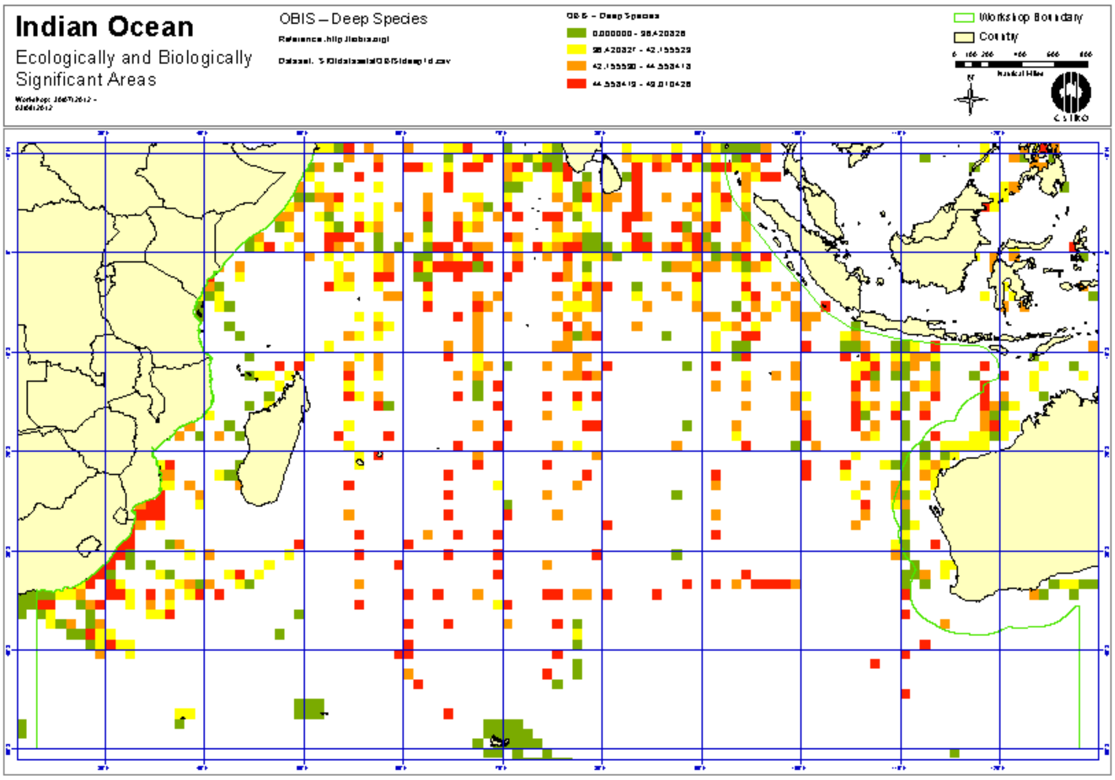

Figure 3.21: OBIS ES(50) for deep species

3.7.4 Mammals

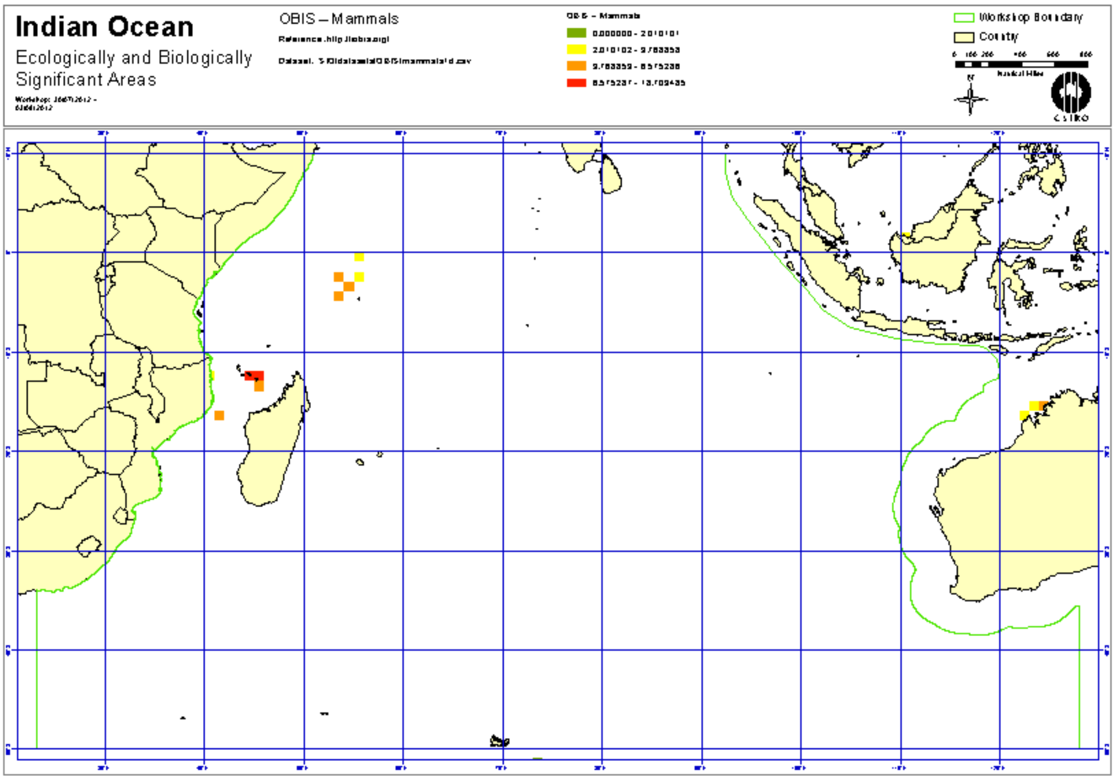

Figure 3.22: OBIS species count for mammals

3.7.5 Turtles

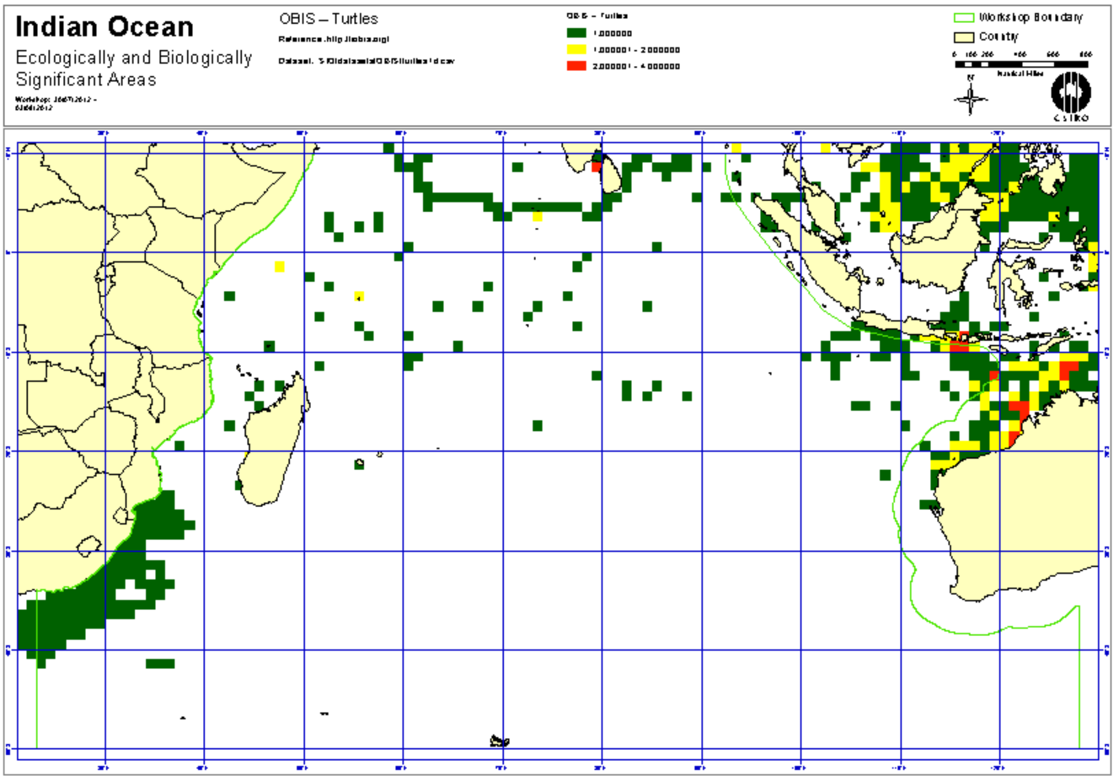

Figure 3.23: OBIS species count for turtles

3.8 Historical Whale Catches

The Wildlife Conservation Society has digitally captured the Townsend Whaling Charts that were published as a series of 4 charts with the article titled ”The distribution of certain whales as shown by logbook records of American whale ships” by Charles Haskins Townsend in the journal Zoologica in 1935.

The 4 charts (of which three are used here) show the locations of over 50,000 captures of 4 whale species; sperm whales (36,908), right whales (8,415), humpback whales (2,883) and bowhead whales(5,114). Capture locations were transcribed from North American (Yankee) pelagic whale vessel log books dating from 1761 to 1920 and plotted onto nautical charts in a Mercator projection by a cartographer. Each point plotted on the charts represents the location of a whaling ship on a day when one or more whales were taken and is symbolized by month of the year using a combination of color and open and closed circles.

Townsend and his cartographer plotted vessel locations as accurately as possible according to log book records. When plotting locations on an earlier sperm whale chart published in 1931 the cartographer spaced points where locations were very dense, extending areas slightly for a number of whaling grounds. However for charts in preparation at this time Townsend states that this difficulty is avoided by omitting some of the data, rather than extend the ground beyond actual whaling limits. We assume that this statement refers to the 1935 charts but there is still some question as to whether the cartographer did in fact space locations and thus expand whaling grounds

Digitizing errors include missed points, particularly from areas of dense chart locations, and incorrect assignment of month of capture because of difficulty distinguishing between chart colors. However to limit these errors multiple checks of digitized and chart locations were made and color enhancements of chart scans were used to ensure correct month assignments. Overall we are confident that at least 95% of catch locations have been digitized and that at least 95% of month attributes are correct.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica 19, No. 1:1-50, 4 charts.

Townsend, C.H. 1931. Where the nineteenth century whaler made his catch. Zoologica 34, No. 6:173-179.

Reeves, R., Smith, T.D. Josephson, E.A., Clapham, P.J. and Woolmer, G. 2004. Historical observations of humpback and blue whales in the North Atlantic Ocean: Clues to migratory routes and possibly additional feeding grounds. Marine Mammal Science. Vol. 20 (4), pg 774-786.

http://web.archive.org/web/20070926224128/http:/wcs.org/townsend_charts

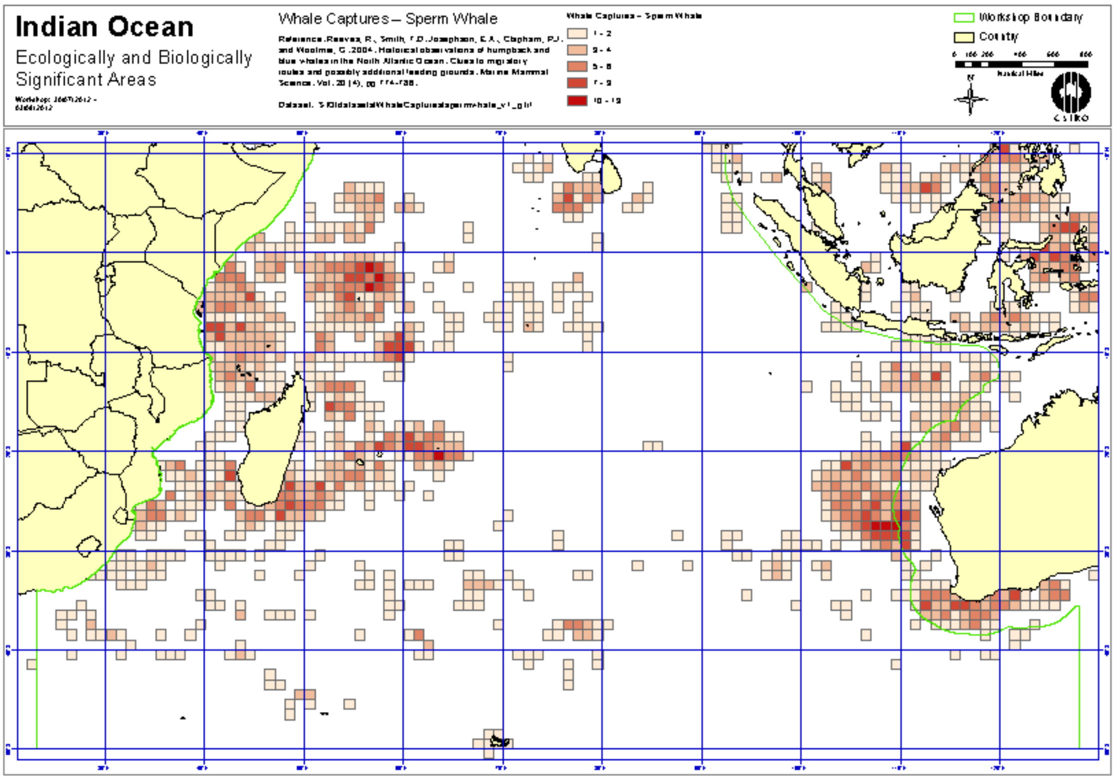

Figure 3.24: Annual Historical Captures of Sperm Whales per 1^o square

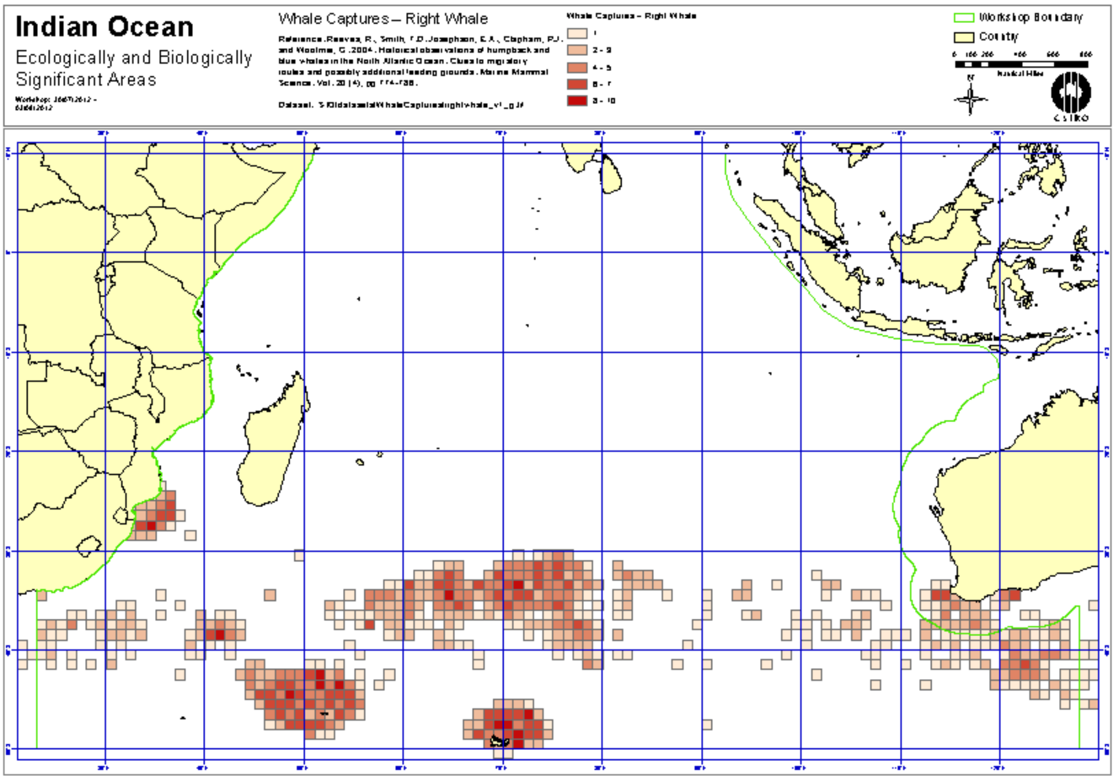

Figure 3.25: Annual Historical Captures of Right Whales per 1^o square

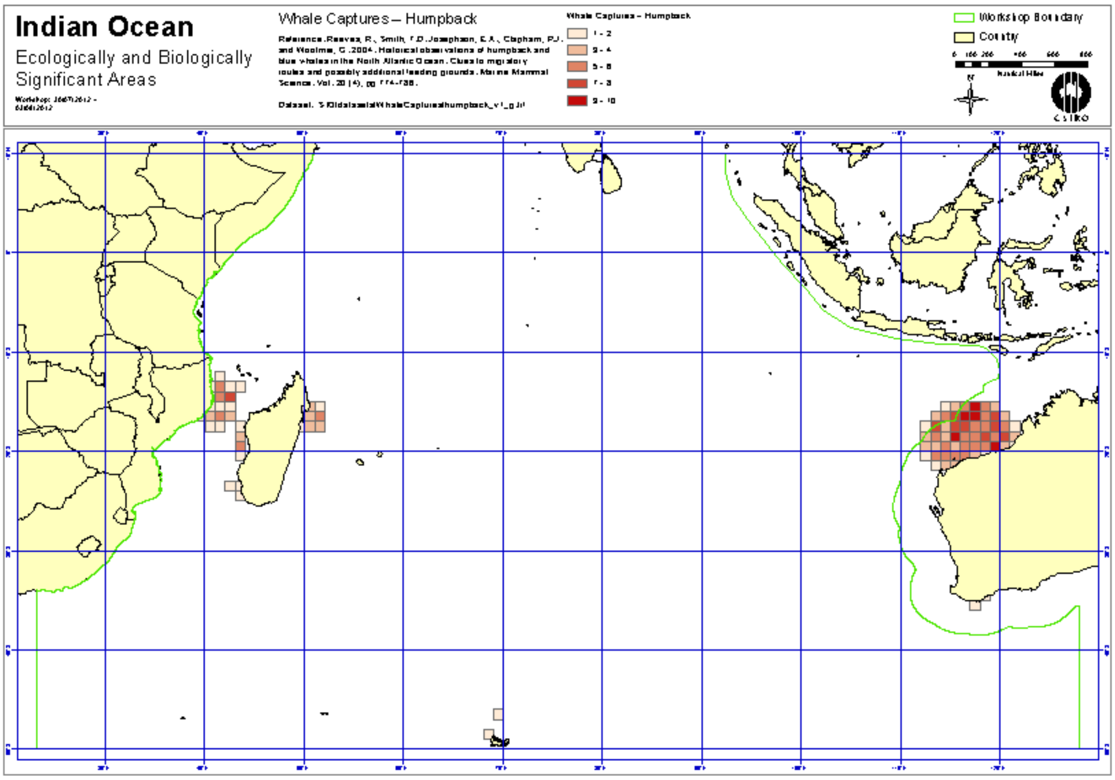

Figure 3.26: Annual Historical Captures of Humpback Whales per 1^o square

4 Physical Data

4.1 Seamount Locations

Seamounts and knolls are undersea mountains, the former rising more than 1000 m from the seafloor. These features provide important habitats for aquatic predators, demersal deep-sea fish and benthic invertebrates. However most seamounts have not been surveyed and their numbers and locations are not well known. Previous efforts to locate and quantify seamounts have used relatively coarse bathymetry grids. Here we use global bathymetric data at 30 arc-sec resolution to identify seamounts and knolls. We identify 33,452 seamounts and 138,412 knolls, representing the largest global set of identified seamounts and knolls to date. We compare estimated seamount numbers, locations, and depths with validation sets of seamount data from New Zealand and Azores. This comparison indicates the method we apply finds 94% of seamounts, but may overestimate seamount numbers along ridges and in areas where faulting and seafloor spreading creates highly complex topography. The seamounts and knolls identified herein are significantly geographically biased towards areas surveyed with ship-based soundings. As only 6.5% of the ocean floor has been surveyed with soundings it is likely that new seamounts will be uncovered as surveying improves. Seamount habitats constitute approximately 4.7% of the ocean floor, whilst knolls cover 16.3%. Regional distribution of these features is examined, and we find a disproportionate number of productive knolls, with a summit depth of o 1.5 km, located in the Southern Ocean. Less than 2% of seamounts are within marine protected areas and the majority of these are located within exclusive economic zones with few on the High Seas. The database of seamounts and knolls resulting from this study will be a useful resource for researchers and conservation planners.

Yesson, C., et al., The global distribution of seamounts based on 30 arc seconds bathymetry data. Deep-Sea Research I (2011), doi:10.1016/j.dsr.2011.02.004

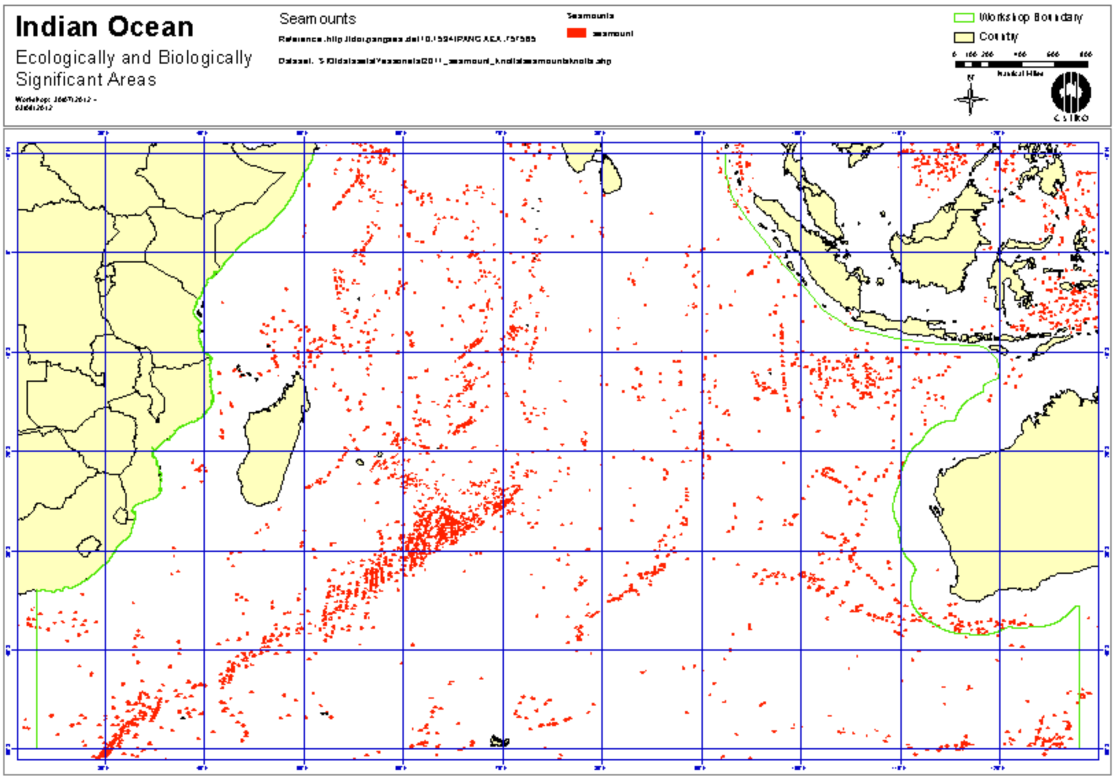

Figure 4.1: Locations of seamounts

4.2 Southern Indian Ocean Benthic Protected Areas

The South West Indian Ridge is a slowly spreading ridge system separating the African, Australian and Antarctic tectonic plates and has a unique geological structure. The seabed in this area rises from depths of 6 000 m and many of the ridges and seamounts of this chain are characterized by massive slips and faults that make bottom trawling difficult, if not impossible, at least with existing technology. As a result, only limited areas can currently be, or have historically been, fished by bottom trawls.

The locations of the benthic protected areas (BPAs) can be grouped into five main areas:

1. the Agulhas Plateau to the extreme south-east Indian Ocean
2. the South West Indian ridge in the southeastern quadrant of the Indian Ocean
3. Walters Shoal on the southerly extension of the Madagascan Ridge
4. the mid-Indian Ridge in the centre of the Indian Ocean and on
5. Broken Ridge in the southeastern Indian Ocean.

FAO (2006) MANAGEMENT OF DEMERSAL FISHERIES RESOURCES OF THE SOUTHERN INDIAN OCEAN. FAO Fisheries Circular No. 1020

4.2.1 Coral benthic protected area

This benthic feature is characterized by the extensive presence of deepwater coral on one of the seamounts (and hence the name) which rises to within 160 m of the surface on the eastern side of a spreading centre, and which extends to 6 000 m depth at its maximum.

Figure 4.2: Coral benthic protected area

4.2.2 Bridle benthic protected area

This region, in the central region of the Southwest Indian Ridge, contains a number of knolls and ridges between 900 and 1 500 m in depth and is surrounded by a substantial area of sediment in the depth range 1 5002 500 m, shown South-east as grey in the side-scan image. Most of these knolls have not been described before. There has been only limited trawl effort in the region with only small catches of orange roughy and oreo dories. There are five historically significant spawning stocks of orange roughy within 50 miles of this BPA.

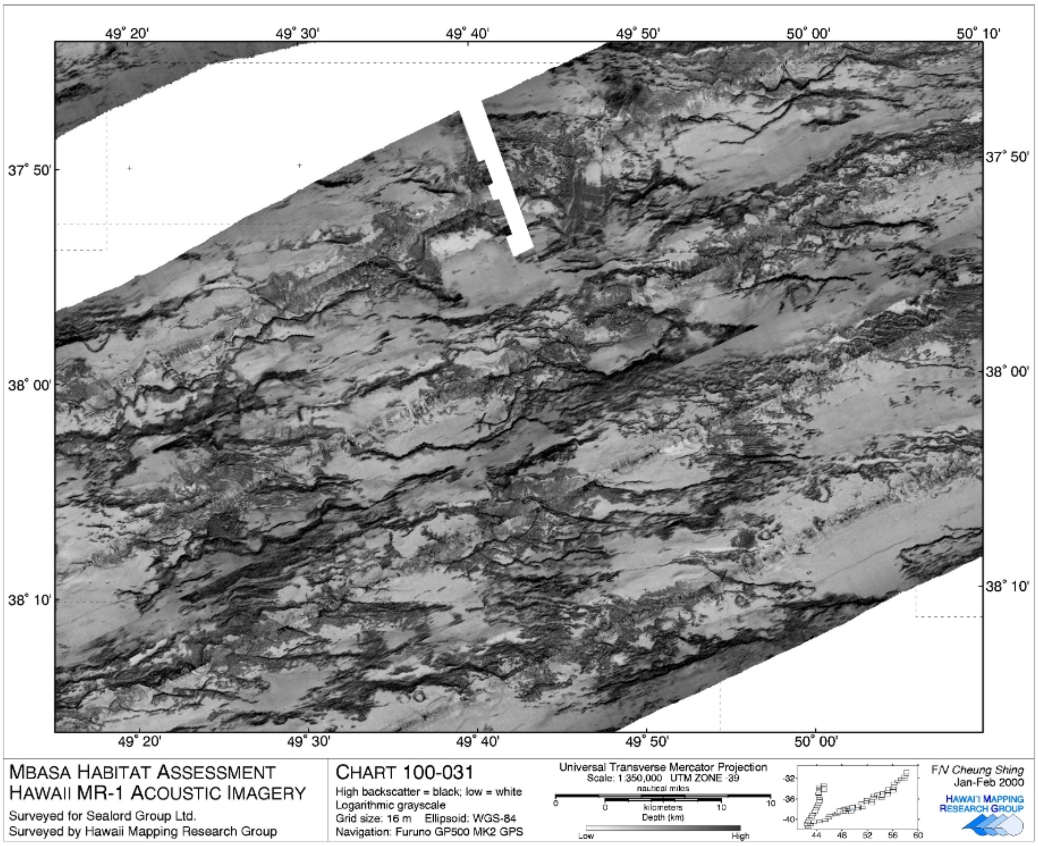

Figure 4.3: Bridle benthic protected area

4.2.3 Fools Flat and Rusky benthic protected area

Rusky benthic protected area This area has rocky extrusions and is characterized by extensive Cnidarian (black coral) coverage. Fishing on the Rusky benthic protected area is restricted to one or two tracks on the feature in the depth range 400500 m. Hence, most of the feature should not have been affected by demersal trawling. It is reported that there has been past fishing by Soviet/Ukrainian vessels across the flats in this region, about the Broken Ridge area.

Fools Flat This region is found on the southern side of Broken Ridge Plateau, to the south of the Rusky BPA. This region was chosen because of the wide range of benthic habitats that it provides. The bank shoals to around 990 m; its southern side (the edge of Broken Ridge) drops down steeply to over 4 000 m. Figures 12 and 13 show two perspectives of this bottom feature. On the southern rim of the ridge are significant stands of unknown species of coral that have elevations of 2030 m and can be seen with sidescan sonar. These, when they have been observed on vessel echo sounders, look like aggregations of fish (but they do not move) hence the term Fools Flat. There appears to be strong upwelling over the south-west boundary and this no doubt has resulted in favourable conditions for the growth of the deepwater corals.

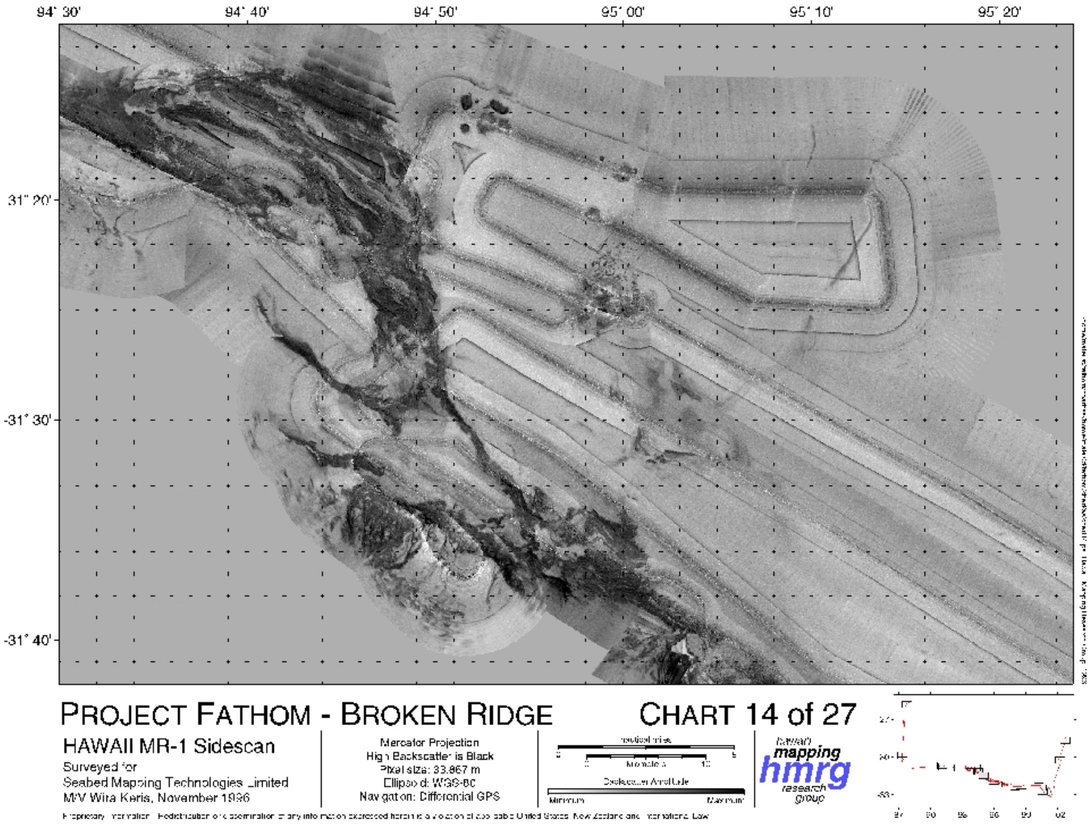

Figure 4.4: Fools Flat and Rusky benthic protected area

4.2.4 East Broken Ridge

This guyot is located at the eastern end of Broken Ridge and is characterized by numerous slips and canyons extending down the sides. It rises from 3 000 m to a depth of 1 060 m. As far as is known it has not been previously described and has not been trawled. Exploration for fish aggregations has been undertaken, but only for one day. The seamount appears to have suitable environmental conditions for the deepwater species of fish that typically occur in the area. It is believed to be biologically pristine and its benthos and topography, which is highly fractured and, in the view of many skippers, makes demersal trawling impossible, is previously undescribed. There are some indications that this feature may have been above sea level at some time in the past.

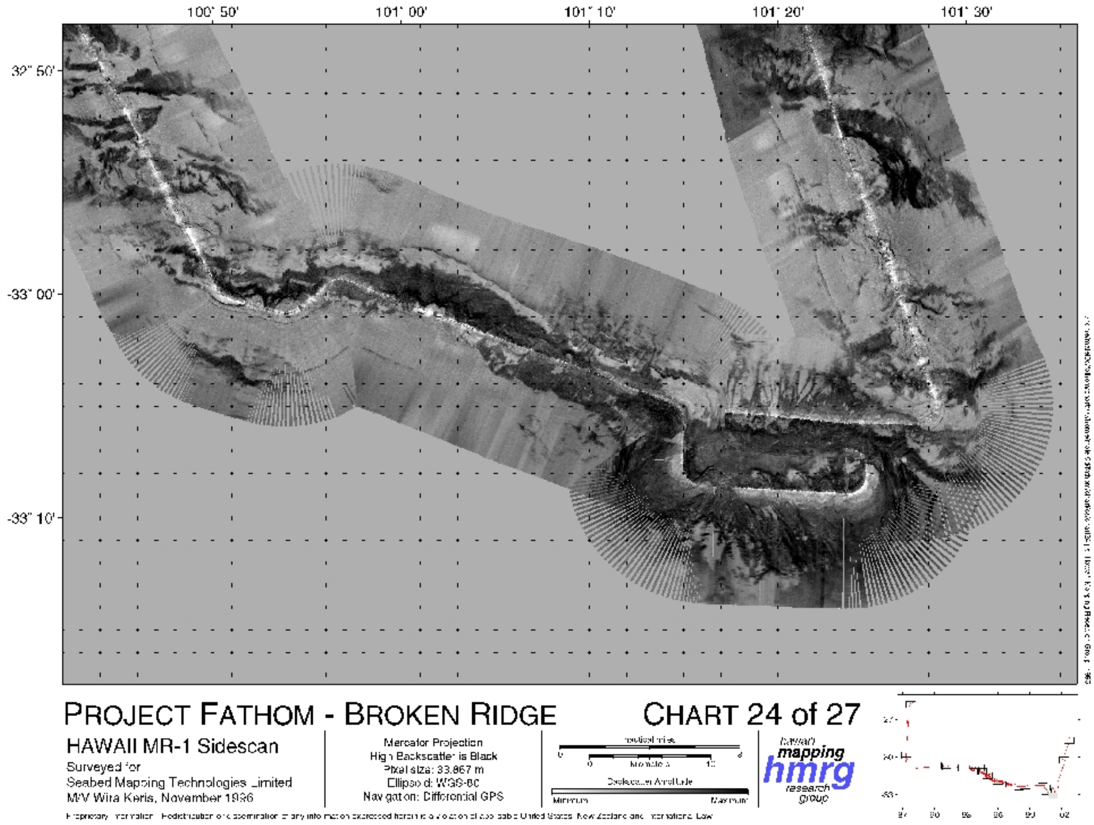

Figure 4.5: East Broken Ridge benthic protected area

4.3 Global Seascapes

Designing a representative network of high seas marine protected areas (MPAs) requires an acceptable scheme to classify the benthic (as well as the pelagic) bioregions of the oceans. Given the lack of sufficient biological information to accomplish this task, we used a multivariate statistical method with 6 biophysical variables (depth, seabed slope, sediment thickness, primary production, bottom water dissolved oxygen and bottom temperature) to objectively classify the ocean floor into 53,713 separate polygons comprising 11 different categories, that we have termed seascapes. A cross-check of the seascape classification was carried out by comparing the seascapes with existing maps of seafloor geomorphology and seabed sediment type and by GIS analysis of the number of separate polygons, polygon area and perimeter/area ratio. We conclude that seascapes, derived using a multivariate statistical approach, are biophysically meaningful subdivisions of the ocean floor and can be expected to contain different biological associations, in as much as different geomorphological units do the same. Less than 20% of some seascapes occur in the high seas while other seascapes are largely confined to the high seas, indicating specific types of environment whose protection and conservation will require international cooperation. Our study illustrates how the identification of potential sites for high seas marine protected areas can be accomplished by a simple GIS analysis of seafloor geomorphic and seascape classification maps. Using this approach, maps of seascape and geomorphic heterogeneity were generated in which heterogeneity hotspots identify themselves as MPA candidates. The use of computer aided mapping tools removes subjectivity in the MPA design process and provides greater confidence to stakeholders that an unbiased result has been achieved.

Harris and Whiteway 2009. High seas marine protected areas: Benthic environmental conservation priorities from a GIS analysis of global ocean biophysical data.Ocean & Coastal Management 52 2238. doi:10.1016/j.ocecoaman.2008.09.009
http://www.gebco.net/data_and_products/gridded_bathymetry_data/
http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html
http://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

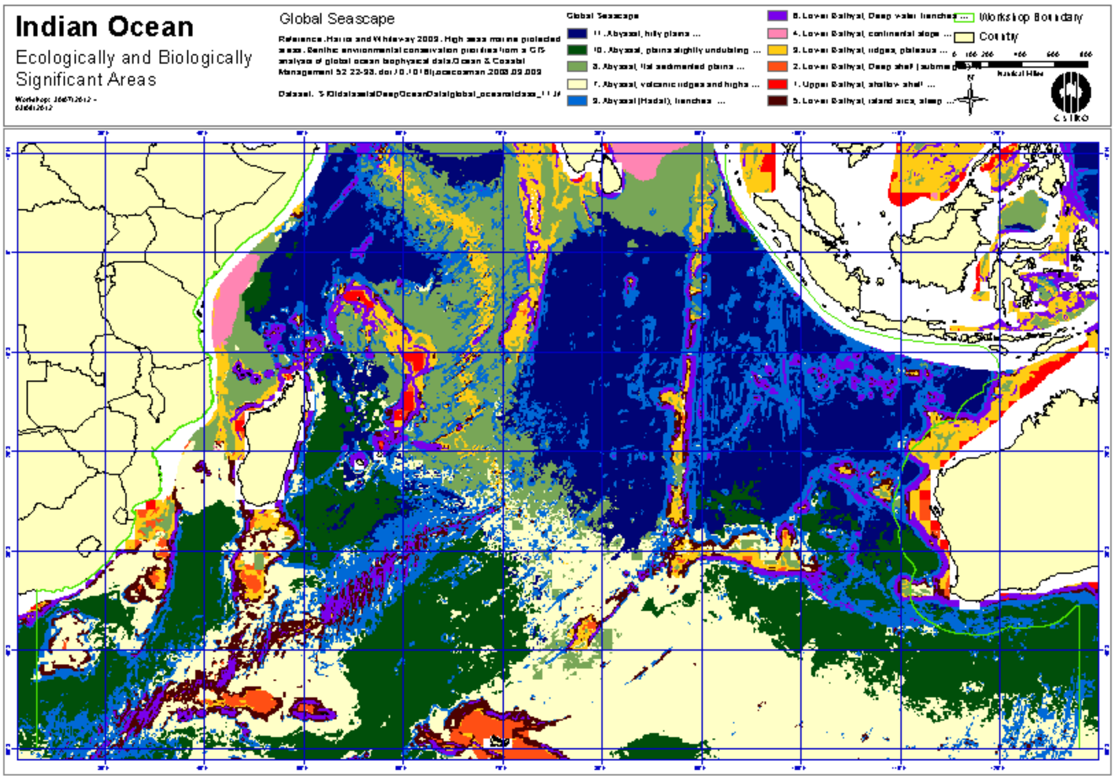

Figure 4.6: Derived Global Seascapes

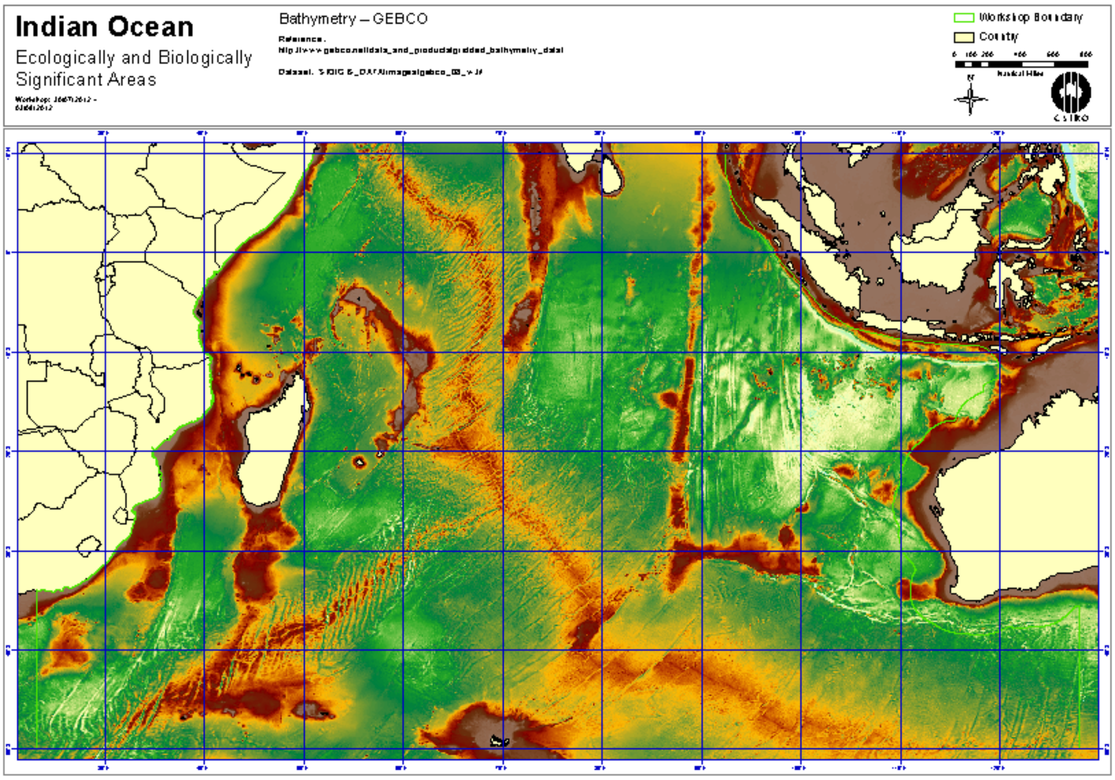

Figure 4.7: GEBCO, a global 30 arc-second grid largely generated by combining quality-controlled ship depth soundings with interpolation between sounding points guided by satellite-derived gravity data. However, in areas where they improve on the existing GEBCO 08 grid, data sets generated by other methods have been included. Land data are largely based on the Shuttle Radar Topography Mission (SRTM30) gridded digital elevation model.

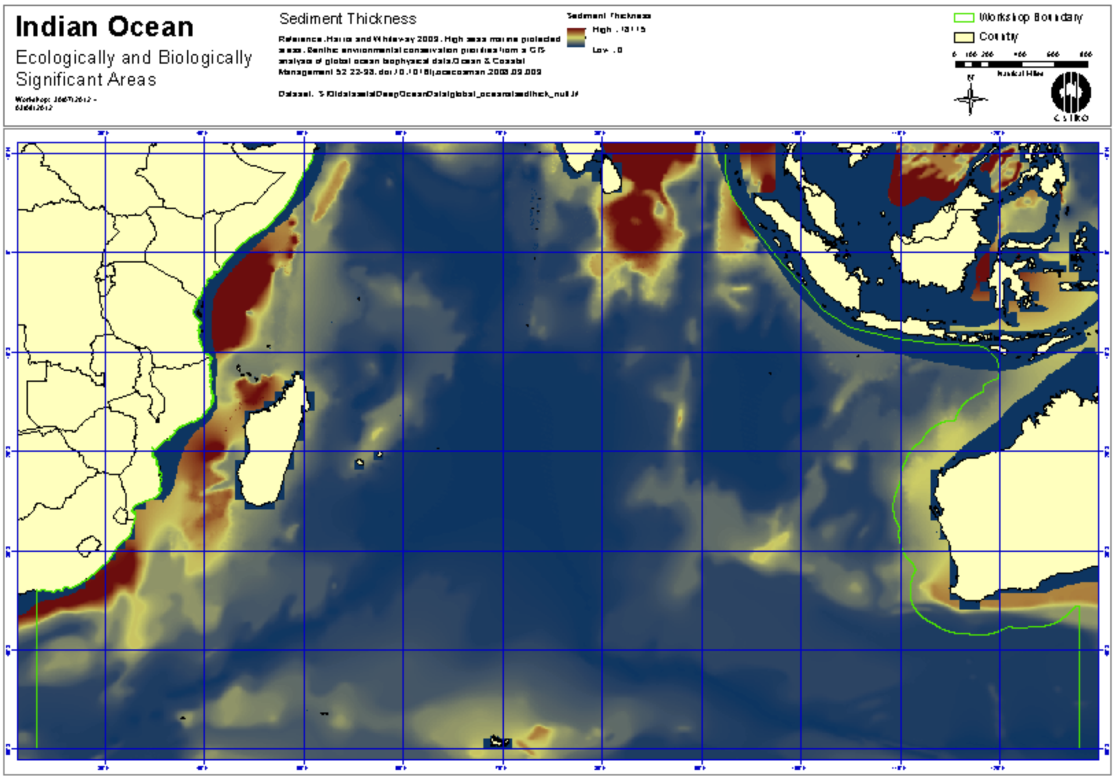

Figure 4.8: Total Sediment Thickness of the Worlds Oceans & Marginal Seas is a digital total sediment thickness database for the worlds oceans and marginal seas compiled by the National Geophysical Data Center (NGDC). The 5 min (w9 km) grid of sediment thickness data were derived from a number of sources by Divins [24]. Note data gaps occur in the area south of Japan, in the Arctic Ocean and Mediterranean Sea, which are not included in this analysis. Sediment thickness Divins DL. National geophysical data center total sediment thickness of the world's oceans and marginal seas.

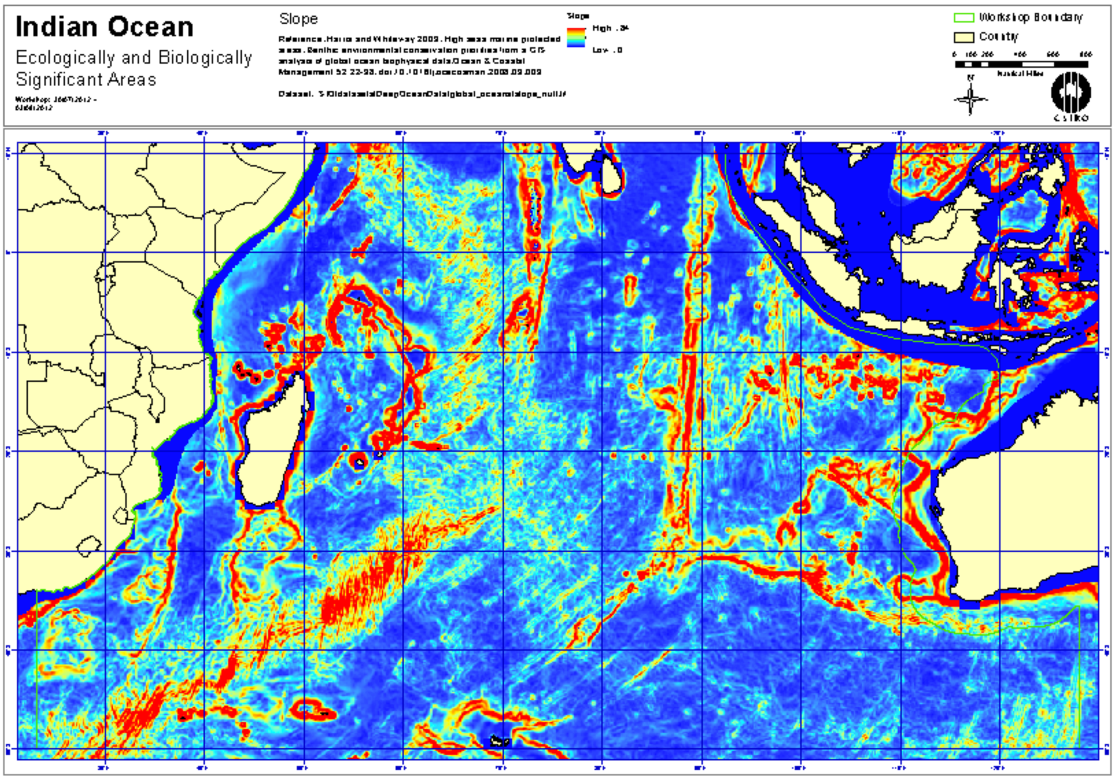

Figure 4.9: Map showing the distribution of seabed slope. Derivation of seabed slope from the ETOPO-2 bathymetry grid used an algorithm in ArcGIS that calculates the maximum slope in a grid cell from the surrounding 8 cells. We found this method gave unrealistically high slope values, presumably due to the noise inherent in the ETOPO-2 bathymetry grid which is accentuated when the maximum slope values between adjacent cells are measured. In order to produce a more realistic estimate of slope, we first smoothed the ETOPO-2 bathymetry grid using a 10-cell moving average filter which we found gave reasonable slope values. Slope derived from ETOPO-2. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center. 2-minute Grided Global Relief Data; 2006.

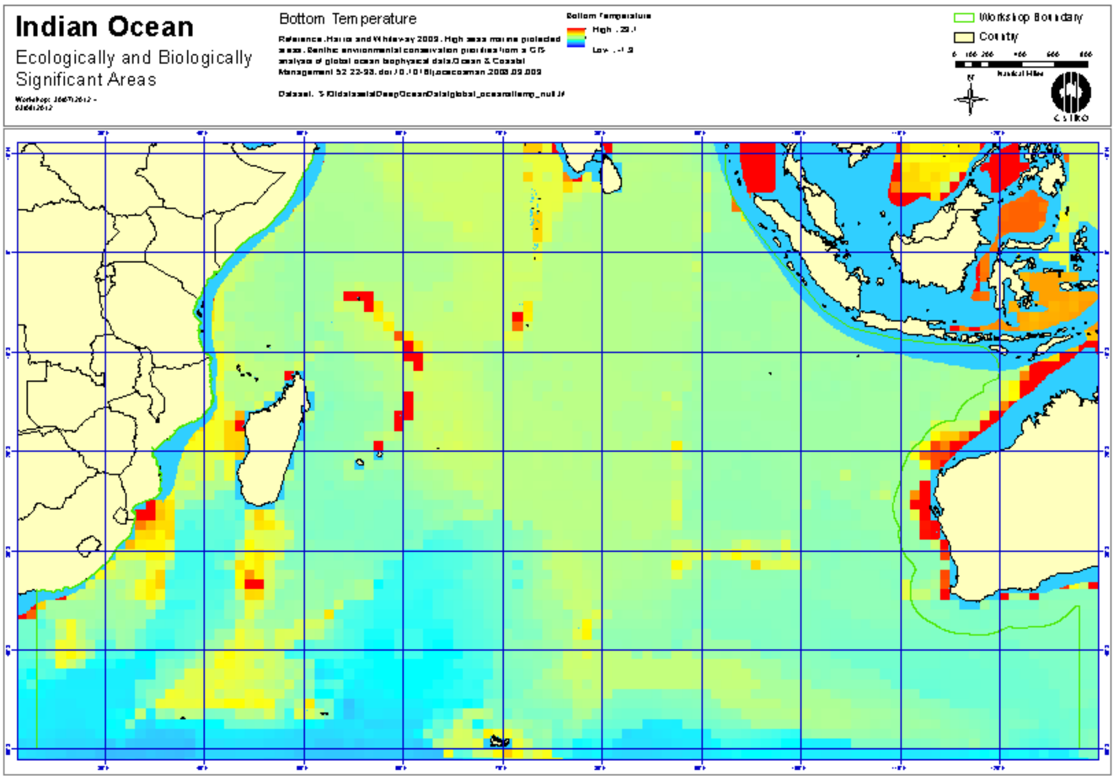

Figure 4.10: Ocean bottom water temperature from the NOAA World Ocean Atlas

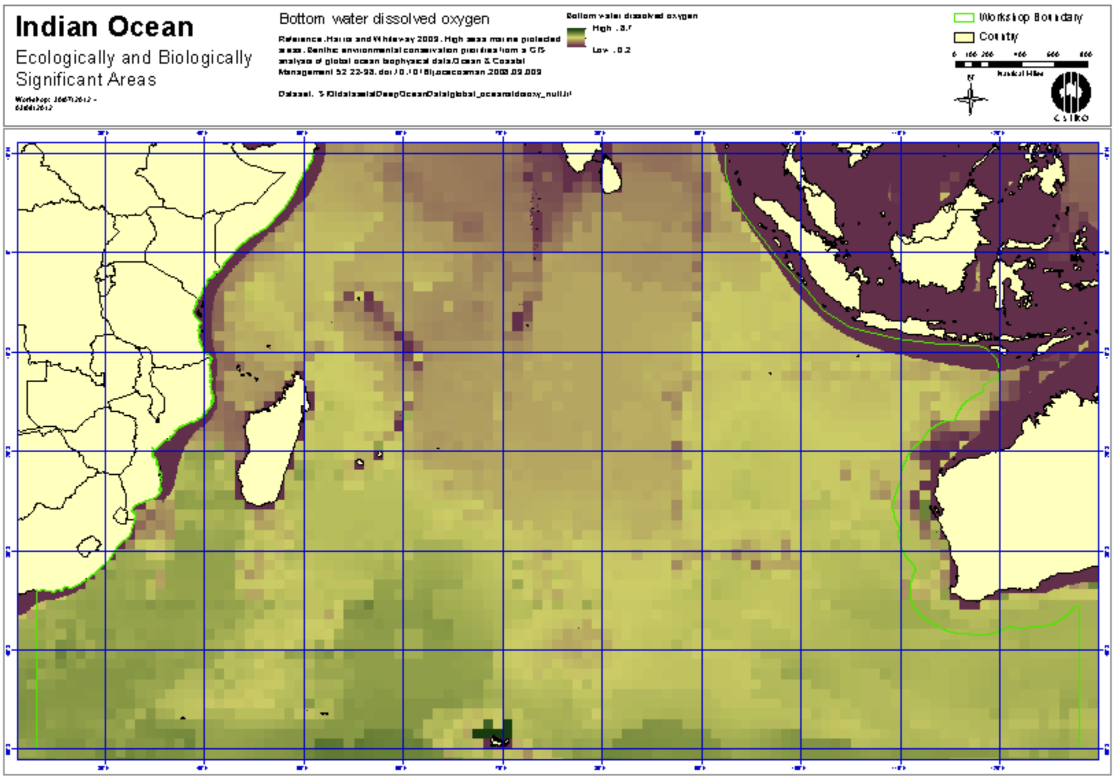

Figure 4.11: Ocean bottom water dissolved oxygen from the NOAA World Ocean Atlas

4.4 Distribution of Canyons

The aim of this study is to assess the global occurrence of large submarine canyons to provide context and guidance for discussions regarding canyon occurrence, distribution, geological and oceanographic significance and conservation. Based on an analysis of the ETOPO1 data set, this study has compiled the first inventory of 5849 separate large submarine canyons in the world ocean. Active continental margins contain 15% more canyons (2586, equal to 44.2% of all canyons) than passive margins (2244, equal to 38.4%) and the canyons are steeper, shorter, more dendritic and more closely spaced on active than on passive continental margins. This study confirms observations of earlier workers that a relationship exists between canyon slope and canyon spacing (increased canyon slope correlates with closer canyon spacing). The greatest canyon spacing occurs in the Arctic and the Antarctic whereas canyons are more closely spaced in the Mediterranean than in other areas. River-associated, shelf-incising canyons are more numerous on active continental margins (n = 119) than on passive margins (n = 34). They are most common on the western margins of South and North America where they comprise 11.7% and 8.6% of canyons respectively, but are absent from the margins of Australia and Antarctica. Geographic areas having relatively high rates of sediment export to continental margins, from either glacial or fluvial sources operating over geologic timescales, have greater numbers of shelf-incising canyons than geographic areas having relatively low rates of sediment export to continental margins. This observation is consistent with the origins of some canyons being related to erosive turbidity flows derived from fluvial and shelf sediment sources. Other workers have shown that benthic ecosystems in shelf-incising canyons contain greater diversity and biomass than non-incising canyons, and that ecosystems located above 1500 m water depth are more vulnerable to destructive fishing practices (bottom trawling) and ocean acidification caused by anthropogenic climate change. The present study provides the means to assess the relative significance of canyons located in different geographic regions. On this basis, the importance of conservation for submarine canyon ecosystems is greater for Australia, islands and northeast Asia than for other regions. Three different types were identified; (1) incise the shelf and connect to rivers, (2) incise the shelf and (3) confined to the slope.

Harris and Whiteway 2011. Global distribution of large submarine canyons: Geomorphic differences between active and passive continental margins. Marine Geology 285 (2011) 6986. doi:10.1016/j.margeo.2011.05.008

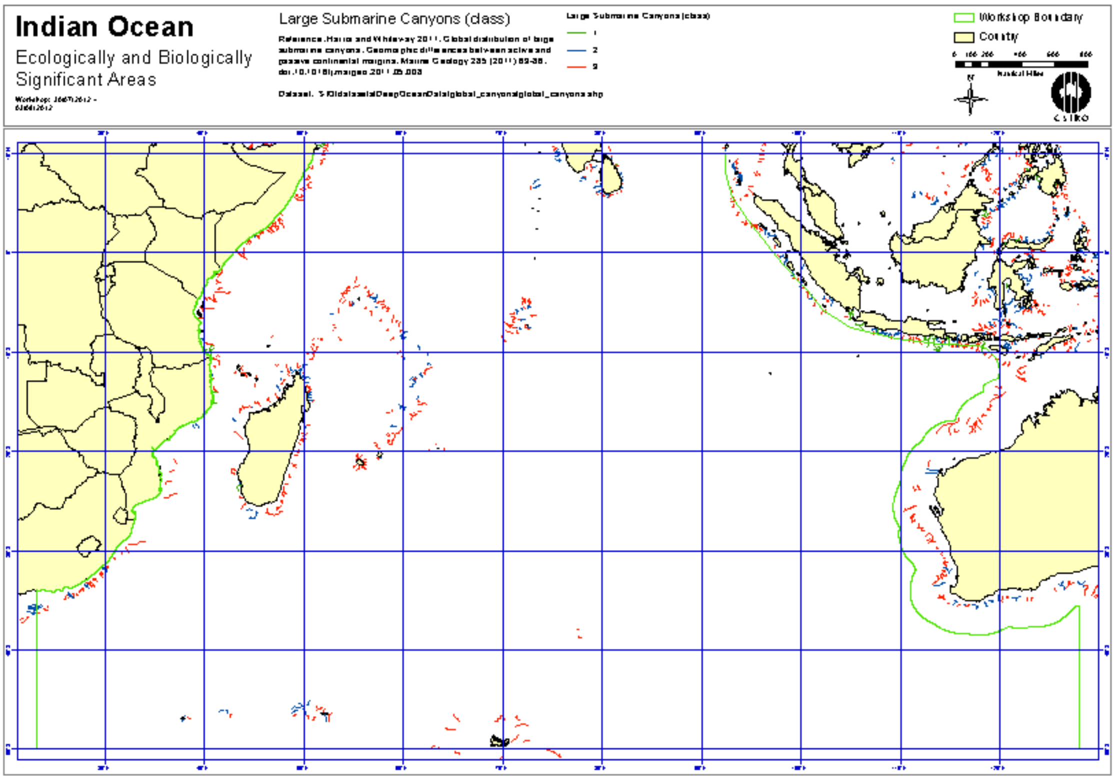

Figure 4.12: Large Submarine Canyons

4.5 Vents and Seeps

ChEss (Chemosynthetic Ecosystem Science) was a field project of the Census of Marine Life programme (CoML). The main aim of ChEss was to determine the biogeography of deep-water chemosynthetic ecosystems at a global scale and to understand the processes driving these ecosystems. ChEss addressed the main questions of CoML on diversity, abundance and distribution of marine species, focusing on deep-water reducing environments such as hydrothermal vents, cold seeps, whale falls, sunken wood and areas of low oxygen that intersect with continental margins and seamounts. Since the discovery of hydrothermal vents in 1977 and of cold seep communities in 1984, over 500 species from vents and over 200 species from seeps have been described (Van Dover et al., 2002. Science 295: 1253-1257). The discovery of chemosynthetically fuelled communities on benthic OMZs and large organic falls to the deep-sea such as whales and wood have increased the number of habitats and fauna for investigation. New species are continuously being discovered and described from sampling programmes around the globe and therefore ChEssBase is in active development and new data are being entered periodically. Currently, ChEssBase includes data on 1739 species from 193 chemosynthetic sites around the globe. These data contain information (when available) on the taxonomy, diagnosis, trophic level, reproduction, endemicity and habitat types and distribution. There are now 1879 papers in our reference database.
http://www.noc.soton.ac.uk/chess/database/db_home.php

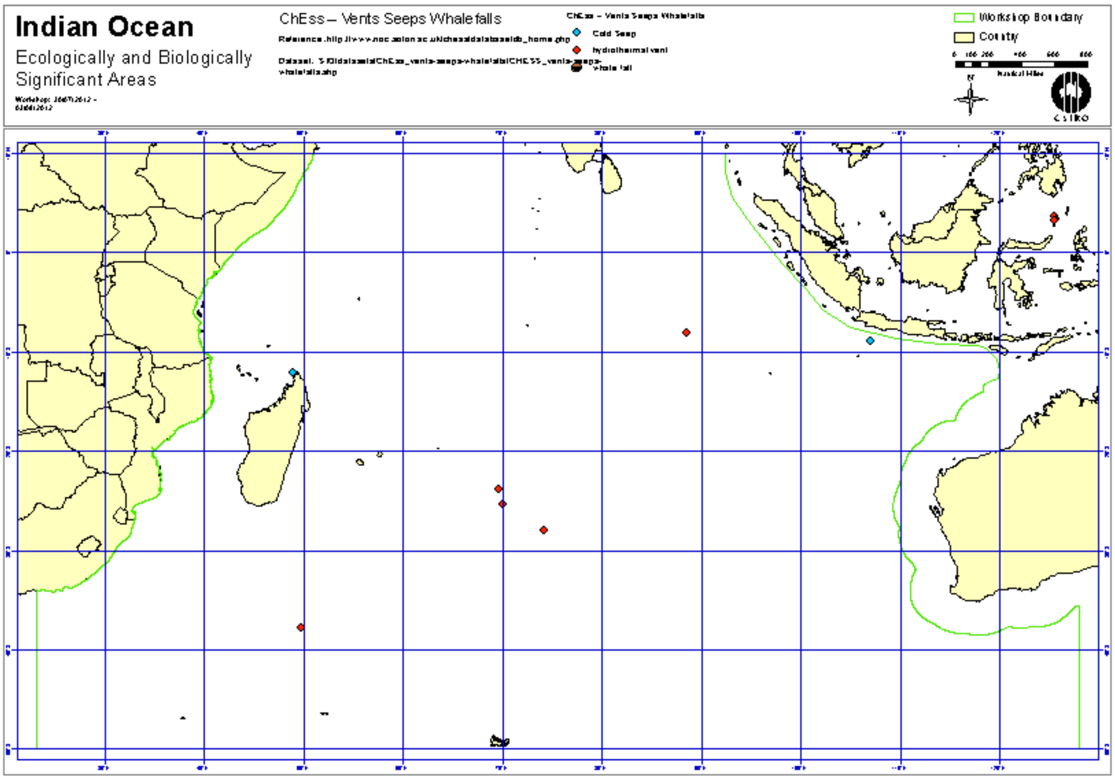

Figure 4.13: Vents and Seeps

The ultraslow-spreading Southwest Indian Ridge is a major tectonic province, representing one of the important end-member mid-ocean-ridge types for its very slow and oblique spreading, and providing the only known route for migration of chemosynthetic deep-sea vent fauna between the Atlantic and Indian Oceans. We report the investigation of the first active high temperature hydrothermal field found on any ultraslow mid-ocean ridge worldwide. Located on Southwest Indian Ridge at 3747S, 4939E, it consists of three zones extending 1000 m laterally, and it is one of four recently discovered active and inactive vent sites within a 250-km long magmatically robust section. Our results provide the first direct evidence for potentially widespread distribution of hydrothermal activity along ultraslow-spreading ridgesat least along magmatically robust segments. This implies that the segment sections with excess heat from enhanced magmatism and suitable crustal permeability along slow and ultraslow ridges might be the most promising areas for searching for hydrothermal activities. It is surprising that the special vent fauna appear to indicate some complex affinity to those on the Central Indian Ridge, southern Mid-Atlantic Ridge, and the southwest Pacific Ocean.

Chunhui Tao et al. (2012) First active hydrothermal vents on an ultraslow-spreading center:Southwest Indian Ridge. GEOLOGY, 40(1): 4750; doi:10.1130/G32389

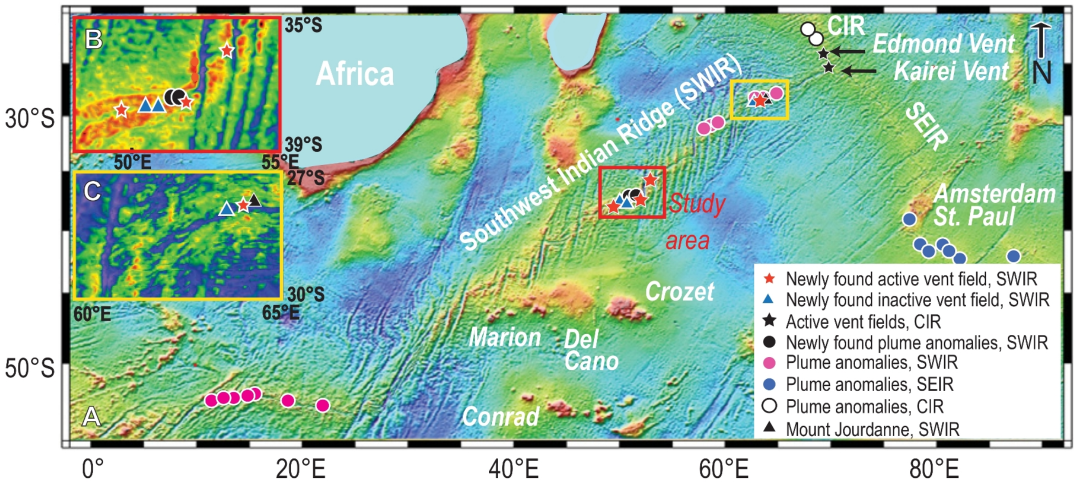

Figure 4.14: Location of the study area on the Southwest Indian Ridge (SWIR). A: Study area (red box) is in the central eastern part of the SWIR, 900 km north of the Crozet hotspot (satellite gravimetric map). Black stars are the two known active fields: Kairei (Hashimoto et al., 2001) and Edmond (Van Dover et al., 2001) sites, on the Central Indian Ridge (CIR). Circles are the hydrothermal anomalies located along the SWIR, CIR, and Southeast Indian Ridge (SEIR) (German et al., 1998; Mnch et al., 2001; German, 2003; Fujimoto et al., 1999; Bach et al., 2002; Lin and Zhang, 2006; Tao et al., 2009; Herzig and Pluger, 1988; Scheirer et al., 1998; Plger et al., 1990). Red stars and blue triangles are newly found active and inactive vent fields, respectively. B and C: Close-up maps of the two study areas on the SWIR near 47E55E (B) and 60E65E (C), respectively (bathymetric map).

4.6 Physical Ocean Climatologies

4.6.1 Temperature Climatology (degrees C)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

A number of global ocean climatologies are presently available, such as NODC's World Ocean Atlas. CARS is different as it employs extra stages of in-house quality control of input data, and uses an adaptive-lengthscale loess mapper to maximise resolution in data-rich regions, and the mapper's "BAR" algorithm takes account of topographic barriers. The result is excellent definition of oceanic structures and accuracy of point values.

http://www.marine.csiro.au/~dunn/cars2009/

CARS2009 covers the full global oceans on a 1/2 degree grid, but until June 2011 only included temperature and salinity fields. The T and S fields were created in July 2009 and were was based on World Ocean Database 2005 (WOD05) [July 2008 Update], surface-pressure-corrected Argo global archives to May 2009, WOCE Global Hydrographic Program (v3.0), and many other datasets available up to 2008. See the updates section below for history of occasional subversion releases. The nutrient fields created in June 2011 were based on WOCE and WOD09 (March 2011 download).

References - primary CARS citation:

Ridgway K.R., J.R. Dunn, and J.L. Wilkin, Ocean interpolation by four-dimensional least squares -Application to the waters around Australia, J. Atmos. Ocean. Tech., Vol 19, No 9, 1357-1375, 2002

- algorithm details:

Dunn J.R., and K.R. Ridgway, Mapping ocean properties in regions of complex topography, Deep Sea Research I : Oceanographic Research, 49 (3) (2002) pp. 591-604 - CARS seasonal fields and MLD:

Scott A. Condie and Jeff R. Dunn (2006) Seasonal characteristics of the surface mixed layer in the Australasian region: implications for primary production regimes and biogeography. Marine and Freshwater Research, 2006, 57, 1-22.

Metadata

CARS2009 metadata record: MarLIN record: 8539, Anzlic identifier: ANZCW0306008539

The webpage is itself the authoritative reference for CARS2009.

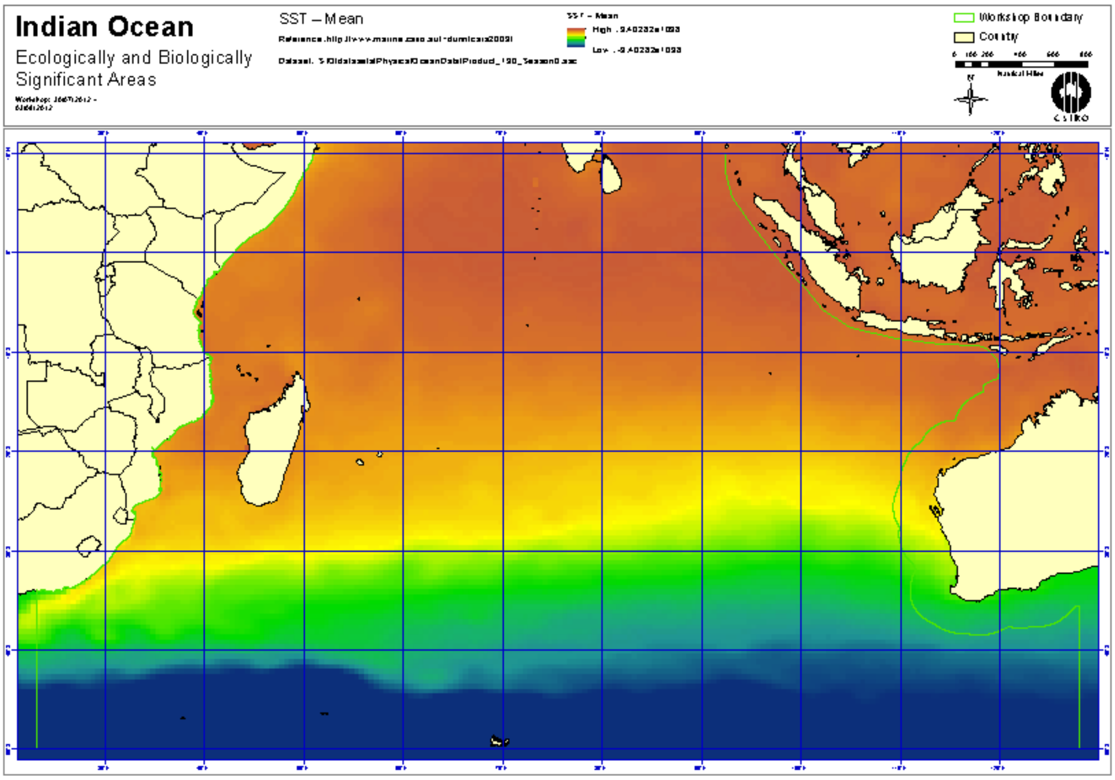

Figure 4.15: Annual SST

4.6.2 Salinity Climatology (PSU)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

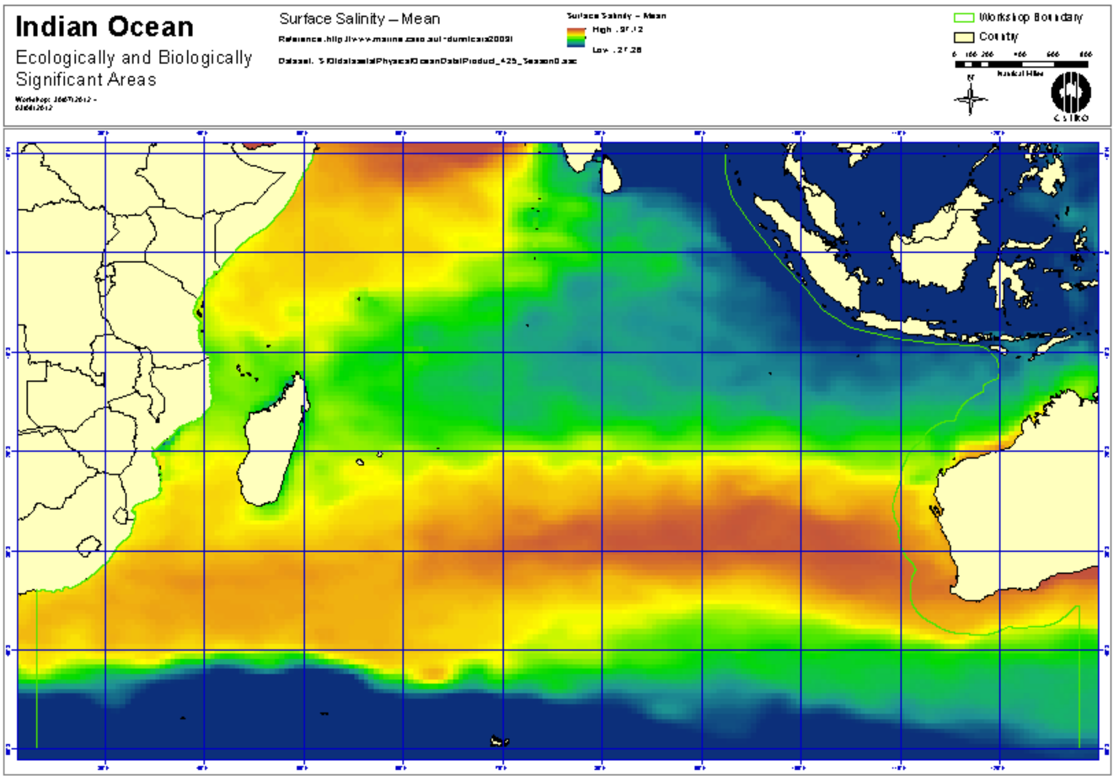

Figure 4.16: Annual Salinity

4.6.3 Oxygen Climatology (ml/l)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

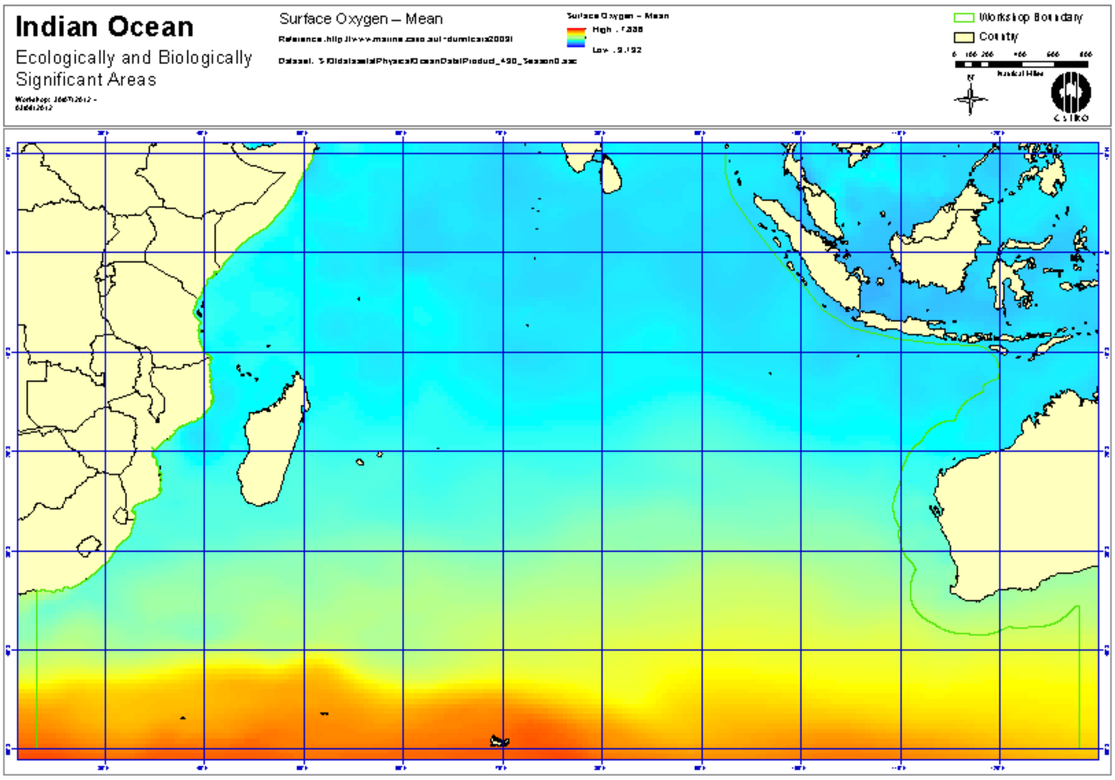

Figure 4.17: Annual Oxygen

4.6.4 Nitrate Climatology (uM)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

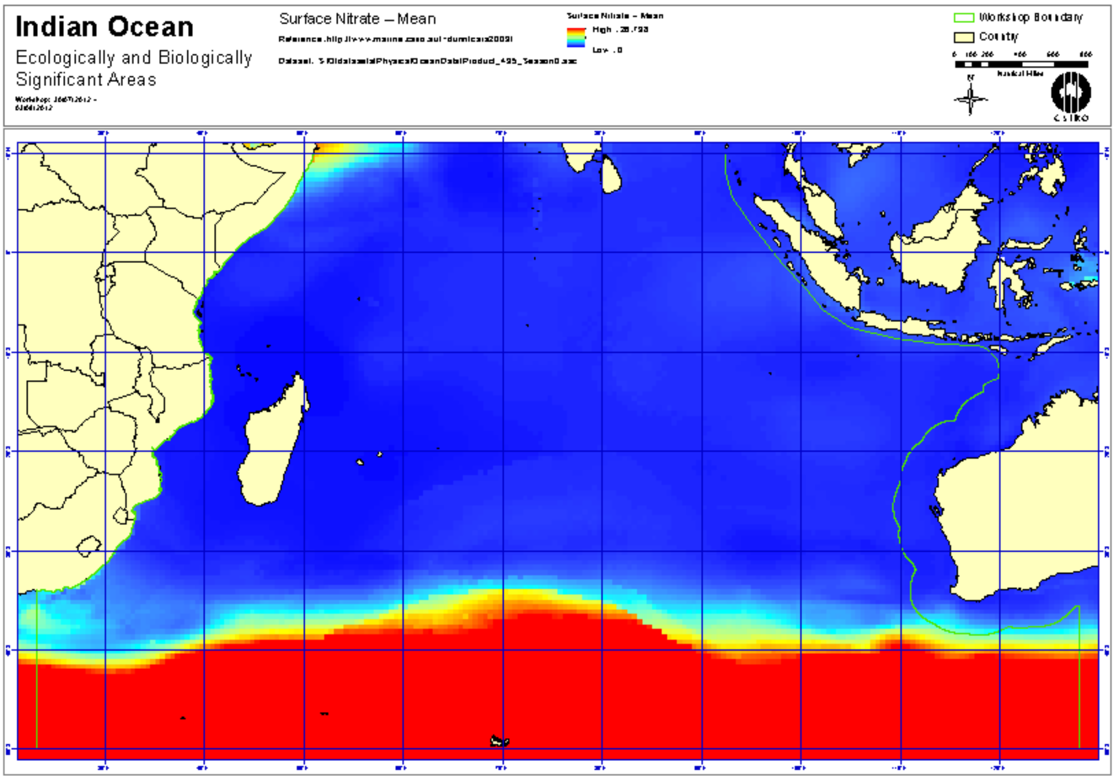

Figure 4.18: Annual Nitrate

4.6.5 Silicate Climatology (uM)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

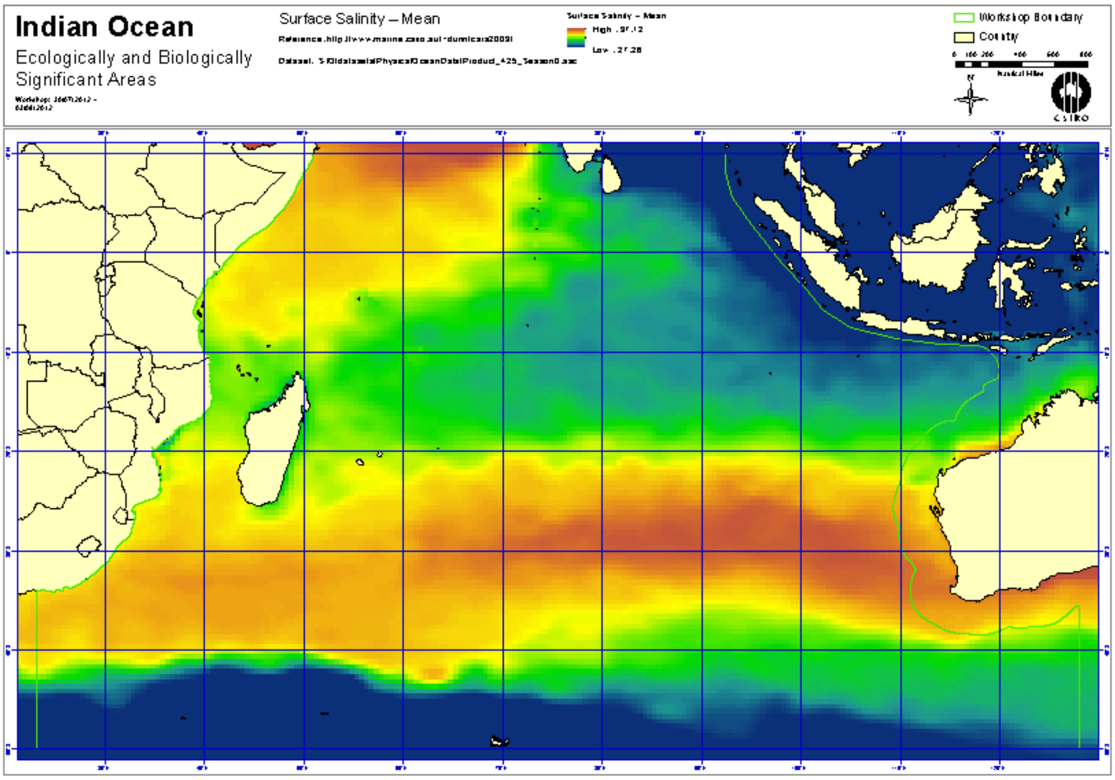

Figure 4.19: Annual Silicate

4.6.6 Phosphate Climatology (uM)

CARS is a digital climatology, or atlas of seasonal ocean water properties. It comprises gridded fields of mean ocean properties over the period of modern ocean measurement, and average seasonal cycles for that period. It is derived from a quality-controlled archive of all available historical subsurface ocean property measurements - primarily research vessel instrument profiles and autonomous profiling buoys. As data availability has enormously increased in recent years, the CARS mean values are inevitably biased towards the recent ocean state.

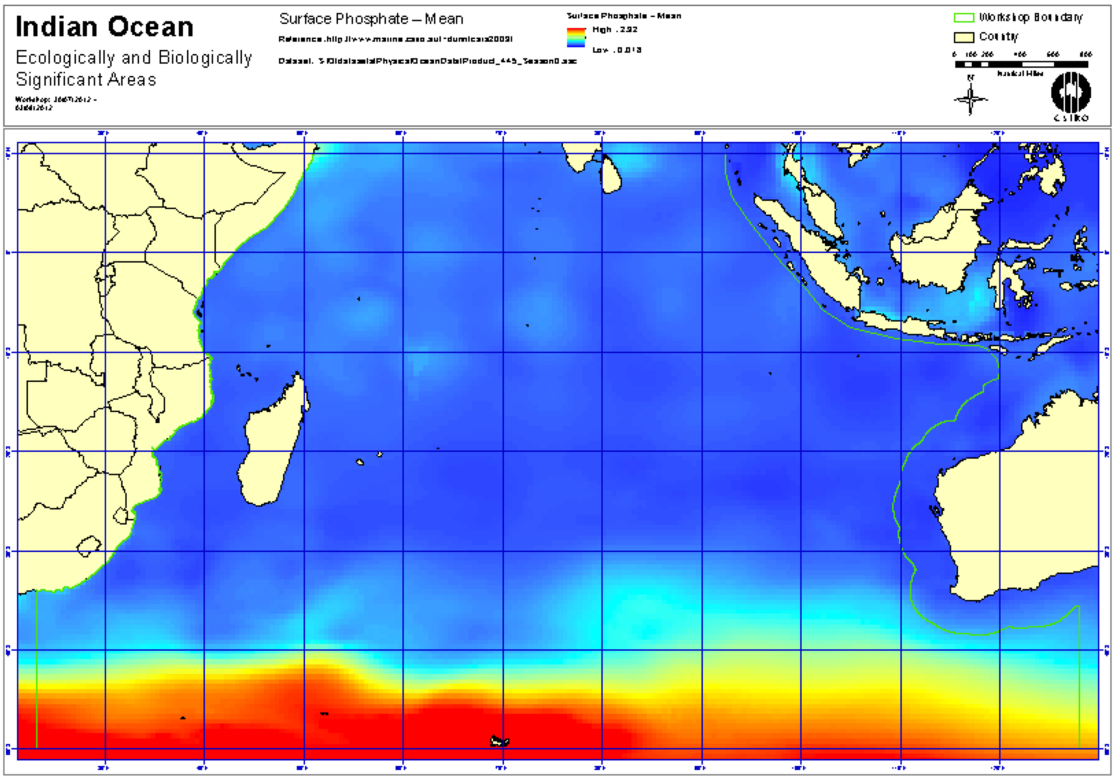

Figure 4.20: Annual Phosphate

4.6.7 Sea Surface Altimetry

Average annual sea surface height. Data derived from satelite measurment (TOPEX/POSEIDON and ERS-1) and gives the annual sea surface height.

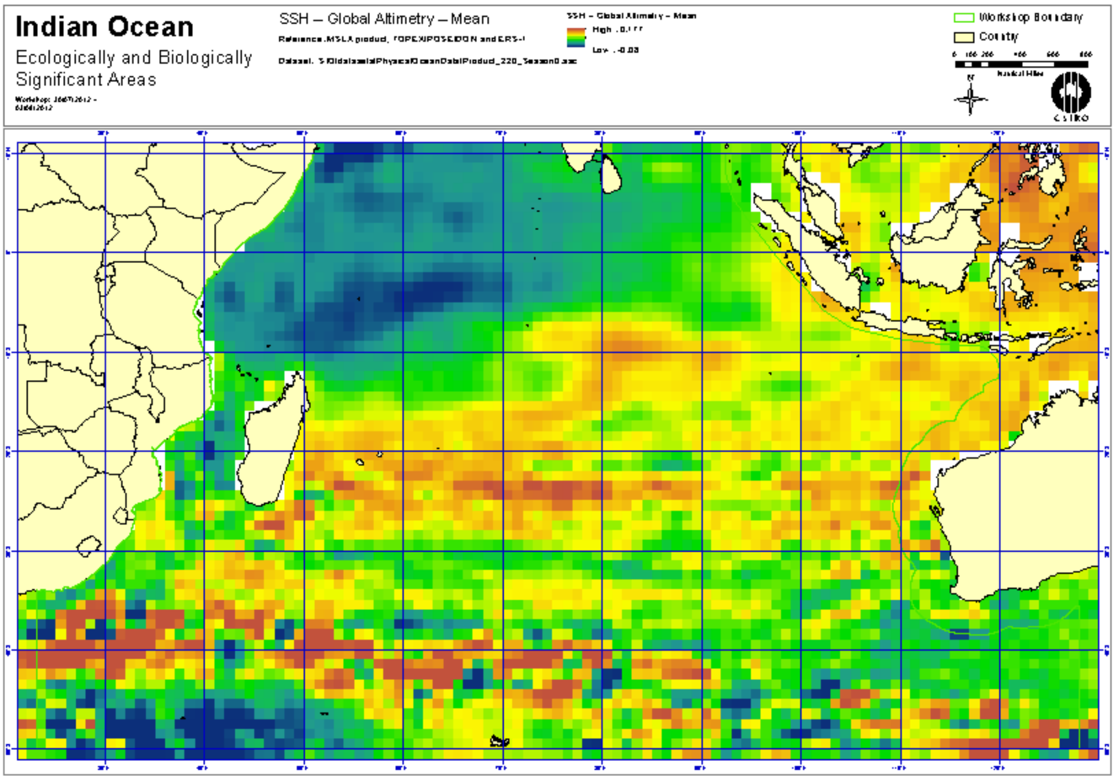

Figure 4.21: Annual sea surface height

4.6.8 SeaWiFS Chlorophyll A concentration

SeaWiFS data compiled by Thomas Moore and CMR Remote Sensing, courtesy of the NASA SeaWiFS Project and Orbimage. NASA also expects at least one author of any paper using Seawifs to be personally on their registered Seawifs users list. This is done by applying to NASA and can easily be done via the web at http://seawifs.gsfc.nasa.gov/SEAWIFS/LICENSE/checklist.html.

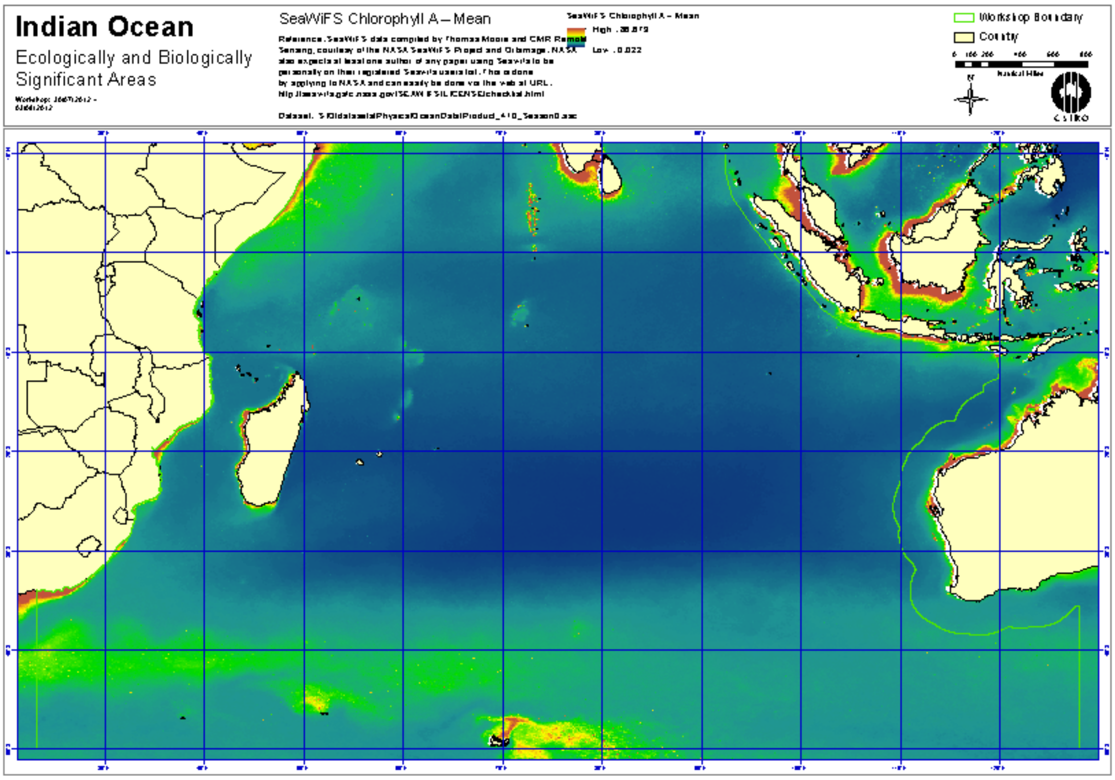

Figure 4.22:

4.6.9 VGPM Global Ocean Productivity

The VGPM is a ”chlorophyll-based” model that estimate net primary production from chlorophyll.

Community guidance for developing this website was to provide a single productivity product as a Standard product.For this, we have initially chosen the Vertically Generalized Production Model (VGPM) (Behrenfeld and Falkowski, 1997a) as the standard algorithm. The VGPM is a ”chlorophyll-based” model that estimate net primary production from chlorophyll using a temperature-dependent description of chlorophyll-specific photosynthetic efficiency.For the VGPM, net primary production is a function of chlorophyll, available light, and the photosynthetic efficiency.

http://www.science.oregonstate.edu/ocean.productivity/VGPMGlobalOceanPro
png

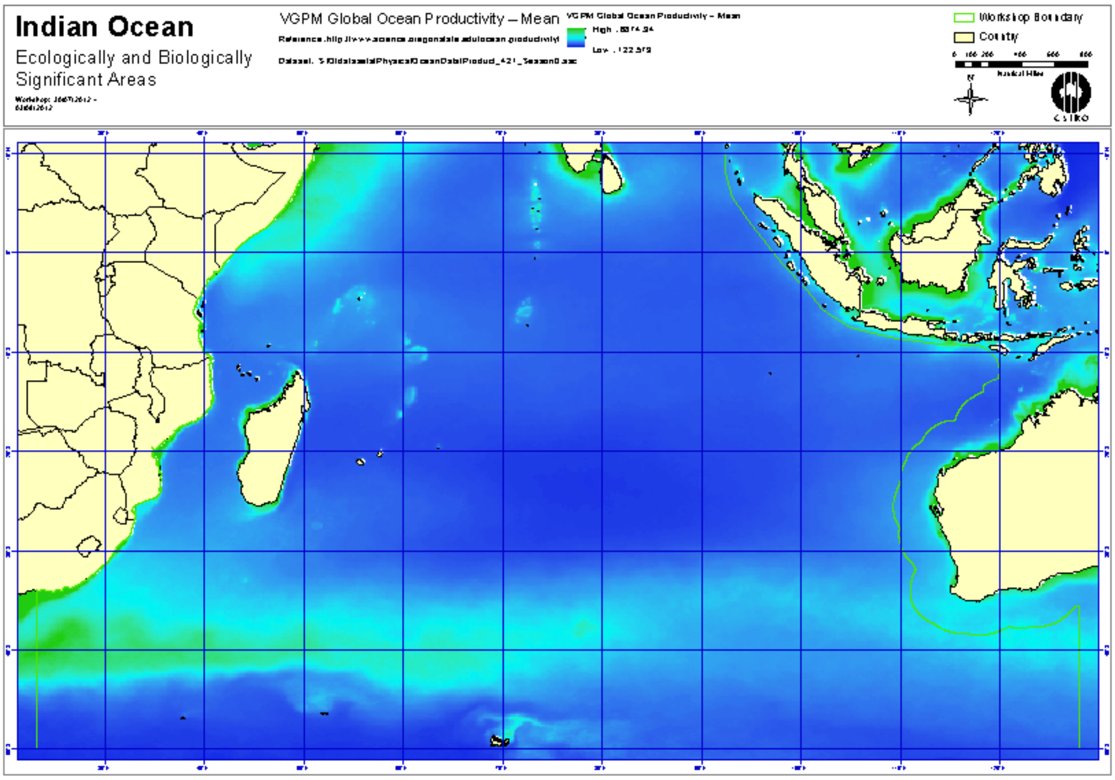

Figure 4.23: Annual VGPM Global Ocean Productivity

4.6.10 Mixed Layer Depth Climatology (m)

Production in the surface ocean is constrained by nutrient availability (at depth) and sufficient light (from the surface). The MLD can influence this productivity and has a seasonal cycle, being deeper due to wind mixing in winter, and shallow in summer due to warming and stratification.

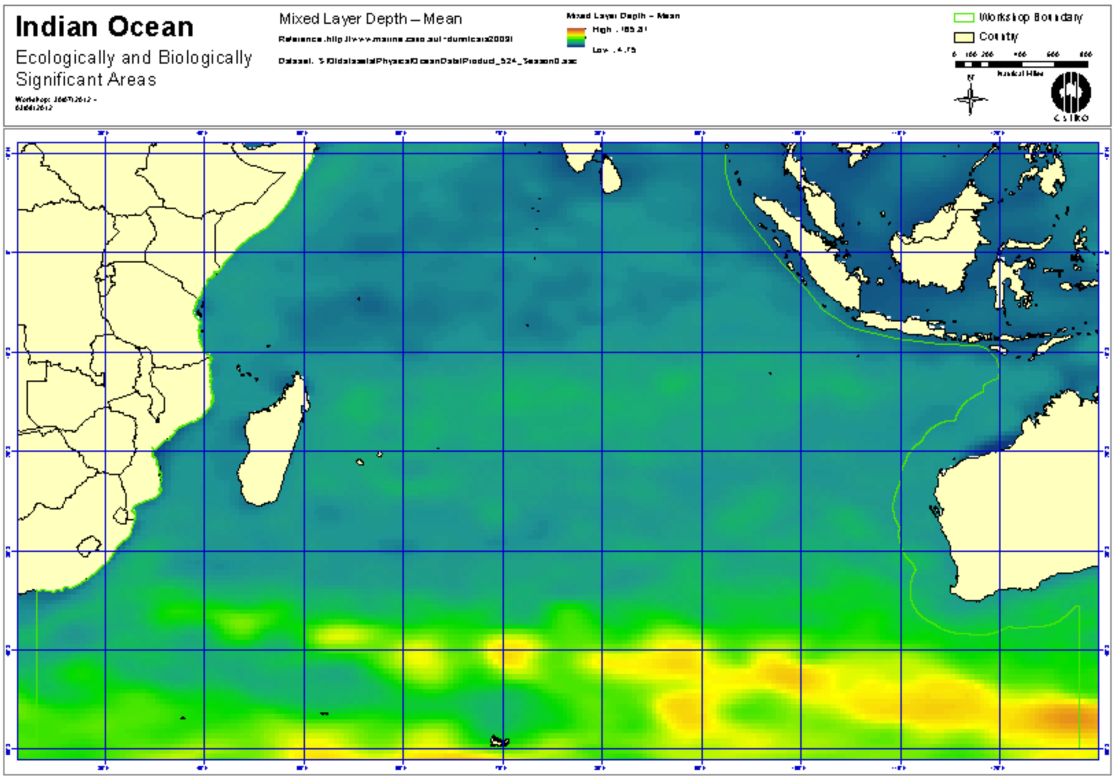

Figure 4.24: Annual Mixed Layer Depth

4.6.11 Frontal Index

Derived product Thermal fronts mark the boundary between waters of different temperature. They can be productive areas due to mixing of water masses and important for foraging animals of many species, including tunas, whales, seabirds and turtles. We applied a methodology for determining an SST front using edge detection, described in Cayula and Cornillon (1995). Hobday and Hartog (in preparation) extend this method to generate an index of frontal activity for the region of interest. Pixels in individual images are allocated to a front, and then the presence of frontal pixels summed over a period of time. The index presented here is gridded in quarter degree boxes and averaged over an 8-day week. These were averaged for the selected seasons or years as presented herein. The resulting contours are then mapped onto a 0.25 degree grid that measures the frontal density in each of these grid cells.

Cayula J-F, Cornillon P (1995) Multi-Image Edge Detection for SST Images. Journal of Atmospheric and Oceanic Technology 12, 821-829.

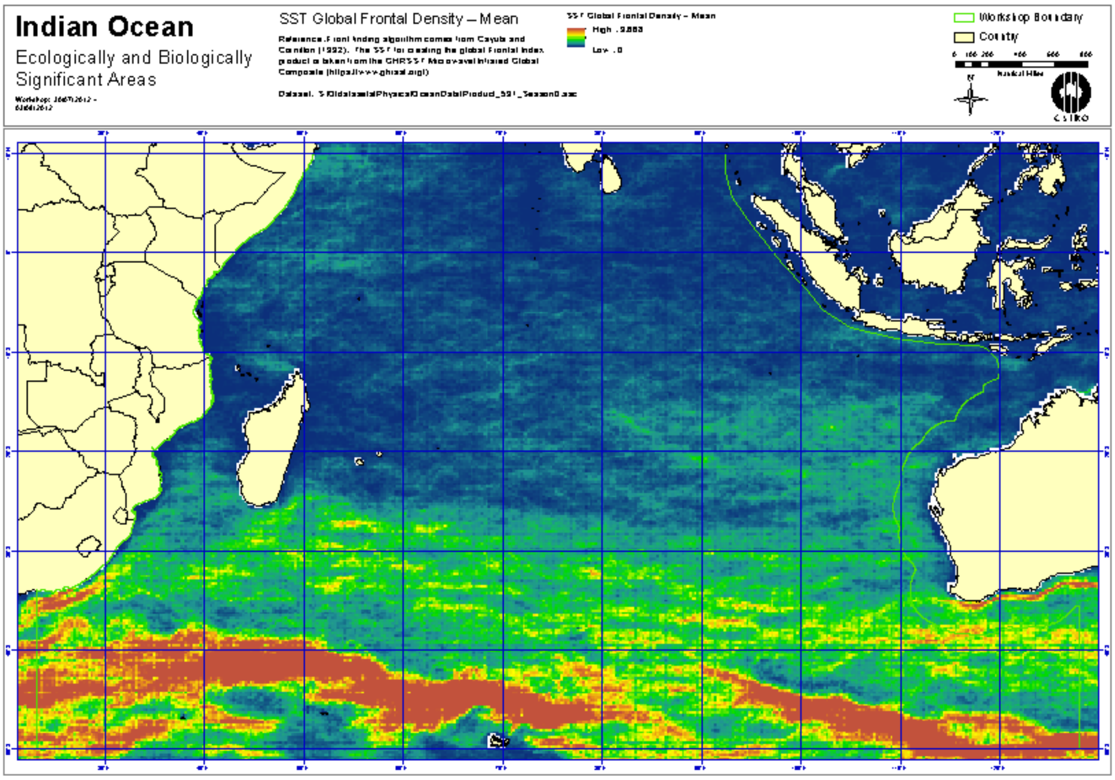

Figure 4.25:

4.6.12 Eddy Kinetic Energy

Locations where shear between water masses is high can generate productivity due to mixing. One measure of this mixing is estimated using Eddy Kinetic Energy (EKE). For example, regions of high tuna abundance occurred in relatively high EKE (Zainuddin et al 2006). EKE was calculated from the velocity maps based on sea surface height. Using the u and v values from the CARS synTS u and v products, EKE is defined as

$$0.5 * (U^2 + V^2)$$

Zainuddin M, Kiyofujia H, Saitohb K, Saitoh S-I (2006) Using multi-sensor satellite remote sensing and catch data to detect ocean hot spots for albacore (Thunnus alalunga) in the northwestern North Pacific. Deep-Sea Research II 53, 419-431.

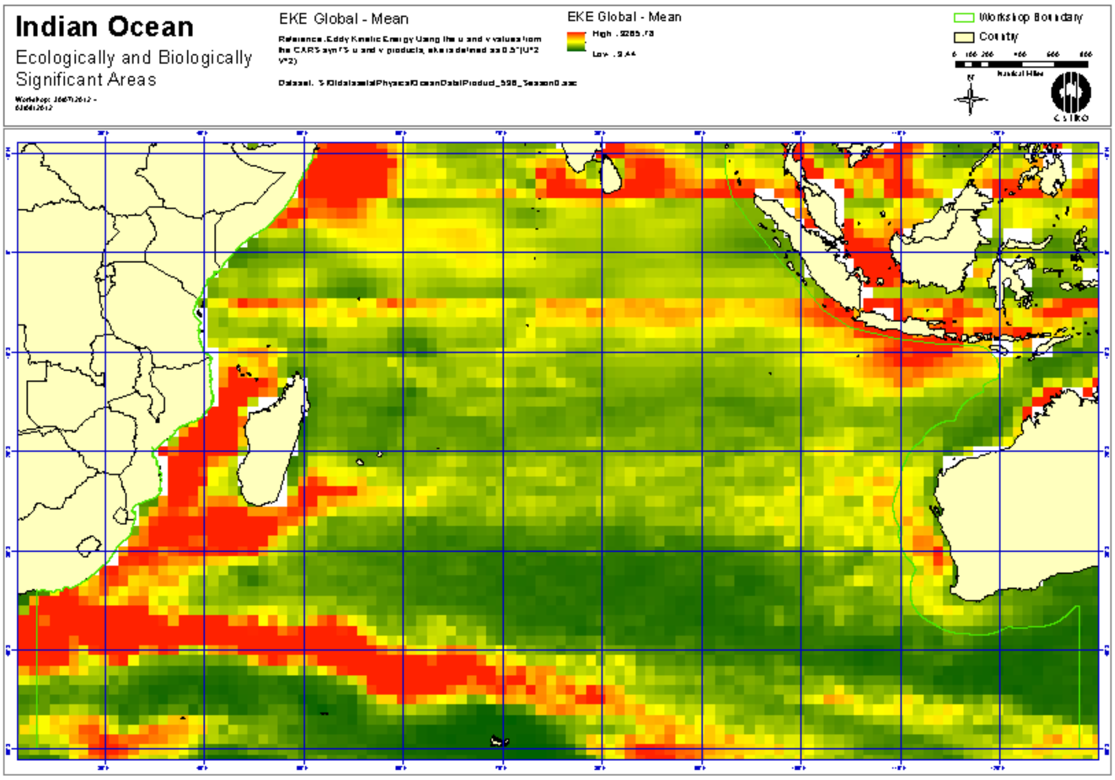

Figure 4.26: Annual Eddy Kinetic Energy

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