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EASTERN TROPICAL AND TEMPERATE PACIFIC REGIONAL WORKSHOP TO FACILITATE THE DESCRIPTION OF ECOLOGICALLY OR BIOLOGICALLY SIGNIFICANT MARINE AREAS
Galápagos Islands, Ecuador, 28 to 31 August 2012

DATA TO INFORM THE CBD EASTERN TROPICAL AND TEMPERATE PACIFIC REGIONAL WORKSHOP TO FACILIATE THE DESCRIPTION OF ECOLOGICALLY OR BIOLOGICALLY SIGNIGICANT MARINE AREAS

Note by the Executive Secretary

1. The Executive Secretary is circulating herewith a background document on data to inform the CBD Eastern Tropical and Temperate Pacific Regional workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas. The information document was prepared by the Marine Geospatial Ecology Lab, Duke University, 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.

Marine Geospatial Ecology Lab

Data to inform the CBD Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas in the Eastern Temperate and Tropical Pacific

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27 - 31 August, 2012

Prepared for the Secretariat of the Convention on Biodiversity (SCBD)

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Contents

Figures

1 Background

The Marine Geospatial Ecology Lab at Duke University, in conjunction with international partners, has identified and mapped a large number of data sets and analyses for consideration by the Convention on Biological Diversity (CBD) Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs) in the Eastern Temperate and Tropical Pacific. Both biological and physical data sets are included. The data is intended to be used by the expert regional workshop convened by the CBD 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 inter-governmentally agreed scientific criteria. Each data set may be used to meet one or more of the EBSA criteria.

Printed maps will be available for annotation at the workshop. Versions of these maps are also available online:

- Maps in English: http://mgel.env.duke.edu/ettp-en
- Maps in Spanish: http://mgel.env.duke.edu/ettp-es

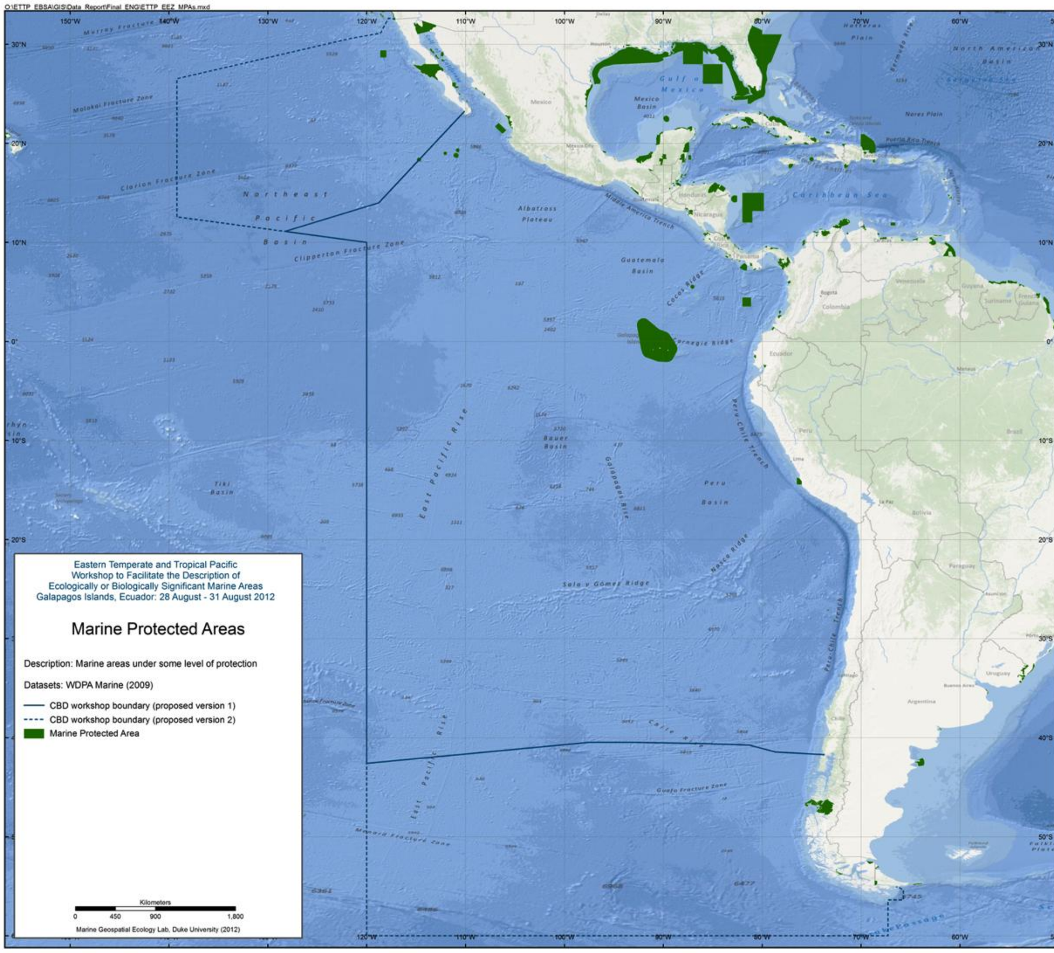

Figure 1.1-1 Proposed workshop boundary and existing Marine Protected Areas

2 Biogeographic Classifications

2.1 Global Open Ocean and Deep Seabed (GOODS) biogeographic classification

The classification was produced by an international and multidisciplinary group of experts under the auspices of a number of international and intergovernmental organizations as well as governments, and under the ultimate umbrella of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and its Intergovernmental Oceanographic Commission (IOC). (source: http://ioc-unesco.org/index.php?option=com_content&task=view&id=146&Itemid=76)

Excerpt from executive summary in the full report:

A new biogeographic classification of the world's 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. The major open ocean pelagic and deep sea benthic zones presented in this report are considered a reasonable basis for advancing efforts towards the conservation and sustainable use of biodiversity in marine areas beyond the limits of national jurisdiction in line with a precautionary approach. Ongoing work may further refine and improve the classification provided here, however the authors of this report believe that any further refinement to biogeographical provinces need not delay action to be undertaken towards this end, and that such action be supported by the best available scientific information.

Reference:

UNESCO. 2009. *Global Open Oceans and Deep Seabed (GOODS) – Biogeographic Classification*. Paris, UNESCO-IOC. (IOC Technical Series, 84.)

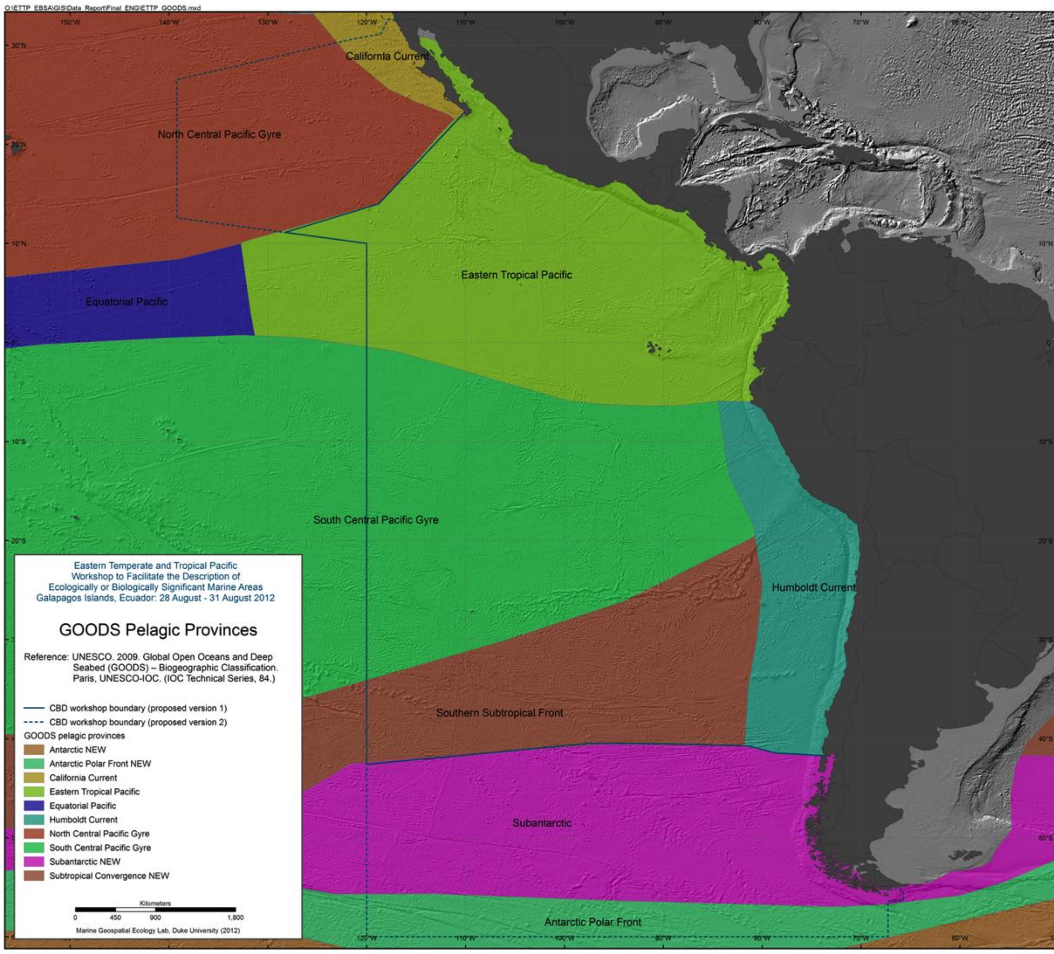

Figure 2.1-1 GOODS Pelagic Provinces

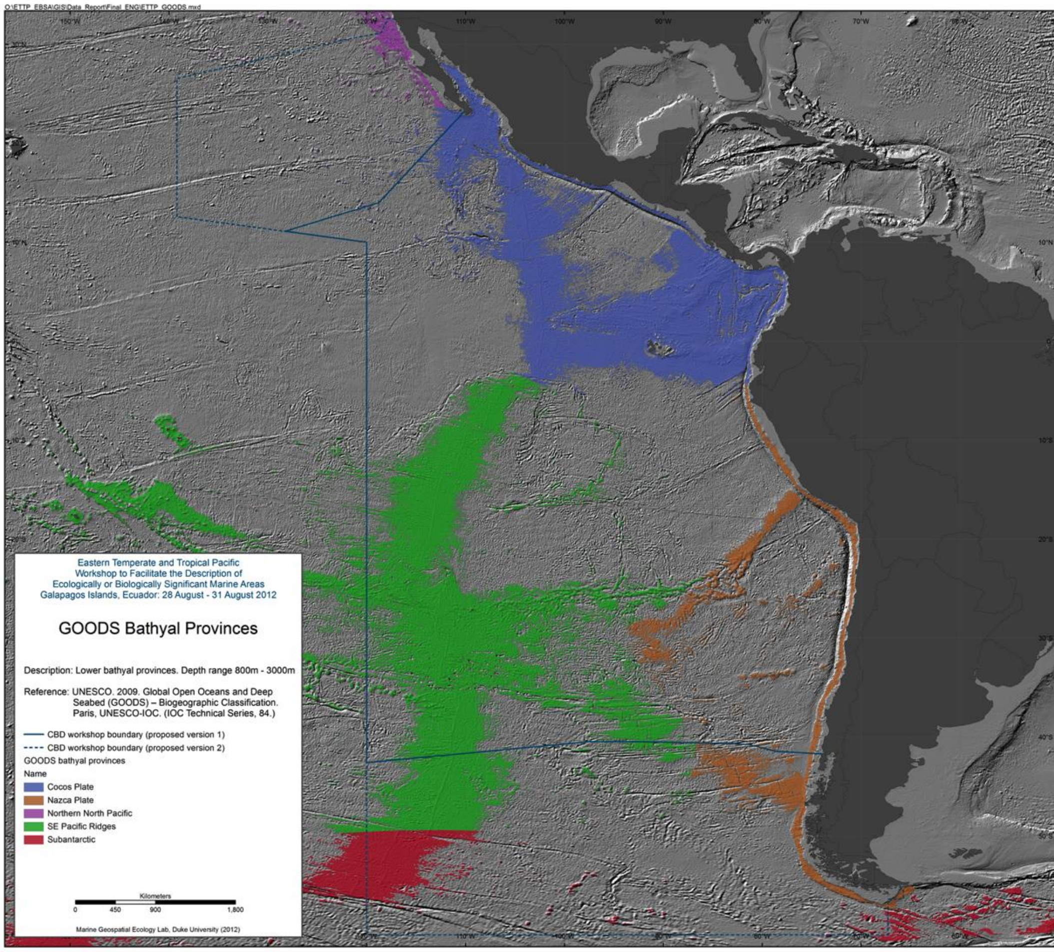

Figure 2.1-2 GOODS Bathyal Provinces

2.2 Marine Ecoregions of the World (MEOW)

MEOW is a biogeographic classification of the world's coasts and shelves. It is the first-ever comprehensive marine classification system with clearly defined boundaries and definitions and was developed to closely link to existing regional systems. The ecoregions nest within the broader biogeographic tiers of Realms and Provinces.

MEOW represents broad-scale patterns of species and communities in the ocean, and was designed as a tool for planning conservation across a range of scales and assessing conservation efforts and gaps worldwide. The current system focuses on coast and shelf areas (as this is where the majority of human activity and conservation action is focused) and does not consider realms in pelagic or deep benthic environment. It is hoped that parallel but distinct systems for pelagic and deep benthic biotas will be devised in the near future.

The project was led by The Nature Conservancy (TNC) and the World Wildlife Fund (WWF), with broad input from a working group representing key NGO, academic and intergovernmental conservation partners.
(source: http://www.worldwildlife.org/science/ecoregions/marine/item1266.html)

Reference:
Spalding, M. D. Fox, H. E. Allen, G. R. Davidson, N. Ferdana, Z. A. Finlayson, M. Halpern, B. S. Jorge, M. A. Lombana, A. Lourie, S. A., (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience 2007, VOL 57; numb 7, pages 573-584.

Data available from: http://www.vliz.be/vmdcdata/vlimar/downloads.php#MEOW

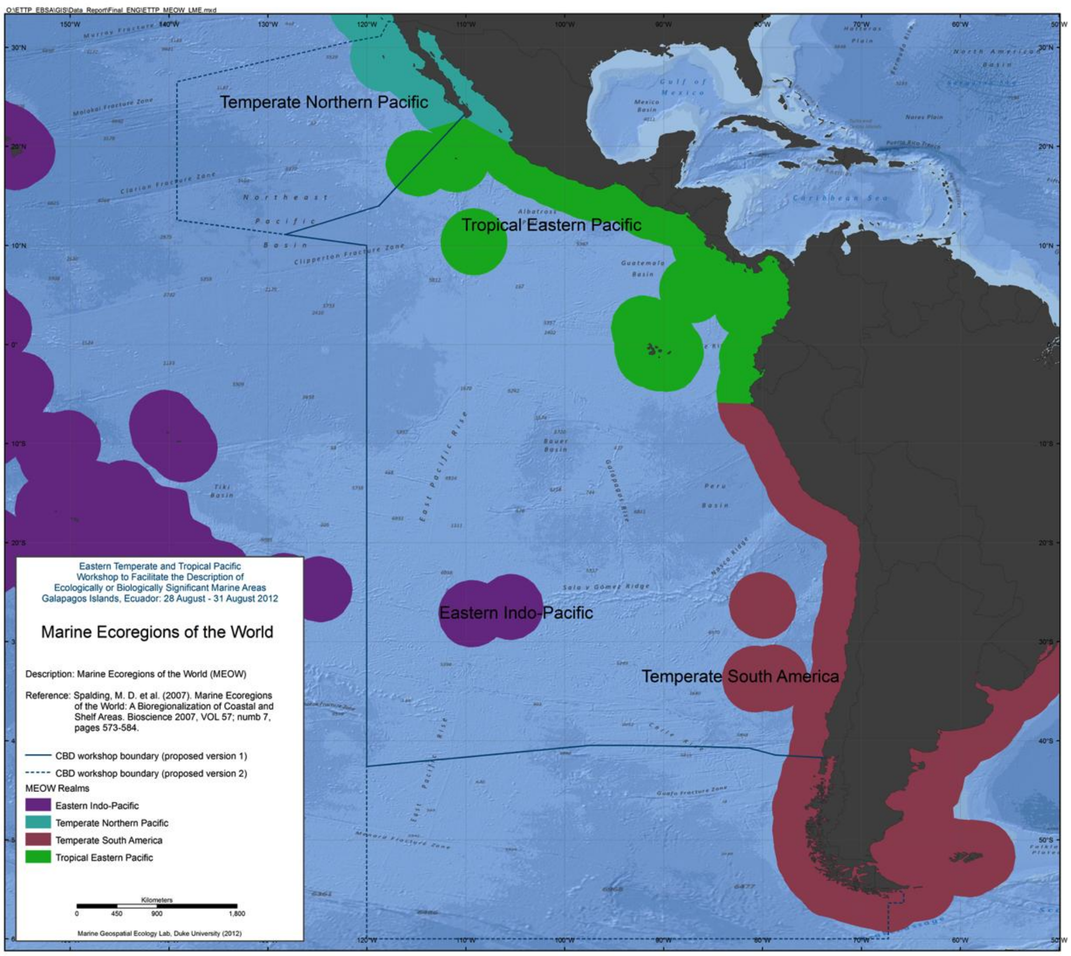

Figure 2.2-1 MEOW Realms

2.3 Large Marine Ecosystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundary of continental shelves and the seaward margins of coastal current systems. Fifty of them have been identified. They are relatively large regions (200 000 km^2 or more) characterized by distinct bathymetry, hydrography, productivity and trophically dependent populations.

The LME approach uses five modules:

- *productivity module* considers the oceanic variability and its effect on the production of phyto and zooplankton
- *fish and fishery module* concerned with the sustainability of individual species and the maintenance of biodiversity
- *pollution and ecosystem health module* examines health indices, eutrophication, biotoxins, pathology and emerging diseases
- *socio-economic module* integrates assessments of human forcing and the long-term sustainability and associated socio-economic benefits of various management measures, and
- *governance module* involves adaptive management and stakeholder participation.

(source: http://www.fao.org/fishery/topic/3440/en)

Reference:
FAO. © 2005-2012. Fisheries and Aquaculture topics. Large Marine Ecosystems. Topics Fact Sheets. Text by J.J. Maguire and Jorge Csirke. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 15 February 2012]. http://www.fao.org/fishery/topic/3440/en

Data available from: http://www.lme.noaa.gov/

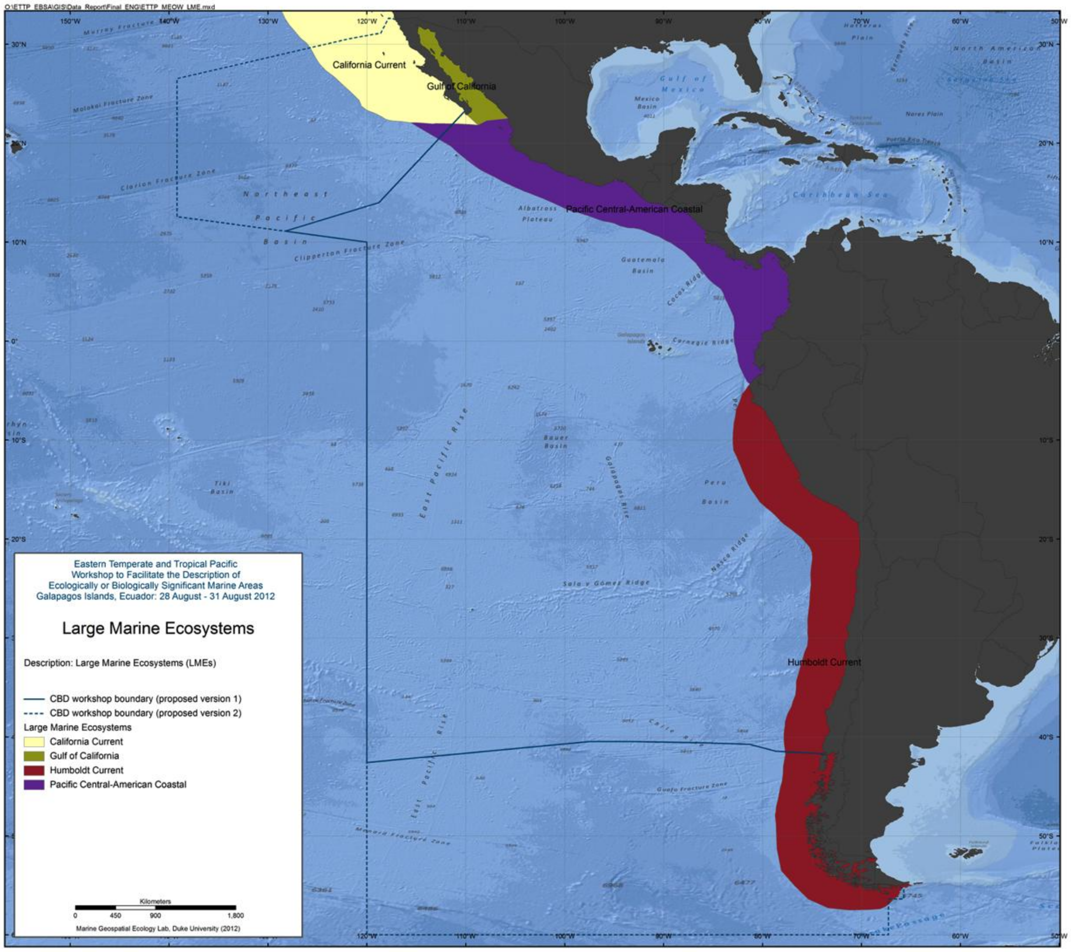

Figure 2.3-1 Large Marine Ecosystems

2.4 Longhurst Marine Provinces

This dataset represents a partition of the world oceans into provinces as defined by Longhurst (1995; 1998; 2006), and are based on the prevailing role of physical forcing as a regulator of phytoplankton distribution. The dataset represents the initial static boundaries developed at the Bedford Institute of Oceanography, Canada. Note that the boundaries of these provinces are not fixed in time and space, but are dynamic and move under seasonal and interannual changes in physical forcing. At the first level of reduction, Longhurst recognised four principal biomes (also referred to as domains in earlier publications): the Polar Biome, the Westerlies Biome, the Trade-Winds Biome, and the Coastal Boundary Zone Biome. These four Biomes are recognisable in every major ocean basin. At the next level of reduction, the ocean basins are partitioned into provinces,

roughly ten for each basin. These partitions provide a template for data analysis or for making parameter assignments on a global scale.
(source: VLIZ (2009). Longhurst Biogeographical Provinces. Available online at http://www.vliz.be/vmdcdata/vlimar/downloads.php. Consulted on 2012-02-15.)

References:
Longhurst, A.R. (2006). Ecological Geography of the Sea. 2nd Edition. Academic Press, San Diego, 560p.

Data available from: http://www.vliz.be/vmdcdata/vlimar/downloads.php

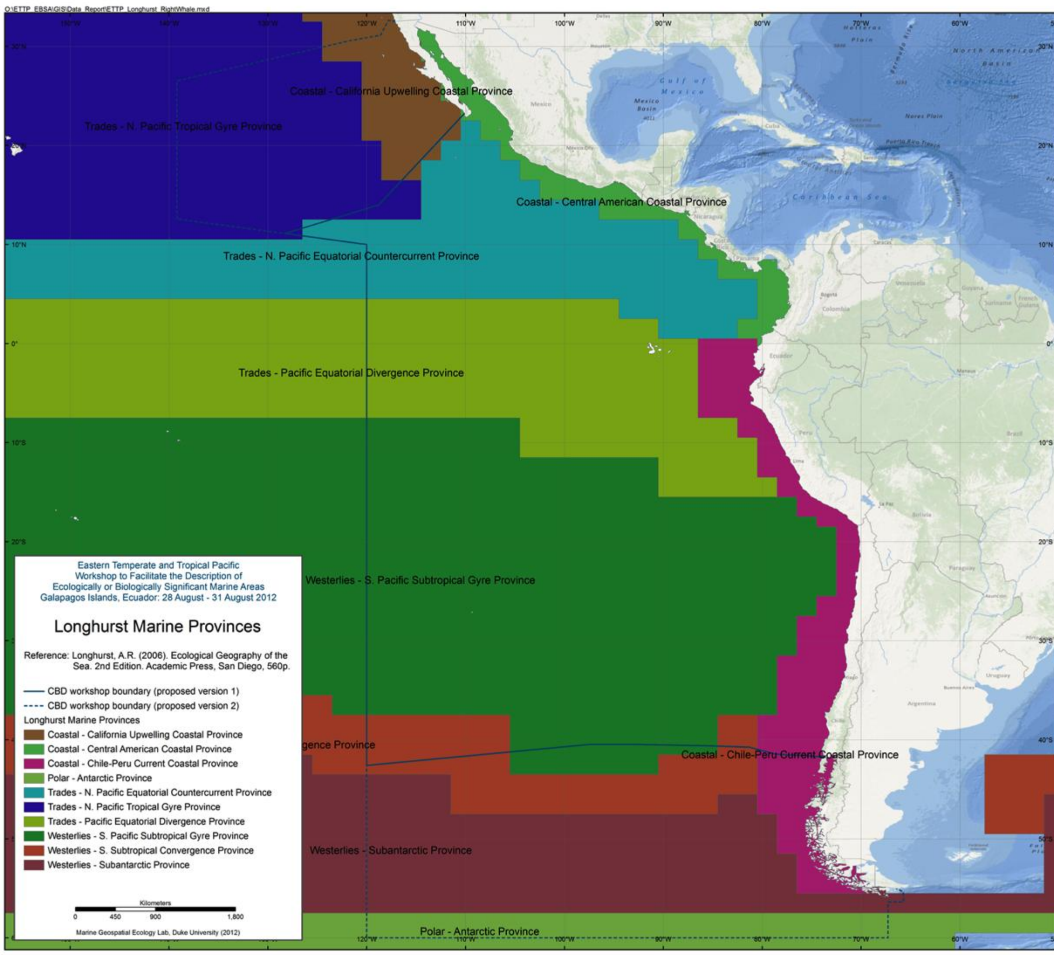

Figure 2.4-1 Longhurst Marine Provinces

3 Biological Data

3.1 Distribution of Coral Reefs, Seagrasses and Mangroves

The UNEP World Conservation Monitoring Centre (UNEP-WCMC) is a collaboration between the United Nations Environment Programme, the world's foremost intergovernmental environmental organization, and WCMC(UK), a UK-based charity. UNEP-WCMC is UNEP's specialist biodiversity assessment arm, and the Centre for UNEP's collaboration with WCMC 2000.
(source: http://www.unep-wcmc.org/about-us_17.html)

Global Distribution of Coral Reefs (2010) data available from:
http://data.unep-wcmc.org/datasets/13

Global Distribution of Seagrasses (2005) data available from:
http://data.unep-wcmc.org/datasets/10

Global Distribution of Mangroves (1997) data available from:
http://data.unep-wcmc.org/datasets/6

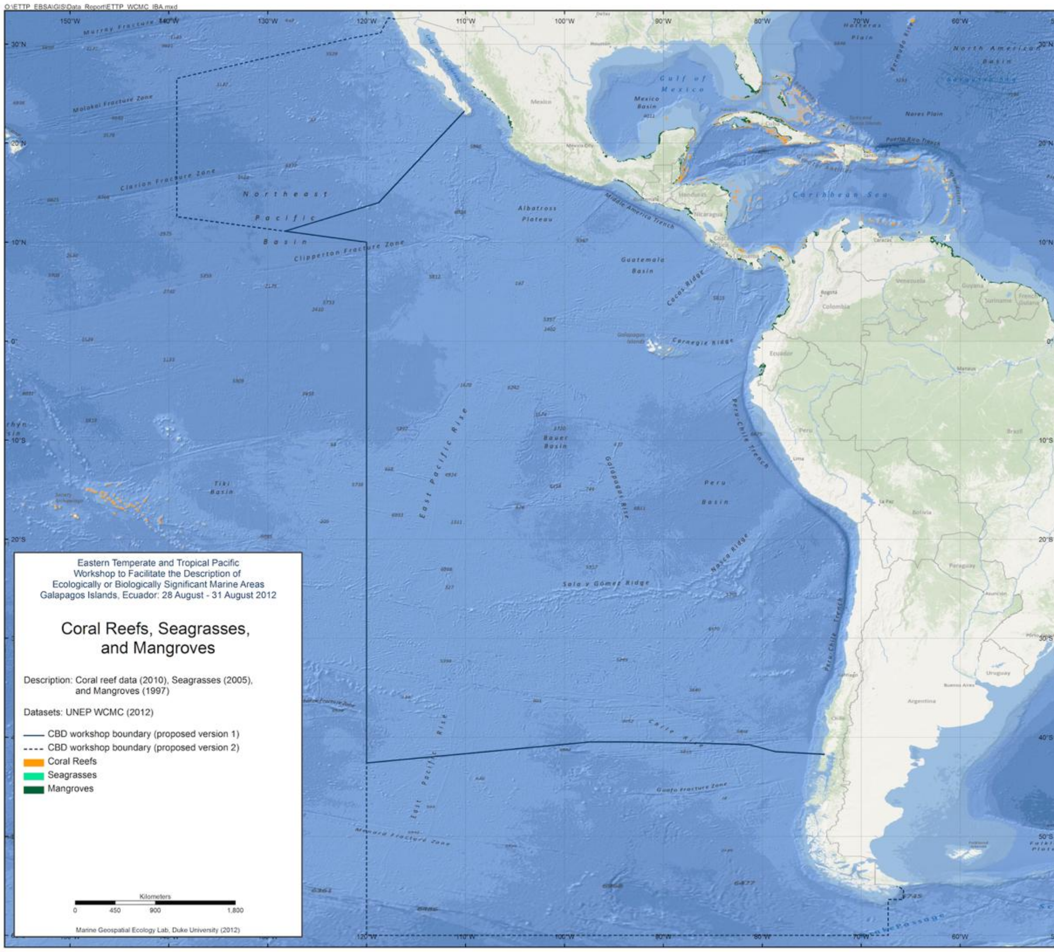

Figure 3.1-1 Coral Reefs, Seagrasses, and Mangroves

3.2 Historical Whale captures

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 1931the 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.
(source: http://web.archive.org/web/20070926224128/http:/wcs.org/townsend_charts)

Using a used a geographic information system (ArcMap 10.x, ESRI, Redlands, CA), capture point locations for each species were aggregated into 1-degree cells.

References:

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.

Data available from:
http://web.archive.org/web/20070926224128/http://wcs.org/townsend_charts#GIS Data

3.2.1 Sperm Whales

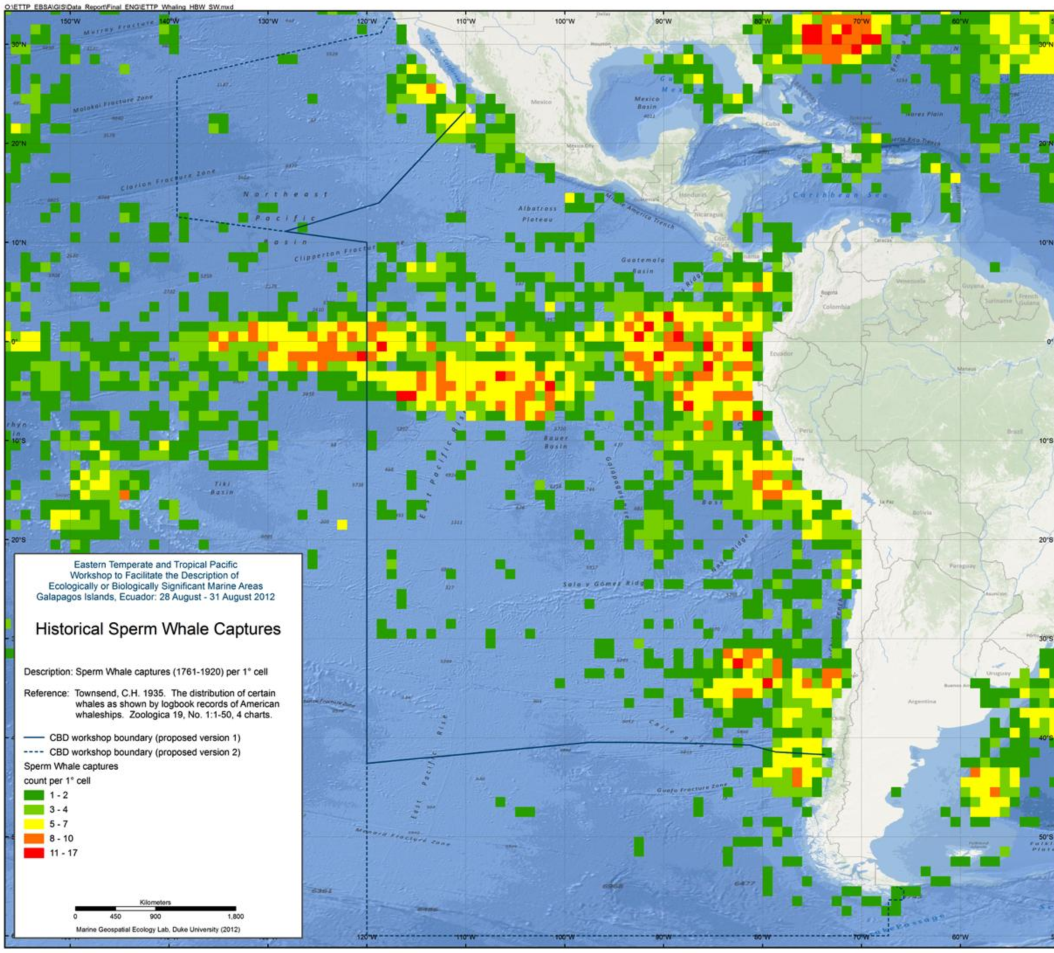

Figure 3.2-1 Historical Sperm Whale Captures

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3.2.2 Right Whales

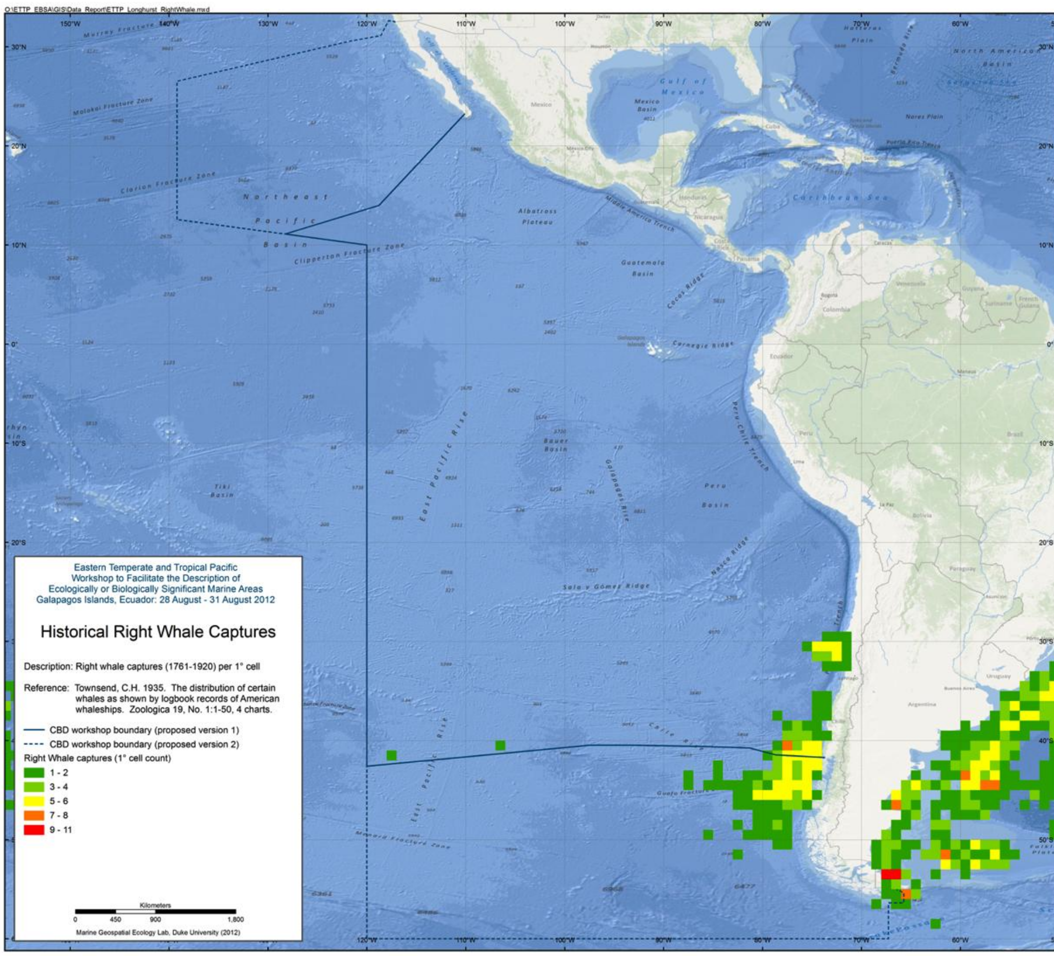

Figure 3.2-2 Historical right whale captures

3.2.3 Humpback Whales

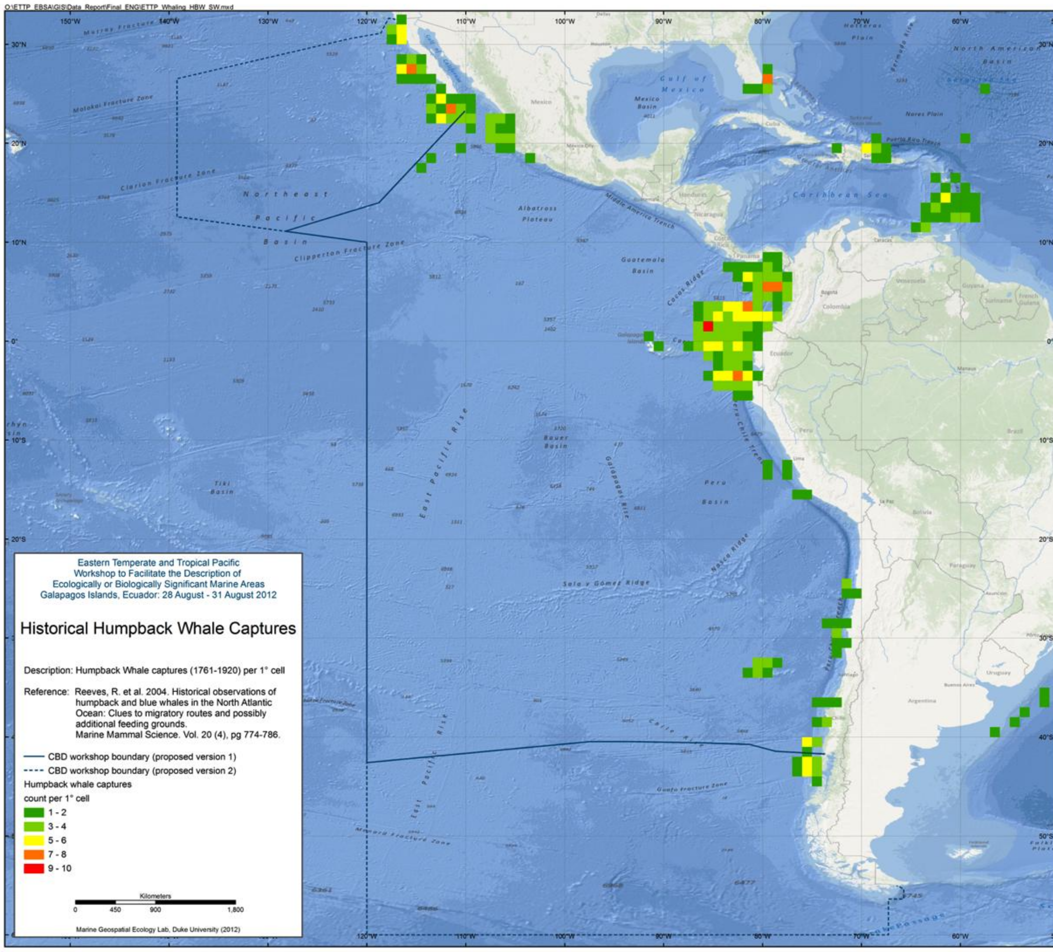

Figure 3.2-3 Historical Humpback Whale Captures

3.3 Catches of Commercial Pelagic Species

Figures of pelagic commercial species catch were drawn from the FAO Tuna Atlas data service. Maps of total purse seine catch from 1996-2012 for yellowfin, bigeye, and skipjack tuna are presented below. The symbols used to represent these data are consistent across the maps.

An additional map presenting longline catch data is drawn from the 2011 Inter-American Tropical Tuna Commission report, the Regional Fisheries Management Organization for the study area. This map shows data on bigeye tuna catch as compared to yellowfin, averaged for the years 2006-2010. This map does not display comparable data to the other three maps. It covers a smaller temporal range, and shows the average annual catch over that range, rather than the total catch.

Reference: http://www.fao.org/figis/geoserver/tunaatlas/
Inter-American Tropical Tuna Commission Fishery Status Report No. 10, http://iattc.org

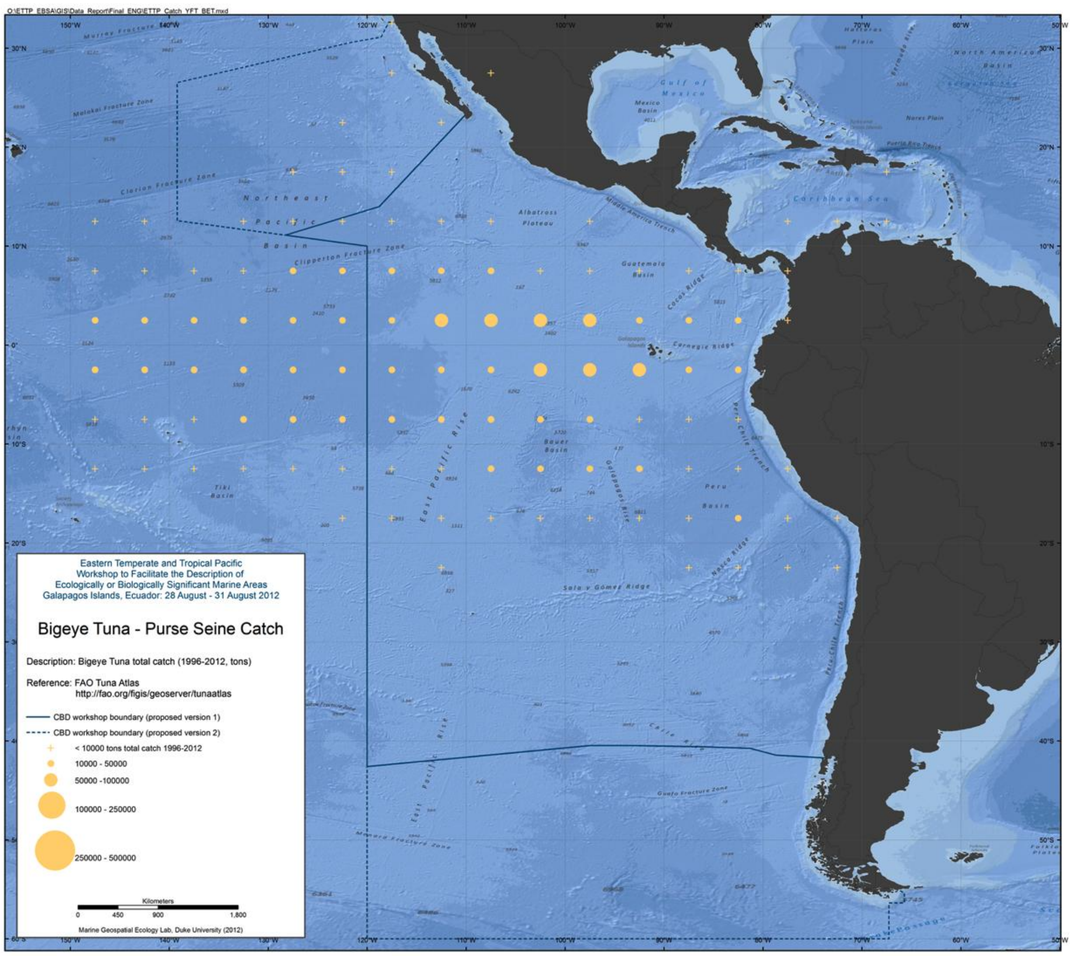

Figure 3.3-1 IATTC Bigeye Tuna Purse Seine Catch Statistics (5 deg)

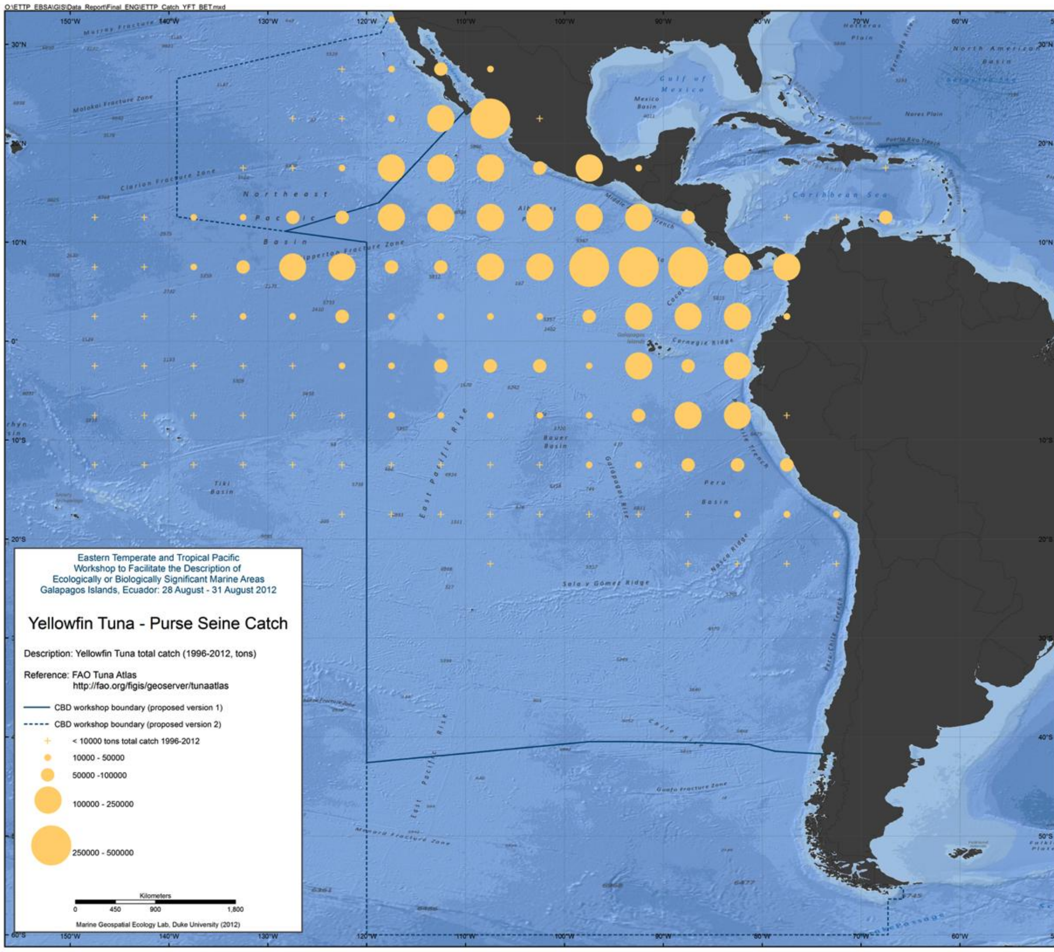

Figure 3.3-2 IATTC Yellowfin Tuna Purse Seine Catch Statistics (5 deg)

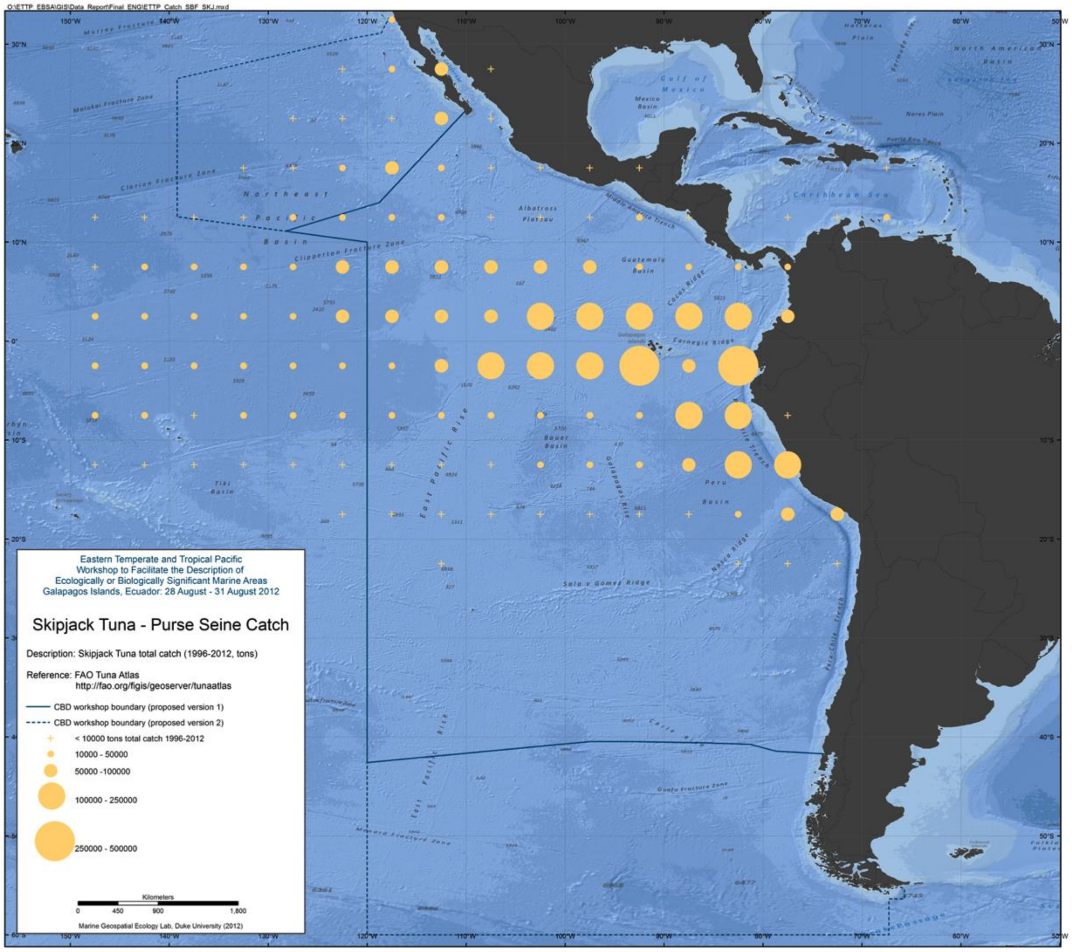

Figure 3.3-3 IATTC Skipjack Tuna Purse Seine Catch Statistics (5 deg)

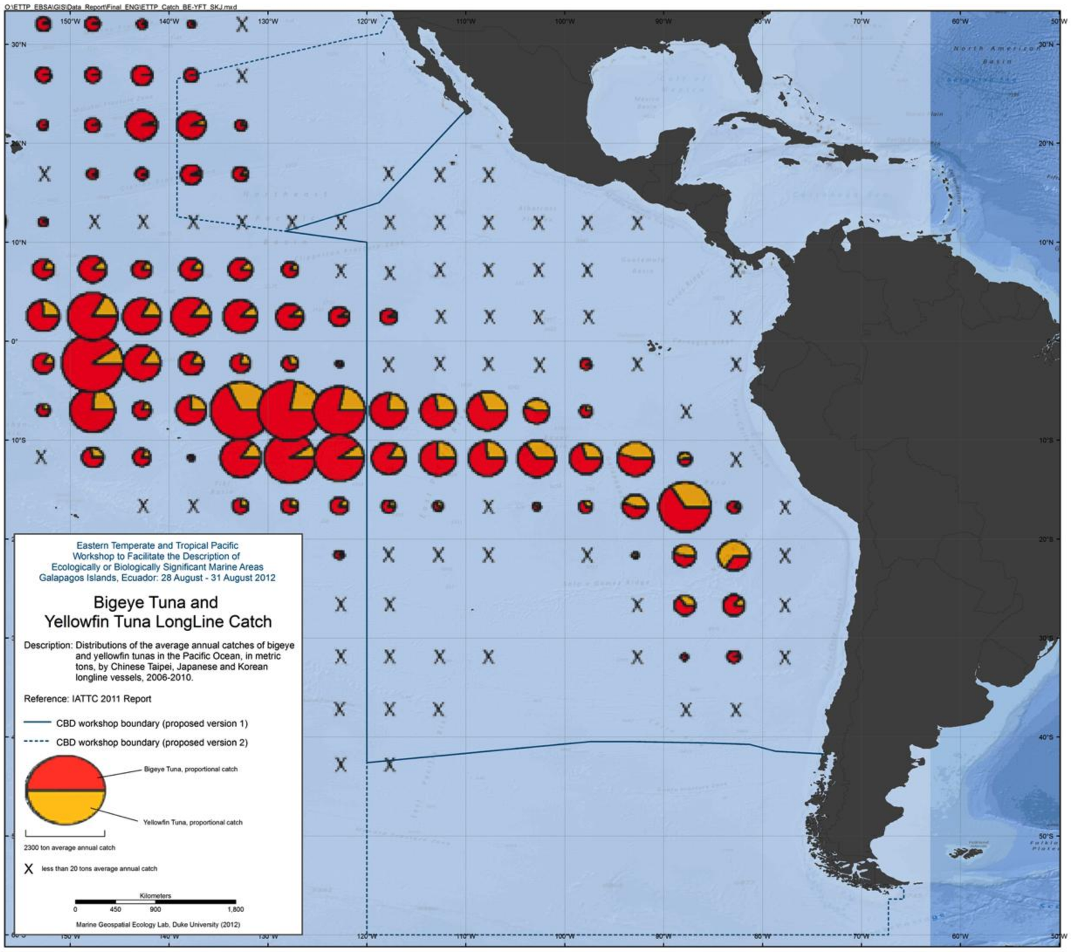

Figure 3.3-4 IATTC Bigeye Tuna and Yellowfin Tuna Longline Catch Statistics (5 deg)

3.4 Leatherback turtle internesting utilization distribution

Eastern Pacific (EP) leatherback turtles (*Dermochelys coriacea*) have declined by up to 90% during the past 2 decades and are currently classified as Critically Endangered by the IUCN. Utilization distribution (UD) of the region occupied by 46 leatherback turtles during 4 nesting seasons (2004-2007) is displayed. All turtles were tagged and released while nesting in Parque Nacional Marino Las Baulas, Costa Rica.

Reference: Shillinger, G., Swithenbank, A., Bograd, S., Bailey, H., Castelton, M., Wallace, B., Spotila, J., et al. (2010). Identification of high-use internesting habitats for eastern Pacific leatherback turtles: role of the environment and implications for conservation. Endangered Species Research, 10:215–232. doi:10.3354/esr00251

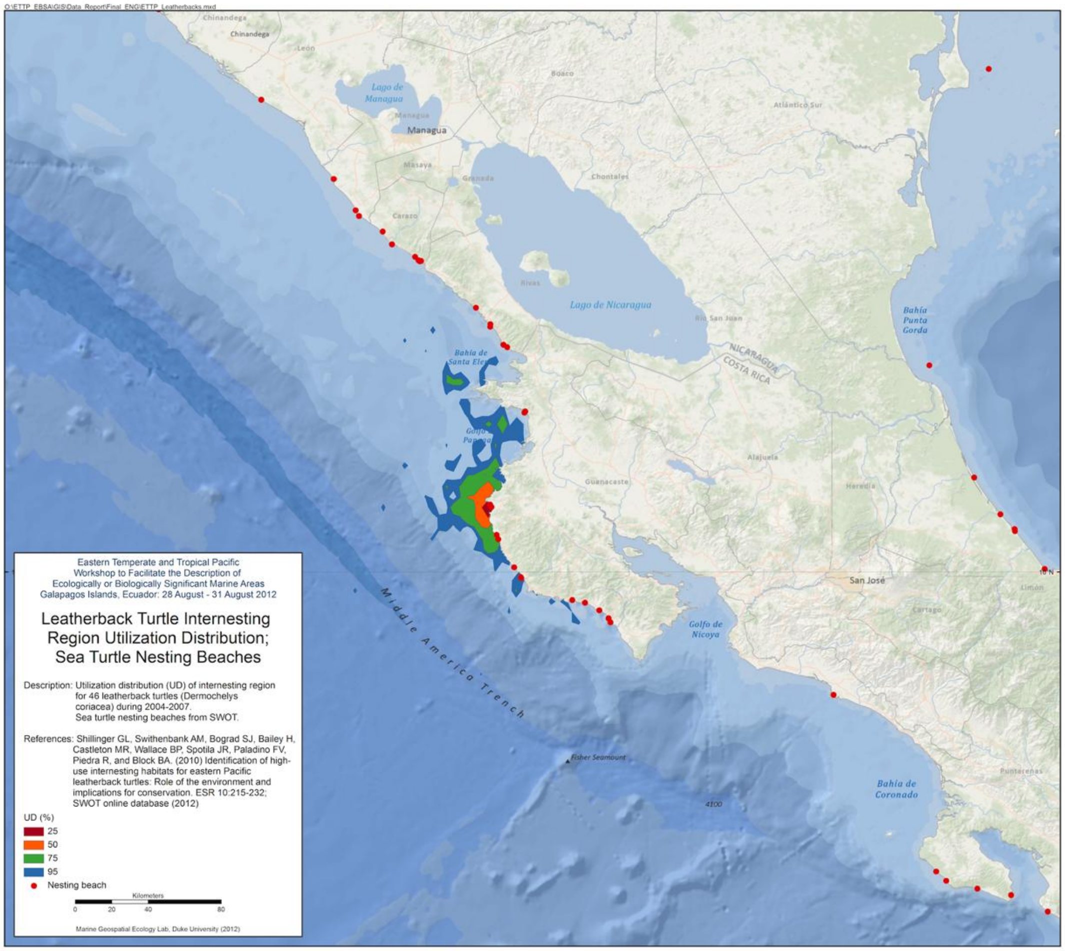

Figure 3.4-1 Leatherback Turtle Internesting Utilization Distribution

3.5 Leatherback turtle home-range utilization distribution

Eastern Pacific leatherback turtle home-range utilization distribution is mapped for 2004, 2005, and 2007 combined. Much of the high use area coincides with the lowest climatological EKE (<30 $cm^2\ s^{-2}$) in the region (i.e., the South Pacific Gyre). The gridded utilization distribution maps were produced using a mesh size of 100 km2 and a fixed-kernel search radius of 0.58 for all years combined. The 95% utilization contour was used to define turtle high-use regions throughout the eastern tropical and South Pacific and the 75% contour to delineate the migration corridor.

Reference: Shillinger GL, Palacios DM, Bailey H, Bograd SJ, Swithenbank AM, et al. (2008) Persistent leatherback turtle migrations present opportunities for conservation. PLoS Biol 6(7): e171. doi:10.1371/journal.pbio.0060171

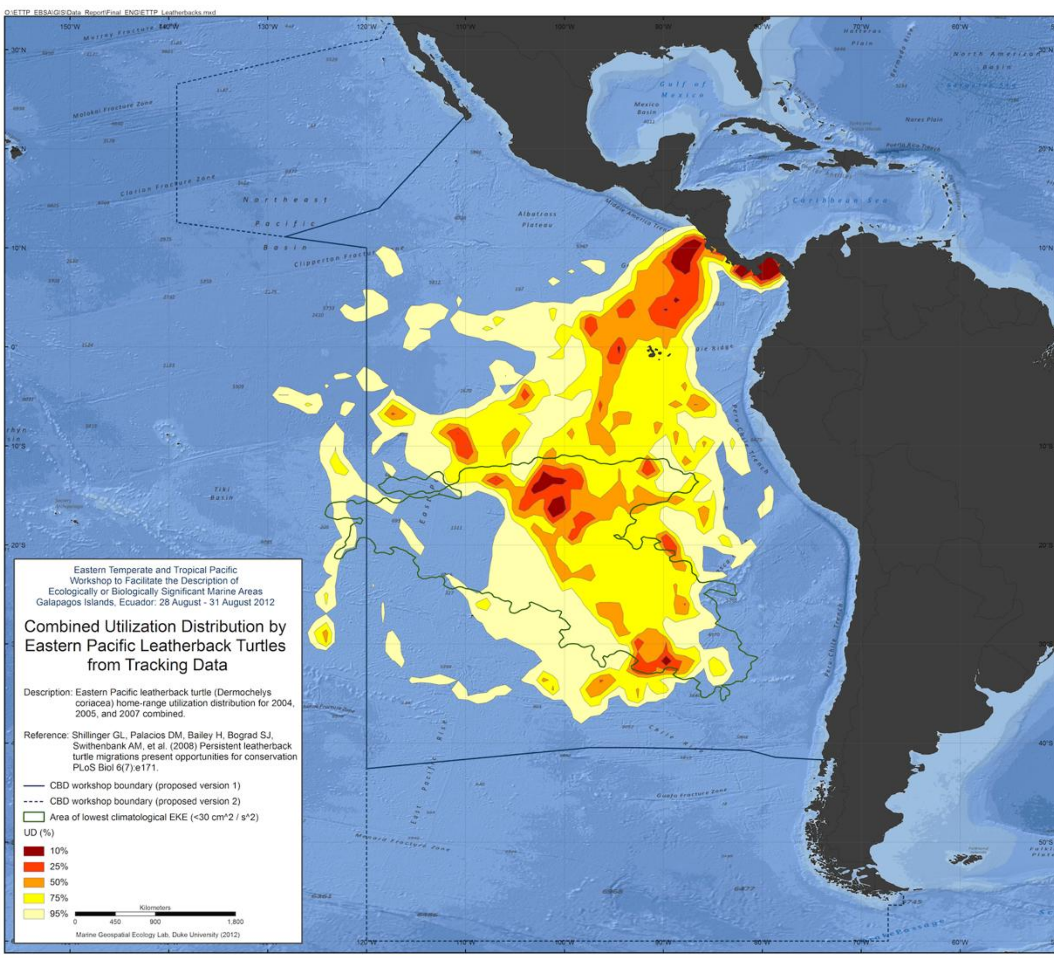

Figure 3.5-1 Leatherback Turtle Home-range Utilization Distribution

3.6 SWOT nesting beaches

SWOT — the State of the World's Sea Turtles — is a partnership led by the Sea Turtle Flagship Program at Conservation International (CI), the IUCN Marine Turtle Specialist Group (MTSG), and supported by the Marine Geospatial Ecology Lab (MGEL) at Duke University.

However, the lifeblood of the effort is the network of more than 550 people and projects that contribute data to the SWOT database, the only comprehensive, global database of sea turtle nesting sites. The SWOT team has completed six years of data collection including the global nesting locations of all seven marine turtle species: green, leatherbacks, loggerheads, hawksbills, flatbacks, olive and Kemp's ridleys. SWOT now collects data for all species in its annual data collection.

In addition to collating nesting abundance and distribution information for all species, SWOT now hosts data compiled by the MTSG Burning Issues Working Group that includes Regional Management Units for all seven marine turtle species, including all available georeferenced mtDNA and nDNA stocks. These files can be viewed on the SWOT website and downloaded for analyses once the Terms of Use are agreed to. Furthermore, SWOT also supports recommendations for monitoring effort schemes that will allow for comparison of long-term nesting abundance and trend estimates for regional and global populations of sea turtle species. These advances will solidify SWOT as the premier global monitoring system for sea turtles. Information on Minimum Data Standards are available at http://seaturtlestatus.org/data/standards.

The current SWOT database contains sea turtle nesting records from over 120 countries all over the world. This online tool, hosted by OBIS-SEAMAP, builds on previous work initiated and supported by WIDECAST organization as well as data from several other regional sea turtle organizations. Records coming from projects that are both a part of a regional organization are flagged as such. The WIDECAST Atlas can still be accessed as a stand-alone application. New data from the WIDECAST network is added to the SWOT database annually.
(source: http://mgel.env.duke.edu/projects/swot/)

Reference:
DiMatteo, A., E. Fujioka, B. Wallace, B. Hutchinson, J. Cleary and P. Halpin. 2009. SWOT Database Online. Data provided by the SWOT Team. World Wide Web electronic publication.

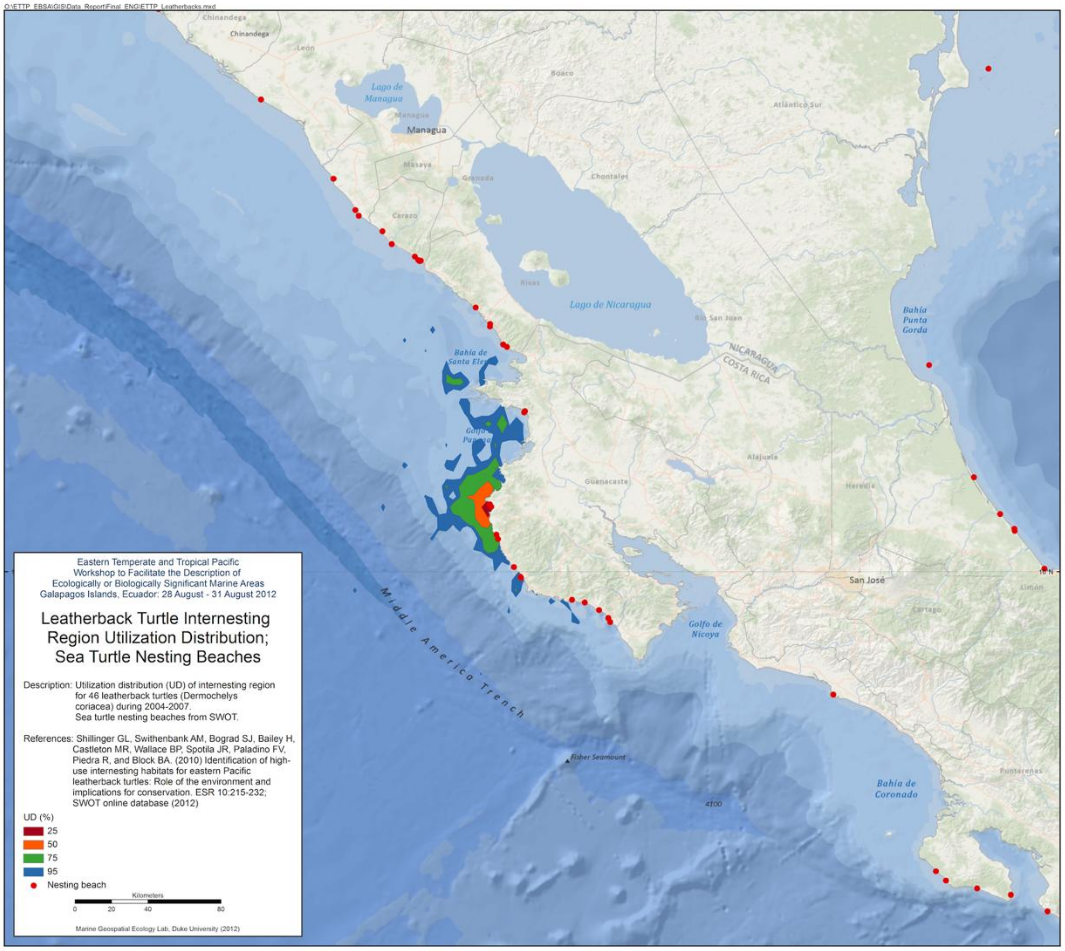

Figure 3.6-1 Sea Turtle Nesting Beaches

3.7 Ocean Biogeographic Information System (OBIS) Data

The Ocean Biogeographic information System (OBIS) seeks to absorb, integrate, and assess isolated datasets into a larger, more comprehensive picture of life in our oceans. The system hopes to stimulate research about our oceans to generate new hypotheses concerning evolutionary processes, species distributions, and roles of organisms in marine systems on a global scale. The abstracts that OBIS generates are maps that contribute to the 'big picture' of our oceans: a comprehensive, collaborative, worldwide view of our oceans.

OBIS provides a portal or gateway to many datasets containing information on where and when marine species have been recorded. The datasets are integrated so you can search them all seamlessly by species name, higher taxonomic level, geographic area, depth, and time; and then map and find environmental data related to the locations.
(source: http://www.iobis.org/about/index)

Reference: Vanden Berghe, E. (editor)(2007). The Ocean Biogeographic Information System: web pages. Available on http://www.iobis.org. Consulted on 3 August 2012.

The data provided here are summaries of available OBIS data. Species Richness and Hurlbert's Index (ES[50]) data summaries for 1 degree grids are provided for all species, mammals, turtles, shallow species (<100m depth), deep species(>100m depth), and species on the IUCN Red List. Data gaps do exist in OBIS and thus these summaries are not exhaustive.

Data available from: http://iobis.org/mapper/

3.7.1 All Species - Biodiversity

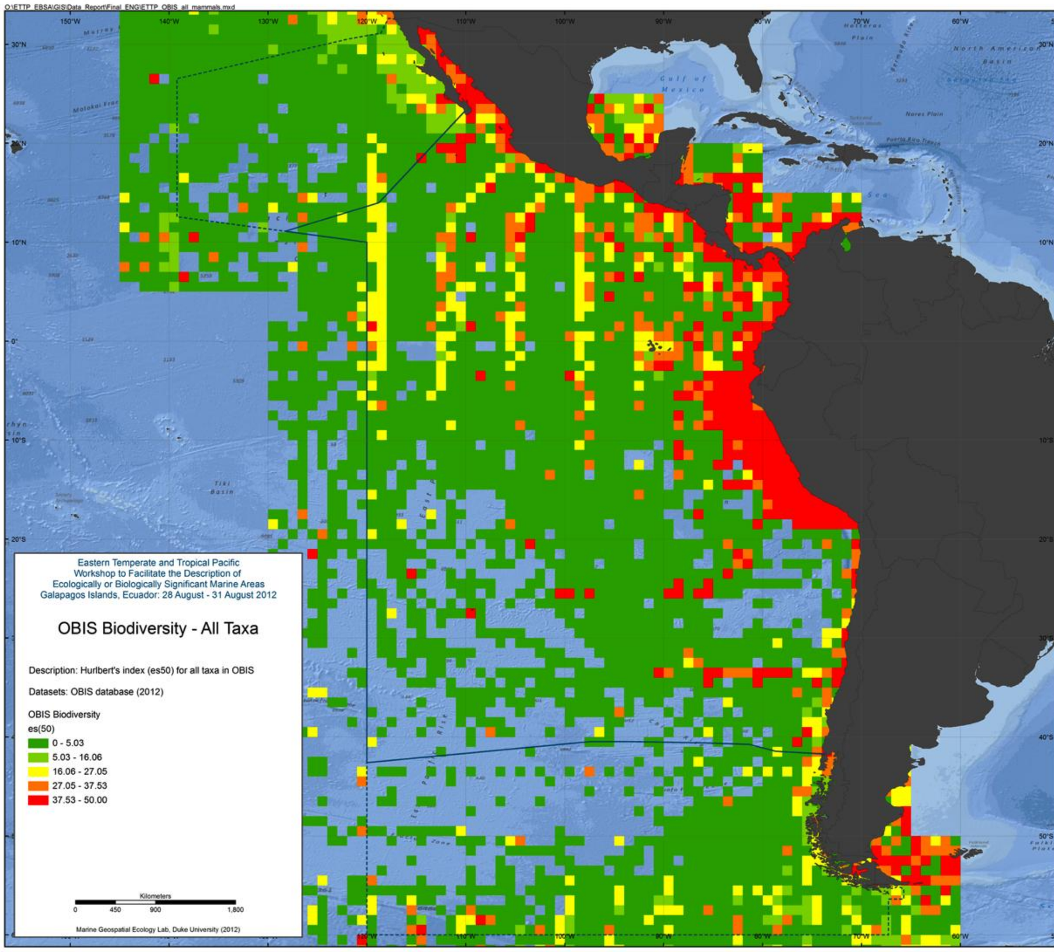

Figure 3.7-1 ES(50) for All Taxa

3.7.2 Mammals – Species Richness

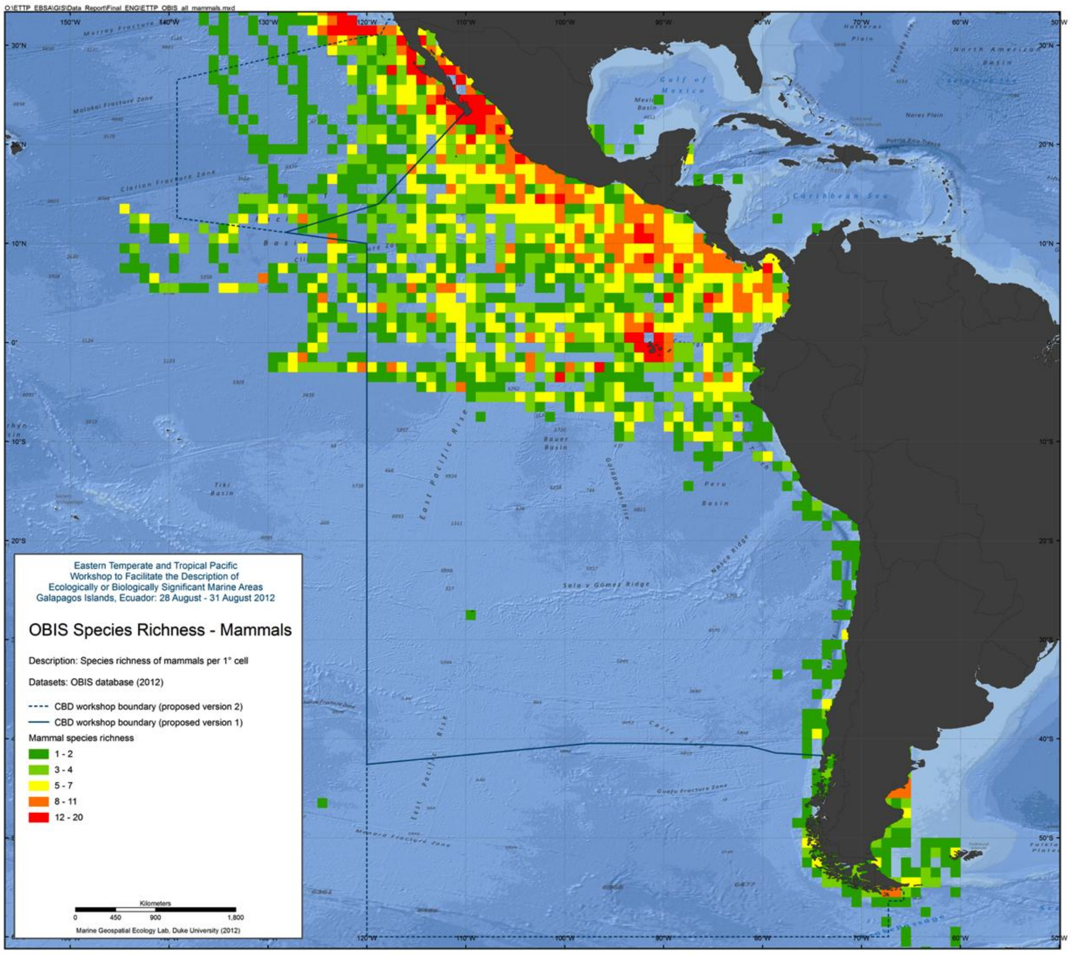

Figure 3.7-2 Species Richness for Mammals

3.7.3 Turtles – Species Richness

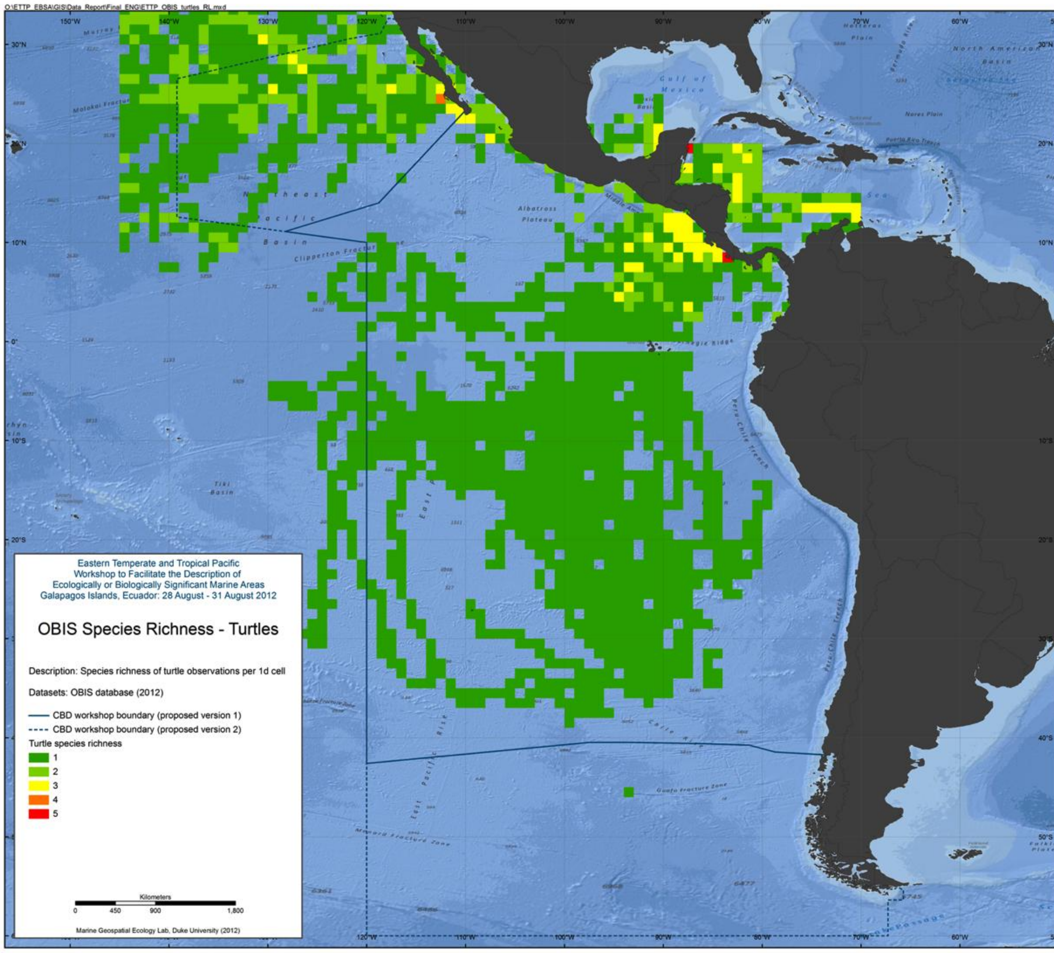

Figure 3.7-3 Species Richness for Turtles

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3.7.4 Shallow Species - Biodiversity

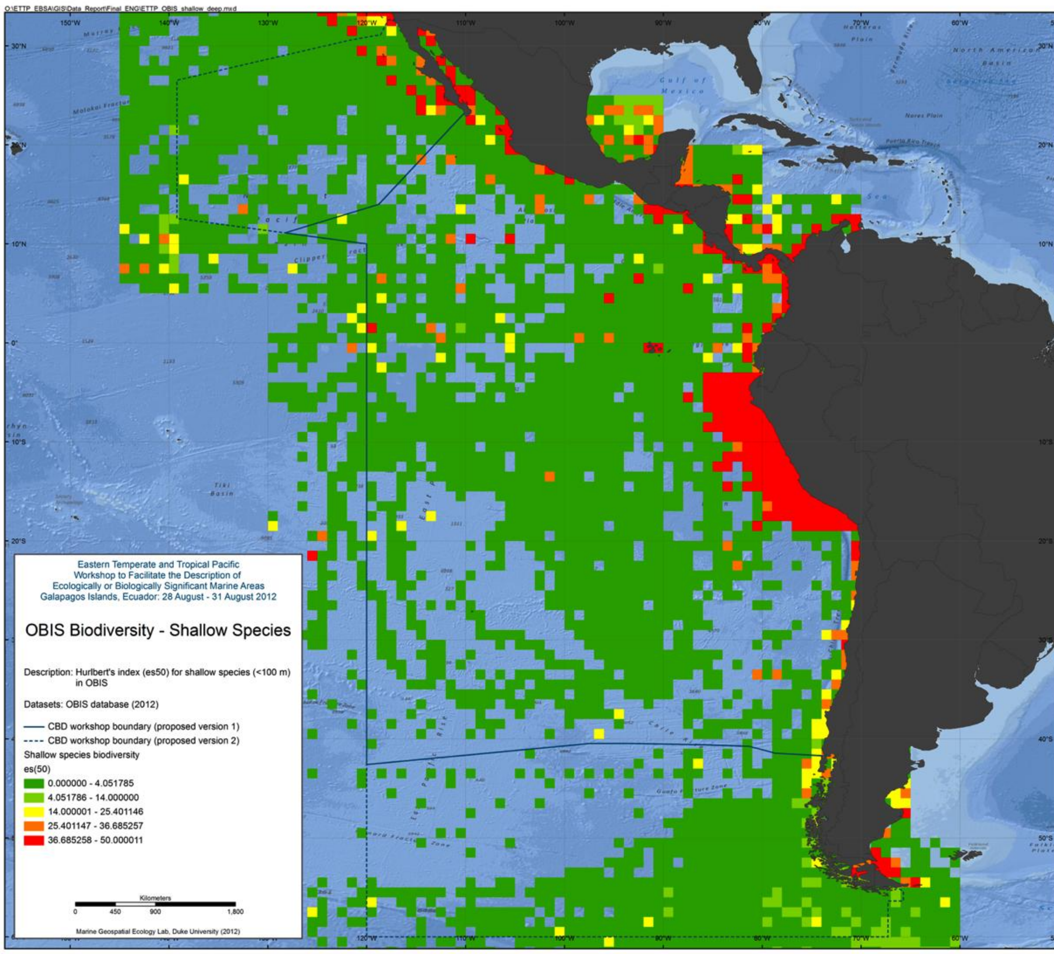

Figure 3.7-4 ES(50) for Shallow Species

3.7.5 Deep Species - Biodiversity

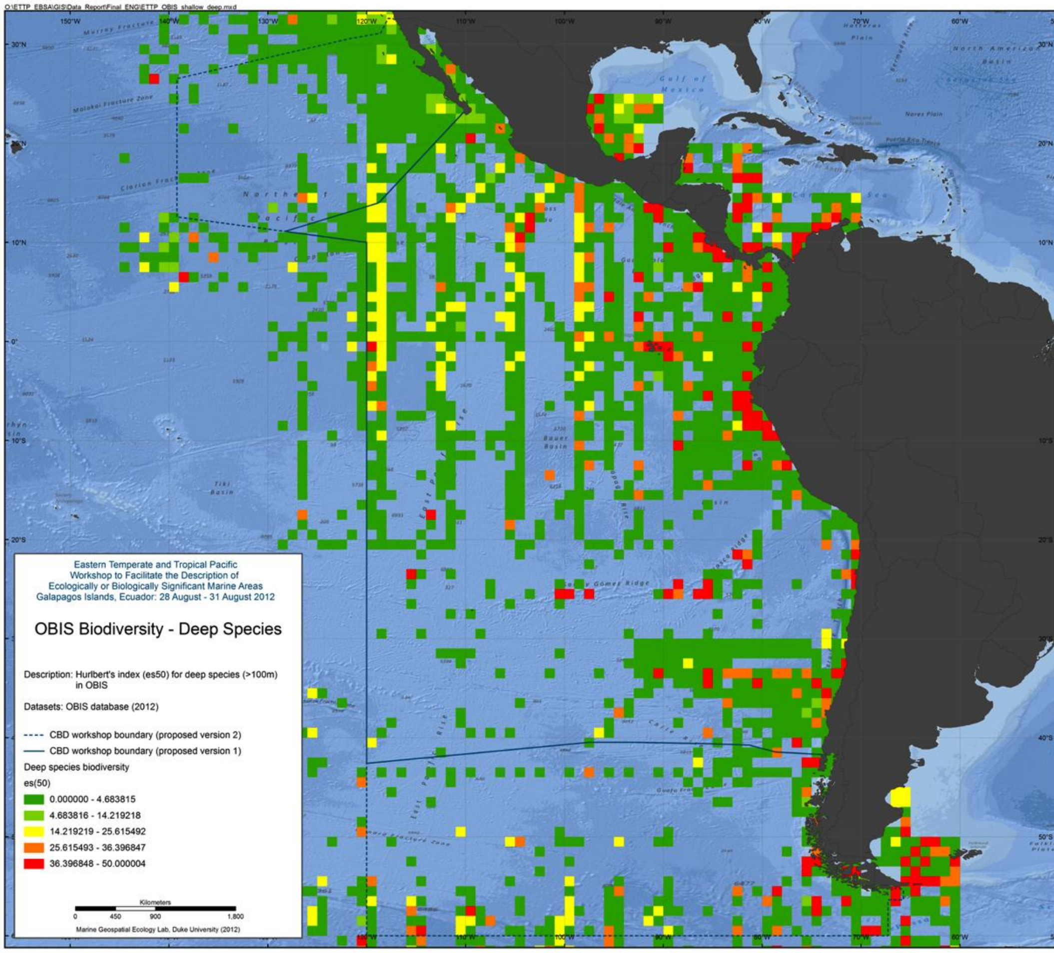

Figure 3.7-5 ES(50) for Deep Species

3.7.6 IUCN Red List species – Species Richness

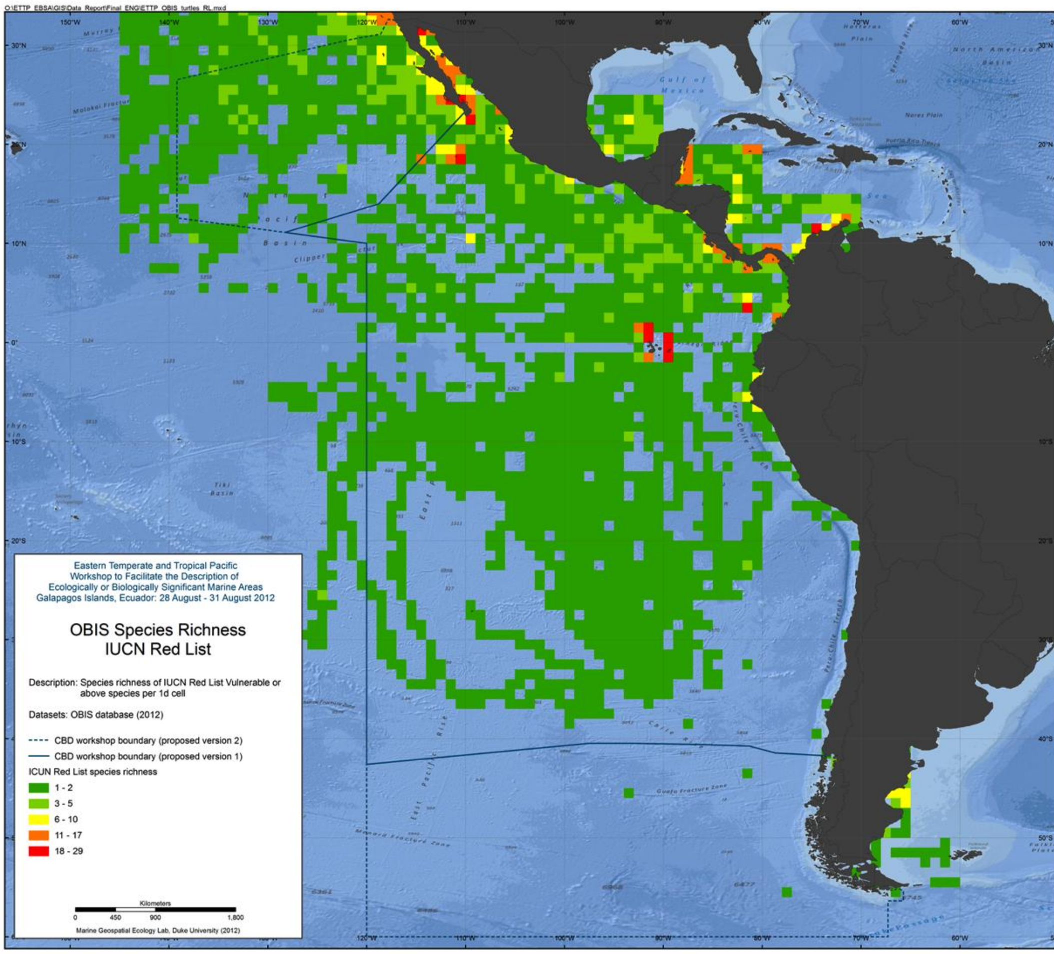

Figure 3.7-6 Species Richness for IUCN Red List species

3.8 Predictions of Deep Sea Corals

Abstract:

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 km^2) global grids for environmental, chemical and physical data of the world's 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 modeling efforts to identify vulnerable marine ecosystems for inclusion in future marine protected areas and reduce coral bycatch by commercial fisheries.

Reference:

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

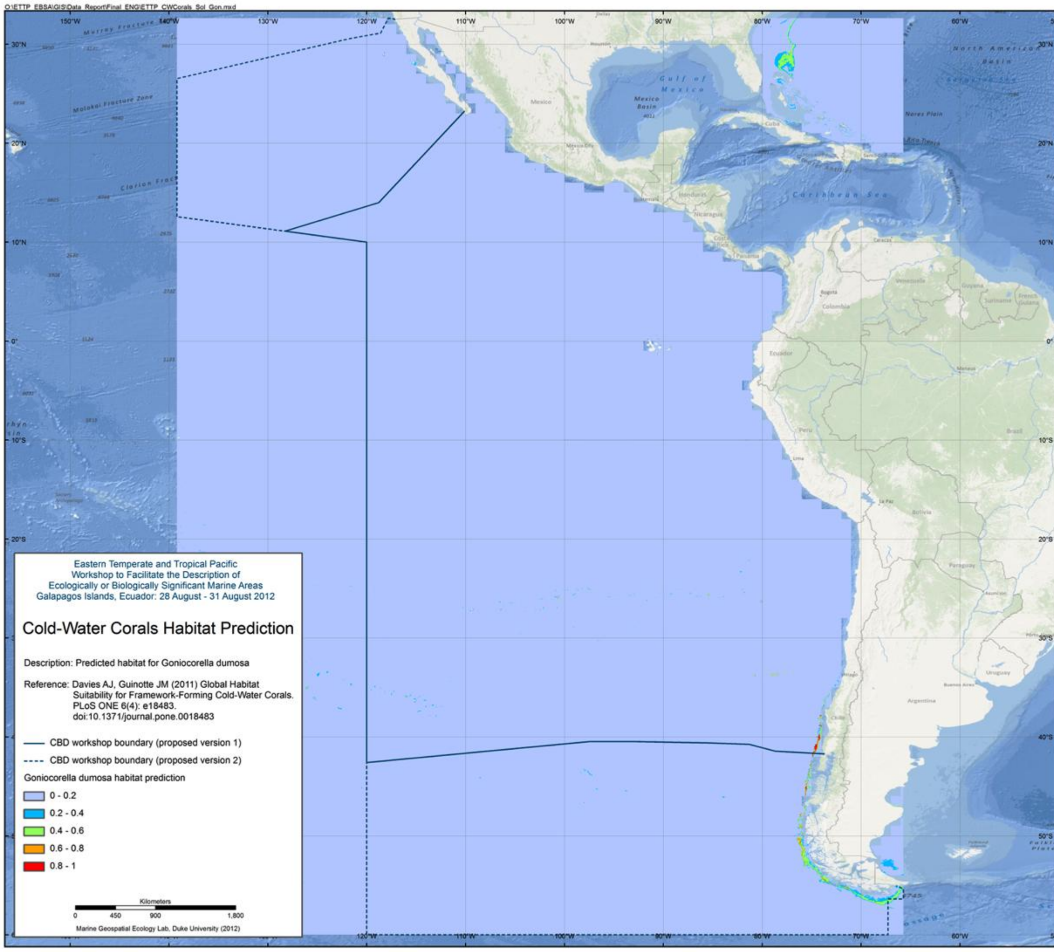

Figure 3.8-1 Goniocorella dumosa Habitat Prediction

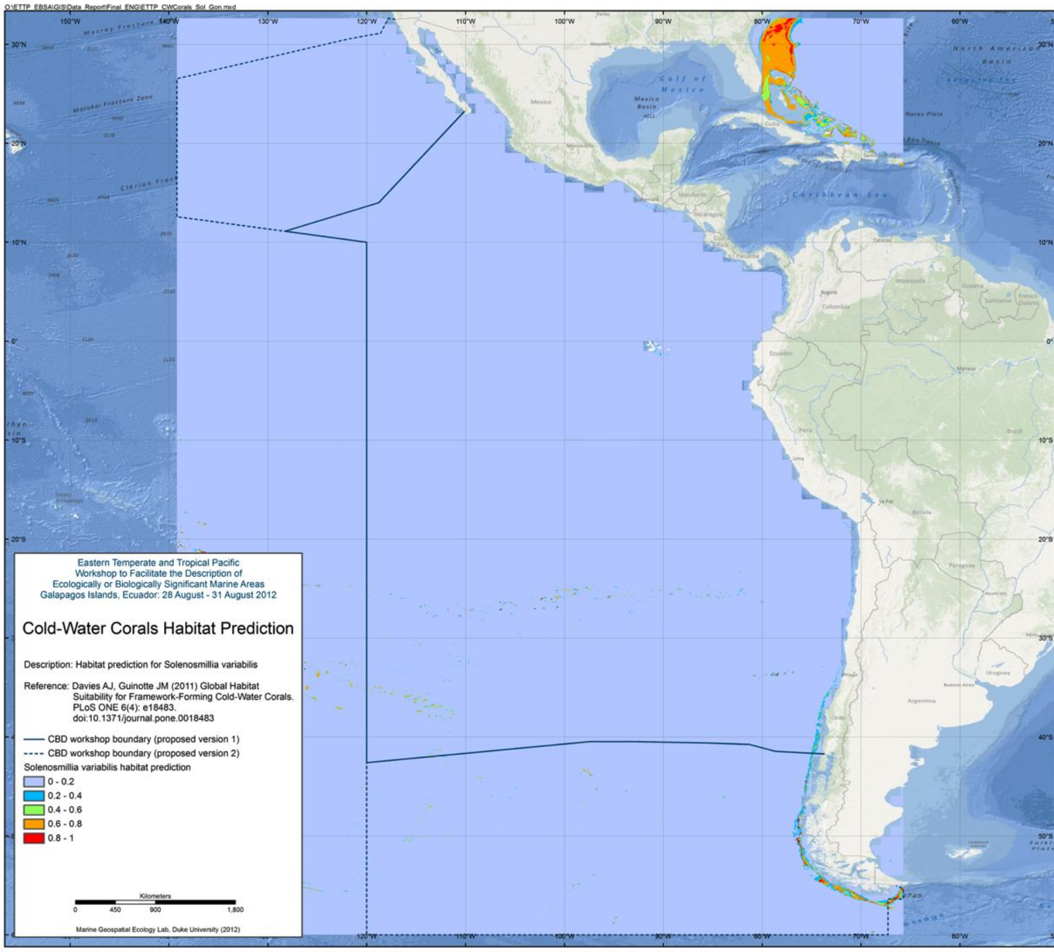

Figure 3.8-2 Solenosmilia variabilis Habitat Prediction

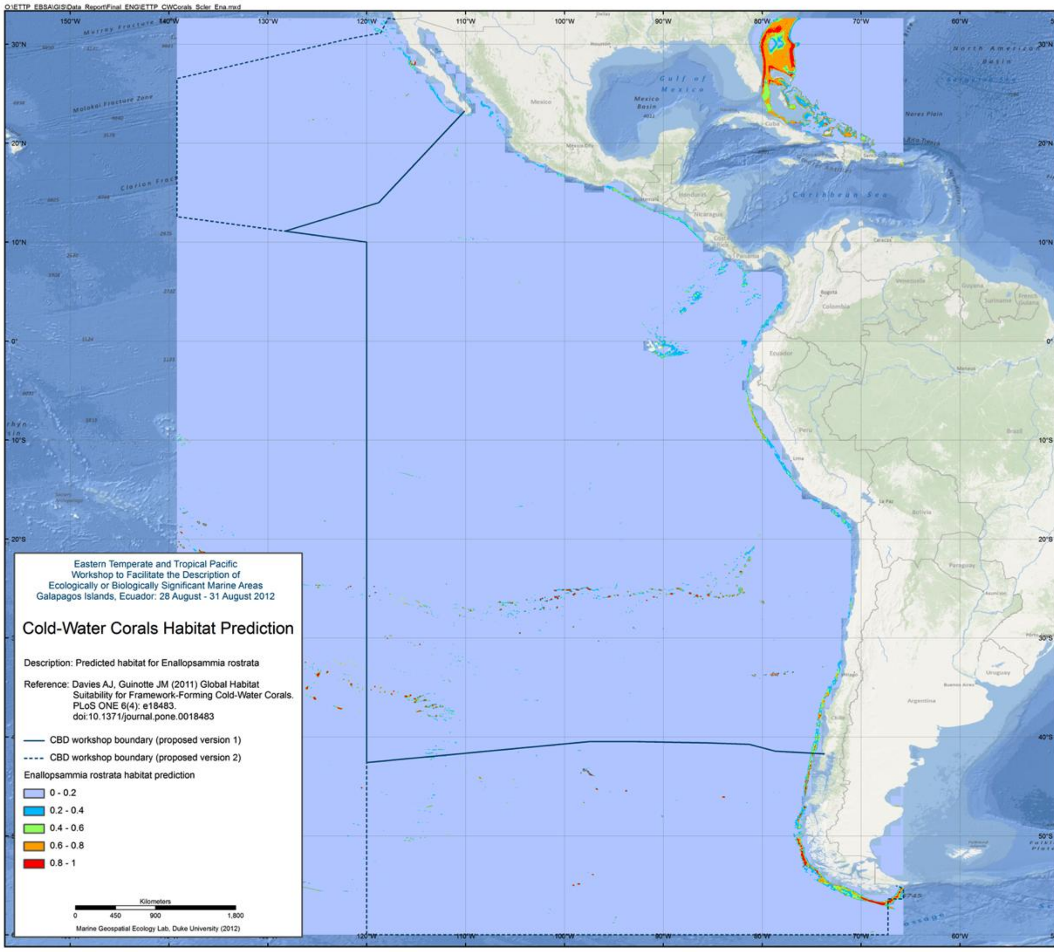

Figure 3.8-3 Enallopsammia rostrata Habitat Prediction

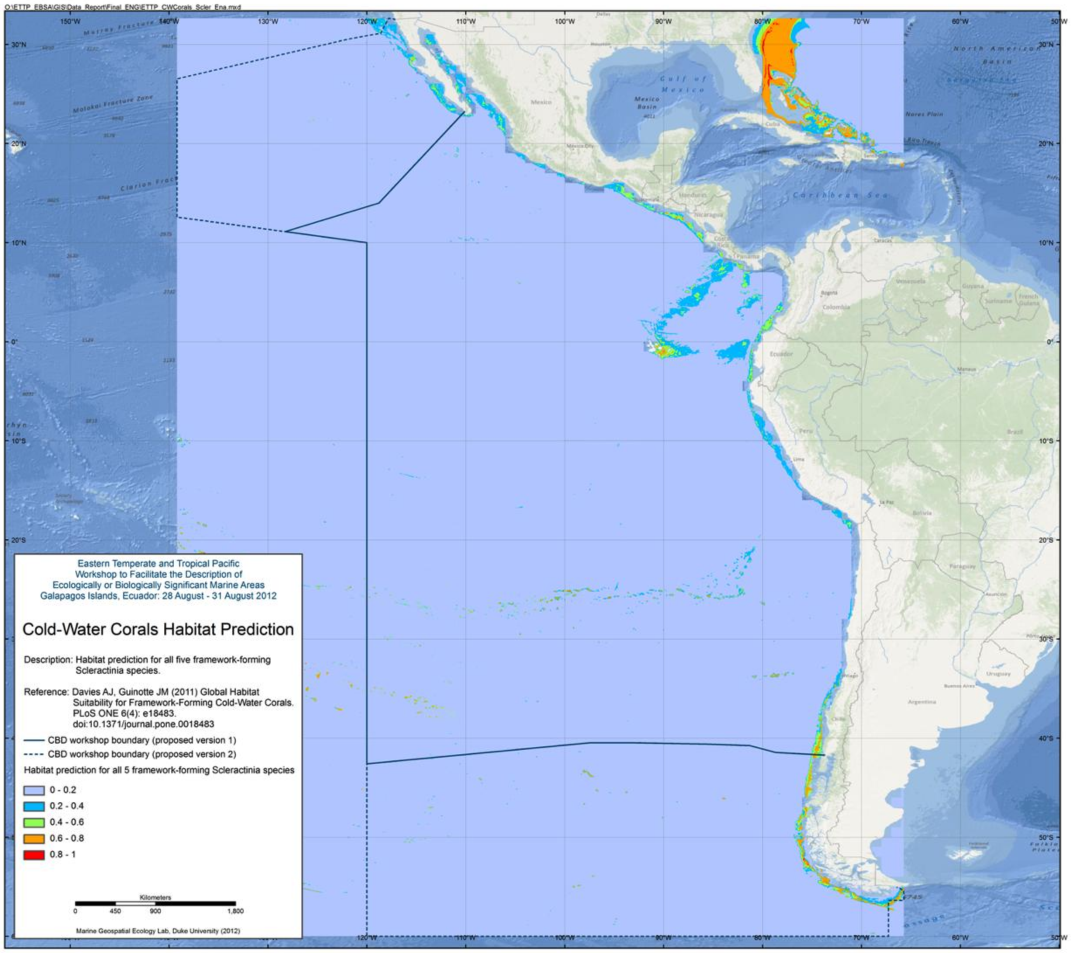

Figure 3.8-4 Framework-forming Scleractinia spp. Habitat Prediction

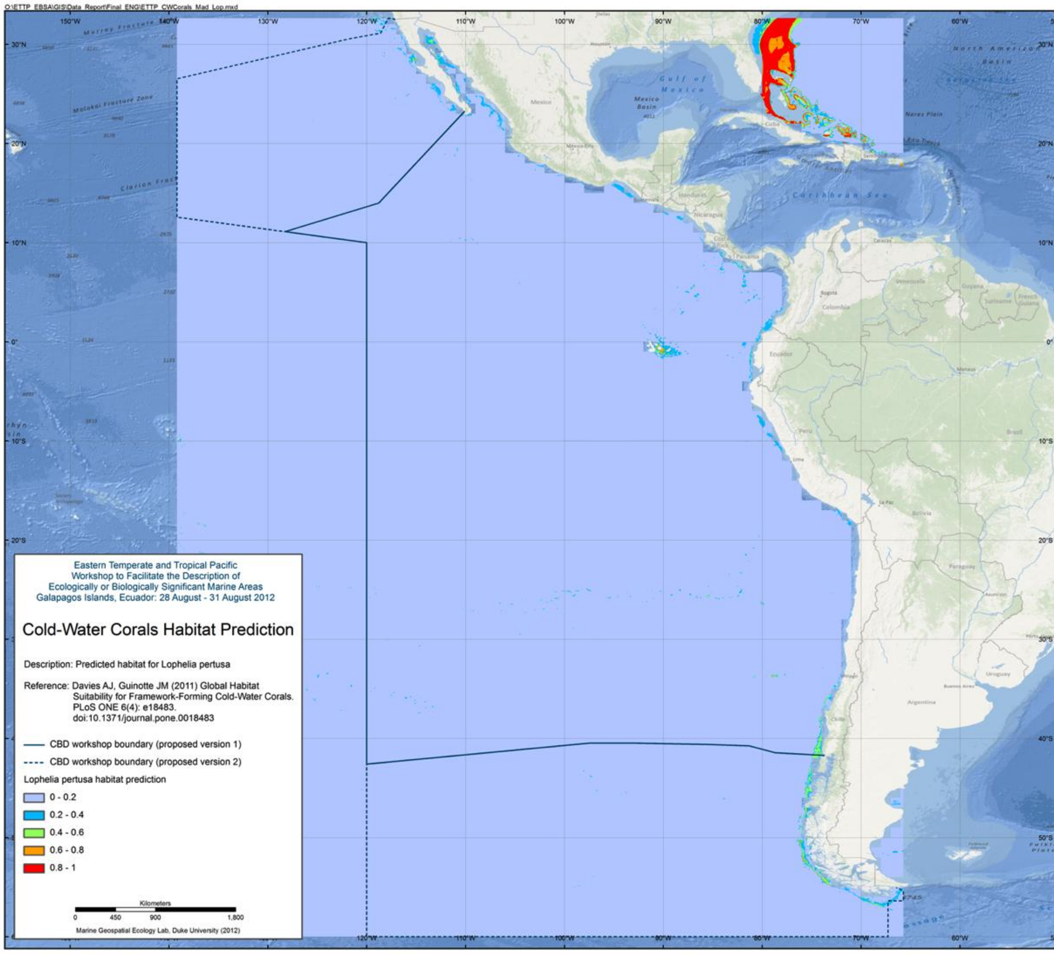

Figure 3.8-5 Lophelia pertusa Habitat Prediction

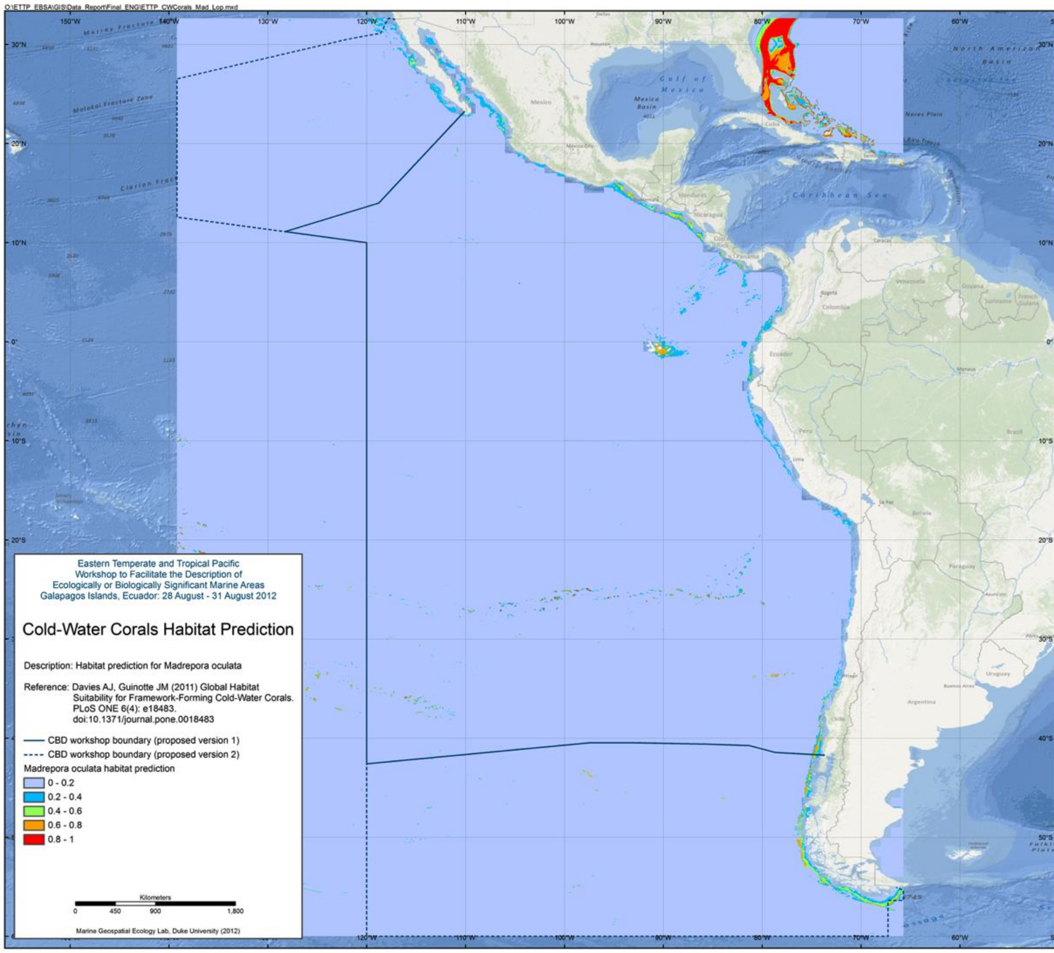

Figure 3.8-6 Madrepora oculata Habitat Prediction

3.9 Important Bird Areas

BirdLife Important Bird Areas (IBAs) have been used to inform the identification of EBSAs in both the previous EBSA regional workshops for the NE Atlantic and S Pacific. Previously the data provided has been used to either support the designation of an EBSA for a range of taxa and habitats, or to identify EBSAs solely on the basis of bird data.

IBAs have been identified using several data sources:

1. Terrestrial seabird breeding sites are shown with point locality and species that qualifies at the IBA
   – see http://www.birdlife.org/datazone/site/search
2. Marine areas around breeding colonies have been identified based on literature review where possible to guide the distance required by each species. Where literature is sparse or lacking, extensions have been applied on a precautionary basis.

– see http://seabird.wikispaces.com/

3. Sites identified by satellite tracking data via kernel density analysis, first passage time analysis and bootstrapping approaches.
   - www.seabirdtracking.org

Together these IBAs form a network of sites of importance to coastal, pelagic, resident and or migratory species. EBSA criteria of particular relevance are “important for life-history stages”, “threatened species”, “diversity” and “fragility”. For further information Google “IBAs vs EBSAs”.

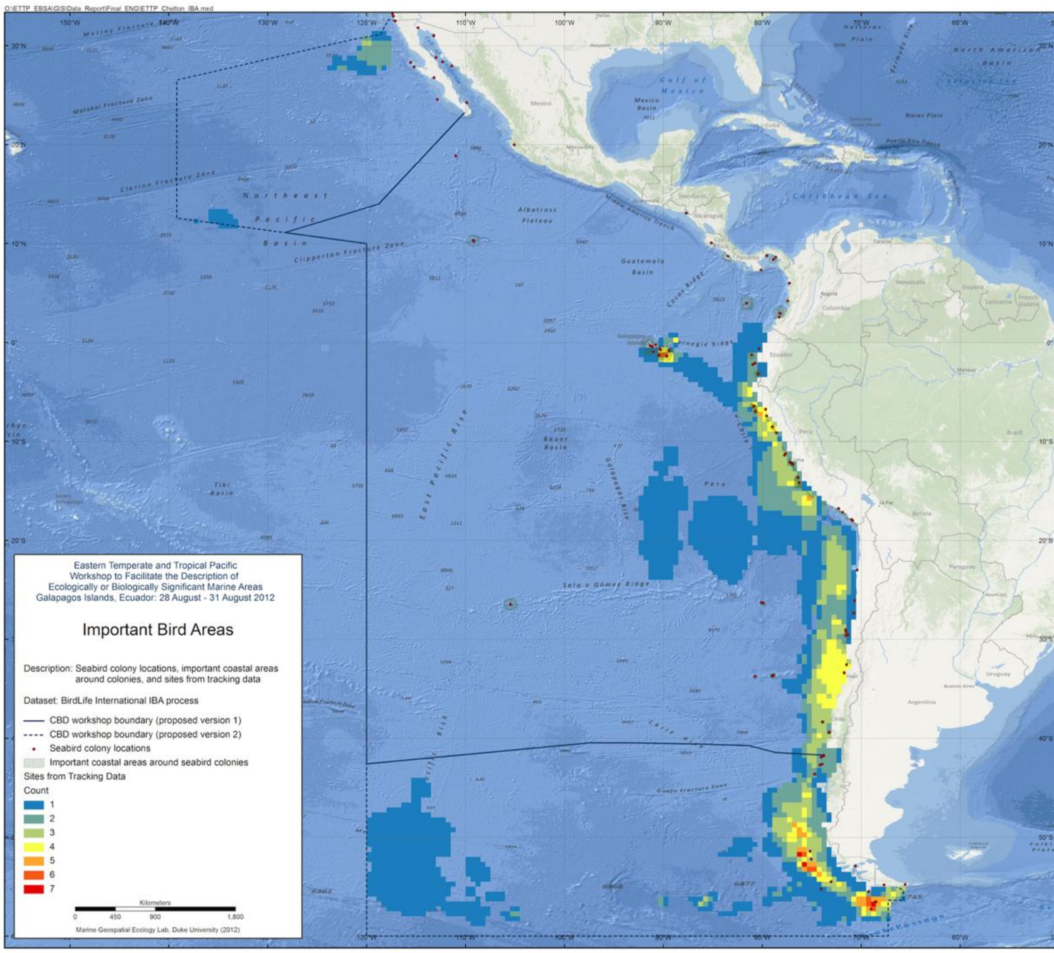

Figure 3.9-1 Important Bird Areas (IBAs)

3.10 Galápagos Fur Seal and Sea Lion Tagging

Data on the movement and ecology of Galápagos fur seals (Arctocephalus galapagoensis) and Galápagos sea lions (Zalophus wollebaeki) have been collected from several tagging projects around the islands of San Cristobal, Floreana, Fernandina and Caamaño in the Galápagos archipelago.

References: Villegas-Amtmann et al. (2008), Villegas-Amtmann et al. (2009), Villegas-Amtmann et al. (2010), Villegas-Amtmann and Costa (2010), Jeglinski et al. (2012)

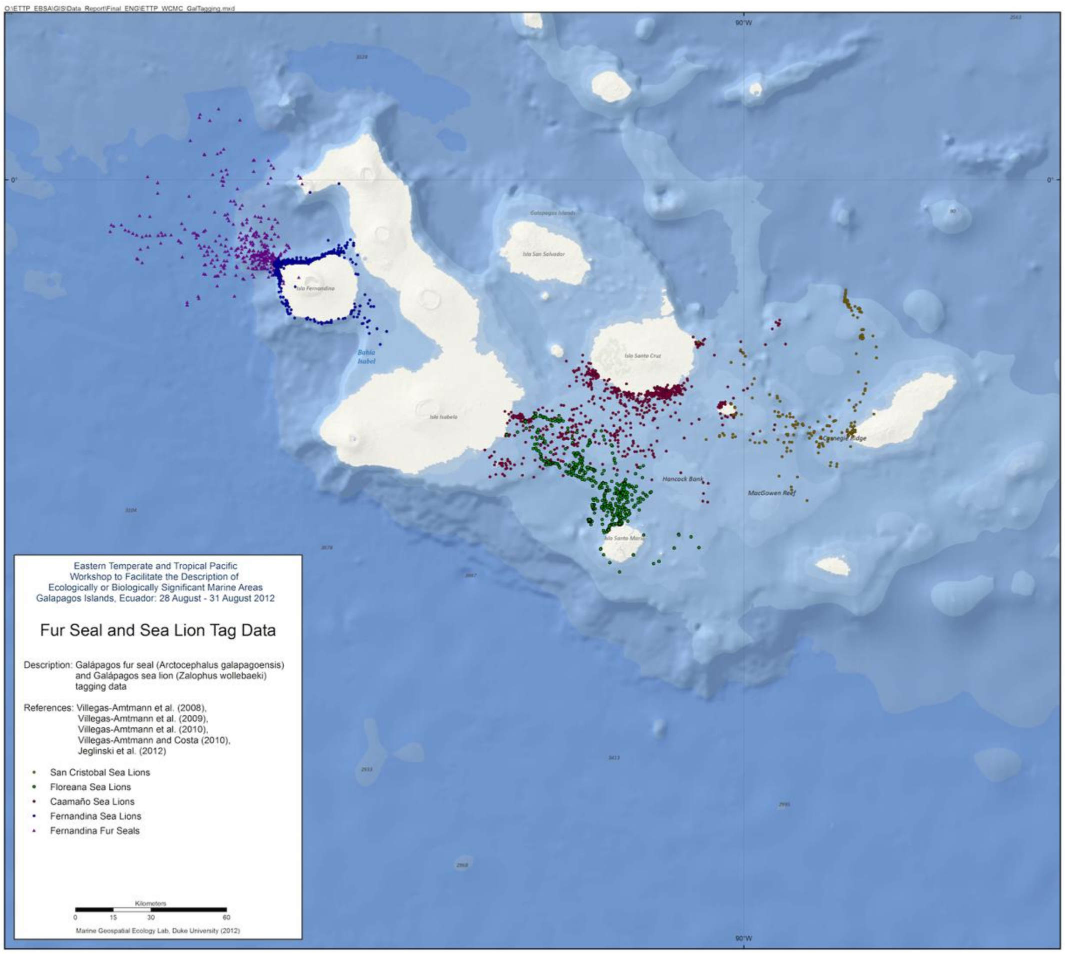

Figure 3.10-1 Galapagos Fur Seal and Sea Lion Tag Data

3.11 Marine Mammal Habitat Suitability Models

Habitat suitability modeling was recently conducted for five whale species in implementing the first component of the "broad-scale marine spatial planning of migration routes and critical habitats for marine mammals in the eastern Pacific" project (UNEP/CPPS/Spain). The project aims to support the management and conservation of migratory and widely distributed marine mammals in the eastern Pacific by means of large-scale spatial planning using an ecosystem approach. The species included: 1) blue whale (Balaenoptera musculus), including Northeast and Southeast Pacific populations; 2) Bryde's whale (Balaenoptera brydei = edeni); 3) humpback whale (Megaptera novaeangliae), including Northeast and Southeast Pacific populations; 4) southern right whale (Eubalaena australis), and 5) sperm whale (Physeter macrocephalus).

The georeferenced information for GIS analysis was compiled through the Regional Information System on Marine Biodiversity and Protected Areas in the Southeast Pacific - SIBIMAP, developed by the Permanent Commission for the South Pacific - CPPS. In this analysis 11,598 records were used. The data came from many sources, including scientific articles, websites of national institutions, reports and publications of international organizations, global databases and datasets provided directly by researchers. Data was separated in two periods Dec-May and June-Nov. The model Maxent which uses presence-only data and six associated environment variables (sea surface temperature, surface salinity, depth, slope, surface chlorophyll a, and persistent surface pelagic fronts) was used in this exercise. Detail of the methodology and scope can be found in the document CPPS/PNUMA (2012).

Reference:

CPPS/PNUMA. 2012. Atlas sobre distribución, rutas migratorias, hábitats críticos y amenazas para grandes cetáceos en el Pacífico oriental. Comisión Permanente del Pacífico Sur - CPPS / Programa de las Naciones Unidas para el Medio Ambiente - PNUMA. Guayaquil, Ecuador. 75p.

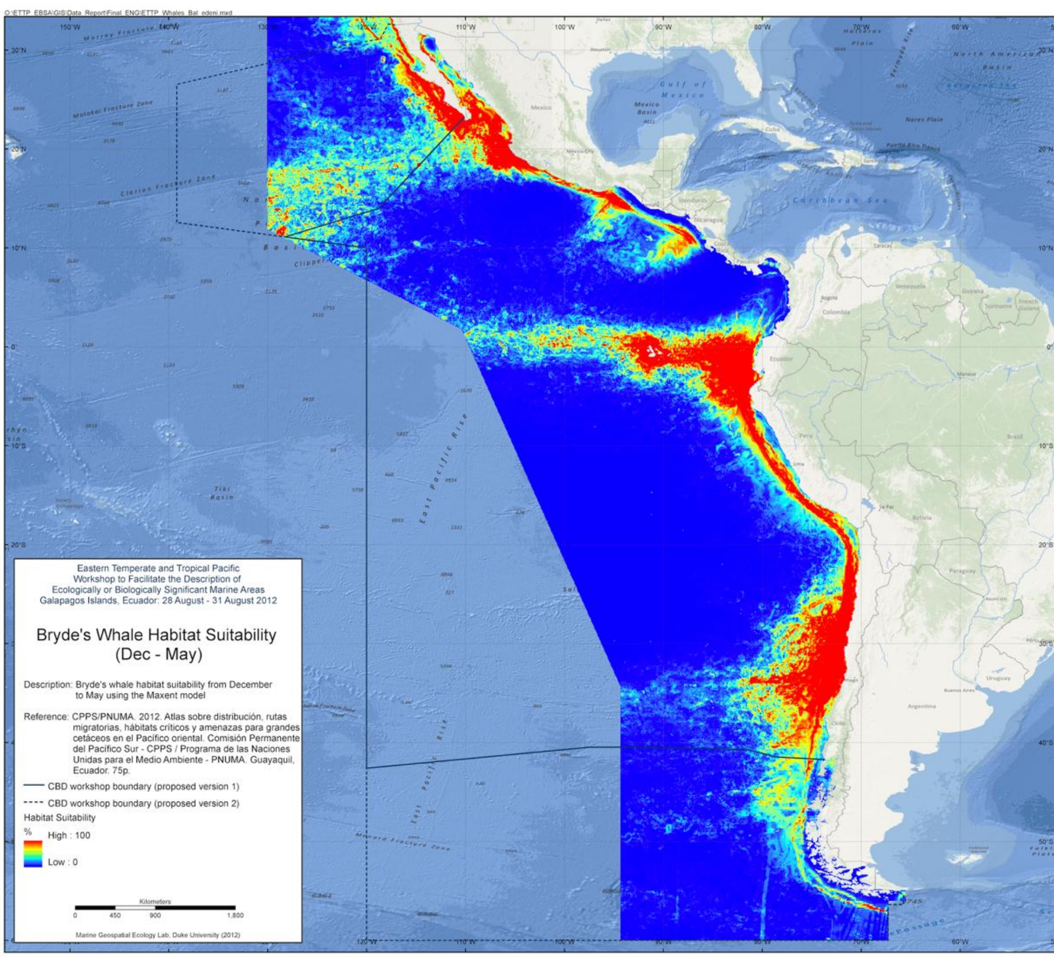

Figure 3.11-1 Bryde's Whale Habitat Suitability (Dec – May)

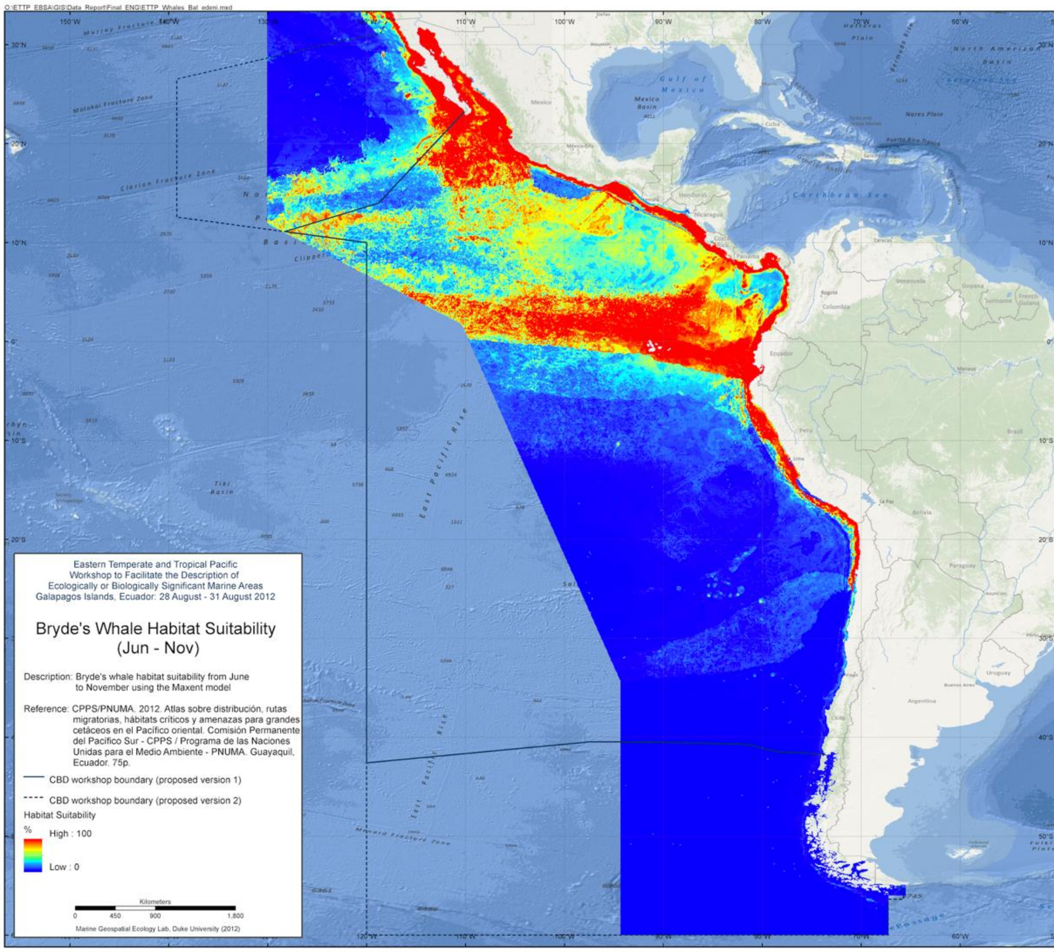

Figure 3.11-2 Bryde's Whale Habitat Suitability (Jun - Nov)

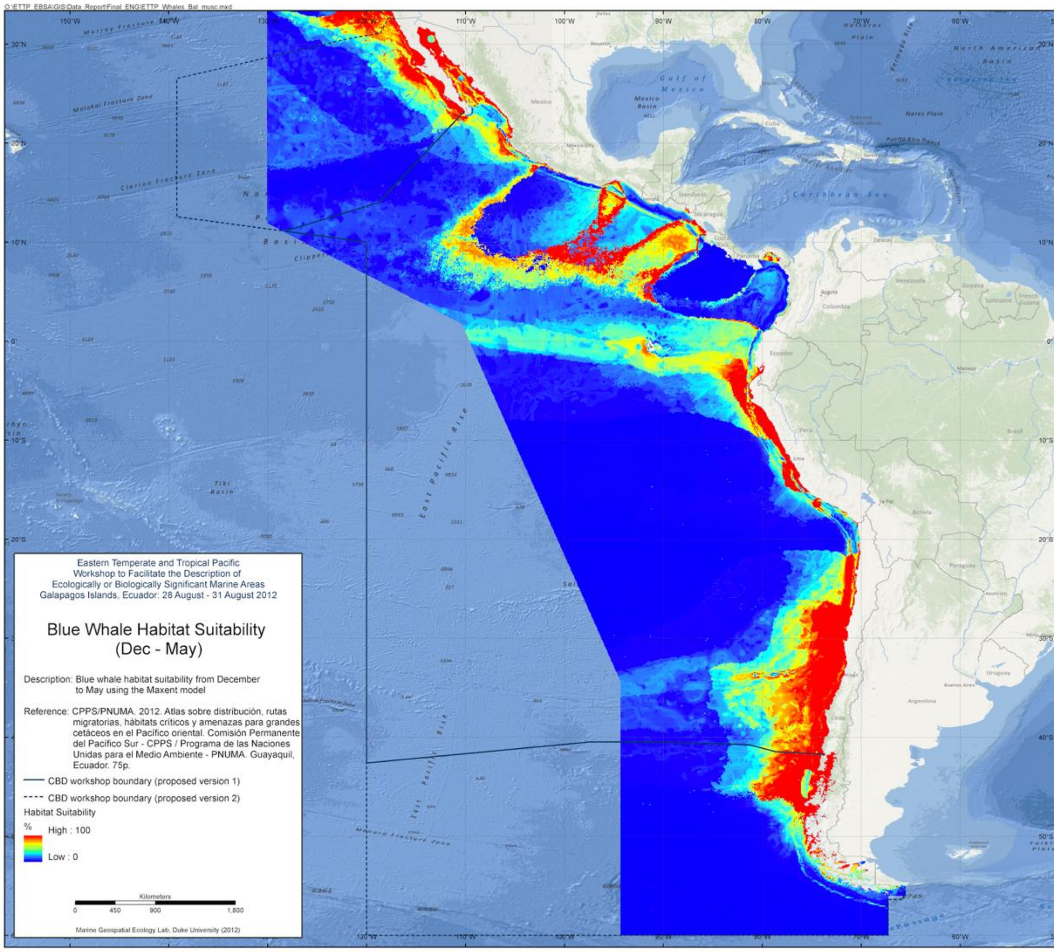

Figure 3.11-3 Blue Whale Habitat Suitability (Dec – May)

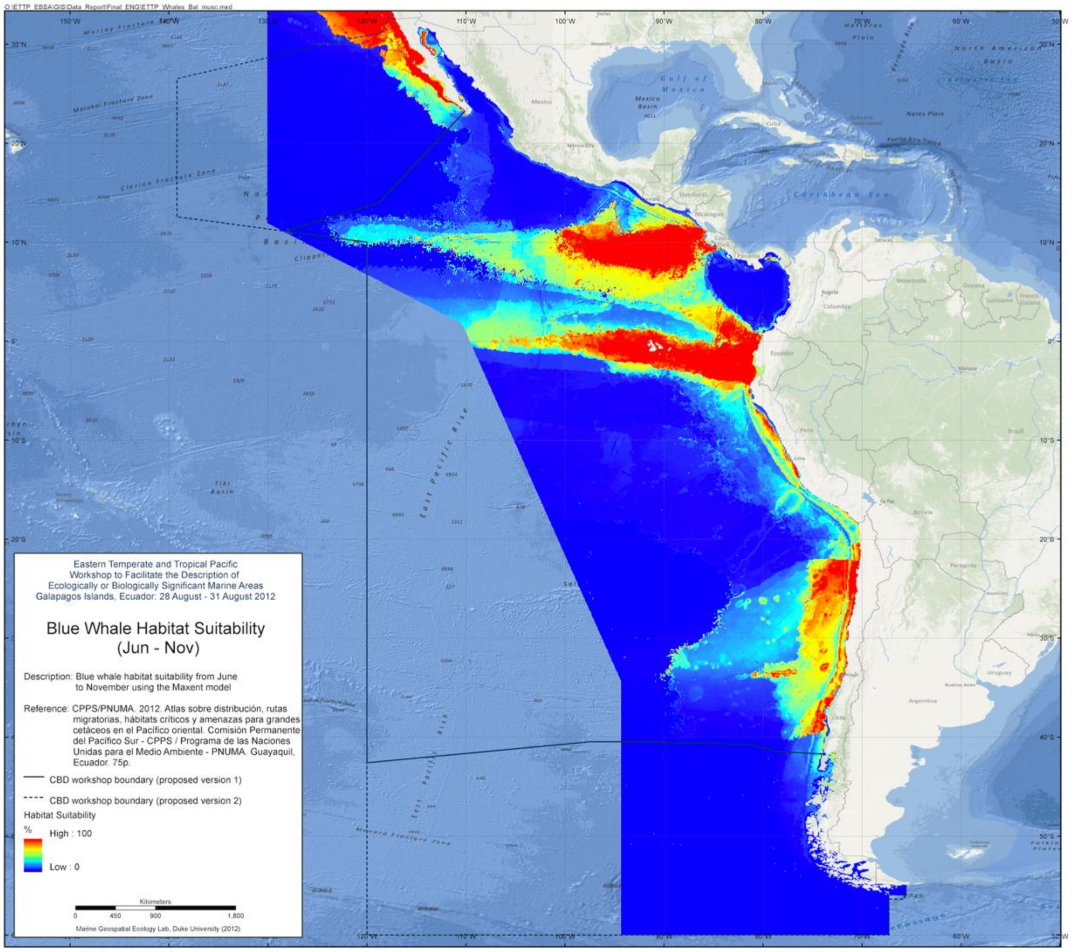

Figure 3.11-4 Blue Whale Habitat Suitability (Jun - Nov)

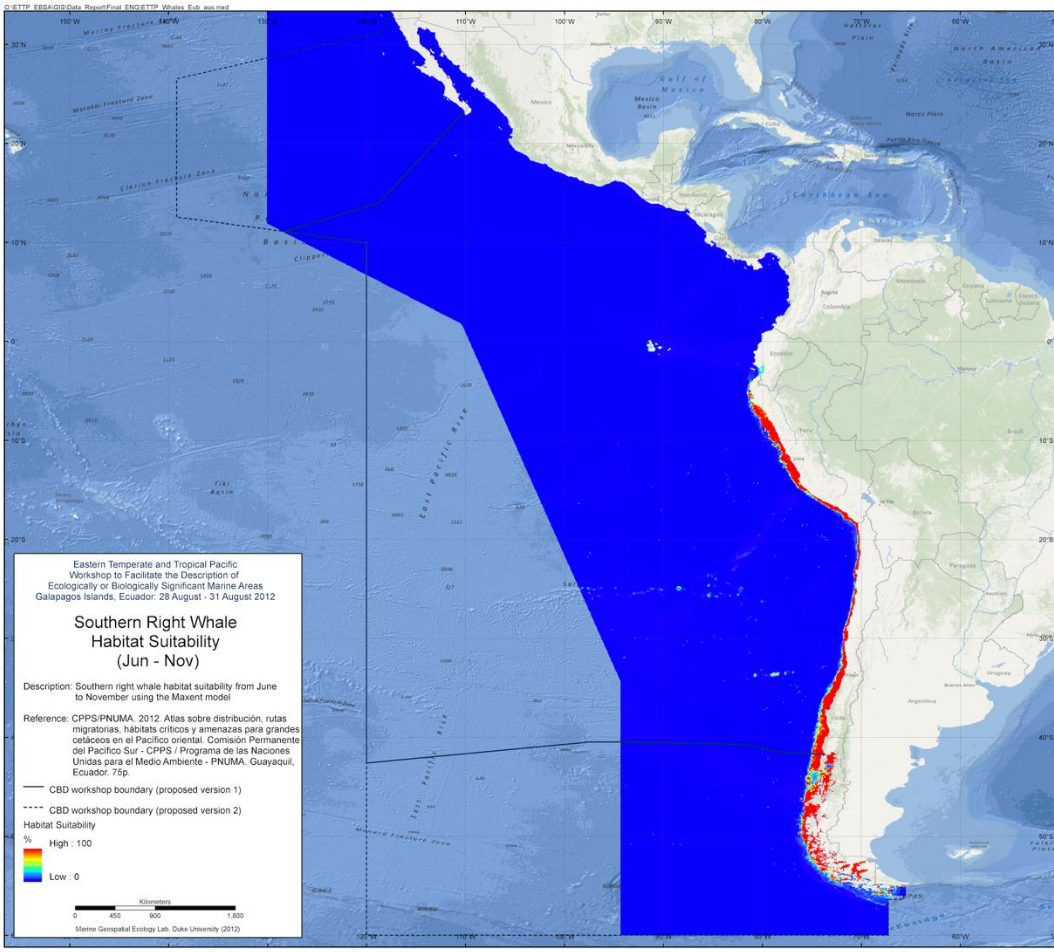

Figure 3.11-5 Southern Right Whale Habitat Suitability (Jun - Nov)

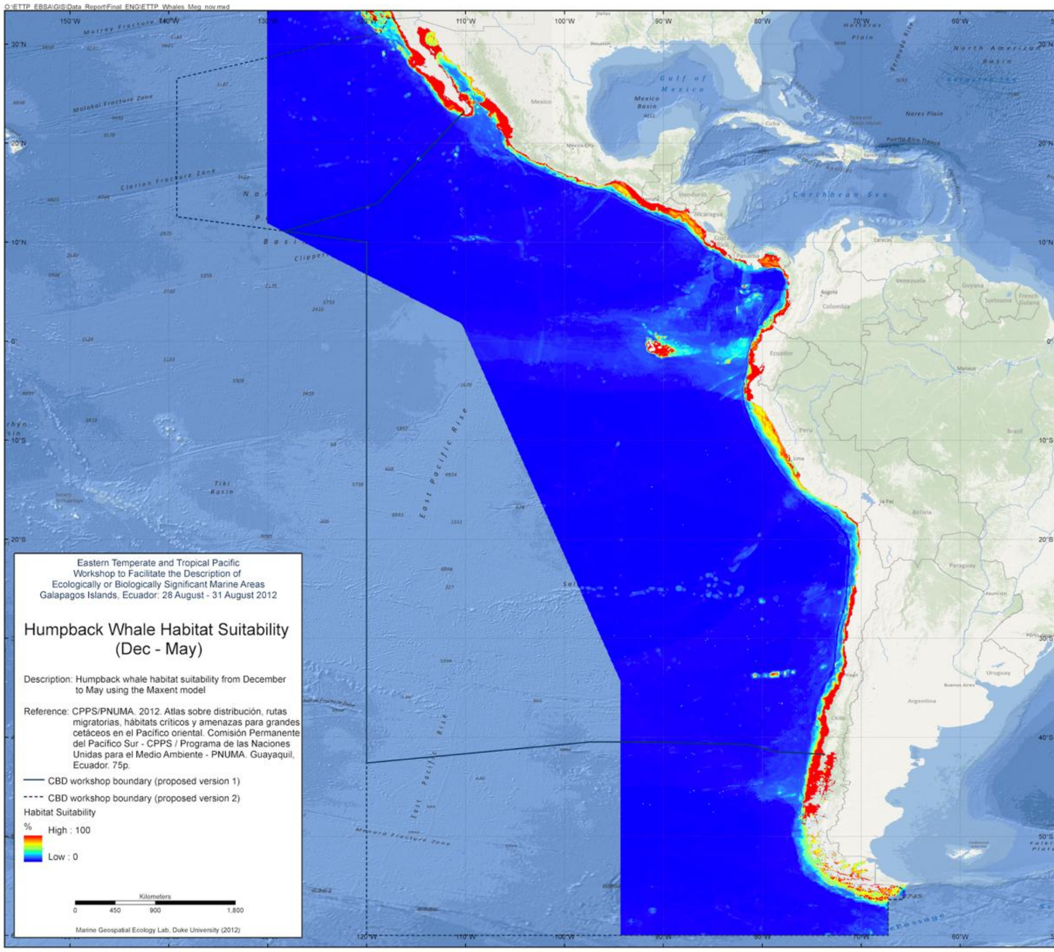

Figure 3.11-6 Humpback Whale Habitat Suitability (Dec – May)

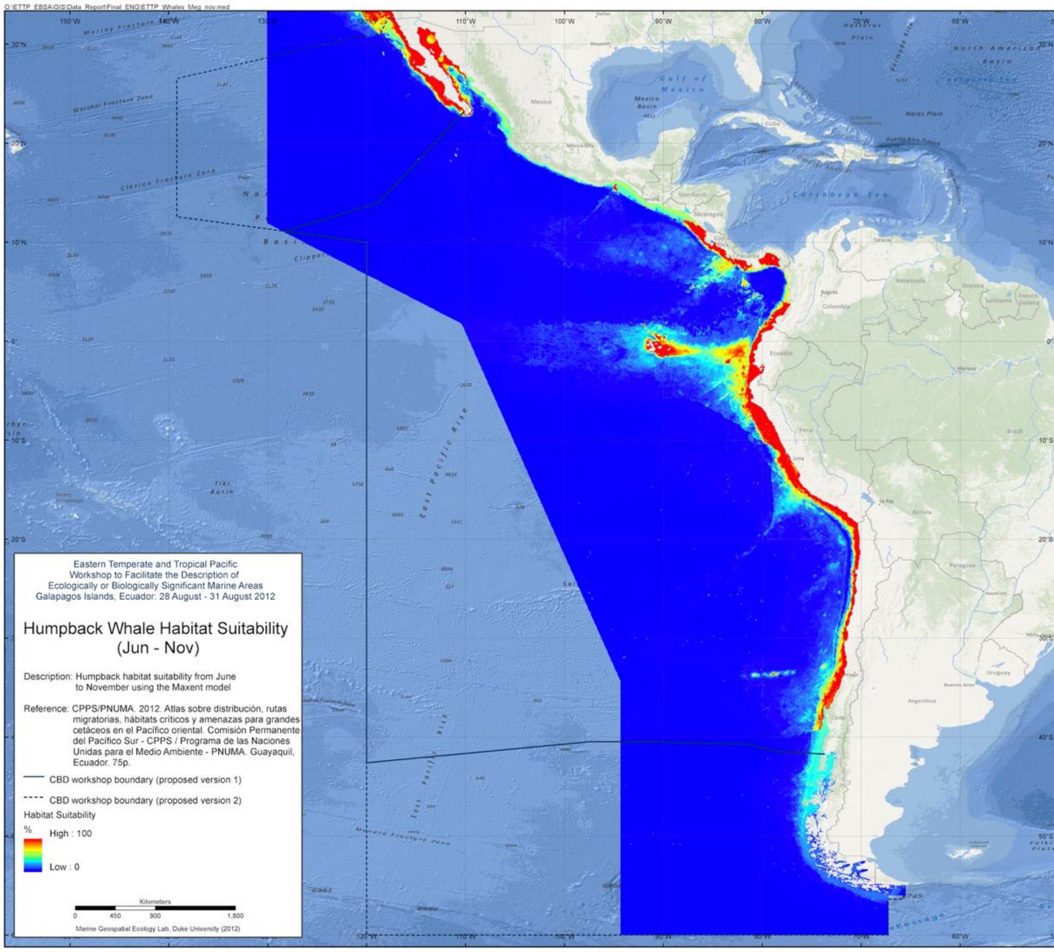

Figure 3.11-7 Humpback Whale Habitat Suitability (Jun - Nov)

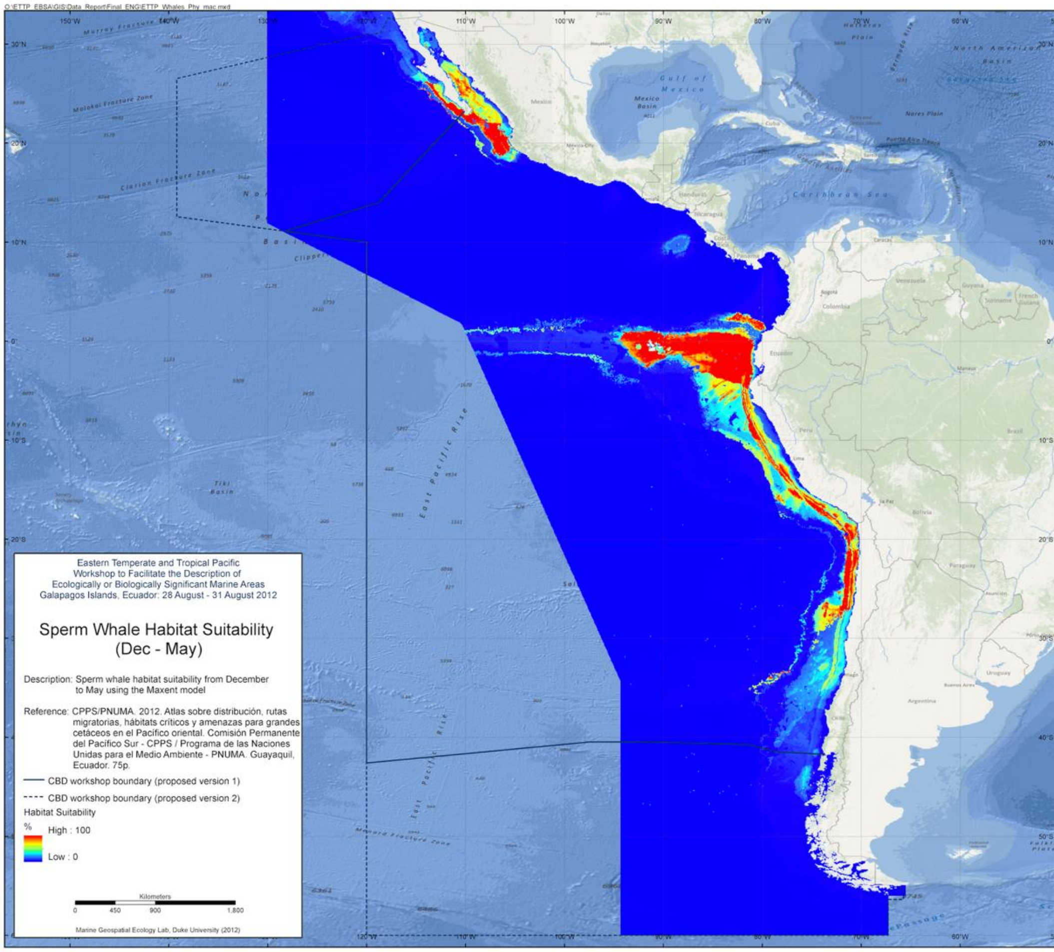

Figure 3.11-8 Sperm Whale Habitat Suitability (Dec – May)

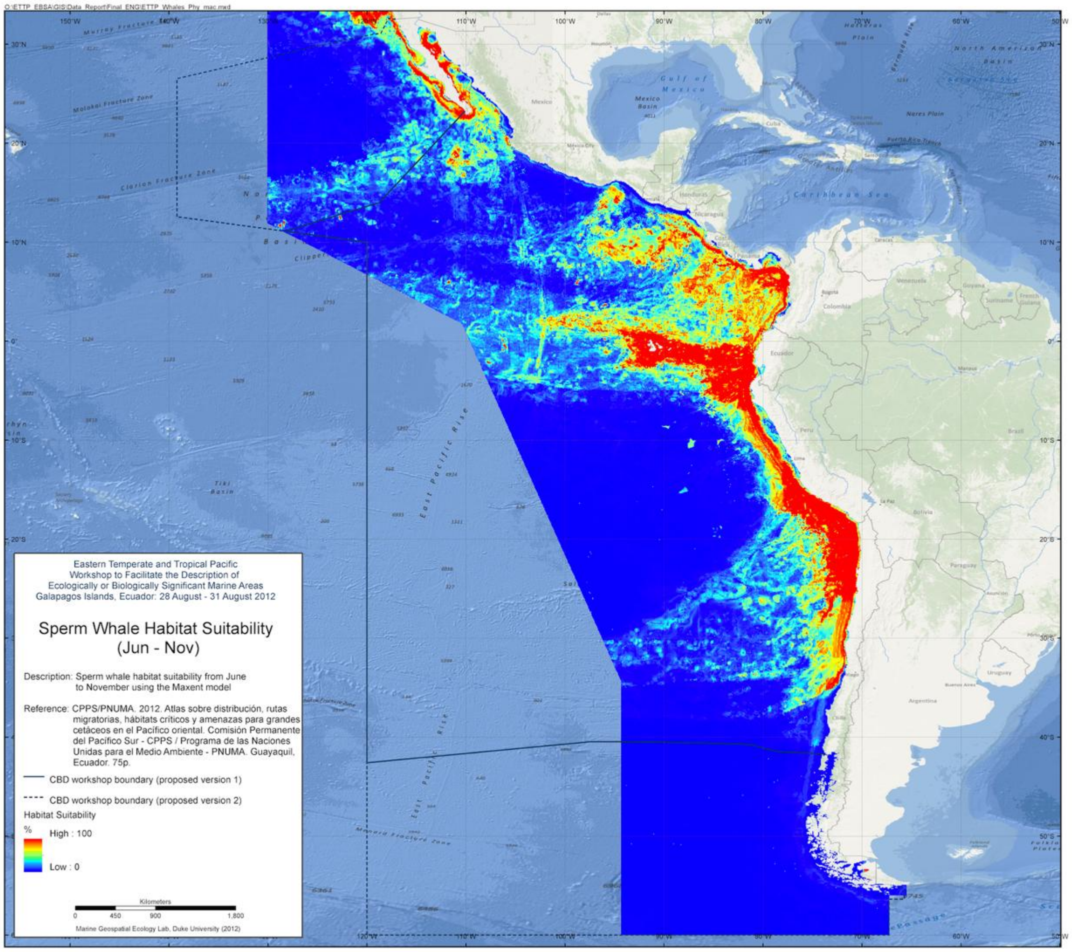

Figure 3.11-9 Sperm Whale Habitat Suitability (Jun - Nov)

4 Physical Data

4.1 Seamounts

Abstract:
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-second 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 shipbased 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 o1.5 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.

Reference:

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

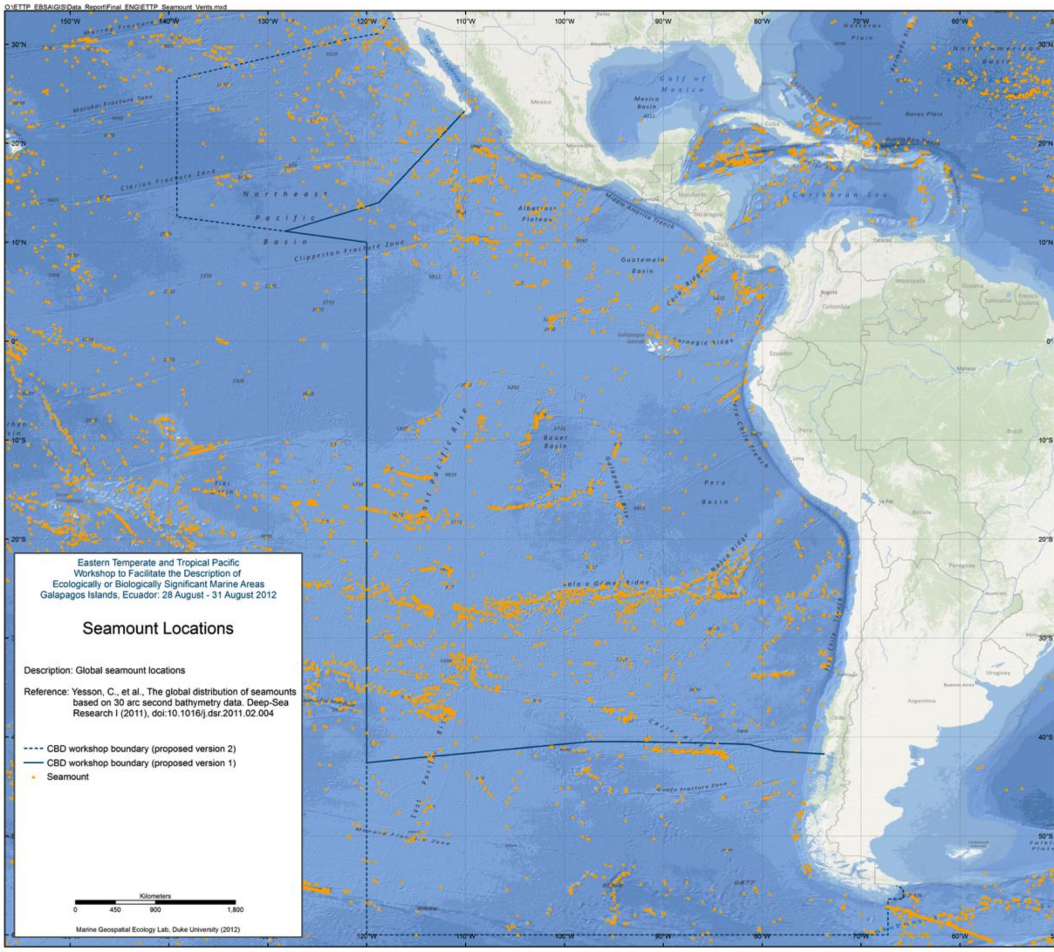

Figure 4.1-1 Seamount Locations

4.2 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.
(source: http://www.noc.soton.ac.uk/chess/)

ChEssBase is a dynamic relational database available online since December 2004. The aim of ChEssBase is to provide taxonomical, biological, ecological and distributional data of all species described from deep-water chemosynthetic ecosystems, as well as bibliography and information on the habitats. These habitats include hydrothermal vents, cold seeps, whale falls, sunken wood and areas of minimum oxygen that intersect with the continental margin or 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.
(source: http://www.noc.soton.ac.uk/chess/database/db_home.php)

Data available from:
ChEssBase: http://www.noc.soton.ac.uk/chess/database/db_home.php
InterRidge: http://www.interridge.org/irvents/maps

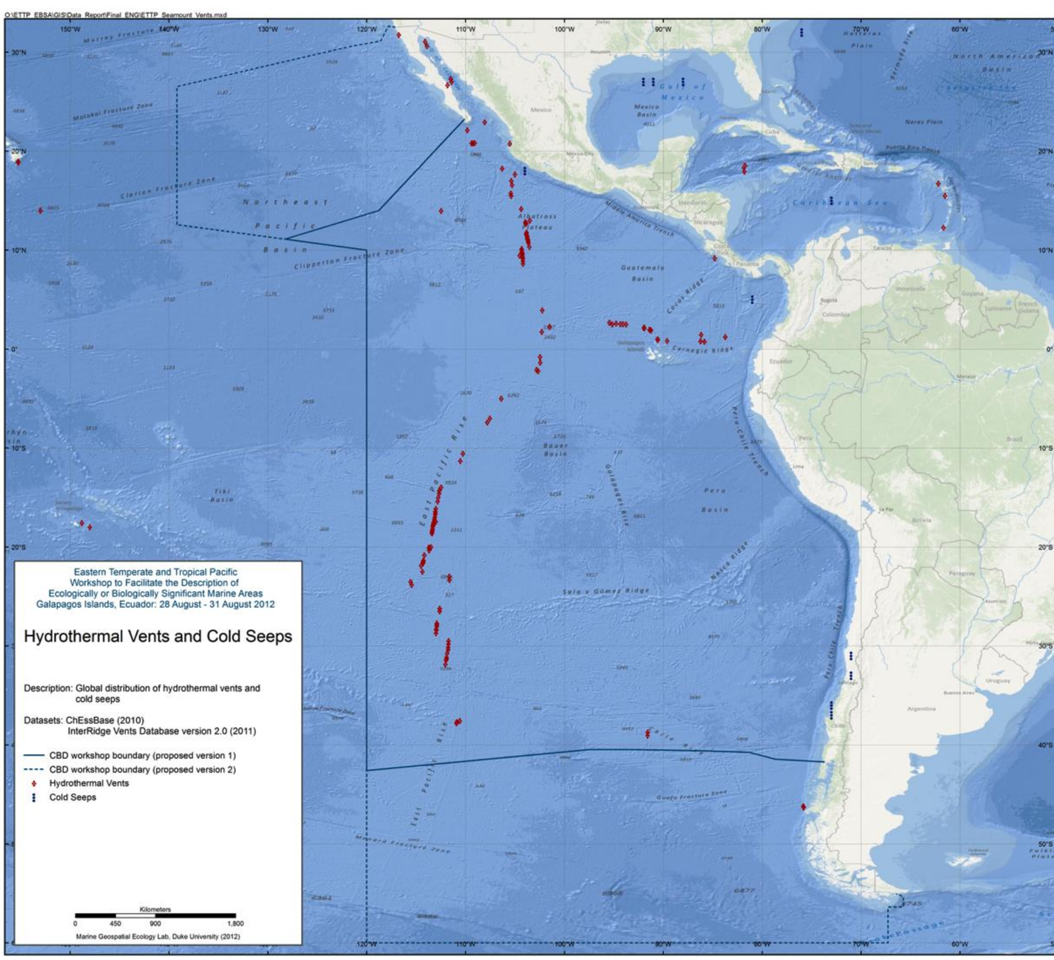

Figure 4.2-1 Hydrothermal Vents and Cold Seeps

4.3 Bathymetry (GEBCO)

The GEBCO_08 Grid is 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.
(source: http://www.gebco.net/data_and_products/gridded_bathymetry_data/)

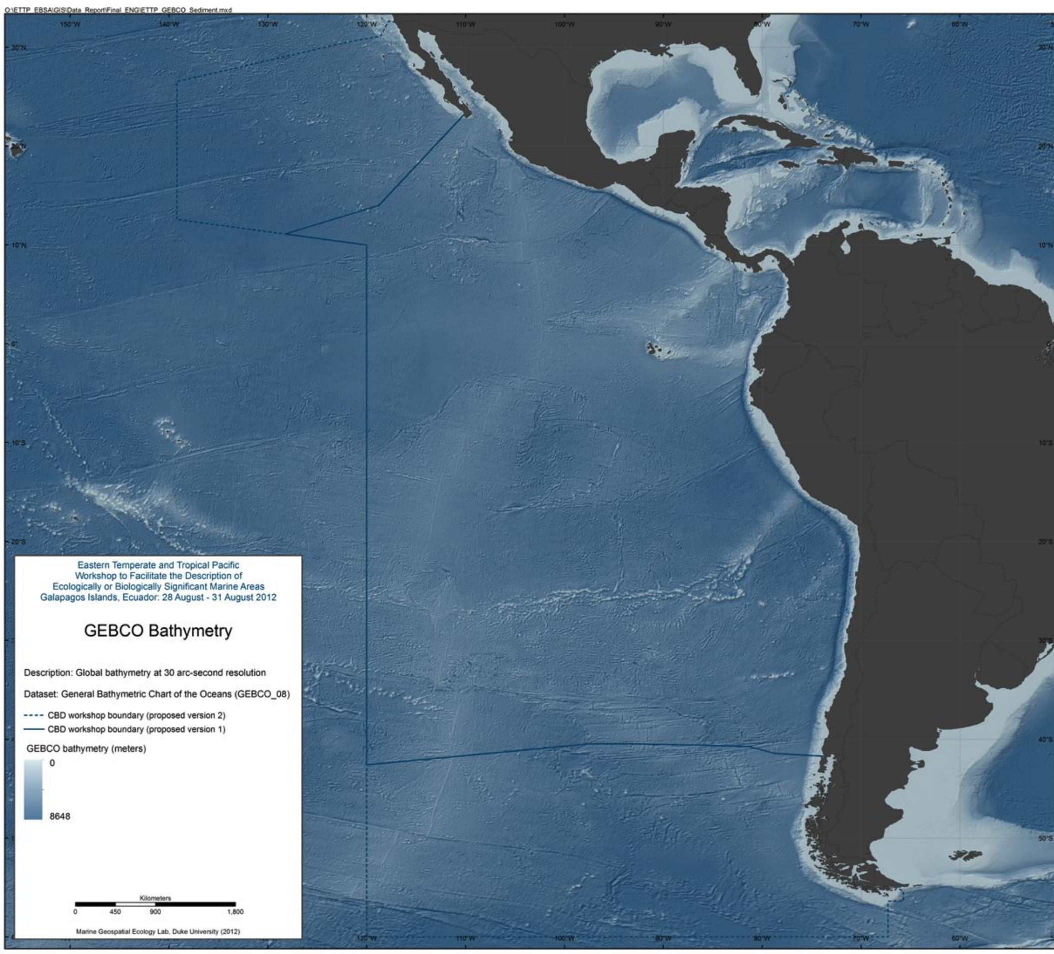

Figure 4.3-1 GEBCO 30 Arc-second Bathymetry

4.4 Distribution of Large Submarine Canyons

Abstract:
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.

Reference:
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

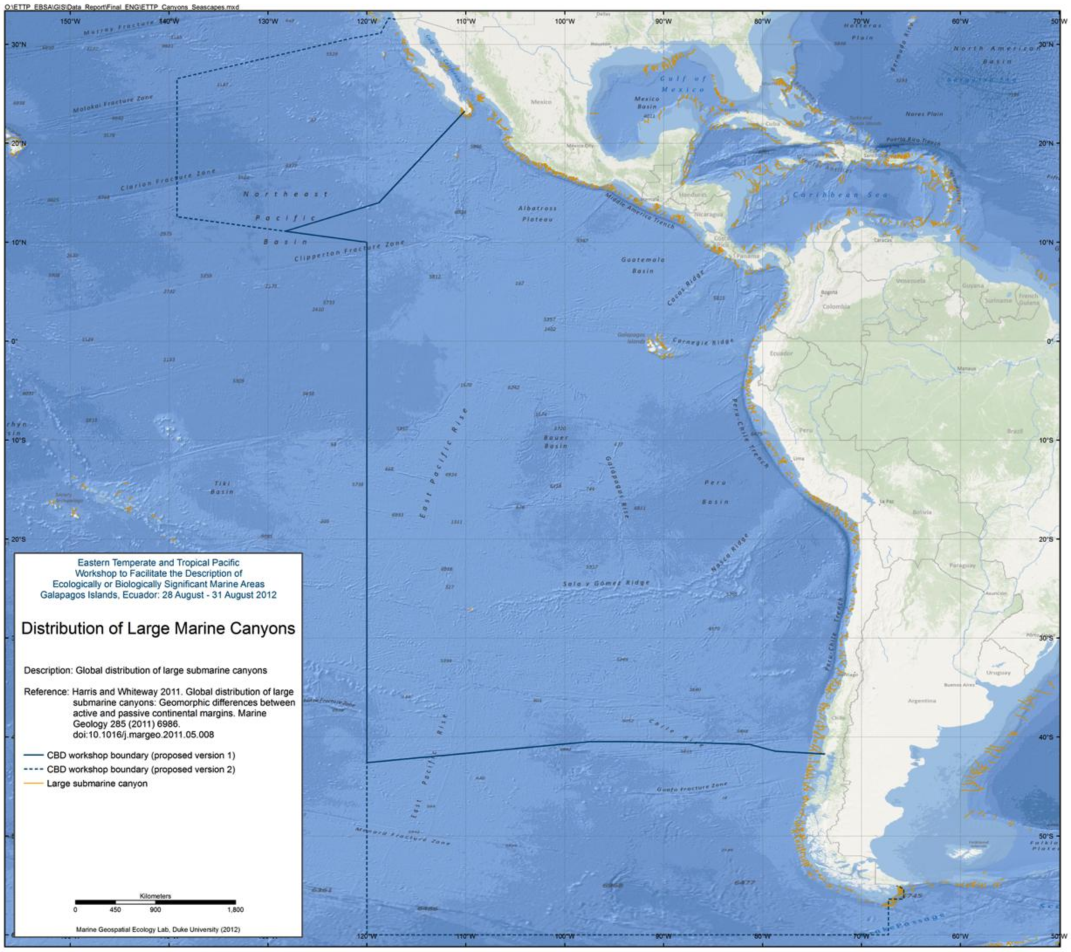

Figure 4.4-1 Large Marine Canyons

4.5 Total Sediment Thickness of the Worlds Oceans & Marginal Seas

A digital total-sediment-thickness database for the world's oceans and marginal seas has been compiled by the NOAA National Geophysical Data Center (NGDC). The data were gridded with a grid spacing of 5 arc-minutes by 5 arc-minutes. Sediment-thickness data were compiled from three principle sources: (i) previously published isopach maps including Ludwig and Houtz [1979], Matthias et al. [1988], Divins and Rabinowitz [1990], Hayes and LaBrecque [1991], and Divins [2003]; (ii) ocean drilling results, both from the Ocean Drilling Program (ODP) and the Deep Sea Drilling Project (DSDP); and (iii) seismic reflection profiles archived at NGDC as well as seismic data and isopach maps available as part of the IOC's International Geological-Geophysical Atlas of the Pacific Ocean [Udinstev, 2003].

The distribution of sediments in the oceans is controlled by five primary factors:

1. Age of the underlying crust
2. Tectonic history of the ocean crust
3. Structural trends in basement
4. Nature and location of sediment source, and
5. Nature of the sedimentary processes delivering sediments to depocenters

The sediment isopach contour maps for the Pacific were digitized by Greg Cole of Los Alamos National Laboratory, for the Indian Ocean by Carol Stein of Northwestern University, and the South Atlantic and Southern Ocean by Dennis Hayes of Lamont-Doherty Earth Observatory. The digitized data were then gridded at NGDC using the algorithm for "Gridding with Continuous Curvature Splines in Tension" of Smith and Wessel [1990].

The data values are in meters and represent the depth to acoustic basement. It should be noted that acoustic basement may not actually represent the base of the sediments. These data are intended to provide a minimum value for the thickness of the sediment in a particular geographic region. (source: http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html)

Reference: Divins, D.L., NGDC Total Sediment Thickness of the World's Oceans & Marginal Seas, Data retrieved 25 January 2012, http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html

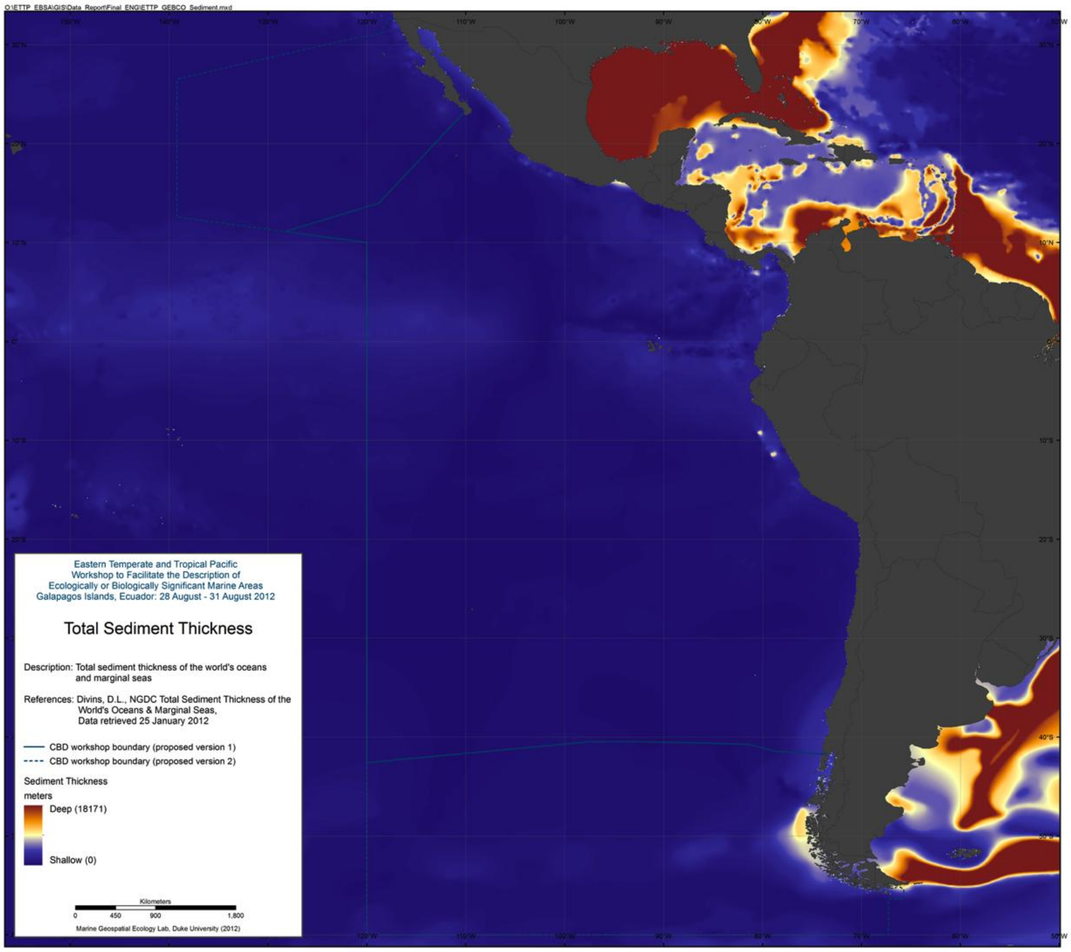

Figure 4.5-1 Total Sediment Thickness

4.6 Global Seascapes

Abstract:
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.

Reference:

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

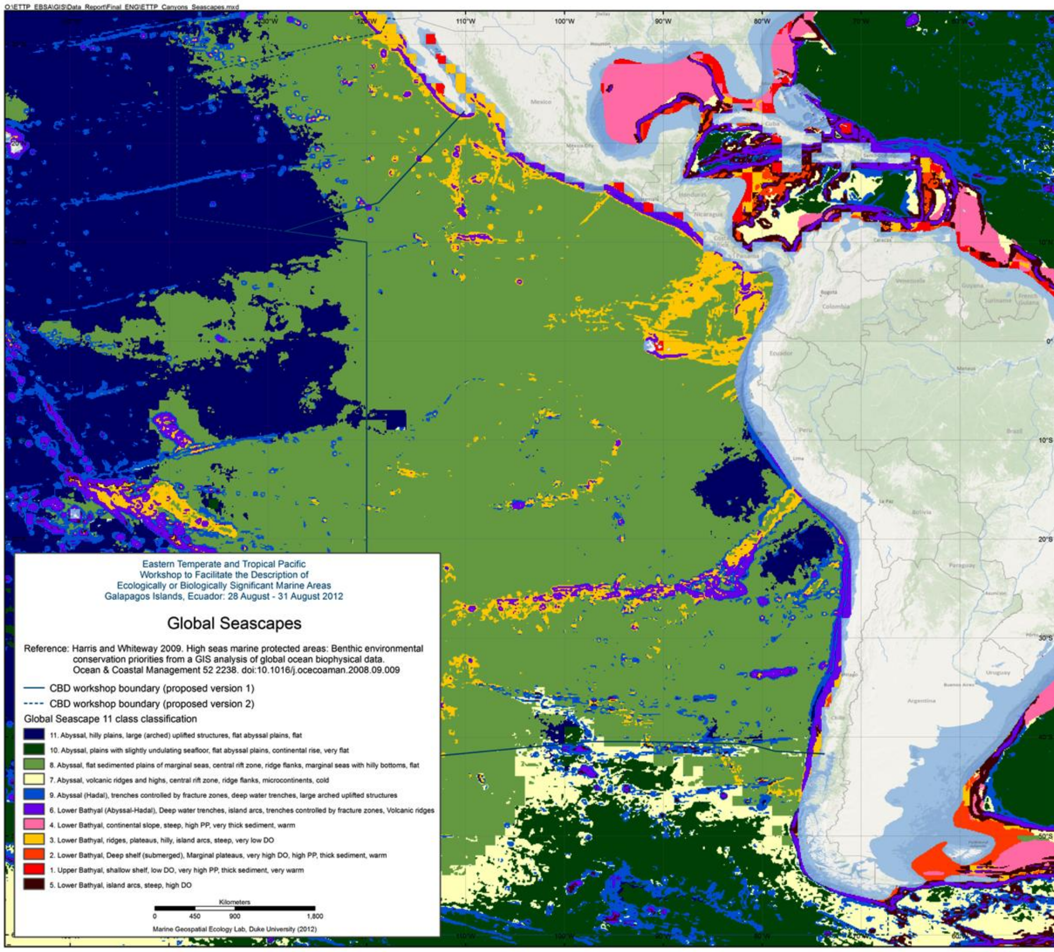

Figure 4.6-1 Global Seascapes

4.7 CSIRO Atlas of Regional Seas (CARS) Physical Ocean Climatologies

For items 4.7.1 through 4.7.6, data were downloaded and processed from the CSIRO Atlas of Regional Seas (CARS).

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.
(source: http://www.marine.csiro.au/~dunn/cars2009/)

References:
1. 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

2. 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

3. 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.

4. Metadata:
CARS2009 metadata record: MarLIN record: 8539, Anzlic identifier: ANZCW0306008539

4.7.1 Salinity Climatology

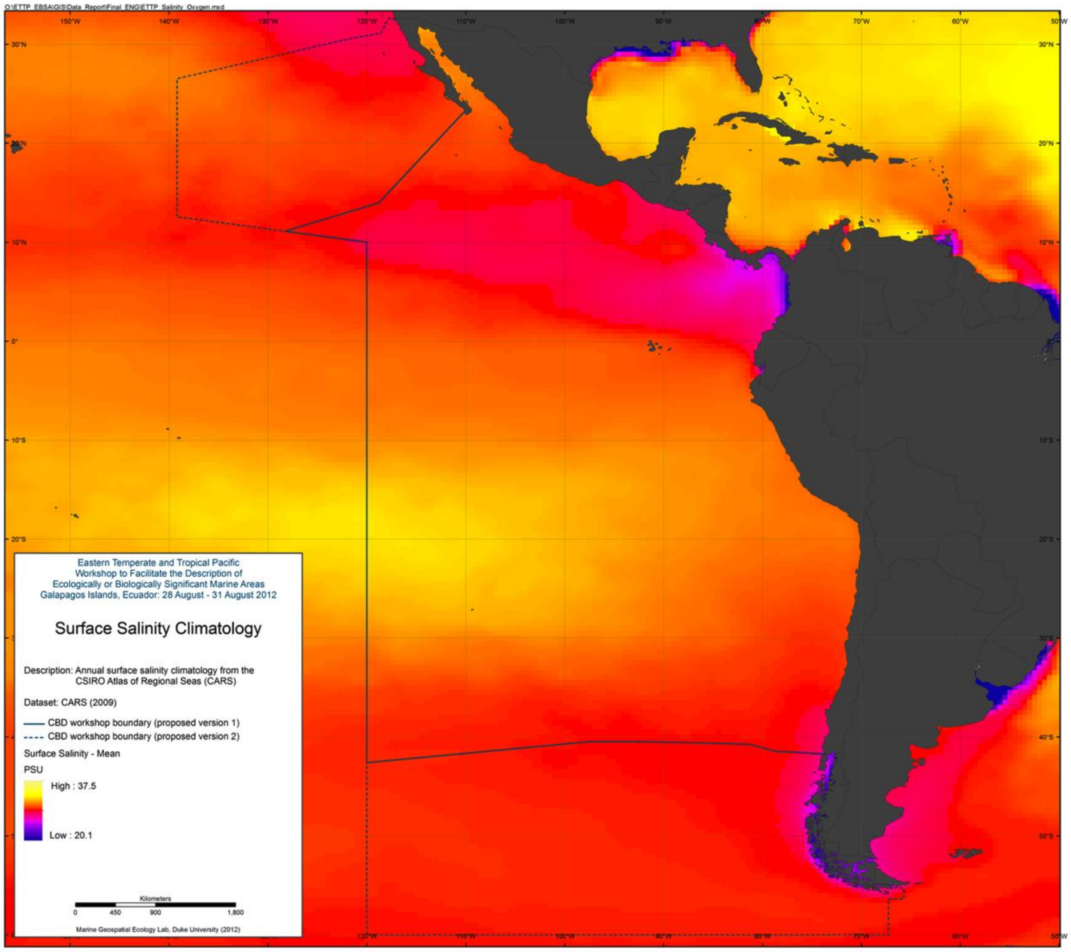

Figure 4.7-1 Surface Salinity Climatology

4.7.2 Oxygen Climatology

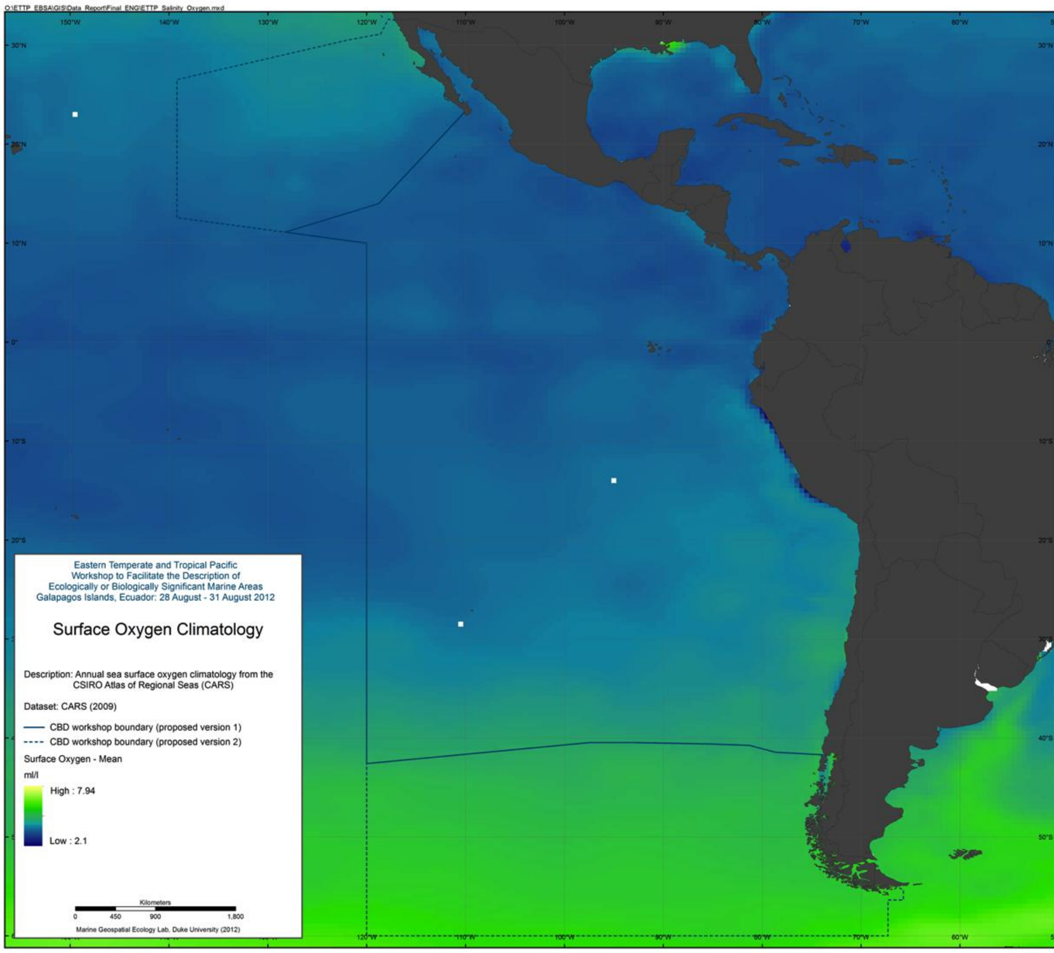

Figure 4.7-2 Surface Oxygen Climatology

4.7.3 Nitrate Climatology

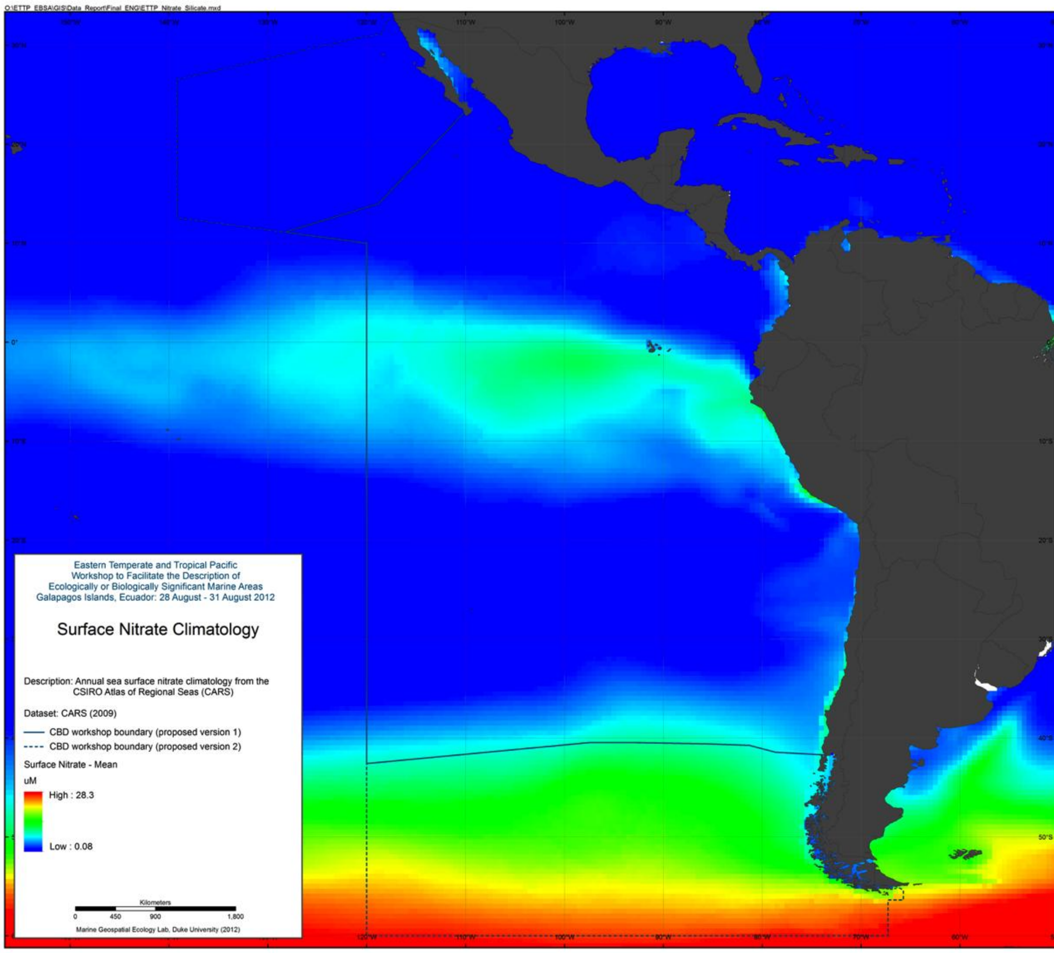

Figure 4.7-3 Surface Nitrate Climatology

4.7.4 Silicate Climatology

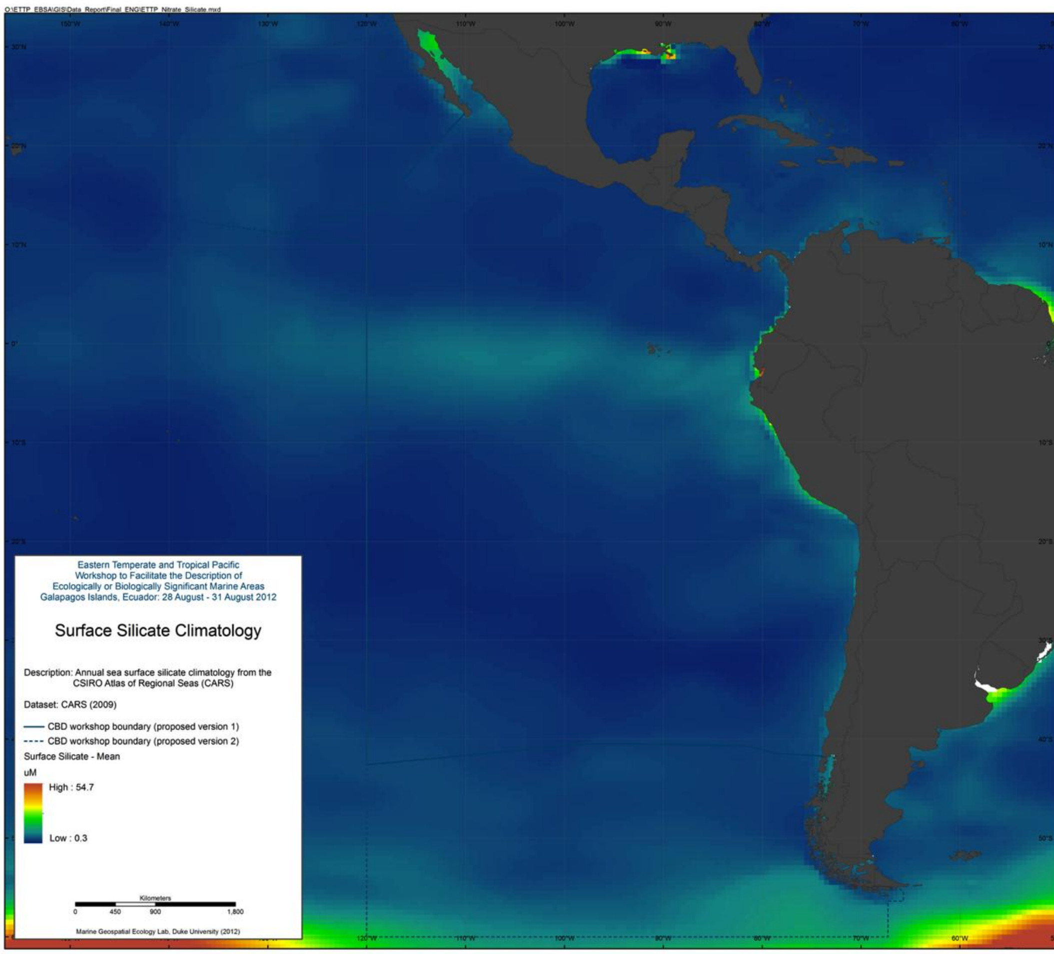

Figure 4.7-4 Surface Silicate Climatology

4.7.5 Phosphate Climatology

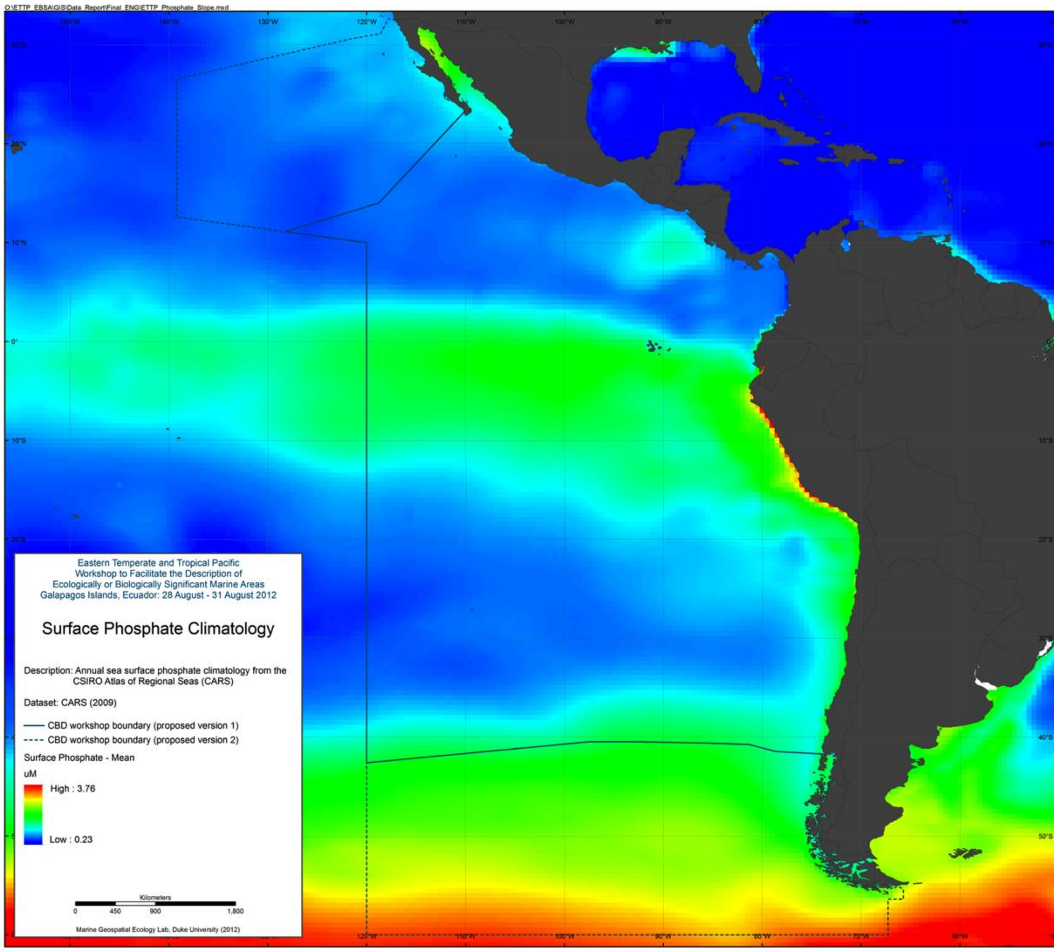

Figure 4.7-5 Surface Phosphate Climatology

4.7.6 Mixed Layer Depth Climatology

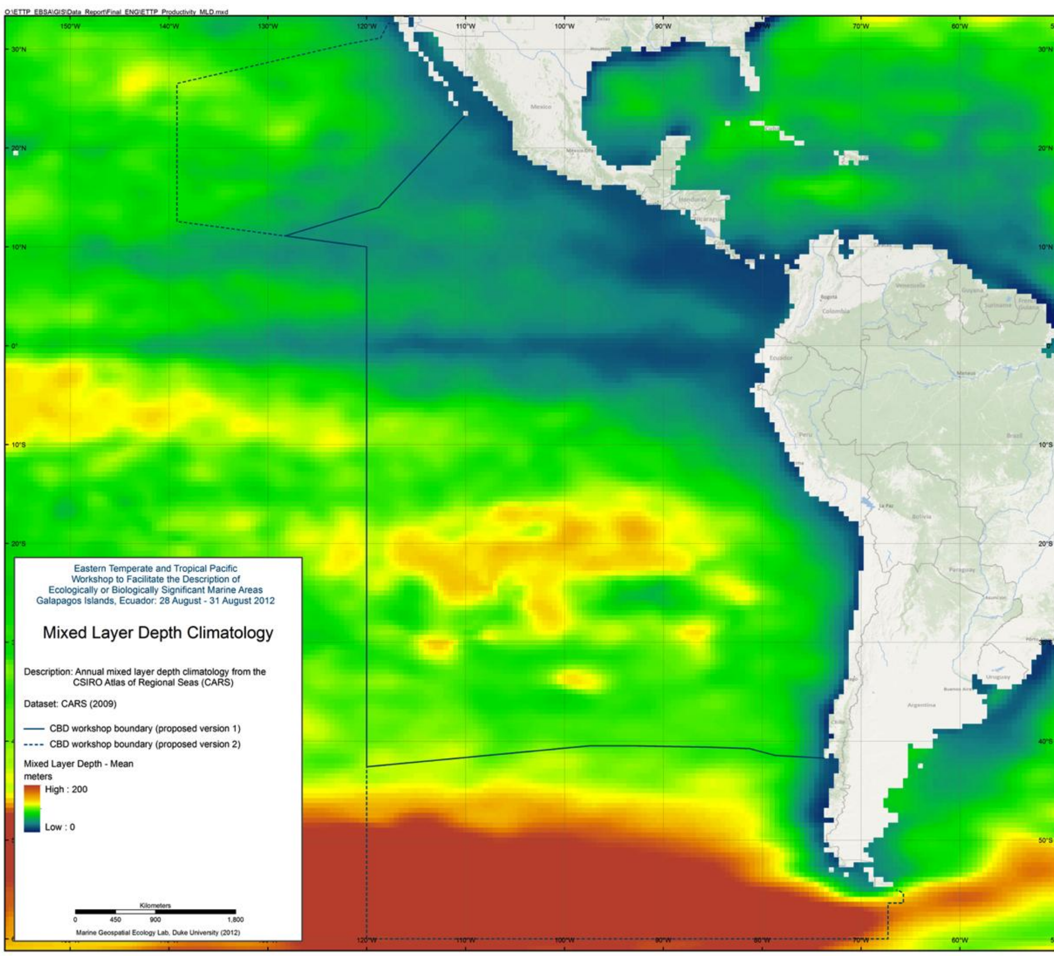

Figure 4.7-6 Mixed Layer Depth Climatology

4.8 Ocean Surface Temperature

The 4k AVHHR Pathfinder dataset, published by the NOAA National Oceanographic Data Center (NODC), provides a global, long-term, high resolution record of sea surface temperature (SST) using data collected by NOAA's Polar-orbiting Operational Environmental Satellites (POES).

For this effort, a cumulative climatology (1982 - 2009) was created using the "Create Climatological Rasters for AVHHR Pathfinder V5 SST" tool in the Marine Geospatial Ecology Tools (MGET) for ArcGIS (Roberts et al., 2010). Four climatologies were generated: Cumulative Climatology; Cumulative ENSO Warm Phase (El Niño) Climatology; Cumulative ENSO Cool Phase (La Niña) Climatology; Cumulative ENSO Neutral Climatology.

References:

Casey,K.S., T.B. Brandon, P. Cornillon, and R. Evans (2010). "The Past, Present and Future of the AVHRR Pathfinder SST Program", in Oceanography from Space: Revisited, eds. V. Barale, J.F.R. Gower, and L. Alberotanza, Springer

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

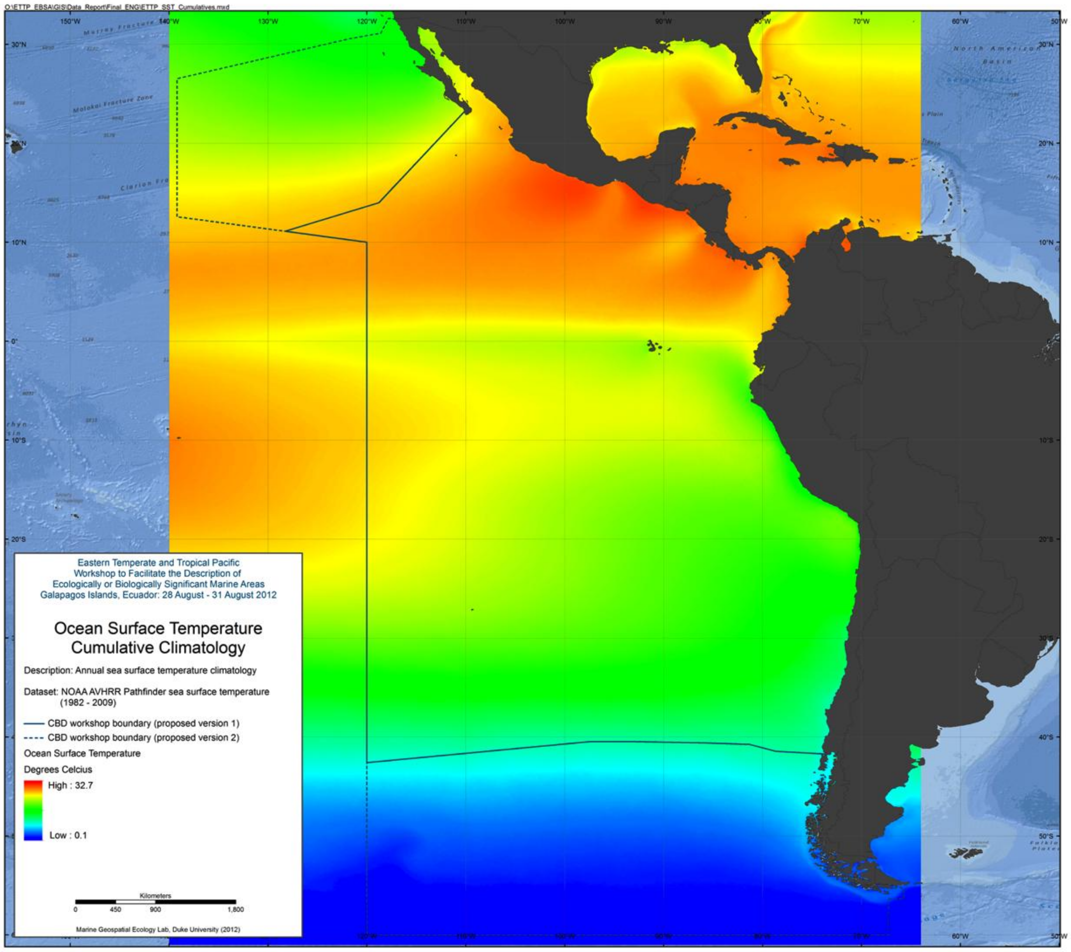

Figure 4.8-1 Ocean Surface Temperature – Cumulative Climatology

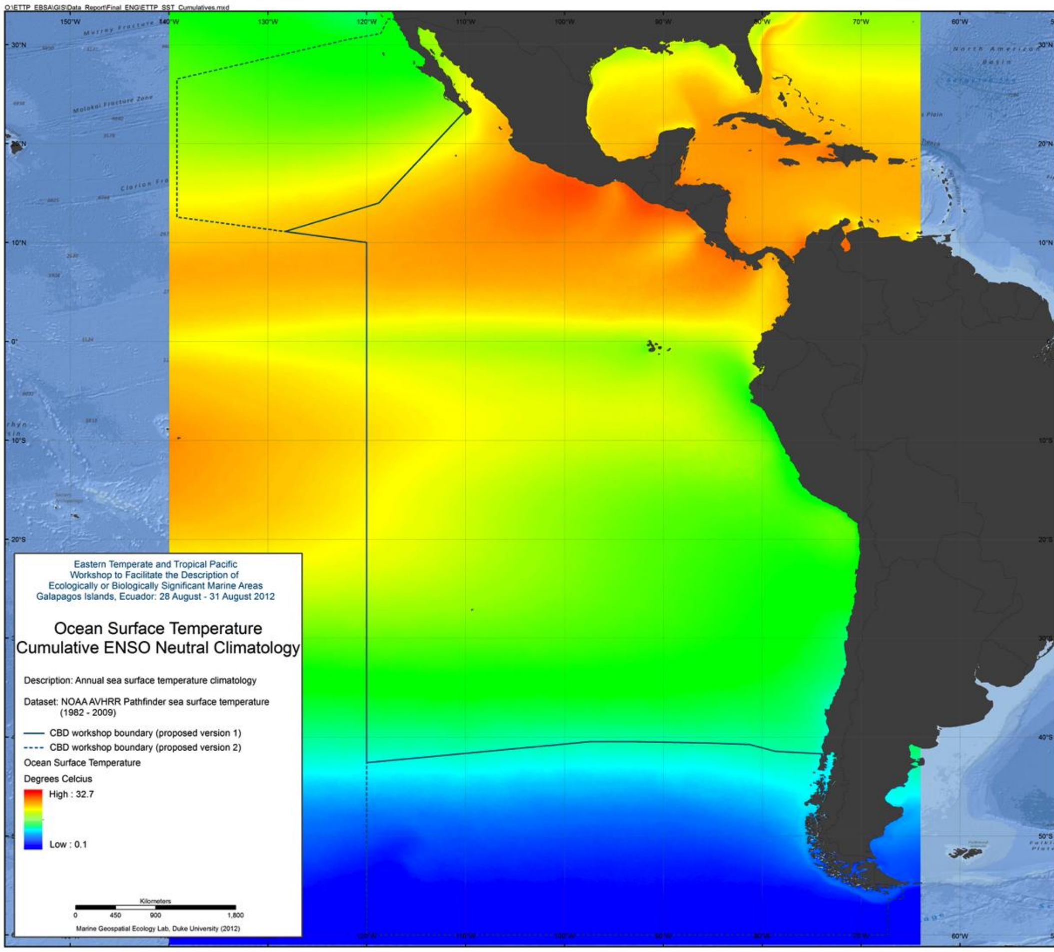

Figure 4.8-2 Ocean Surface Temperature – Cumulative ENSO Neutral Climatology

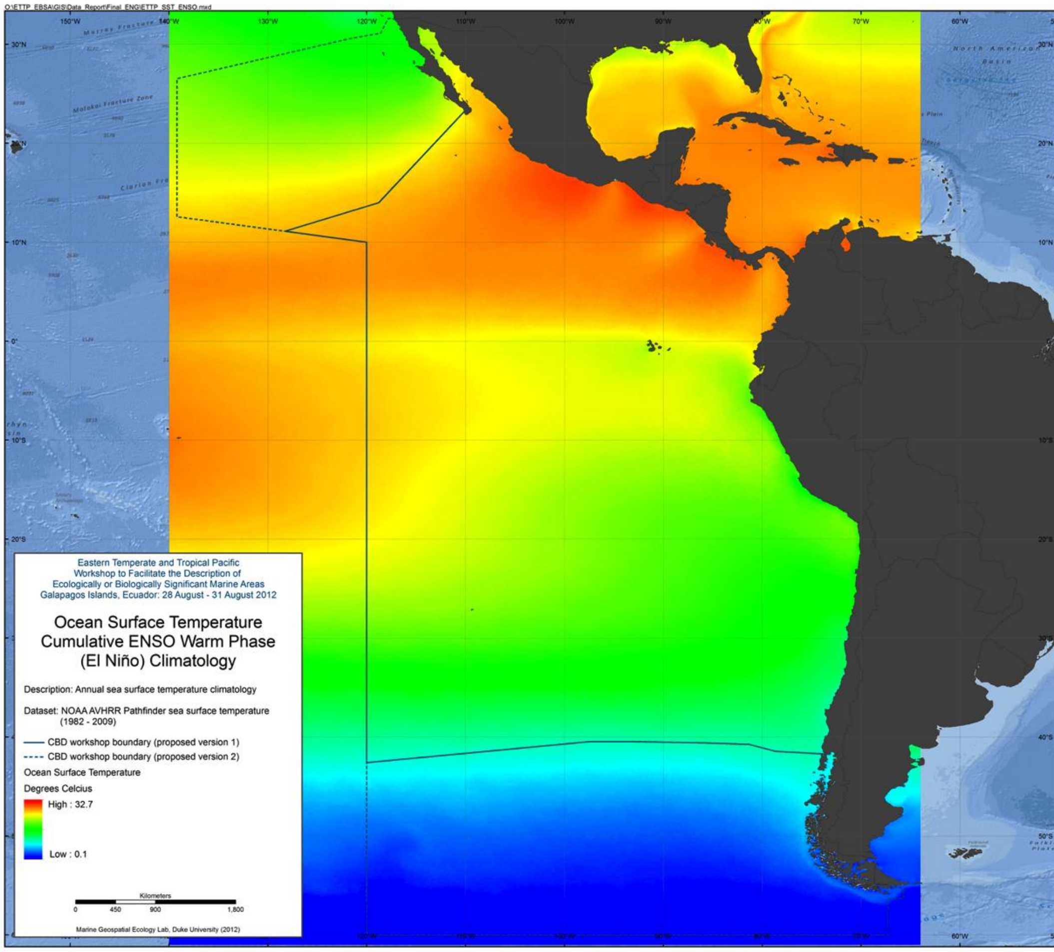

Figure 4.8-3 Ocean Surface Temperature – Cumulative ENSO Warm Phase Climatology

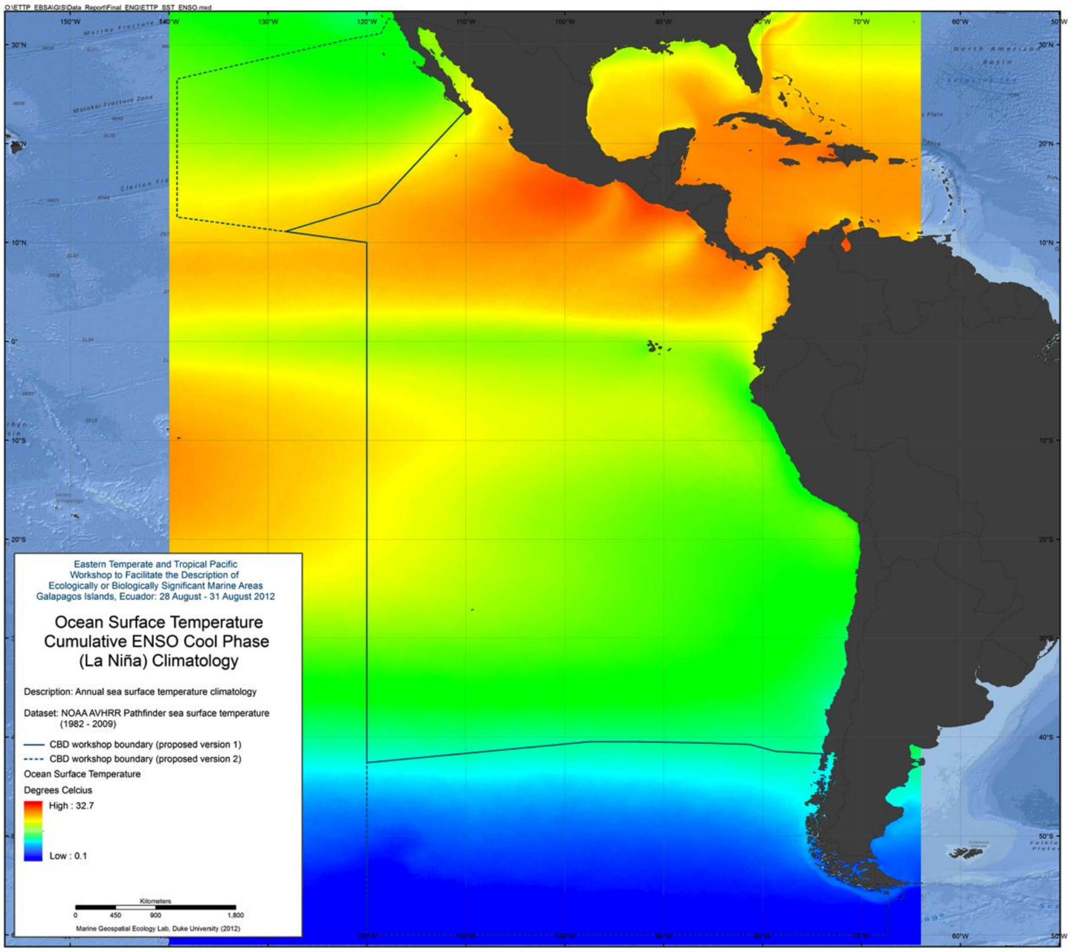

Figure 4.8-4 Ocean Surface Temperature - Cumulative ENSO Cool Phase Climatology

4.9 Sea Surface Temperature Front Probability

Dr. Peter Miller of the Plymouth Marine Laboratory provided composite maps of sea surface temperature fronts based on analyses of 9km resolution Advanced Very High Resolution Radiometer (AVHRR) and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data from 2006-2011. The composite front technique combines the location, gradient, persistence and proximity of all fronts observed over a given period into a single map. It is important to emphasize that: (a) front detection is based on local window statistics specific to frontal structures, not simply on horizontal SST gradients; and (b) fronts are not detected on monthly SST composites, but rather on individual SST 'snapshots' that reveal the detailed thermal structure without averaging artifacts. 8-day composite front maps were used to generate seasonal front climatologies which enabled identification of strong, persistent and frequently occurring features. Such frontal systems could be key factors influencing the distribution of productivity and diversity.

Reference:
Miller, P.I. (2009) Composite front maps for improved visibility of dynamic sea-surface features on cloudy SeaWiFS and AVHRR data. Journal of Marine Systems, 78(3), 327-336.

Miller P. and S. Christodoulou (in press) Frequent locations of ocean fronts as an indicator of pelagic diversity: application to marine protected areas and renewables. Marine Policy.

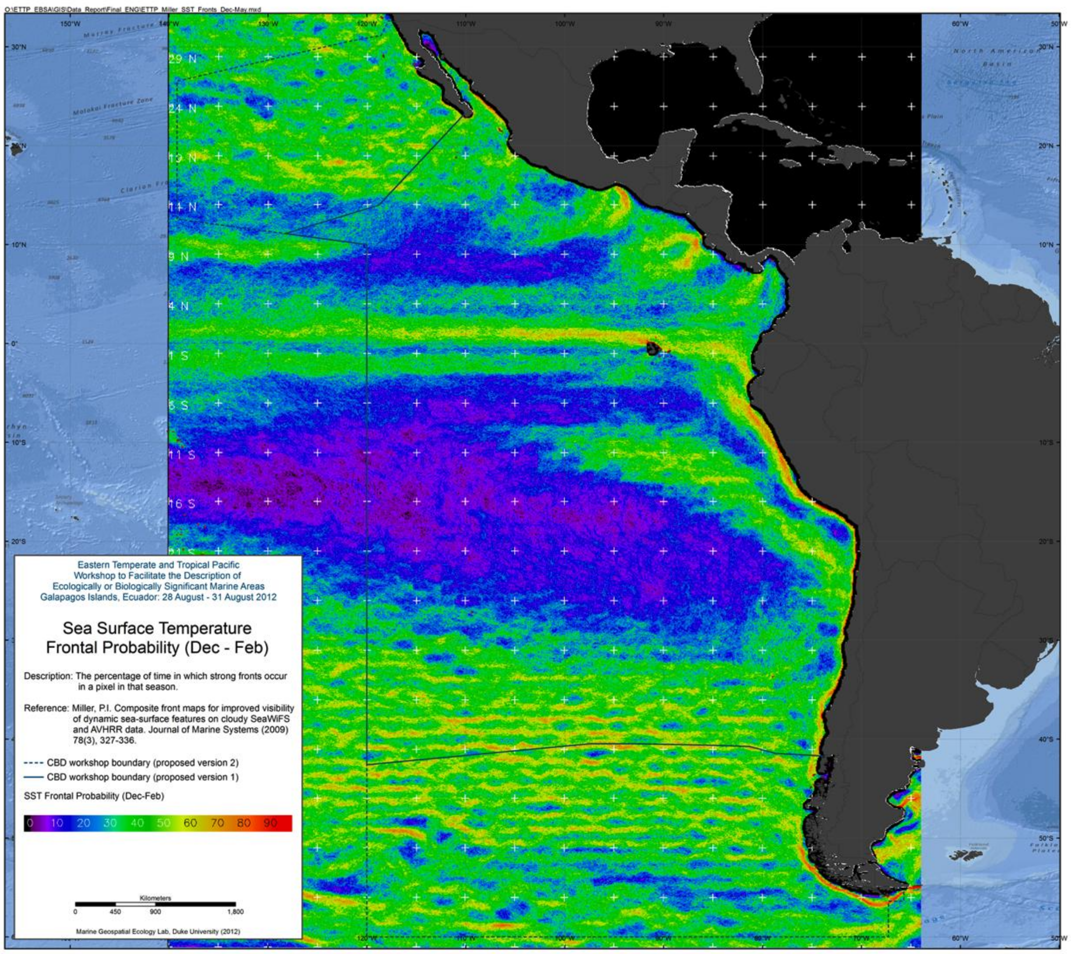

Figure 4.9-1 Sea Surface Temperature Front Probability (Dec – Feb)

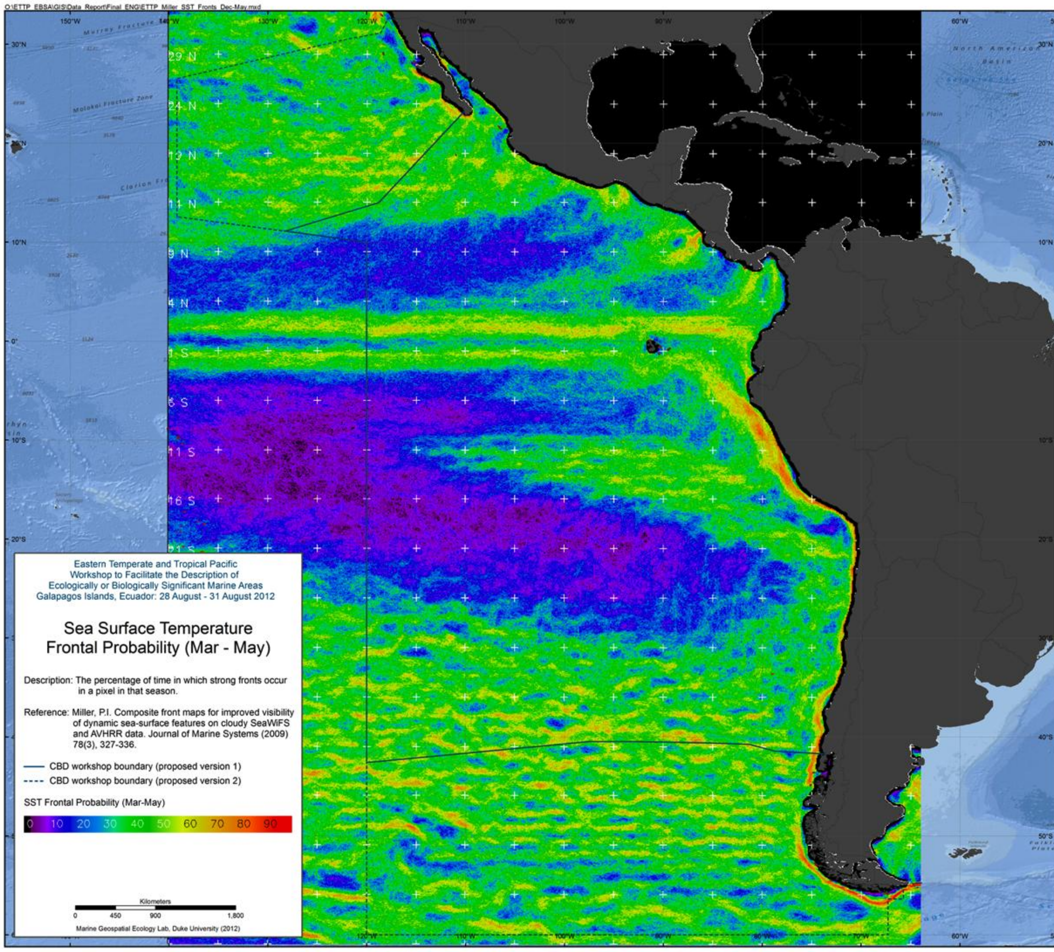

Figure 4.9-2 Sea Surface Temperature Front Probability (Mar - May)

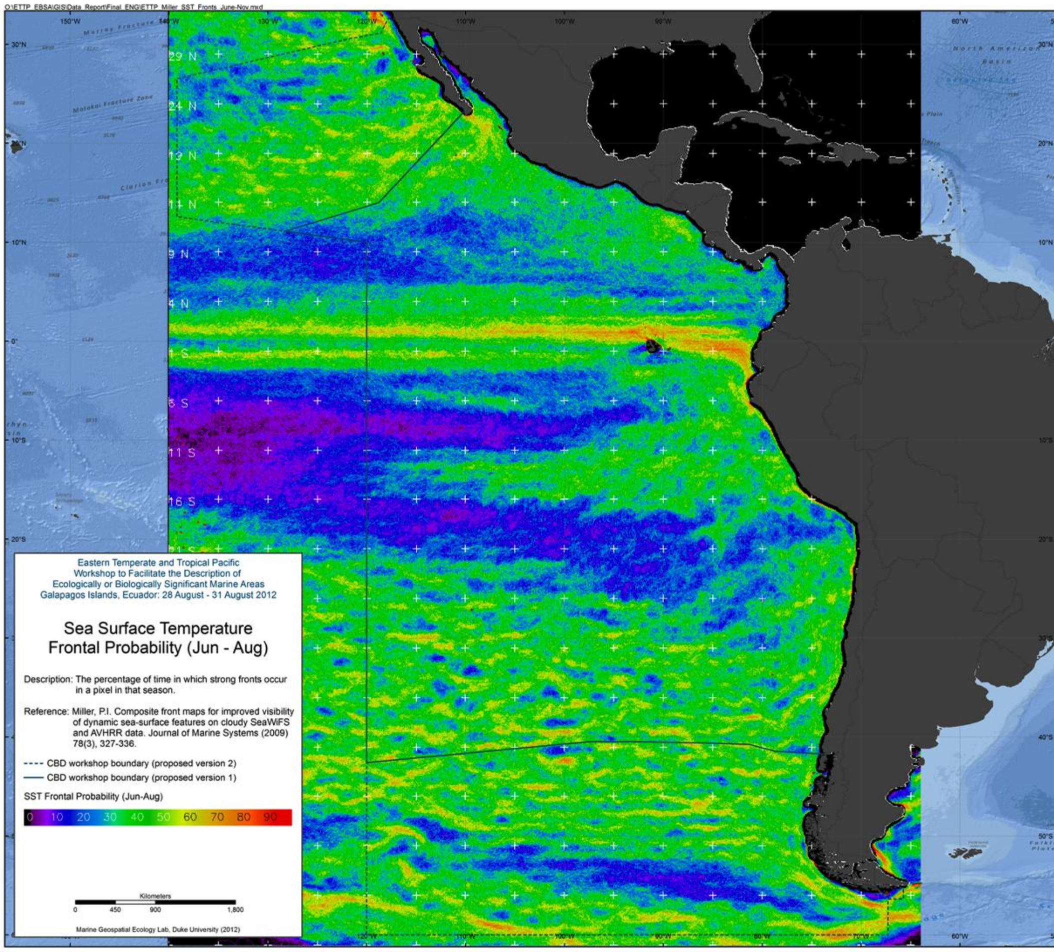

Figure 4.9-3 Sea Surface Temperature Front Probability (Jun - Aug)

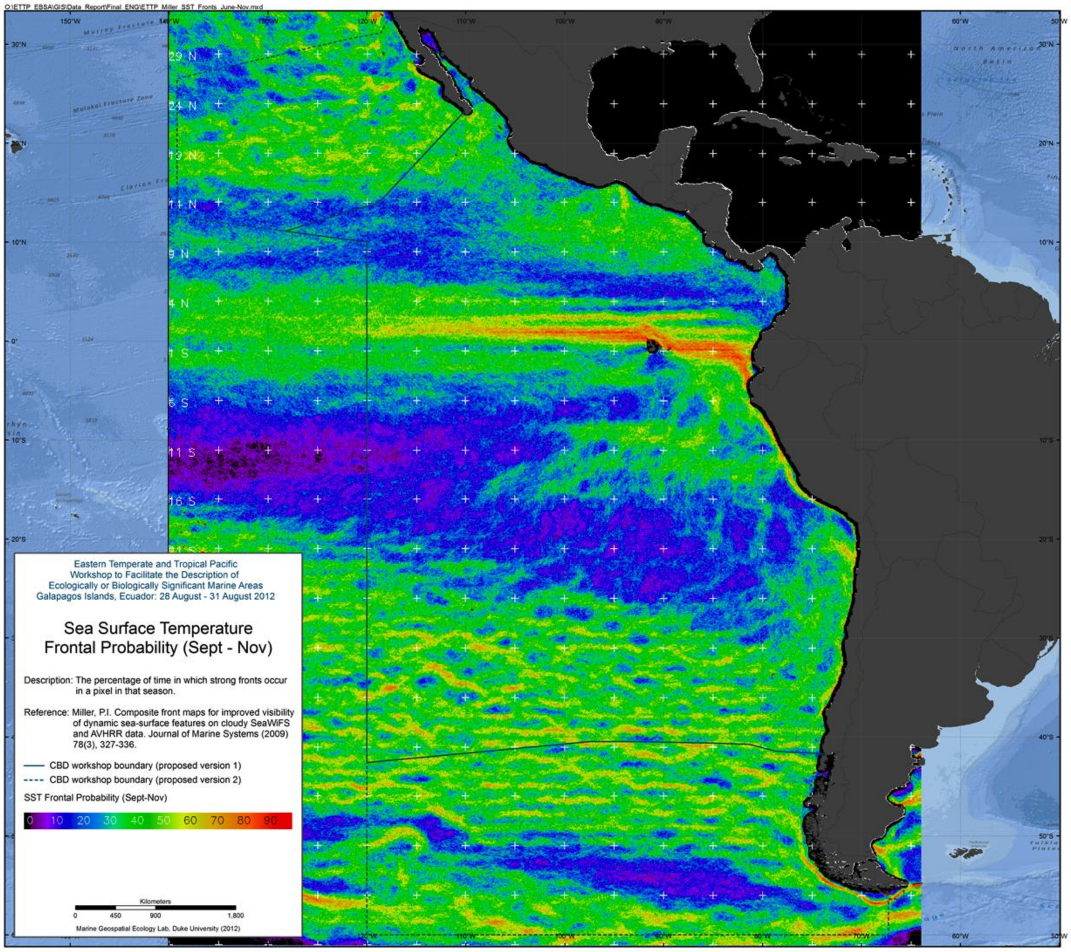

Figure 4.9-4 Sea Surface Temperature Front Probability (Sept - Nov)

4.10 SeaWiFS Chlorophyll A concentration

The purpose of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Project is to provide quantitative data on global ocean bio-optical properties to the Earth science community. Subtle changes in ocean color signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications. The SeaWiFS Project will develop and operate a research data system that will process, calibrate, validate, archive and distribute data received from an Earth-orbiting ocean color sensor.
(source: http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/SEAWIFS_BACKGROUND.html)

For this effort, a cumulative climatology (2001-2010) was created using the “Create Climatological Rasters for NASA OceanColor L3 SMI Product” tool in the Marine Geospatial Ecology Tools (MGET) for ArcGIS (Roberts et al., 2010). Four climatologies were generated: Cumulative Climatology;

Cumulative ENSO Warm Phase (El Niño) Climatology; Cumulative ENSO Cool Phase (La Niña) Climatology; Cumulative ENSO Neutral Climatology.

Reference:

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

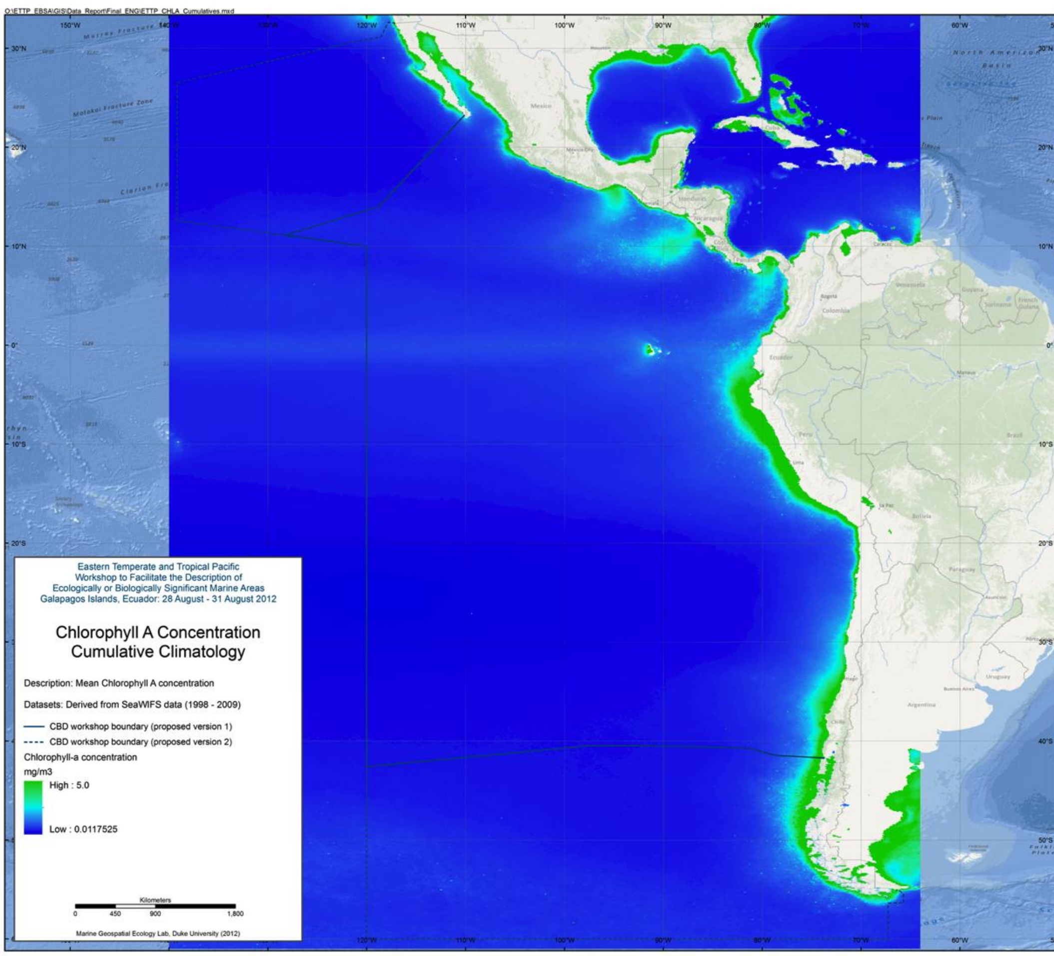

Figure 4.10-1 Chlorophyll A Concentration - Cumulative Climatology

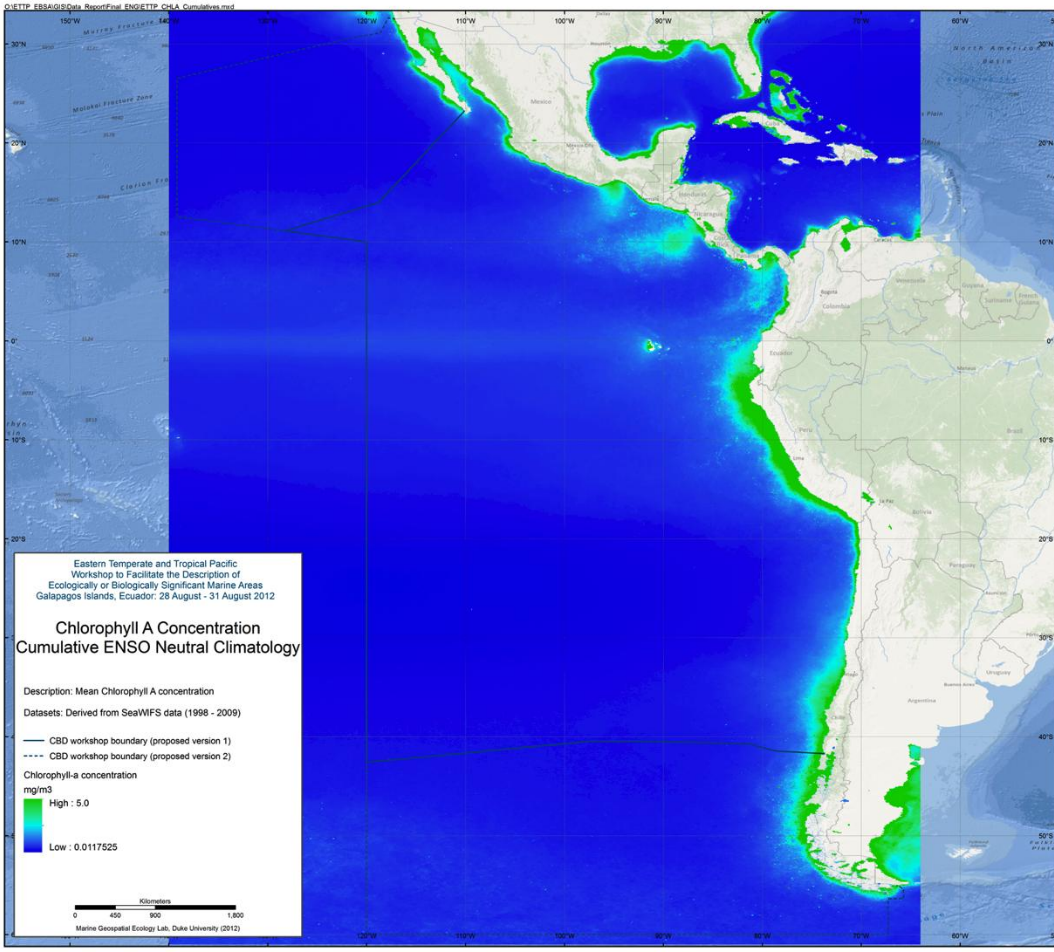

Figure 4.10-2 Chlorophyll A Concentration - Cumulative ENSO Neutral Climatology

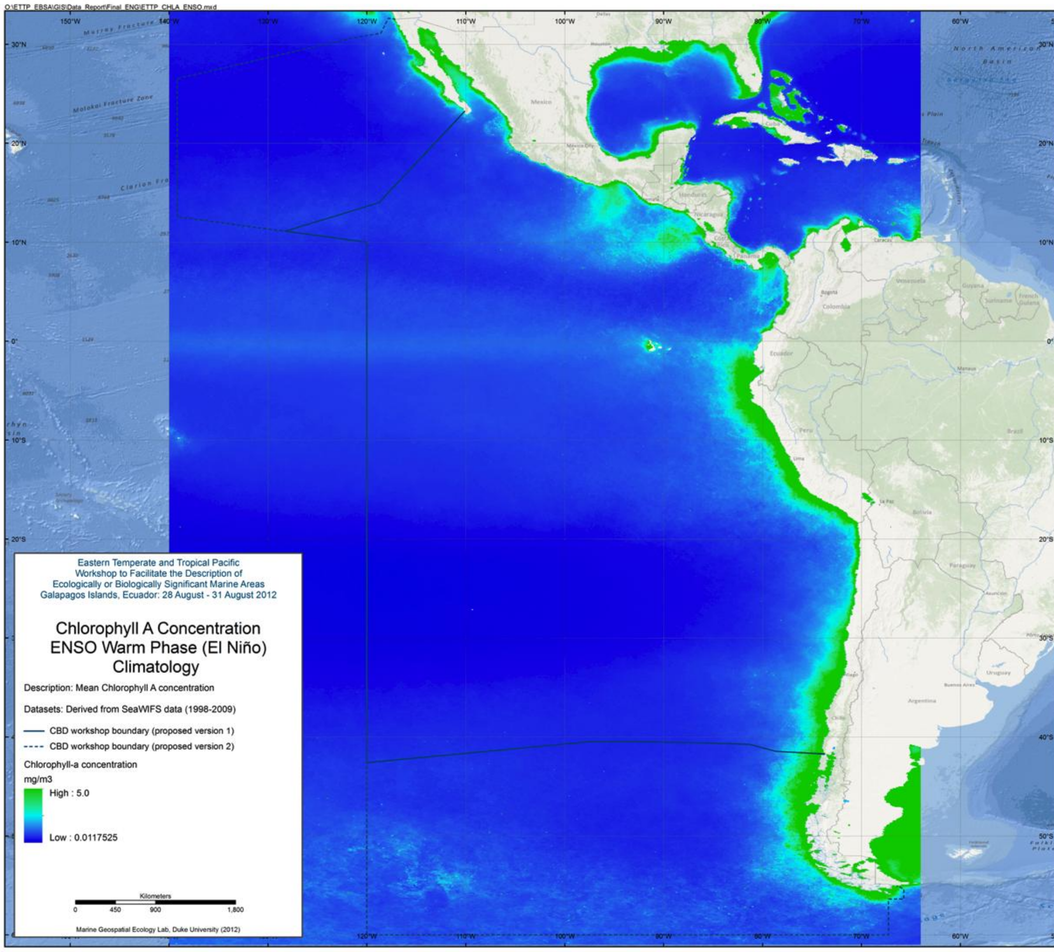

Figure 4.10-3 Chlorophyll A Concentration - Cumulative ENSO Warm Phase Climatology

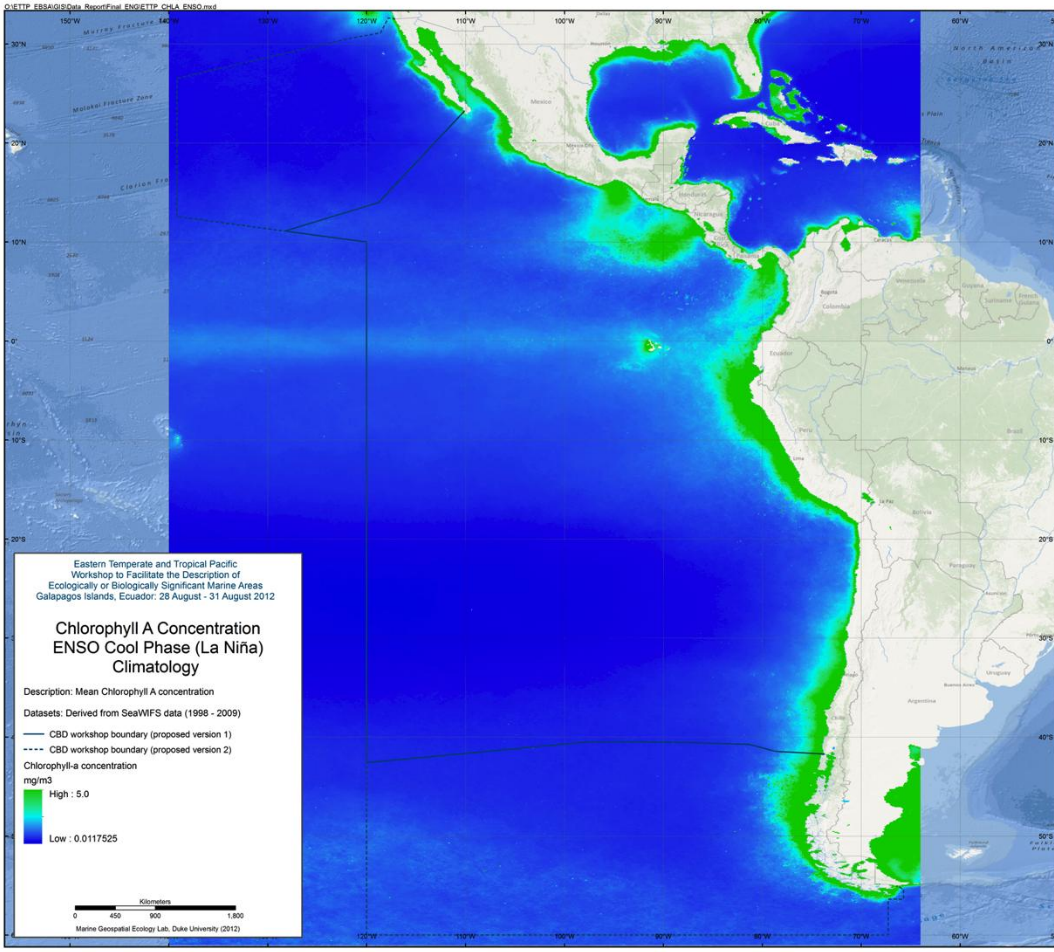

Figure 4.10-4 Chlorophyll A Concentration - Cumulative ENSO Cool Phase Climatology

4.11 VGPM Ocean Productivity

Standard Ocean Productivity Products are based on the original description of the Vertically Generalized Production Model (VGPM) (Behrenfeld & Falkowski 1997), MODIS surface chlorophyll concentrations (Chl_{sat}), MODIS sea surface temperature data (SST), and MODIS cloud-corrected incident daily photosynthetically active radiation (PAR). Euphotic depths are calculated from Chl_{sat} following Morel and Berthon (1989).
(source: http://www.science.oregonstate.edu/ocean.productivity/standard.product.php)

Reference:

Behrenfeld, M. J. & Falkowski, P. G. Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology And Oceanography* 42, 1–20 (1997).

For this effort, a cumulative climatology was created from Standard VGPM data derived from MODIS AQUA data from 2003-2007.

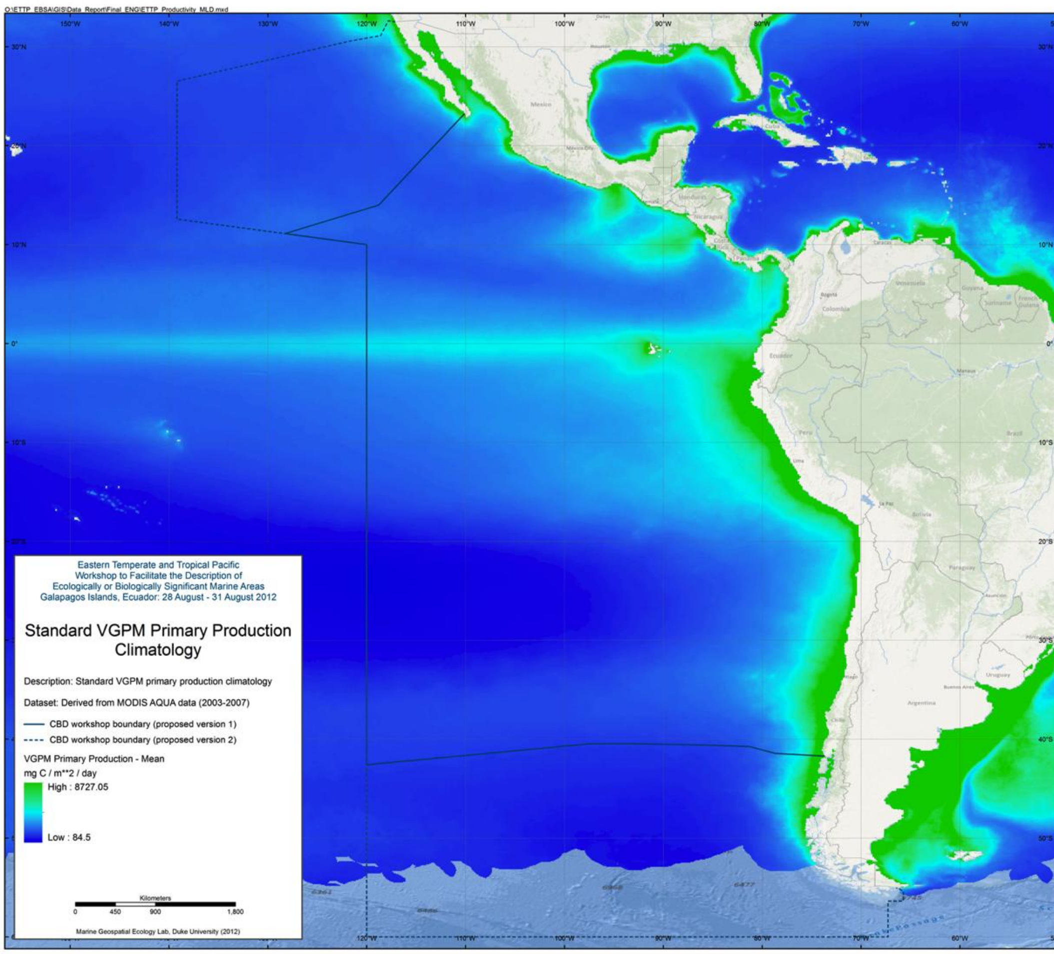

Figure 4.11-1 Standard VGPM Ocean Productivity

4.12 Sea Surface Height

The Archiving, Validation and Interpretation of Satellite Oceanographic data (AVISO) group publishes various products derived from satellite altimetry data, including estimates of sea surface height (SSH), geostrophic currents, wind speed modulus, and significant wave height. To maximize

accuracy and spatial and temporal resolution and extent, AVISO merges observations from multiple satellites, including Topex/Poseidon, Jason-1, Jason-2, GFO, ERS-1, ERS-2, and EnviSat. Most Aviso products are one of these "merged" datasets, although a few products are based on observations from a single satellite.
(source: http://code.nicholas.duke.edu/projects/mget)

For this effort a cumulative climatology was created from AVISO Global DT-Ref Merged MADT SSH data, from 2001-2010, using the “Create Climatological Rasters for Aviso SSH” tool in the Marine Geospatial Ecology Tools (MGET) for ArcGIS (Roberts et al., 2010). Four climatologies were generated: Cumulative Climatology; Cumulative ENSO Warm Phase (El Niño) Climatology; Cumulative ENSO Cool Phase (La Niña) Climatology; Cumulative ENSO Neutral Climatology.

Reference:
Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

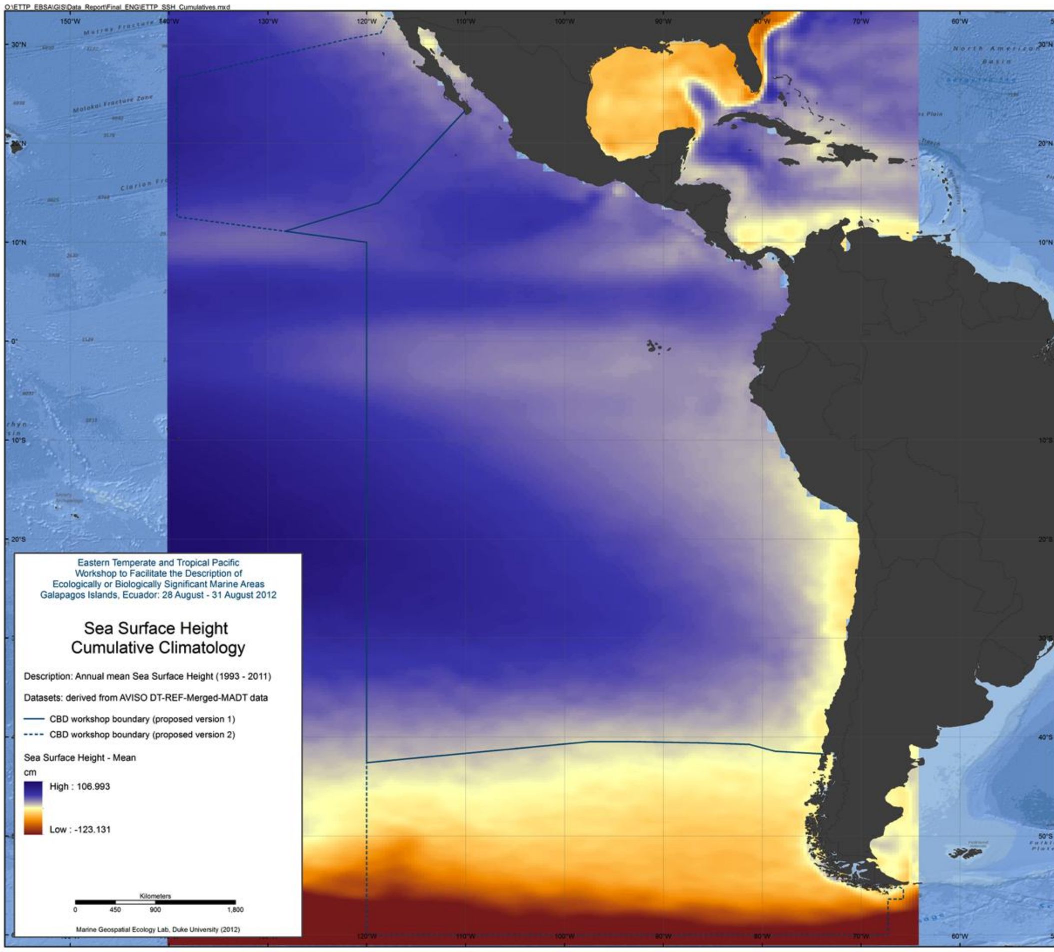

Figure 4.12-1 Sea Surface Height - Cumulative Climatology

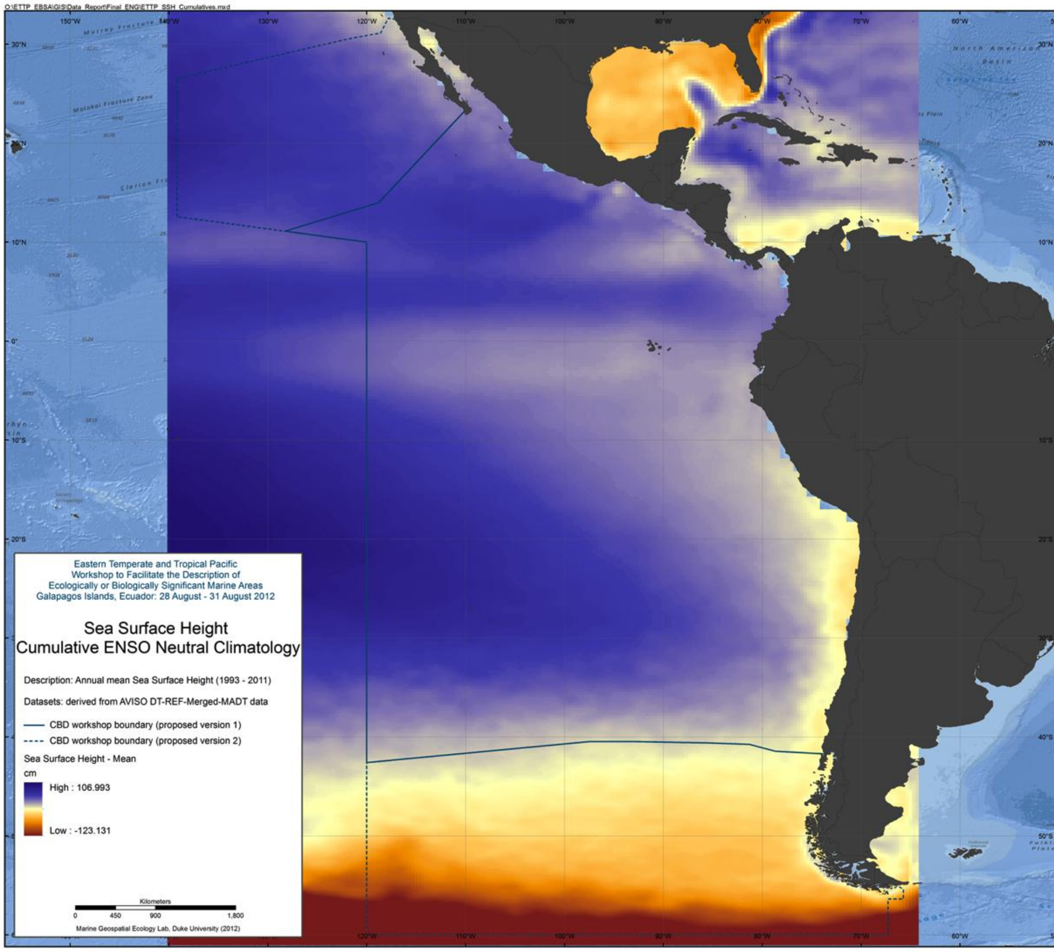

Figure 4.12-2 Sea Surface Height - Cumulative ENSO Neutral Climatology

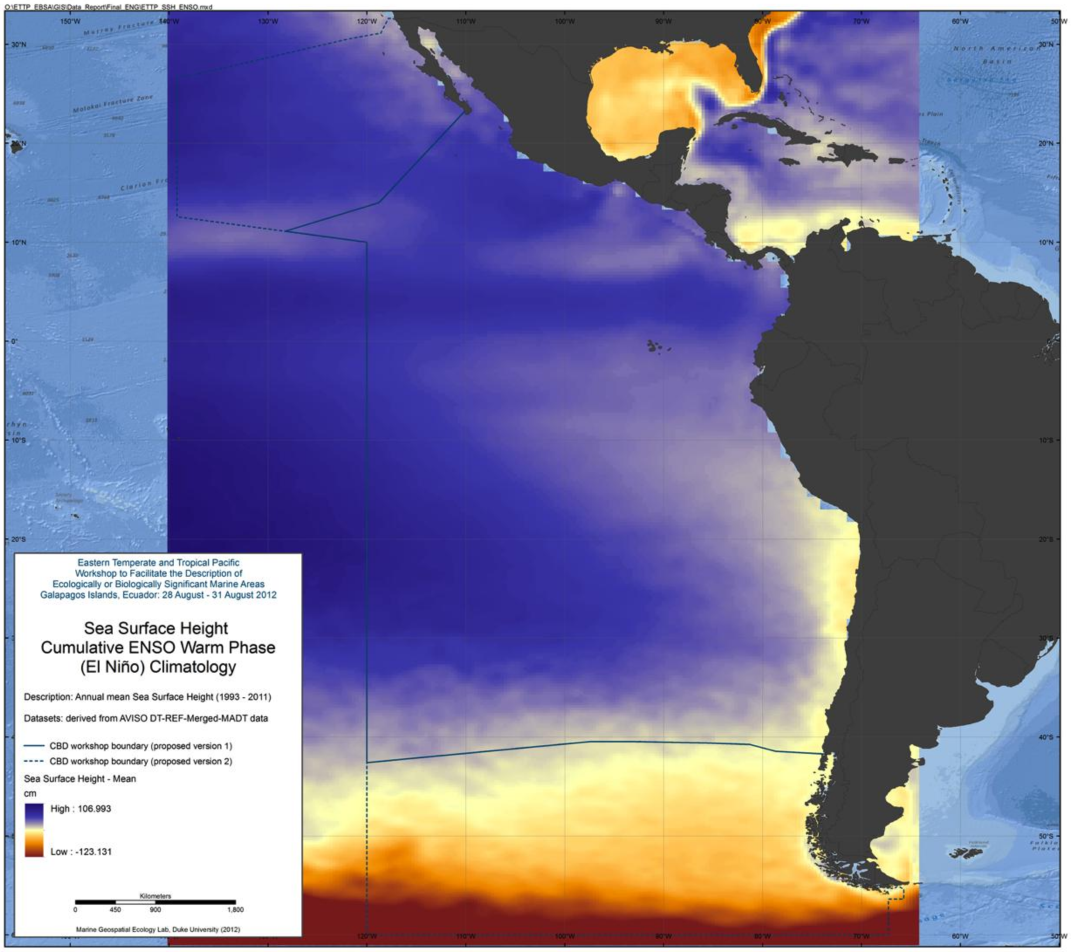

Figure 4.12-3 Sea Surface Height - Cumulative ENSO Warm Phase Climatology

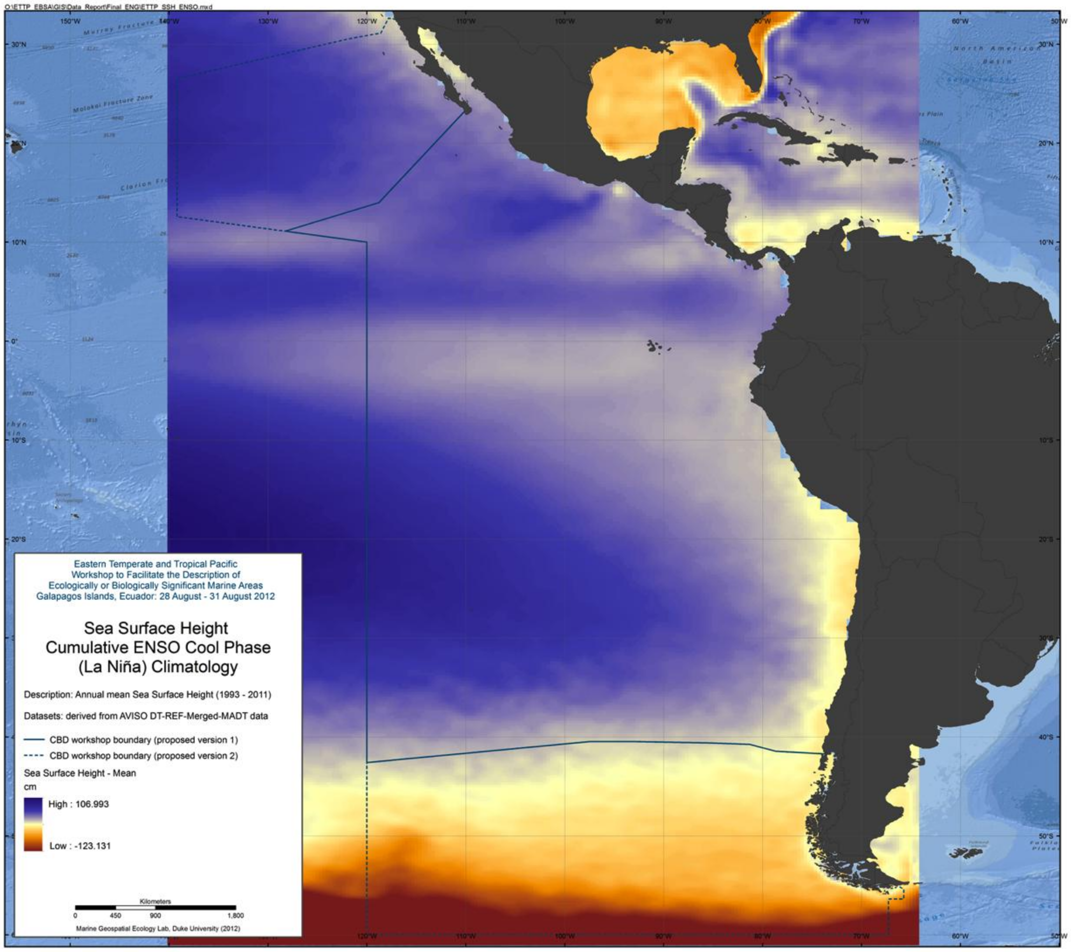

Figure 4.12-4 Sea Surface Height - Cumulative ENSO Cool Phase Climatology

4.13 Mesoscale Eddy Density

Dudley B. Chelton and Michael G. Schlax maintain a database of trajectories of mesoscale eddies for the 18-year period October 1992 - January 2011. The eddies are based on the SSH fields in Version 3 of the AVISO Reference Series. Only eddies with lifetimes of 4 weeks or longer are retained; the trajectories are available at 7-day time steps. (source: http://cioss.coas.oregonstate.edu/eddies/)

A density raster of eddy centroids was created from the Chelton database (http://cioss.coas.oregonstate.edu/eddies/). First, the NetCDF file was converted to a SpatiaLite database using the MGET tool "Convert Mesoscale Eddies NetCDF to SpatiaLite". Next, the "Extract Mesoscale Eddy Centroids from SpatiaLite" and "Extract Mesoscale Eddy Tracklines from SpatiaLite" tools were run specifying the date range (1993 - 2010) and the region of interest. For the tracks, only eddies that persisted at least 17 weeks were selected. By joining the centroids and tracks features, we obtained all centroids for eddies that persisted at least 17 weeks. The density raster was created from the Point Density ArcMap tool using 0.5 degree cell size and 0.5 x 0. 5 rectangular window.

References:
Chelton, D.B., M.G. Schlax, and R.M. Samelson (2011). Global observations of nonlinear mesoscale eddies. Progress in Oceanography 91: 167-216.

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

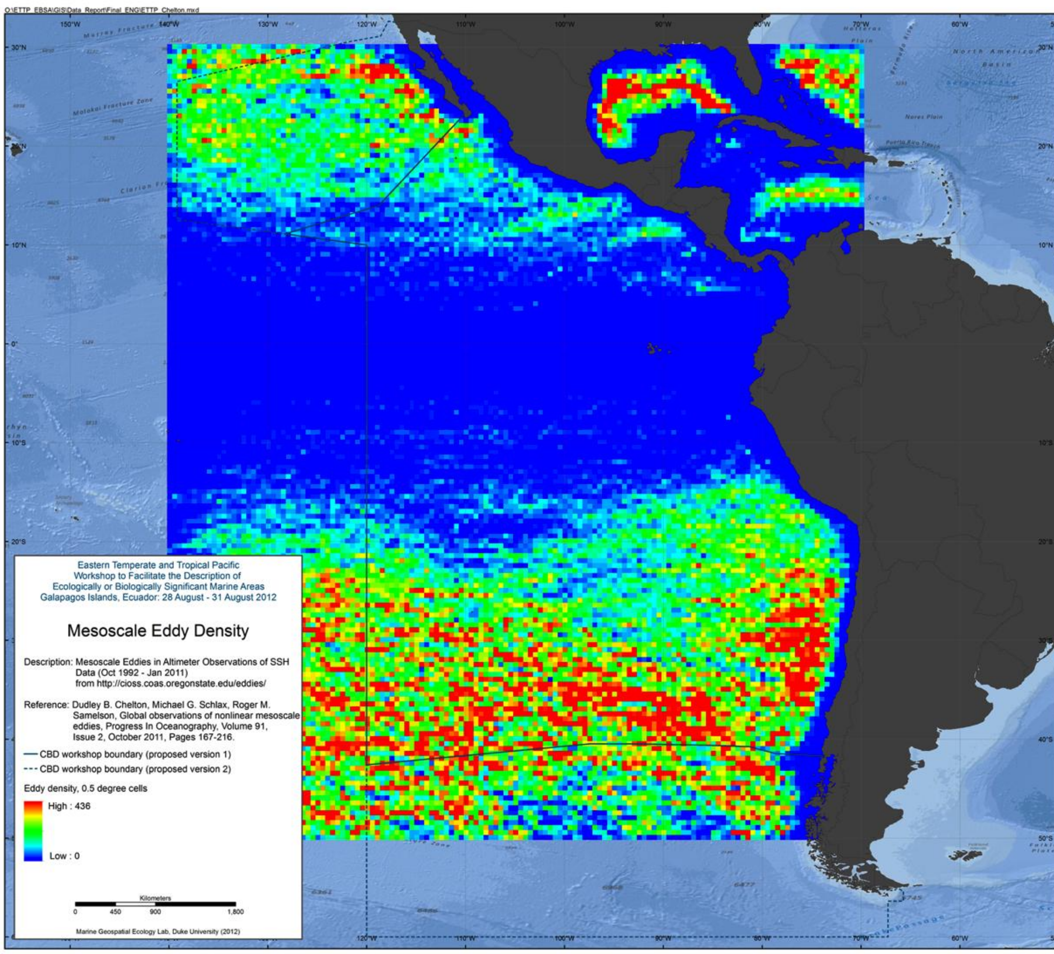

Figure 4.13-1 Mesoscale Eddy Density

4.14 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). EKE was calculated from the velocity maps based on sea surface height. Using the U and V components from NOAA Ocean Surface Current Analyses - Real Time (OSCAR) currents data, EKE is defined as $0.5*(U^2 + V^2)$ and was calculated using OSCAR data from 2001-2010, inclusive.

For this effort, a cumulative EKE climatology (2001-2010) was created using the "Create Climatological Rasters for Aviso Geostrophic Currents Product" tool in the Marine Geospatial Ecology Tools (MGET) for ArcGIS (Roberts et al., 2010). Four climatologies were generated: Cumulative Climatology; Cumulative ENSO Warm Phase (El Niño) Climatology; Cumulative ENSO Cool Phase (La Niña) Climatology; Cumulative ENSO Neutral Climatology.

Reference:

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

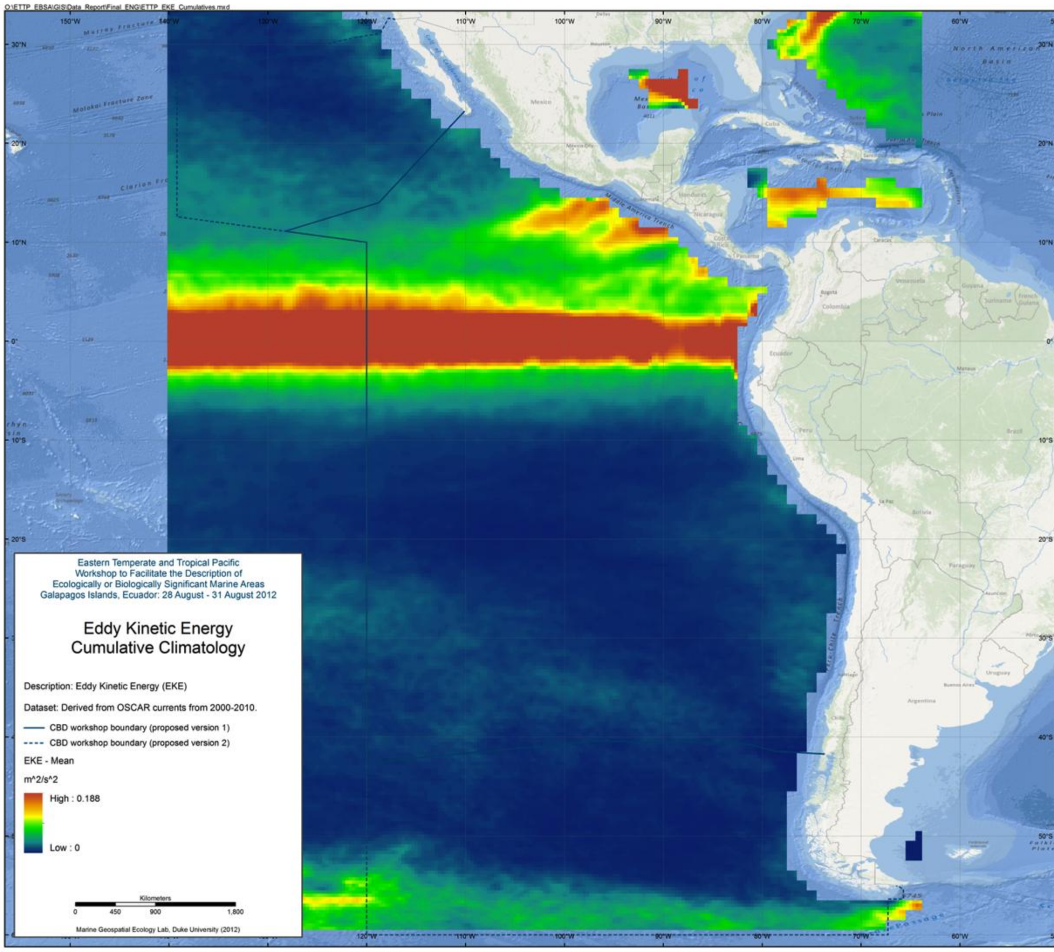

Figure 4.14-1 Eddy Kinetic Energy - Cumulative Climatology

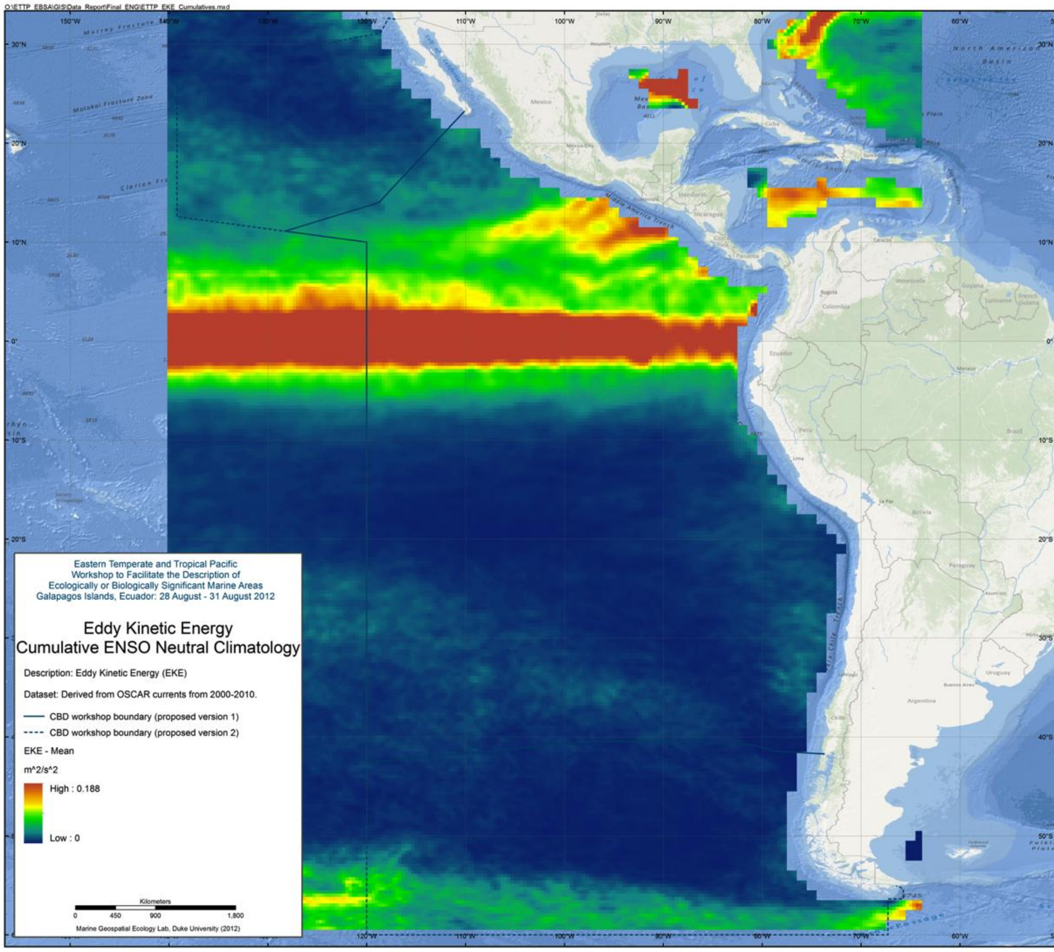

Figure 4.14-2 Eddy Kinetic Energy - Cumulative ENSO Neutral Climatology

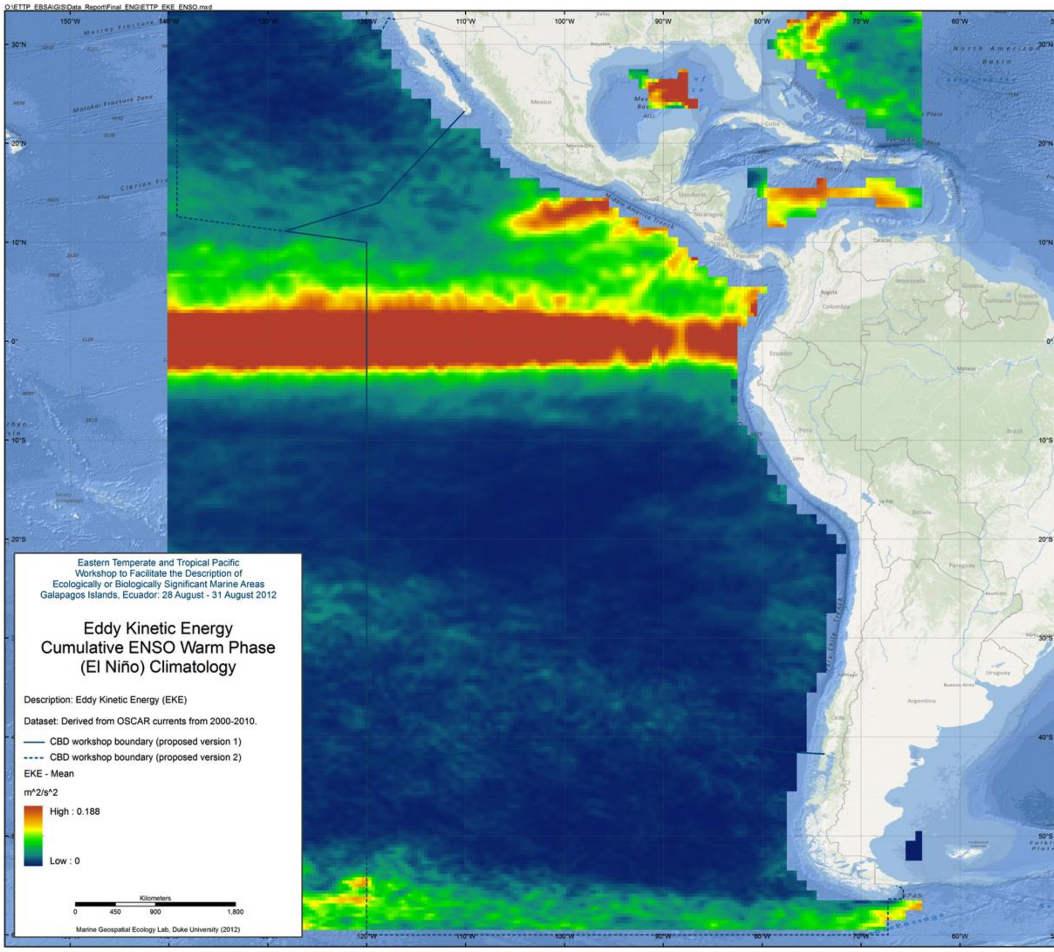

Figure 4.14-3 Eddy Kinetic Energy - Cumulative ENSO Warm Phase Climatology

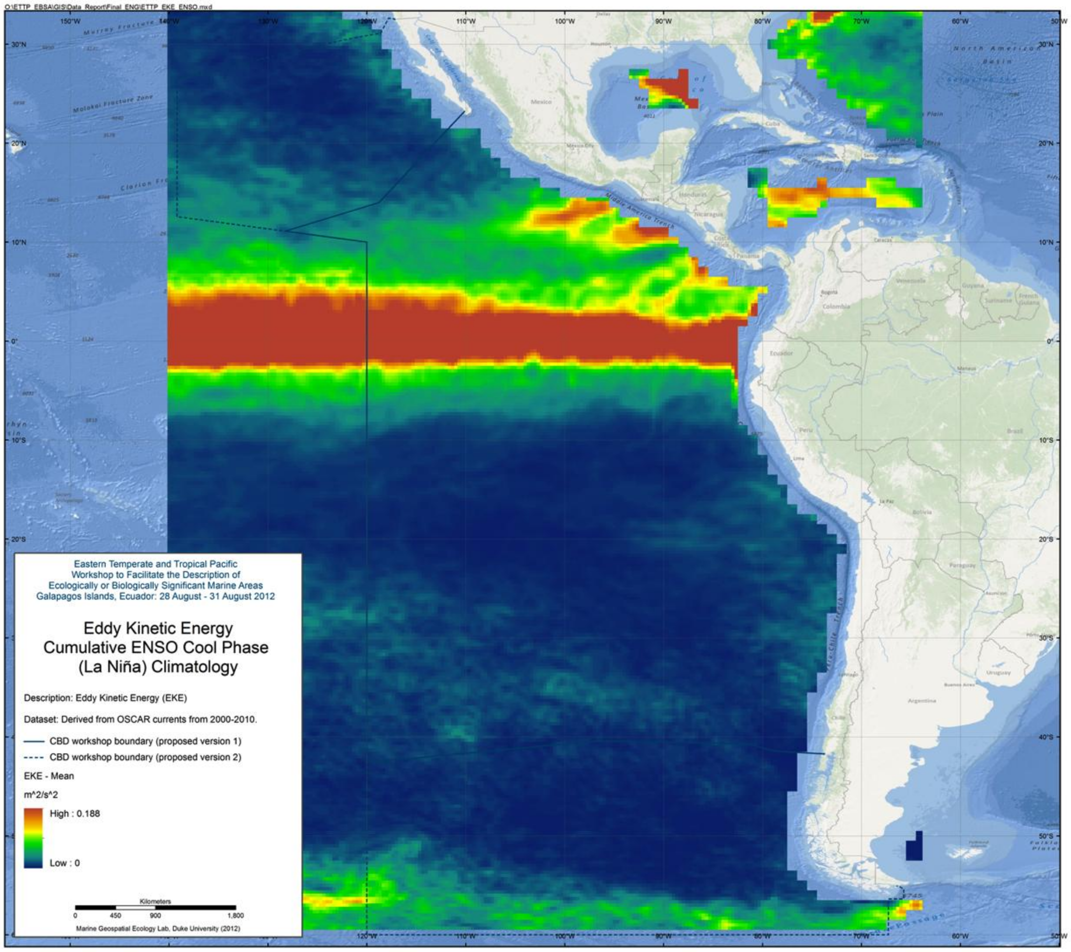

Figure 4.14-4 Eddy Kinetic Energy - Cumulative ENSO Cool Phase Climatology

4.15 Surface Current Velocity

The NOAA Ocean Surface Current Analysis - Real Time (OSCAR) project publishes global estimates of ocean surface currents by combining satellite observations from altimeters that measure the height of the sea surface (e.g. TOPEX/Poseidon), scatterometers that estimate ocean wind vectors (e.g. QuikSCAT), and sea surface temperature sensors (e.g. AVHRR). The goal is to provide ocean current estimates that are more accurate than those based on altimetry alone, particularly in tropical regions, by combining geostrophic, Ekman, and Stommel shear dynamics and a complementary term from the surface buoyancy gradient.

For this effort, cumulative climatologies (2000 - 2010) for ocean current velocity were created using the “Create Climatological Rasters for OSCAR Currents” tool with the “mag” geophysical parameter in the Marine Geospatial Ecology Tools (MGET) for ArcGIS (Roberts et al., 2010). Four climatologies were generated: Cumulative Climatology; Cumulative ENSO Warm Phase (El Niño)

Climatology; Cumulative ENSO Cool Phase (La Niña) Climatology; Cumulative ENSO Neutral Climatology.

References:
Bonjean, F. and Lagerloef, G.S.E. (2002) Diagnostic Model and Analysis of the Surface Currents in the Tropical Pacific Ocean. J. Physical Oceano. 32(10):2938-2954.

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml, and P.N. Halpin (2010). Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207.

http://www.oscar.noaa.gov/

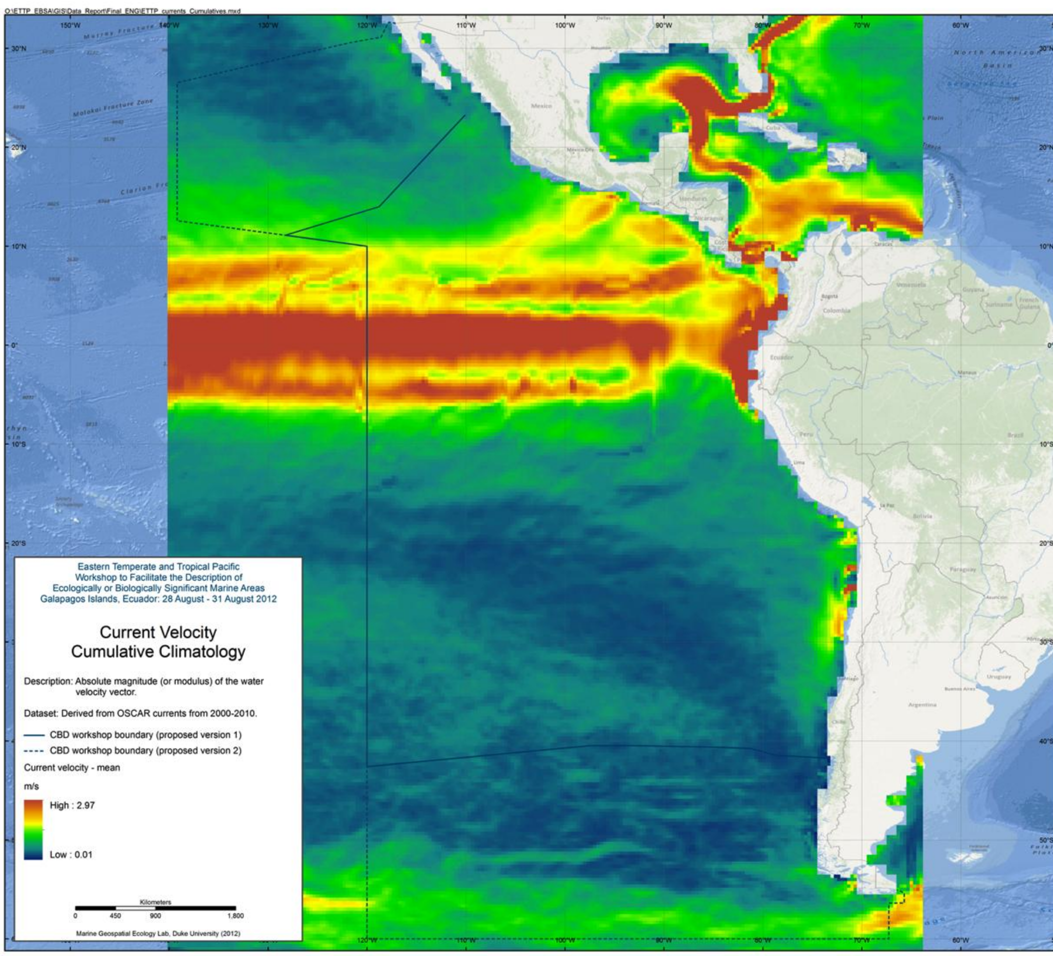

Figure 4.15-1 Surface Current Velocity - Cumulative Climatology

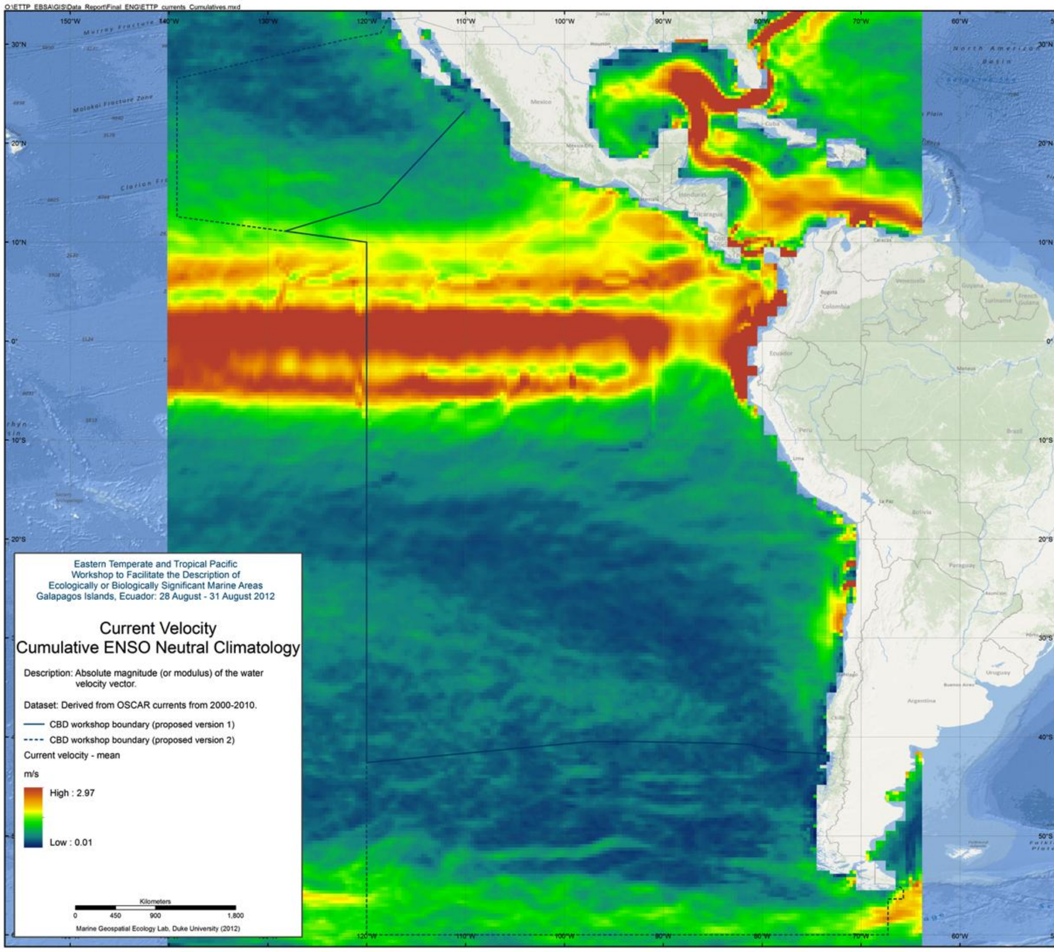

Figure 4.15-2 Surface Current Velocity - Cumulative ENSO Neutral Climatology

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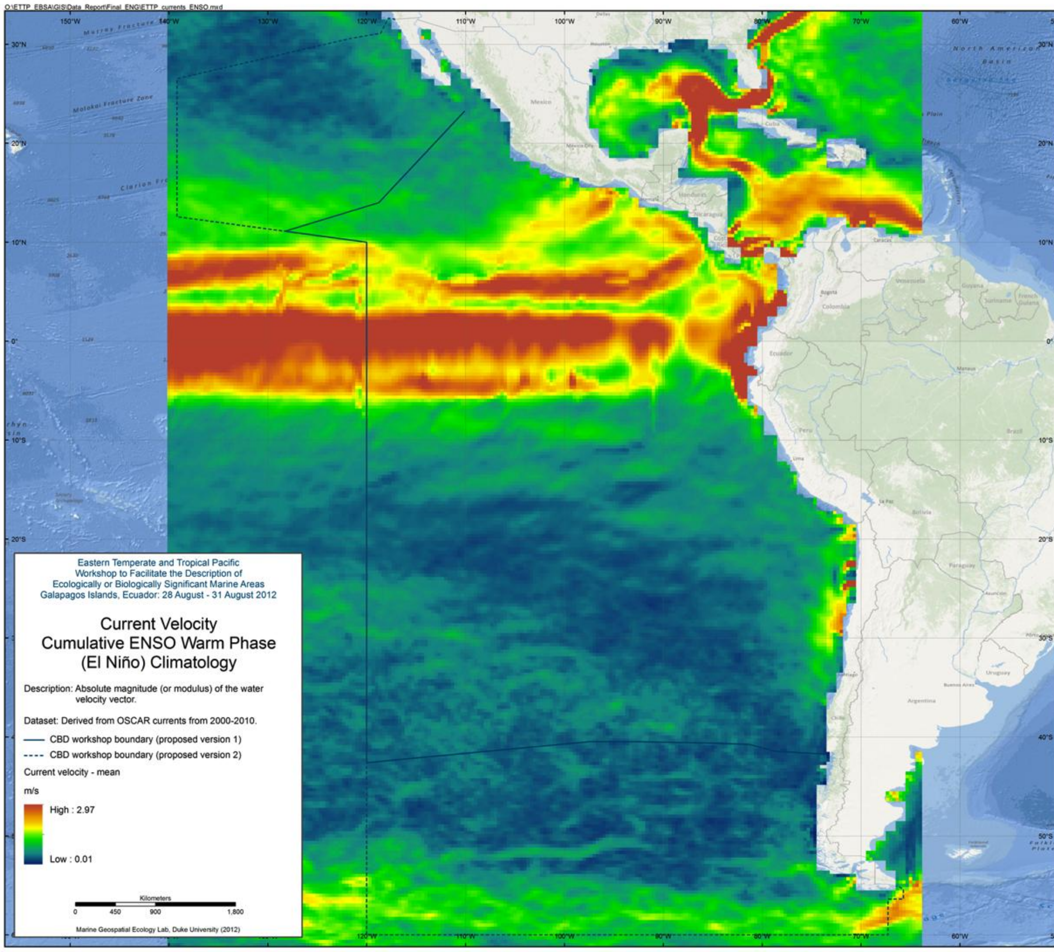

Figure 4.15-3 Surface Current Velocity - Cumulative ENSO Warm Phase Climatology

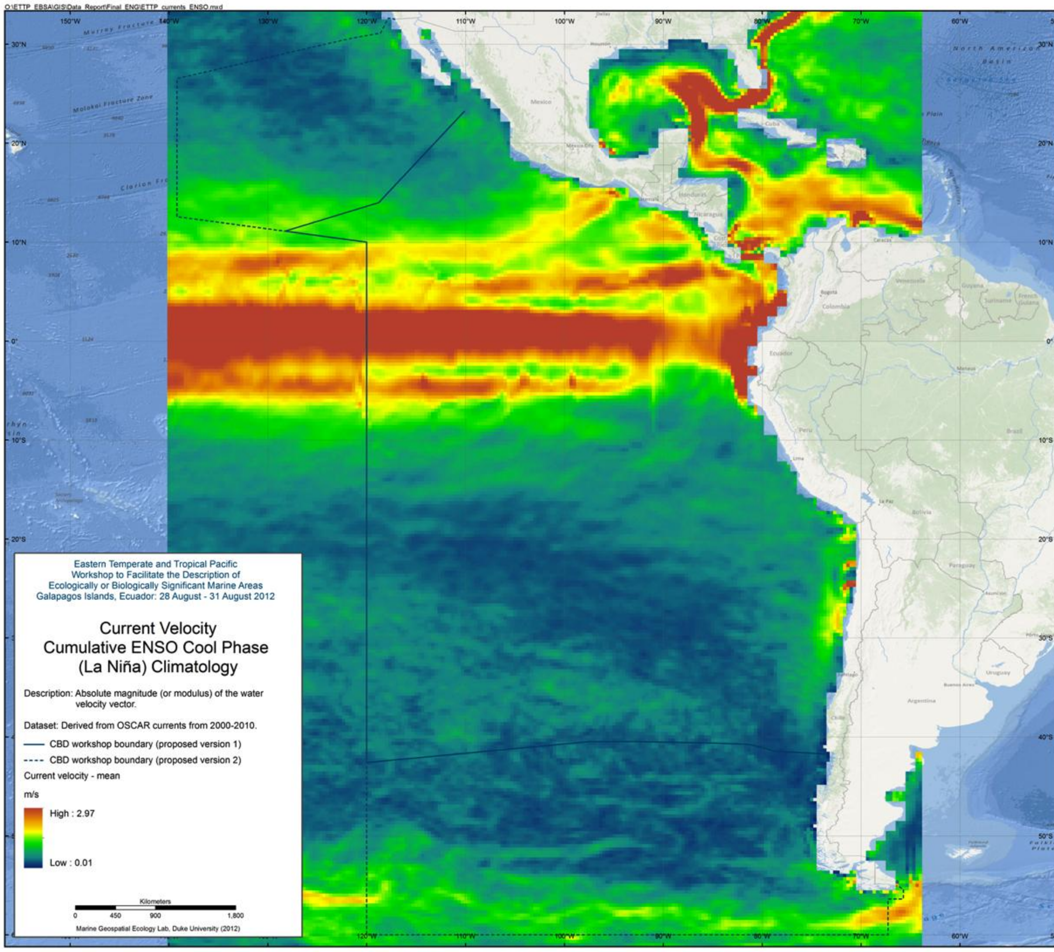

Figure 4.15-4 Surface Current Velocity - Cumulative ENSO Cool Phase Climatology

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Peter Miller (Plymouth Marine Lab, UK)

Ei Fujioka (Marine Geospatial Ecology Lab, Duke University)

Patricio Bernal (Global Ocean Biodiversity Initiative)

Fernando Felix (Comisión Permanente del Pacífico Sur)

Jihyun Lee, Jacquie Grekin, Gisela Talamas (CBD Secretariat)