Case Study 14

Distribution of Peruvian Anchovy Fleets in Relation to Oceanic Parameters

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14.1 Introduction

In Peru, the anchovy stock is the most important pelagic resource for the industrial fishery. Due to its abundance, it exhibits the largest stock for purse-seine fishing, destined almost exclusively for the production of fish meal and fish oil. The anchovy industrial fleet is comprised of 1,200 vessels, which capture an average of 6 to 8 million tons annually. These fleets are observed by the Argos System, which monitors the spatial location of licensed vessels along the Peruvian Coast. The anchovy species lives mainly in cool, coastal waters (16° to 18°C) with a salinity between 34.9 to 35.1 (characteristic of the Humboldt Current). Their distribution is affected by seasonal variations such as coastal upwelling of cold waters (essential for high marine production) and El Niños.

There is a strong relationship between the anchovy resource and the environment, which can be monitored during the fishing season using satellite imagery of sea surface temperature (AVHRR), Chlorophyll-a concentration (MODIS-Aqua) and sea surface salinity (NCOM-Navy Coastal Ocean Model). The integration of the oceanographic data and the geographic location of anchovy fishing operations, which use GIS (Geographic Information Systems), aims to determine the interrelation between oceanographic parameters obtained by satellite and the distribution of the anchovy resources to determine potential fishing zones, given that anchovy are a pelagic species forming shallow shoals.

14.2 Background

Satellite imagery, such as sea surface temperature (SST), has been widely used in a range of studies to address the surface thermal structure of the oceans, the variability of SST in the common fishing zones between Argentina and Uruguay

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(Pettigani et al., 1992), and the surface circulation and upwelling in the Chilean fishery (Barbieri et al., 1987, Yañez et al. 1995). In the north of Chile, SST variability presents spatiotemporal patterns that are well defined.

Since 1998, all Peruvian anchovy fleets are required to use the Vessel Monitoring Systems (VMS) to monitor the activities of fishing vessels. With this, control and surveillance has increased greatly and it has become an essential tool for managing fishery resources (FAO, 1988).

14.3 Data and Methods

The main objective of this case study is to analyze the relationship between the variability of oceanographic parameters such as SST, chlorophyll-a (Chl-a), and sea surface salinity (SSS) in Peruvian coastal waters, and the spatial location of fishing operations. This analysis was executed in the GIS environment using ArcGIS 9.2.

In recent years, applications of GIS have increased in the general area of oceanography. GIS can be used as an analysis tool for mapping and monitoring ocean surface processes related to fisheries. For this case study, we relied on one of the GIS principles: the ability to overlap different thematic layers from a variety of data sources and types. This can provide information about the anchovy fleet dynamics in relation to oceanographic parameters. Satellite imagery and position data from fishing operations were integrated using the ArcGIS 9.2 software. Daily maps were generated using filled contour maps, JPEG images and point data sets, over the duration of the fishing season. Each map contains the related Argos data, thus permitting investigation into the correlation between ocean surface properties and the location of the fishing fleets.

14.3.1 Study Area

The study area is located along Peruvian coastal waters (South East Pacific Ocean), between 3° to 16°S latitude and 73° to 82°W longitude (Figure 14.1). This area is dominated by the Humboldt Current System which is characterised by an extremely high productivity of marine living resources as a result of coastal upwelling of cool nutrient-rich waters.

14.3.2 Characteristics of the Satellite Data

For this case study we used daily satellite SST and Chl-a data obtained from the AVHRR and MODIS-Aqua sensors respectively, and SSS data from the Navy Coastal Ocean Model (NCOM) of the Naval Research Laboratory of USA. In addition daily Argos information was used to derive the location of fishing vessels during the fishing season from 21 April to 6 May 2008.

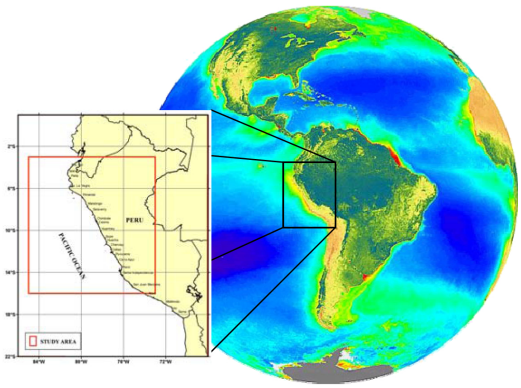

Figure 14.1 Study area off the coast of Peru

14.3.2.1 Sea Surface Temperature

SST is an important oceanic parameter because of its significant role in the exchange of heat, moisture and gases across the air-sea interface. It is also indicative of ocean surface process and features such as upwelling, fronts, eddies and current boundaries. SST data was received daily from NOAA's AVHRR sensor via the U.S. Naval Oceanographic Office (NAVOCEANO). This requires a data subscription. The spatial resolution of the data is 11 km and the temporal resolution daily. The data was downloaded to our server through Cute FTP Professional in ASCII format.

14.3.2.2 Chlorophyll-a concentration

Chlorophyll-a is an indicator of phytoplankton biomass and can be used to calculate rates of primary production through the process of photosynthesis. Level 3 Chl-a data from NASA's MODIS-Aqua satellite was obtained from the Goddard Space Flight Center (GSFC), OceanColor web page in HDF format (http://oceancolor.gsfc.nasa.gov/cgi/l3, see Esaias et al., 1998). The data does not require data subscription and is freely-available in near real-time. The spatial resolution of the data is 9 km and the temporal resolution 3 days or 8 days.

14.3.2.3 Sea Surface Salinity

Salinity is also an important conservative parameter for the distribution and abundance of marine resources. Salinity data was obtained from the U.S. Navy Operational Global Ocean Model (NCOM) that serves as the Navy's operational global Nowcast/Forecast system. SSS images were downloaded from the Naval Research Laboratory web page (http://www7320.nrlssc.navy.mil/global_ncom/humbl.html) in JPEG format. No data subscription is required, and the data consists of real-time nowcast results from the 1/8° global version of the Navy Coastal Ocean Model,

available on a daily basis.

14.3.2.4 Argos Data

The Satellite Vessel Location System (SVLS) was implemented to help the fishery administration and industry manage and monitor the fishing vessels, the operation area and fishing activities more efficiently. This system allows the authorities to permanently keep track of where the vessels are operating via their trajectories. The Argos System provides information on all licensed seine fishing vessels dedicated to the extraction of anchovy. Each vessel is equip with a receiver-transmitter, which automatically receives information from GPS satellites and sequentially transmits reports of geographical position, name, registration, speed, direction and course of the vessels. This information is received, processed and distributed by CLS-Peru.

14.4 Demonstration

Data can be downloaded from the web pages mentioned above, and georeferenced and processed in the ArcGIS environment using the five steps listed below. As an example of the procedure to be followed, we will process one file from the third week in April 2008 for SST, Chl-a, SSS, as well as process the Argos data. All example files for this case study can be found on the IOCCG website at http://www.ioccg.org/handbook/anchovy/.

1. For SST, five ZIP files in txt format were ordered from NAVOCEAN and downloaded on our our server using Cute FTP. Open the file imarpe_k10_21APR08.txt and save this in xls format. The file can then be opened in ArcGIS using the menu Tools/Add XY Data/ imarpe_k10_21APR08$. Using the Edit function, choose the coordinate system: Geographic Coordinate System/ World/ WGS84. A new file imarpe_k10_21APR08$ Events is created in the Table of Contents and is then exported to shapefile to create georeferenced points (right click on the last file Events, Data/Export Data/ Export: All features/ Output shapefile: tsm_apr21.shp (new name). A new shapefile is created and file Events are removed. The Inverse Distance Weight (IDW) interpolation method is used. This function should be used when the set of points is dense enough to capture the extent of local surface variation needed for analysis. IDW determines cell values using a linear-weight combination set of sample points. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less influence the cell has on the output value. In ArcGIS, activate the ArcToolbox, and select 3D Analyst Tools/ Raster Interpolation/ IDW/ Input point features: tsm_apr21.shp value: TSM to generate a filled contour map of SST. The result is a raster interpolation Idw_tsm_apr21. You can change the colour scale by right clicking: Properties/

Symbology.

2. For Chl-a, the zipped file named A20081122008114.L3m_3D_CHLO_4.bz2 (downloaded from NASA's OceanColor web page and also available on the IOCCG website at www.ioccg.org/handbook/anchovy/), can be processed using Windows Image Manager (WIM) software. Unzip the file to extract the data and rename to a .hdf file (A20081122008114.L3m_3D_CHLO_4.hdf) which can be loaded in WIM using File / Open / A20081122008114.L3m_3D_CHLO_4 [Type: HDF file (*.hdf; *.r8; CHLO;*.rc)]. Then, extract imagery and value data for the study area only, using File/Cut Image and by entering values of each pixel corresponding to the geographical coordinates of each end point of the new cut image i.e. 2208, 2136, 2688, 2688. Save the file in JPEG format using the commands File/ Save as/ chla_21-23apr_2008 [Type: JPEG (*.jpg)] / Save. Finally, the image (chla_21-23apr_2008.jpg) was georeferenced in ArcGIS using Add Data, and right click in each corner of the image to enter the corresponding geographical coordinates.

3. For SSS, the JPEG image named sss_21apr_2008.jpg, previously downloaded from Naval Research Laboratory of USA web page, was georeferenced in ArcGIS using the criteria outlined above.

4. The Argos data can be exported in DBF tables (file available on the IOCCG website) and opened in ArcGIS using the menu Tools/Add XY Data/ pel21042008.dbf$. In Edit chose the coordinate system: Geographic Coordinate System/ World/ WGS84.prj. A new file of pel21042008.dbf$ events is created in the Table of Contents and must be exported to shapefile to create georeferenced points. Right click on the last file Events, Data/Export Data/ Export: All features/ Output shapefile: pel21042008.shp (new name. File Events must be removed and a new shapefile containing geographical position, name, registration, speed, direction and course of the vessels must be created. All these steps should be repeated for each day of the fishing season.

5. GIS is the most appropriate framework for integrating satellite imagery with vector data sets (points). Once all the data is in the same format in the ArcGIS environment, it must be integrated with the oceanographic parameters and the spatial position of the anchovy vessels. For the integration, open a new map in ArcGIS using File/Open/Blank Document and add the shapefile Peru_coastline.shp base map; and then the filled contour maps, JPG images and Argos shapefile using Add Data. Imagery of SST, Chl-a and SSS can be overlayed with the respective Argos data to analyze the distribution and dynamics for each day of the season. The data can be exported using File/ Exported Map/ Map name/ JPEG/ 200 dpi (Figure 14.2). The output consists of 5 images for SST, 5 images for Chl-a and 5 images for SSS.

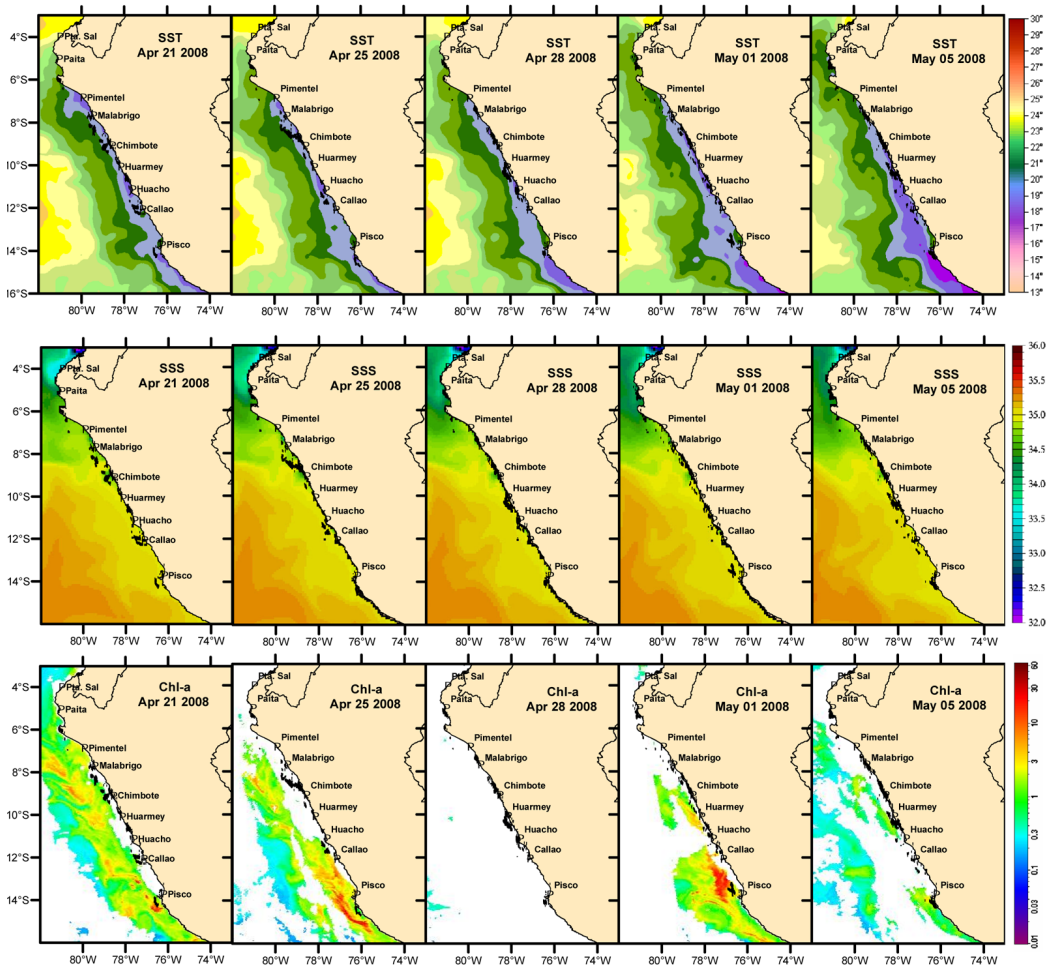

Figure 14.2 Distribution of sea surface temperature (SST, top), sea surface salinity (SSS, middle) and Chlorophyll-a concentration (Chl-a, bottom) off the coast of Peru, South America in relation to the location of anchovy fishing vessels (black dots). Three-day composite images are shown for fishing operations from 21 April to 6 May, 2008.

14.5 Questions

Q1. What are the ranges of SST, Chl-a and SSS for the greatest concentration of vessels during the fishing season?

Q2. Between which latitudes are the majority of fishing vessels located?

Q3. In what areas are the fishing operations concentrated, in relation to distance from the coast?

14.6 Answers

A1: At the beginning of the 2008 fishing season (21/04/08), warm water (> 25°C) is observed outside the 200 nautical mile (NM) contour from the coast, while in coastal areas, an intensification of coastal upwelling is observed, with temperatures < 19°C. Maps of chlorophyll-a (three-day composite images) were characterised by abundant cloud cover during this period, resulting in patchy information on chlorophyll distribution. In general, the highest chlorophyll concentrations (0.3 to 15 mg m^{-3}) at this time of the year are found within 100 nm from the coast. The main centers were located offshore from the ports of Pisco and Huarmey. Fishing operations were concentrated at the edges of the chlorophyll fronts, near the nuclei of higher chlorophyll concentrations (> 10 mg m^{-3}). Sea surface salinity presented a quasi-homogeneous distribution for this period and with no major changes in water mass at the fishing sites. Cold coastal waters with a salinity < 35.0 are found along the coast from Port Chimbote down to the southern border of Peru, and extend up to 100 NM offshore. Fishing operations were conducted mainly in the cool coastal waters with a salinity range from 34.8 to 35.1.

A2. The principal concentration of fishing operations is located between the latitudes of 7° to 12°S.

A3. The anchovy fishing operations are generally concentrated near the coast, and are associated with cold coastal water. In this case study, fishing vessels operated between 5 to 40 NM offshore.

14.7 References

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