WORLD MARITIME UNIVERSITY

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SATELLITE APPLICATIONS AS AN OCEAN AND COASTAL ZONE MANAGEMENT TOOL

Three cases studies.

By

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I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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DEDICATION

To my mother Emilia Ahón O.
and my father Francisco Iriarte B.
They taught me this

El dia más bello, hoy
The most beautiful day: today
La acción más facil, equivocarse
The easiest thing: to make mistakes
La raiz de todos los males, el egoismo
The root of all bad: egoism
La distracción más bella, el trabajo
The most beautiful relaxing distraction: work
El resguardo más eficaz, la sonrisa
The best answer: the smile
La ruta más rápida, el camino recto
The fastest way: a straight road
La mejor satisfacción, la meta lograda
The best satisfaction: the achieved goal

Emilia Ahón O.

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ABSTRACT

Satellite applications are being used in land, sea, air and space studies and management applications in the sea covering a wide spectrum of fields, such as oceanography (bathymetry, tides, waves, sea level, currents, surface water temperature), fisheries (resources distribution and monitoring of fisheries), shipping (fleet monitoring, communication, safety and rescue, pollution detection and monitoring), and navy (security, strategy, safety). Further, satellites can be used in the process of educating people onboard.

The present research is a study of three satellite applications for Ocean and Coastal Zone Management (OCZM). Radar sensors which are used in bathymetric exploration are useful in the oil pipeline industry and in coastal navigation. Thermal and radar imaging have been used to detect indirectly the resource distribution of the tuna fisheries and lately also other fisheries. The Global Position System (GPS) and data communications today permit fleet monitoring, although the focus of this dissertation is on the fishing fleet. The development of any fleet monitoring system can follow the same principle.

An interesting point is the cost — although this technology may appear expensive, it is in effect not. One of the objectives of this dissertation is to compare the value of traditional methods and satellite applications. With this I intend to give a new perspective of the capabilities of the new technology and its application in developing countries.

The Ocean and Coastal Zone (OCZ) is a very wide area. Normally, the control and monitoring of this would take days, if traditional systems are used, and all analyses would be post-facto. Satellites can provide a wide variety of applications besides data communications technology. They can send position, type of vessel, speed, and other

parameters in near-real time and therefore the ability of OCZM can be substantially increased. Herein lies the interest in exploring the employment of satellites as OCZ management tools.

The methodology followed in the development of this paper is to conduct an analysis of remote sensing capabilities. This includes comparing remote sensing images and data with traditional methods of obtaining and analysing data for the management of the natural resources within the coastal and ocean areas of a country. In addition, Internet capabilities and library resources have been used extensively to research the arena of satellite science.

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List of Abbreviations

ALT	Radar Altimeter
AMI	Active Microwave Instrument
AMSS	Aeronautical Mobile Satellite Service
ARGOS	Advanced Research and Global Observation Satellite
ATSR-M	Along-Track Scanning Radiometer and Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
BAS	Bathymetry Assessment Systems
CASI	Compact Airborne Spectrographic Images
CES	Coast Earth Stations
CFP	Common Fisheries Policy
COP	Coastal Ocean Program
COZ	Coastal and Ocean Zone
CZCS	Coastal Zone Colour Scanner
CZM	Coastal Zone Management
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessments
EMS	Environmental Management System
EREP	Earth Resources Experiment Package
EU	European Union
FAO	United Nations Food & Agriculture Organisation
GEO	Geostationary Orbit
GESAMP	Joint Group of Experts on Scientific Aspects of Marine Environmental Protection
GIS	Geographic Information Systems
GMDSS	Global Maritime Distress and Safety System
GOES	Geostationary Operational Environmental Satellite
GPS	Global Position System
GTS	Global Telecommunications System

HEO	Highly Elliptical Orbit
HF	High frequency
HIRIS (HIRS)	High Resolution Infrared Sounder
IFREMER	The French Institute of Research and Exploitation of the Sea
IGOSS	Integrated Global Ocean Services System
IMARPE	Instituto del Mar del Peru (Peruvian Institute of the Sea)
IMO	International Maritime Organisation
INMARSAT	International Maritime Satellite
INTELSAT	International Telecommunication Satellite
IOC	International Oceanographic Commission
IODE	International Oceanographic Data Exchange
IR	Infra-red
IRS	Indian Remote Sensing
ISM	International Shipping Management Code
ISO	International Organisation for Standardisation
ITOS	Improved Tiros Operational Satellite
ITU	International Telecommunications Union's Radio Regulations
JERS	Japanese Earth Resources Satellite
LANDSAT	Land (Remote Sensing) Satellite
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LMSS	Land Mobile Satellite Service
MARPOL	Marine Pollution Convention
MEIS	Multispectral Electro-optical Imaging Spectrometer
MEO	Medium Earth Orbit
METOP	Meteorological Polar Platform
MMSS	Maritime Mobile Satellite Service
MSS	Multispectral Sensor
NASA	National Space Agency

NESDIS	National Environmental Satellite, Data and Information Services
NIMBUS	NASA/GSF Earth Observation Programme
NOAA	National Oceanographic Atmospheric Administration
NOS	National Ocean Services
OCZM	Ocean and Coastal Zone Management
OZM	Ocean Zone Management
Radar	Radio Detection and Ranging
RF	Radio Frequencies
RMS	Root Mean Square
RX	Reception
RSA	Remote Sensing Analysis
SAR	Synthetic Aperture Radar
SeaWiFS	Sea-Viewing Wide-Field-of-View Space Sensor
SES	Ship Earth Station
SIPESA	Sindicato Pesquero del Peru S.A.
SMS	Synchronous Meteorological Satellite
SOLAS	Safety of Life at Sea Convention
SSB	Single Sideband AM
SSM/I	Special Sensor Microwave/Image
SST	Sea Surface Temperature
T-S	Temperature - Salinity
TIROS	Television and Infrared Observation Satellite
TM	Thematic mapper
TOVS	Tiros Operational Vertical Sounder
TWTA	Travelling Wave Tube Amplifiers
UHF	Ultra High Frequency
UNCLOS	United Nations Law of the Sea
UNEP	United Nations Environment Programme

Far out to sea, a herd of hundreds of dolphins is hunting. At the easternmost edge of the group, a dolphin discovers a large shoal of fish. It shares the news with dolphins near it. Instantly they relay the information to others further away.
(Ocean Explorer, 1994)

1. INTRODUCTION

Within the area of interest to this dissertation, most human activities occur in the Coastal Zone, but activities such as fisheries, oil and mineral industries and shipping exist and can be further developed in the Ocean Zone. The Coastal and Ocean zones are wide and complex areas to be managed, especially if reasonable use of limited financial resources of a country is to be achieved. Costs involved in this management process (i.e. monitoring, control, decision making) are expensive, beyond what many developing countries can afford. In most of these countries there is a lack of updated information, or even worse, there is no monitoring process at all.

Frequency, volume and quality of information are the main parameters that can be measured. This brings up the question on how countries can reduce the cost of monitoring and increase the frequency, volume and quality of information in order to deal with monitoring activities within their entire coastal and ocean zones. Satellites seem to be an excellent management tool to deal with this problem.

Satellite applications for marine environmental monitoring is a broad area. This paper will focus on three cases: (a) radar sensors in bathymetry surveys, (b) thermal and radar imaging of the surface water temperature surface related to resource distribution (school of fish), and (c) GPS and data communications for monitoring of fishing fleets.

This paper provides a vision of the capabilities of these satellite developments and subsequently presents these as alternatives to be used in management decisions. Current applications of satellite science for marine and maritime matters are also addressed. Most satellite applications do not take place in an isolated fashion. In fact many applications are closely related, for example, an oceanographic parameter such as surface water temperature is related to fisheries because it helps to determine the distribution of fishing resources in a specific area of analysis.

Depth structure and the depth itself are being used in fisheries management in order to select better fishing areas; thus, bathymetric information is useful to decide on the promising fishing areas. Applications of bathymetric information can also be found in the oil industry where discussions on the location for pipelines are made less difficult by this data. Satellite applications provide a possibility to reduce costs and time when trying to locate the best place for pipeline installations.

Monitoring fishing vessels is an issue of interest for governments because they will be able to control the fishing effort. Monitoring is also useful for the safety of vessels. Any emergency can immediately be known and therefore the response action can be taken quickly. The Global Maritime Distress and Safety System (GMDSS) is not compulsory for fishing vessels; however, the option of monitoring such a fleet in national and in international waters exists, providing a technical instrument for safety of the fishing vessels.

The process of monitoring a fishing fleet or any maritime fleet can be done by satellite communications and geo-position satellite networks, which have increased substantially in accuracy and number over the last years. This system can decrease operational costs and possibly maintenance costs for the vessels.

Ocean and Coastal Zone Management involves all aspects related to human activities and natural resources. Sustainable development of these resources appears as an imperative action to be taken in order to ensure the resources for future generations.

1.1 Objectives

General:

1. To evaluate costs of satellite application analysis compared to traditional method analysis.
2. To augment the level of data recollection and their evaluation within the Ocean and Coastal Zone Management

Specific:

1. To evaluate "Radar sensing data" for bathymetric exploration in the coastal area.
2. To evaluate the use of "Thermal and radar imaging data" for determining fishing resource distribution within the Ocean and Coastal Zone.
3. To design strategies for monitoring of fishing fleets (national and international).

1.2 Materials and Methods

1.2.1 Place

The study area covers the Coastal and Ocean Zone within the territorial sea of Peru.

1.2.2 Materials

- Legal rules (Peruvian Environment Code; FAO Environmental Code of Conduct for Responsible Fisheries; Peruvian Law of Fisheries)
- ISO 14000 and ISO 9000

- Documentation (i.e. research papers, books, reports)
- IMO rules related with safety, environment and communications.- Global Maritime Distress and Safety System (GMDSS), Marine Pollution Convention (MARPOL) and Safety of Life at Sea Convention (SOLAS)
- SIPESA fleet data (1993)
- Software:
  - Surfer Access System, version 4.10. Copyright © Golden Software Inc., 1989.
  - Microsoft Excel, version 5.0. Copyright © 1985-1993. Microsoft Corporation.
  - Netscape Navigator ™, version 1.1 N. Copyright © 1994-1995 Netscape Communication Corporation.
  - Pegasus Mail for Windows, version 2.2. Copyright © 1992-1995. David Harris.

1.2.3 Methods

- Library research
- Remote sensing analysis.- Technique used to analyse satellite images and data for evaluating natural resources in the earth. Monitoring and sensing are easy in the sense of time consumption, volume and quality of the information. The best example of this is the sea surface temperature image and data to analyse the most likely distribution of tuna in the Pacific Ocean.

1.3 Dissertation structure

Chapter I. Introduction. The general idea about why this topic was chosen; the objective and methodology used in the development of these objectives.

Chapter II. Ocean and Coastal Zone Management (OCZM). This comprehends the definition of Coastal Zone Management and Ocean Zone Management and how Information Management is used to integrate this data in the process of taking a decision for the benefit of the Ocean and Coastal Zone. This chapter concludes with the control and monitoring of the OCZ within the Peruvian Legislation.

Chapter III. Concept of satellite operation. The chapter is a technical description of satellite instruments used to sense and monitor resources on the earth. A presentation of what kind of satellite constellation is currently used in the maritime and marine arena concludes this chapter.

Chapter IV. Concepts in data processing and interpretation. This chapter deals with information management focusing on satellite data processing.

Chapter V. Case Studies in Peruvian OCZM. This chapter is the heart of this document. Starting with the radar sensor, which can provide information to calculate the bathymetry of an area in analysis. After that, the infrared sensor and special radiometer information are used to detect sea surface temperature; posteriorly this data is used to evaluate the most likely zone to fish a particular species. The chapter concludes with the study on monitoring a fishing fleet using satellite communication and global positioning system (GPS).

Chapter VI. Cost comparison between traditional methods and satellite applications. Cost is the most important aspect in any project. A project can be possible, but the economic feasibility sometimes restricts the applicability of new technology; therefore, the project development. This chapter provides information regarding operation and analysis costs of these technologies. Furthermore, time cost is included in this analysis.

Chapter VII. Conclusions and recommendations. The *bibliography* and *appendices* are the last parts of the present dissertation.

In our hands it will change the world for ever. And for the benefit of everyone.
(McAuley, P., "Red Dust", 1993)

2. OCEAN AND COASTAL ZONE MANAGEMENT (OCZM)

The first step in the effective resource management is a proper understanding of the issues involved where the resources are and where they are developed. The next step is to establish the most appropriate policy measures, in other words to define a successful coastal and ocean resource management where identifying projects, conducting feasibility studies and continuous environmental impact assessments (EIA) are required.

However, what is management? What are the coastal and ocean zones? Which are their limits? And, how can they be managed? These are the main questions that the present chapter will try to clarify and develop.

In this process the first issue is management, a term that has been defined by NTC's American Business Terms Dictionary as the art and science of planning, organising, directing, and controlling the work of others to achieve defined objectives (Caruth & Stovall, 1994, page 190). Smith (1995) clearly defines management priorities, which cover two sections: The first concerns management measures that deal with interactions between human activity and the environment itself, also called 'technical management'. The second deals with the complex of external factors acting on the technical management system, and includes co-ordination of technical management, organisational management, strategic management and policy of the whole management system, called 'general management'. Clearly, management is responsible for establishing a policy. A successful implementation of this policy is dependent upon management commitment to the development and effective operation of a quality system.

Ocean and Coastal zone management is in essences resource management. This is a subject that ISO has considered so important that it has developed general guidelines on principles, system and supporting techniques called the ISO 14000 series (ISO, 1991; Healey & Hennessey, 1994; Wolf, 1995; Tibor & Feldman, 1996). This management process which can be defined in function as a quality system, is closely related to review processes which consist of well-structured and comprehensive evaluations encompassing all relevant sources of information.

The World Commission on Environment and Development (UNEP, 1993) has defined as a main goal the sustainable development for all countries in the world, a goal that can provide enough resources for future generations. Here, coastal and ocean zones appear as the richest places where the next generation will be able to find such resources.

In the final version of Agenda 21 adopted in Rio, chapter 17 is devoted to the marine environment: "Protection of Oceans, All Kinds of Seas, including Enclosed and Semi-Enclosed Seas, Coastal Areas, and the Protection, Rational Use and Development of their Living Resources". (Johnston, 1993, page 69). Action is called for on seven fronts:

1) integrated management and sustainable development of coastal areas, including exclusive economic zones (EEZ);
2) marine environmental protection (that is, marine pollution prevention and control);
3) sustainable use and conservation of marine living resources of the high seas;
4) sustainable use and conservation of living marine resources under national jurisdiction;

5) addressing critical uncertainties for the management of the marine environment and climate change;
6) strengthening international, including regional, co-operation and co-ordination; and
7) sustainable development of small islands.

Space-borne data has been used extensively world-wide in studying various components of the coastal environment, such as erosion, inundation, shallow-water, aquaculture, fisheries, coastal geomorphology and reclamation. (Kunte & Gao, 1994; Yang et al., 1995). This information permits the manager to have a vision of the coastal and ocean areas, being able to detect which are the most sensitive areas and taking a decision regarding their protection.

To summarise these lines, management of the coastal and ocean areas must have a scientific and technological approach that combined with the natural and social environments can provide enough input to develop a rational resource exploitation. Therefore, sustainable development of ocean and coastal zones depend on the correct understanding of the resources within these areas and the proper management process taken by the governments or by the entity in-charge of their management.

2.1 Coastal Zone Management (CZM)

The next step in the developing of this paper was to determine what coastal zone is and what the human activities affecting it are. However there are some differences between ocean and coastal activities. There are several authors that consider only one zone in the process of management "Ocean and Coastal Zone Management". Though it is clear that the oceanographic and biologic activities on whole are an integrated process, this chapter presents an isolated zone management "Coastal Zone Management". This point of view is based on the different human activities in the coastal and ocean zone. For example, in the fishing industry, there are some differences between coastal and ocean fisheries, mainly due to the type of fish and oceanographic conditions that the vessel will deal with. The same applies to the oil industry where the oil-drill has different requirements whether the area is close to shore or not. Ongoing and near-shore vessels are clearly differentiated in the shipping industry and in the governmental maritime policy.

Though, the Common Fisheries Policy (CFP) in the EEC Commission has addressed and considered the coastal zone activities within the 12 nm zone (O&CM, 1994), for the present study Coastal Zone will be defined within the 30 nm zone. It is considered as the utmost limit of the artisanal fisheries.

CZM covers the following areas:

- Communications. (Navigation, shipping, port communications and land transport)
- Strategy
- Mineral extraction. (Aggregate dredging and, oil and gas)
- Industry. (Manufacturing and energy generation)
- Fisheries. (Artisanal and industrial)
- Aquaculture. (i.e. fish farming, algae farming, oyster farming)
- Urban land use
- Rural land use
- Recreation. (including tourism)
- Waste disposal
- Coastal engineering
- Conservation
- Research and education

A convenient approach for coastal uses is technical management, which is divided into the following (Ballinger et al., 1994; O & CM, 1994; Smith, 1995):

- Information management is divided into the following: (a) Monitoring which consists of a large number of applied programmes in areas as diverse as meteorology and fisheries research. (b) Surveillance that is primarily associated with military operations, enforcement (as in fisheries protection), and safety (as in navigation management), and (c) Information technology which due to the advent of computer-based database management systems and modelling opens up many opportunities for integrated approaches.
- Assessment, covering areas such as economical and social impact, technology effects, environment and risks.
- Professional practice, being of particular importance: science, surveying, engineering, planning and law.

Observed dysfunction of coastal ecosystems (which are often poorly explained) is the result of multiple aggressions (i.e. pollutants, coastal modifications and over-exploitation). This deterioration can no longer be accepted, not only because it is damaging to major activities, such as tourism or aquaculture, where the quality of the environment is determinant, but above all because these indicators are seen as signs of the unacceptable degradation of the quality of our environment. (IFREMER, 1991, page 15). Solutions to current and future complex coastal problems require timely delivery of the best scientific information in forms useful for decision making. (Sheifer, 1993; Scavia et al., 1995).

Summarising, Coastal Zone Management implies the formulation of strategies applied in an efficient and sustainable way on the coastal resources for the benefit of socio-economics and politics of the society. In Wilson's words (1995, page 1) "the core of the coastal management is how to best promote long-term economic growth that is compatible with sustainable ecosystem health". Furthermore, it is in coastal areas where human activities are quickly developing. It is enough to see the population increasing and the process of developing in the cities or megacities of New York, Shanghai, Manila, Tokyo and Lima among others.

2.2 Ocean Zone Management (OCZ)

For the present document Ocean Zone will be the area beyond the 30 nautical miles but within the 200 nm of the Economic Exclusive Zone (EEZ). Based on the author's experience in fisheries activities, fisheries beyond 30 nm are different to the near-shore fisheries in volume, frequency, use and techniques.

Although there are several activities that happen in the ocean zone, fishing in the high seas is one of the main issues if not the principal problem that has to be managed in this area. High sea fisheries are concerned to highly migratory and straddling fish stocks may occur simultaneously within and beyond the zone or they may be available mainly outside at one time and inside at another. Amounts taken within may affect the catches beyond and vice versa. Overfishing of non-target and target stocks in international waters all have an unknown impact on species interaction and marine ecosystems within national jurisdiction and on the high seas. It is believed that unsound fishing practices and overfishing on the high seas adversely affect the resource base and management efforts within and beyond 200 miles. (Meltzer, 1994, page 261).

As a result, coastal states now assert their right and special interest to take part in the conservation of straddling fish stocks and highly migratory species that occur within their exclusive economic zone. Otherwise, they say, the sovereignty of these states over the 200-mile zone would be illusory. In the development of the law of the sea, Latin American states have always based their claims mainly on two principles: the need to preserve living resources and the nexus between sea and land. (Meltzer, 1994; Armas, 1995).

The United Nations Law of the Sea (art. 63), established that distant water fishing nations have two obligations: (1) to conserve the natural resources; and (2) to co-operate with the adjacent coastal state(s) who are afforded special rights over these stocks. However, there are no enforcement rights enabling coastal states to protect these stocks in the area beyond and adjacent to their fishing zones and there is no compulsory or independent dispute resolution mechanism provided for in the text. (Meltzer, 1994; Armas, 1995).

However there are various industrial activities in the Ocean Zone; the present document focuses its interest on the fisheries in high sea areas, where straddling and highly migratory species such as tuna and mackerel are the most known. Management of these stocks seems to be difficult due to the amplitude of their distribution, and besides, because the international legal instruments (i.e. UNCLOS) have some deficiencies regarding enforcement for this type of resource. Though recent agreements, such as the New York and Canada-Spain (EU), seem to be important new management initiatives because they have agreed to adopt measures to permit enforcement in the area beyond 200 nm. By giving a useful legal instrument to control the fishing effort over straddling and high migratory stocks, these stocks can be effectively protected.

2.3 Information Management

Data and information management is the key to gain improved understanding of what is happening to the environment — both as a result of natural changes and of manmade variability. These changes need to be understood and calibrated, as how quickly they are taking place. Planning methods, control procedures and organisational arrangements appear as a correct strategy in the management of information (Earl, 1989; Castle, 1990; GESAMP, 1990).

The absence of data from a number of developing countries, specially in a regional context, hinders national environmental protection and national development and planning, as well as the evaluation of regional and global facts. To achieve cost-effective data collection and assessment, users and their requirements need to be more clearly identified. In addition, ways of transforming existing information into forms more useful for decision-making are essential, together with targeting the information at different user groups. (UNEP, 1993, page 1).

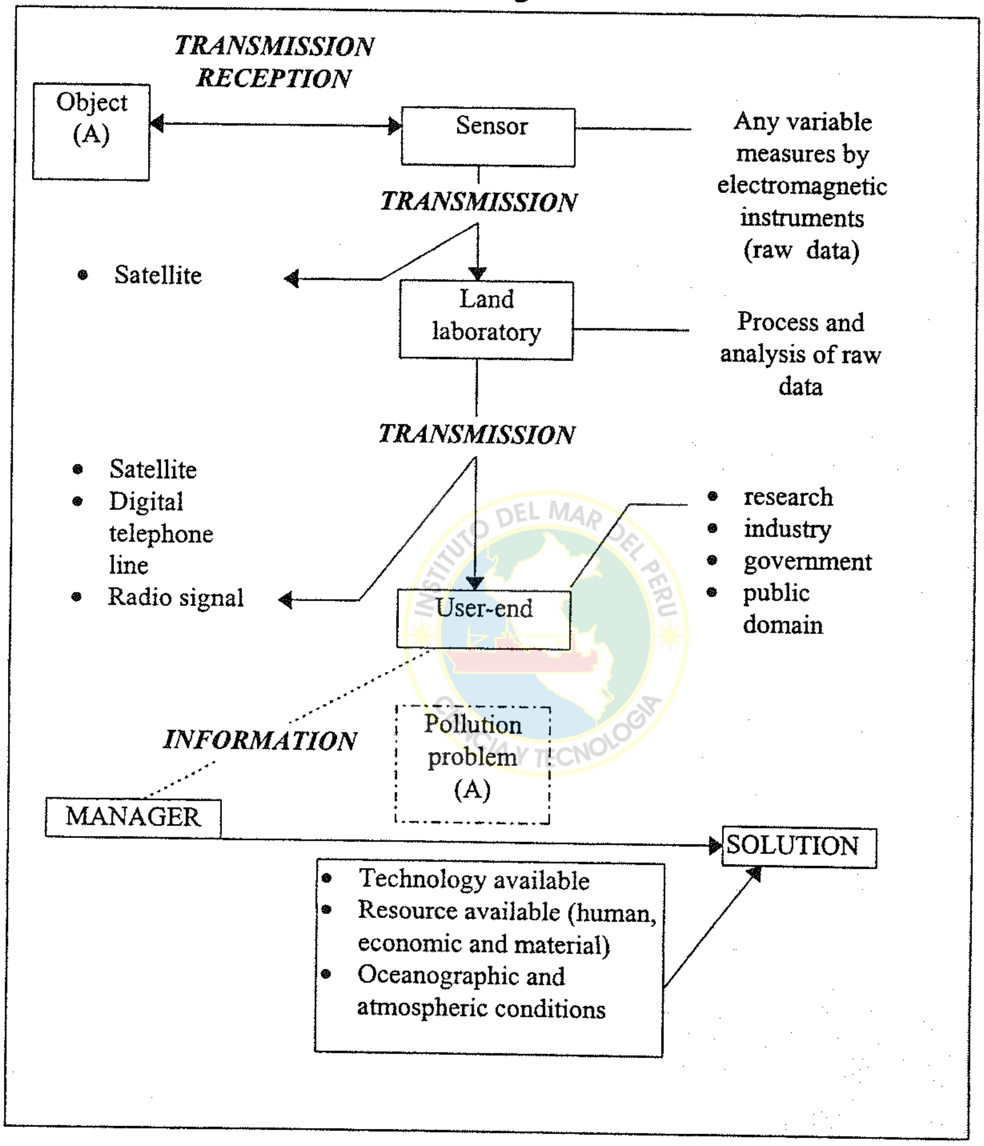
Information technology is not confined to data alone, but includes voice information and image information fully integrated into the process (Folts, 1992, page 3). New technologies have permitted an increase in the volume of data to be obtained and managed, a quick analysis and more precise calculation. An essential part of this development which will be developed in the following lines, is the information technology that permits the distribution or sharing information with different researchers or decision-makers all over the world.

2.3.1 Procedure - Analysis Methodology

After the acquisition or collection of data in spatial and temporal terms, this information is transmitted to the ground station (taking in account accuracy, significance and confidence of the data).

The process of information management (Figure 1) requires a raw data that is subsequently sent by teleprocess (in our case satellite communication). This information is processed using a convenient analysis method; then this information is re-sent to the user-end who will take the processed data or raw data to made a decision. Subsequently, the spatial and temporal analysis is made so a manager can conveniently use this information.

Figure 1. Process of information management



2.3.2 Geographic Information System (GIS)

GIS is a powerful analytical tool that has allowed the improvement of inadequate ground control and base mapping through the incorporation of differential global positioning system technology. Thus, GIS helps the user to assess, document, and improve data quality, as well as to analyse and interpret multivariate spatial scientific data bases. Furthermore, geographic information systems can draw relationships among unrelated elements, assign them geographic significance and tie them to co-ordinates on a satellite image. As an example, the improvement of information analysis and management can be shown in an Environment Impact Assessment that nowadays use GIS as useful instrument. (UNEP, 1993; Corbley, 1994; Mumby et al., 1995).

A GIS is a computer-based system for developing, storing, querying, analysing, and displaying geographically referenced information. Adding imaging processing software and desk-top mapping packages give the users the possibility to visualise and extract information from imagery and later to transform the images into actual maps. These are the causes why this technology has become an extremely popular management tool for terrestrial systems and recently its popularity has grown among marine managers. (Hasting, 1992; Corbley, 1994; Mumby et al, 1995).

Uses of the geographic information system are described by Clayton's words (1991, page 29)

> *Designed as an integrated spatial database for scientist and managers, the map and data-sets are married in a topological spatial relationship that allows maps to be visually combined and overplotted with pertinent data records. This permits the manager to make an informed assessment of the existing pollution and the potential impact on the environment. Similarly, an environmental agency evaluating a permit for ocean dumping could visually examine the potential user conflicts review geological and oceanographic information for emplacement, dissipation, and confinement at the proposed site.*

2.3.3 Areas of application in Ocean and Coastal Zone Management

Remote sensing by satellite is not a panacea. It must be complemented by field or ground data, and this linked data will be useful to understand several processes in the sea. Monitoring of fleets has already started in different countries, e.g. in South-American, Japanese and Australian fishing fleets to indicate some. Also, private companies have started to use this new technology.

Satellite technology provides broad information of Coastal and Ocean areas. Examples of this new alternative can be observed with the IRS 1A (Indian Remote Sensing), which has been built to process data useful in resource management. The Japanese satellite JERS 1 (Japanese Earth Resources Satellite) using L-band wavelength is dedicated to monitoring both water and land features. RADARSAT, a Canadian satellite is currently monitoring oceans, ice, agriculture, geology, hydrology and forestry. The Coastal Zone Colour Scanner (CZCS) is being used on Nimbus-7 to determine sea colour. Oil spill monitoring in the EU network has started to use the advantages of satellite data to provide detailed information of oil slicks around European coastal waters (Sherman, 1992; IOC-UNESCO, 1992; Coastguard, 1995).

This information could be improved in the future providing a very useful help to monitor oil and other pollutants (chemicals). Further, clean-up operations in major spillage could be another area covered by this satellite. However, the methodologies developed for oil spill detection and monitoring at present is most appropriate to aircraft.

Space-borne data covering the ocean and coastal areas can be processed using digital and visual techniques to extract information about them. Satellite images and aerial photographs of the coastal zone can also be analysed, and fluvial, estuarine, marine, vegetation, and near-shore features can be identified and mapped and added to GIS, where the process of analysing seems to be easier due to its graphic capability. (IOC-UNESCO, 1992; Kunte & Wagle, 1994; Mumby et al., 1995).

Coastal decision makers require accurate and immediate information concerning environmental processes and events that may affect the health and stability of the coastal marine environment. GIS provides an ideal environment in which to manipulate classified satellite imagery. Transferring the image to GIS also allows easy modification of the original classification.

It is opportune to indicate that in the framework of sharing and transferring data to support the information needs of coastal managers, the CoastWatch program created by the Coastal Ocean Program (COP), together with the NOAA National Environmental Satellite, Data and Information Services (NESDIS) have been designed to provide rapid dissemination of satellite observation data to regional coastal sites. (Sheifer, 1993; Mumby et al., 1995).

Other example of satellite uses in coastal areas can be observed in an integrated AVHRR (Advance Very High Resolution Radiometer) water quality monitoring program, land-use patterns in the estuarine drainage basin, and tide- and wind-based hydrological modelling in the coastal waters of eastern North Carolina. The application of the satellite framework information over El Niño conditions, which shows the effect on selected coastal fish stocks, is also interesting. Increasing necessity of resource management has impacted positively in the uses of GIS and satellite imagery, such as the case of Belize, where GIS products are increasingly being used as the primary source for management plans. (Celone & Smith, 1992; Mumby et al., 1995).

2.4 Control and Monitoring of the OCZ within the Peruvian Legislation

Law enforcement has always been one of the most useful instruments to have an effective control of resources and activities in waters belonging to any country. Administrative infrastructure, principles and procedures of control and monitoring are given through legal documents. Therefore, an analysis of the legal aspects regarding the marine and maritime management in Peru is presented in the following lines.

The Peruvian General Law of Fisheries (Decree Law No. 25977) establishes the principles of sustaining and renewing fishery resources, as the way to achieve their optimum rational exploitation. As Ferrando & Alcantara (1994) said the Fishing Law regulates fishing activities in keeping with the FAO (United Nations Food & Agriculture Organisation) principle of sustainable growth.

Within the Peruvian Law of Fisheries, Title I: Basic Provisions, articles 6, 7 and 9 provide the framework of controlling the fishing activities. Furthermore, article 7 states:

> *The provisions adopted by the State to ensure the preservation and rational exploitation of fishery products shall be applied beyond the 200 nautical miles of territorial waters to products of different areas that migrate towards adjacent waters or move from these waters towards the Coast due to food, reproduction or breeding habits similar to those of other marine life.* It also includes that *Peru shall encourage with other states the execution of agreements and international treaties in order to ensure compliance with the provisions herein referred to, subject to the principles of responsible fishing.*

Both 1979 and 1993 Constitutions establish that Peru has territorial jurisdiction beyond 200 nautical miles, which is an obstacle to its joining the United Nations Convention Law of the Sea (UNCLOS). Foreign fishing vessels operating outside the

200-nautical-mile limit, and docking in Peruvian ports for technical assistance, fresh water supplies, and fuel are only required to present an affidavit describing the nature of their activities on the high seas, as regulated in the 1985 Supreme Decree. (Ferrando & Alcantara, 1994; Meltzer, 1994)

Regarding the monitoring activities, Title II: Code of Regulations of Fishery Activities, article 12, defines the application of necessary monitoring, control and surveillance procedures to regulate fishing activities.

Control of foreign fishing fleets acting in Peruvian waters has been defined in Title VIII: Register of Fisheries, articles 47 and 50. As the control of fisheries can not be isolated in one ministry, therefore the Law has established Title X: Institutional Co-ordination. Article 67 deals with prevention and control of environmental pollution, and the Ministry of Fisheries must co-ordinate with other ministries, municipalities and pertinent agencies.

Regarding the registration, inspection and control of fishermen and fishing vessels, as well as the training of ship crews, the Coast Guard Bureau is in charge. (Title X, article 69).

An automatic control system has been established through Ministerial Decision No. 293-93-PE. According to this regulation, foreign vessels must maintain special equipment provided by the Fishing Ministry at market price in order to allow the government to monitor their operations. If foreign vessels do not comply with this regulation, their permits will be cancelled immediately. (Ferrando & Alcantara, 1994, page 151).

According to article 70,

> *The Ministry of Defence, through the maritime authority, and according to the provisions issued by the Ministry of Fisheries, shall control and protect fishery products, and shall perform other functions inherent to safety of life at sea and protection of maritime environment.*

Complementing this article, the Ministry of Internal Affairs is also responsible for the control and protection of fisheries' products in such places where the Ministry of Defence cannot exercise its tasks (Title X, article 73).

The Environmental Code, has been in force since 1990. It sanctions the "polluter/pays" principle, classifies environmental violations and sets forth the requirement for environmental impact assessments (EIA) prior to the initiation of any potentially harmful activity. (Ferrando & Alcantara, 1994, page 148). International agreements and/or contracts are indicated in article 75; the Ministry of Foreign Affairs and the Ministry of Fisheries is in charge of co-ordinating those activities.

In article 7 (Fishing operations) of the FAO's Code of conduct for responsible fisheries, it has been established that;

> *7.1.4 States should, in accordance with international law, within the framework of sub-regional or regional fisheries management organisations or arrangements, co-operate to establish systems for monitoring, control, surveillance and enforcement of applicable measures with respect to fishing operations and related activities in waters outside their national jurisdiction. (Fishing News International, 1996, page 46).*

In conclusion, the Peruvian legislation provides the convenient instruments to enforce control and monitoring within its territorial sea. Moreover it has been defined that Peru has jurisdiction beyond 200 nautical miles. The Chilean proposal regarding the Presencial Sea or in Spanish "Mar Presencial" can complement the necessity of

Latin-American countries to have an effective control beyond 200 nm in an international forum.

Regarding monitoring programs, Peru is one of the leading countries in applying an automatic control system using satellite networks. The Peruvian legislation is an important tool to enforce this system.

Advances in software, marketing and product packing all played roles in the swift maturation, but underlying reason for this growth is much simpler: ***new uses for satellite imagery are constantly being discovered and developed.*** *(Corbley, 1995, page 101).*

3. CONCEPT OF SATELLITE OPERATION

The present chapter will show that the understanding of satellites and sensors, and how their capabilities can give advantages to the manager in the decision process. To start this process of understanding it is necessary to define what an artificial satellite is. As the Facts on File Dictionary of Marine Science wrote, an artificial satellite is a manmade object placed in orbit around the earth for scientific, technological, and military uses such as reconnaissance, surveying, meteorological observation, navigational assistance, and communications, for relaying radio and television. (Charton, 1988, page 249).

Time has passed since the first artificial satellite was used by humankind in 1957; new technologies have appeared permitting the development of the satellite science. Thus, there are currently uses of satellite sensors to detect fish schools, pollutants, changes of temperature in the sea, state of icebergs, mapping application (including mineral exploration), forestry, environmental monitoring and agricultural assessment to mention some.

Management of wide areas such as Ocean and Coastal zones are very difficult in time, personnel and operative costs. However new technologies such as satellite science and remote sensing can make it. Satellite systems have progressively evolved from a purely network oriented approach to increasingly user oriented ones. Chase (1994, 1994a) has defined that these changes are based on the following points:

- the increased digitisation of transmissions
- rapid expansion of high performance fibre optic cables causing improvements in spectrum efficiency
- evolution of information and service oriented societies
- progressive extension of satellite lifetime
- increase in the mass of satellite intended for geostationary operation
- increased use of extended portions of the C- and Ku-band allocations for communication purposes

Any manager will be interested in how to get information, and to know timeliness and reliability of the data. However, information regarding data reception and the transmission process using satellite networks (in other words accuracy of information transmitted or received) is also relevant in the process of taking a decision. Why? Because, the quality of the information is as important as the quantity and frequency of that information. Therefore, the manager should know some general aspects of how the sensors obtain information from the earth and how the data is sent and received by the satellite sensors.

3.1 General Considerations

The first questions that come to the mind is how can the sensors get information from the space of the earth and sea? And, how can that information be transmitted through space? The following lines present the answer to that.

3.1.1 Electromagnetic waves

All sensors employ in some form or other a type of electromagnetic wave, which has two components; an electric field measured in volts/metre and a magnetic field measured in amperes-metre. The electromagnetic wave is ruled by the following equation:

$$f * \lambda = c,$$

Where,

c: velocity of light (3×10^8 m/sec)

f: frequency (Hz)

λ: wavelength (m)

The electromagnetic spectrum covers frequencies from 10^3 to 10^{24} Hz or in wavelength from 10^5 to 10^{-14} meters, this electromagnetic waves are employed to sense the earth and for communications. They have to travel a long way through the earth's atmosphere, and in their path attenuations, such as absorption, reflection and refraction will be found. Absorption by air, water vapour and rain are the more significant elements in the process of attenuation.

Sources of electromagnetic radiation can be the sun, the earth and terrestrial objects with a spectral composition that is a function of the nature of the object. Thus, information captured by special sensors installed in an aeroplane, balloons or in a satellite platform is analysed by spectral patterns (spectral analysis) to determine the radio emission and the reflectance of the surface bodies to electromagnetic radiation.

3.2 Satellite Remote Instruments

Sensors are elements that can give a measure of a phenomena or physic condition and later give this information for an analysis. For example, a simple thermometer is a sensor that measures the temperature such as air temperature, water temperature or body temperature, being able to evaluate this information reading directly from the thermometer.

Satellite instruments are sensors that provide information to research, but the difference is that this sensors are far away and in a different environment. Of course, there is some interference that must be overcome such as electromagnetic interference from the sun and earth and some atmospheric phenomena.

How satellite sensors get the information has been described in the section before. In the following the different types of sensor used on satellites will be described and what kind of useful information these instruments get from the earth.

3.2.1 Type of sensors on satellites

The basic sensor is a radiometer which measures the flux of electromagnetic energy. The wide range of measures covers the visible/infra-red ($\lambda \sim 0.4 - 1.2$ μm) and microwave (($\lambda \sim 3 - 30$ cm) parts of the spectrum, which cover frequencies from 0.1 to 1000 GHz.

Table 1. Type of energy captured by satellite sensors

Electromagnetic spectrum	λ range	Type of energy
Ultraviolet	0.3 - 0.4 μm	Reflected
Visible	0.4 - 0.7 μm	Reflected
Near -IR	0.7 -1.2 μm	Reflected
Mid-IR	3 - 5 μm	Reflected
Thermal IR	8 - 14 μm	Emitted
Microwave	1000 μm or 1 mm to beyond	Emitted

Source: (Szekielda, 1988; UNEP, 1992)

The earth observation system can be divided into passive and active systems. Passive systems are limited by the source of electromagnetic energy to acquire an image measuring mainly natural electromagnetic energy. Photographic cameras and electro-optical sensors represent this system. (UNEP/IOC, 1992; Corbley, 1995).

Active systems use their own sources of energy. Radar sensors can be the best example of these systems. Table 1 shows microwave energy (radar sensor operated mainly with this range of the spectrum) has a wavelength of over 1mm requiring a source to emit that wavelength. An example of their application is that microwave radar information is being used to detect oil spills at sea.

Table 2. Principal sensors systems

	0.3 - 1.2 μm	**3 - 5 μm**	**8 - 14 μm**	**1mm - 1m**
Passive	Reflected (sun)	Reflected (sun)	Emitted (earth)	Emitted extremely low earth radiation
Active	Reflected (sensor itself)	Reflected (sensor itself)	Reflected (sensor itself)	Reflected (sensor itself)

Table 2 presents the different satellite sensor systems operating nowadays. As is shown in the active system, the energy required to be detected from the sensor in the different wavelength spectrum is provided for the system itself. In the opposite case is the passive system, which uses natural sources of energy such as the sun and earth to detect or sense the information.

The next table (Table 3) intends to give a list of the principal sensors used in remote sensing subdivided by the system type. An example is the multi-spectral scanners, such as AVHRR, which can measure the sea surface temperature, even when the zone to be sensed it is covered by clouds. This scanner employs different sensors crossing data among them to get useful information. Errors caused by noise in the transmission and reception of the surface sea temperature have been recently corrected, making it possible to obtain a better accuracy of the data captured by the satellite and by the land-bases.

Table 3. Types of sensors used in remote sensing

Sensors	**Band**	**Wavelength**
Passives		
Photographic systems and non-photographic cameras	UV, visible, near IR.	0.3 - 0.9 μm
Thermal Radiometers and scanners.	Mid - IR and Thermal IR	3 - 14 μm 3 - 5 (Re) and 8 - 14μm (Ee)
Multispectral scanners	UV, visible, near - IR, mid - IR and thermal IR	0.3 - 1.4 μm 0.3 - 5 (Re) and 8 - 14 μm (Ee)
Microwave Radiometers and scanners	shorter microwave	1mm - 30 cm (Ee).
Actives		
Radar (Radio Detection and Ranging)	Microwave	1 mm - 1 m (Re)
Lidar (Light Detection and Ranging)	UV, visible and near - IR	0.3 - 1 μm.

Lidar is an active sensor that has been previously used in aircraft monitoring of oil spills giving good results. However, the costs involved in that process have limited its use, but space borne sensors can provide a better chance to develop this technology for the benefit of the environment and the economy of the organisation dealing with the management of coastal and ocean areas.

3.2.2 Remote Sensing of the Sea

Of special interest for the OCZ manager is remote sensing of the sea due to the earth being 2/3 covered by water. Therefore, a brief history of this study process is given in the following lines. Furthermore the most useful sensors used in this arena will be introduced.

Satellite remote sensing for the earth started in 1960 with the TIROS (Television infrared observation satellite). Later in 1964, the NIMBUS program followed with meteorological sensors such as advanced video-camera systems, automatic picture transmission and high - resolution infrared radiometers. After that ITOS (Improved TIROS Operational Satellite) become operative in 1970 and since then several TIROS have been used to sense the earth. Other satellites that appeared in that decade were GOES, SKYLAB - EREP (Earth Resources Experiment Package) and SMS (Synchronous Meteorological Satellite).

In 1978, SEASAT appeared as the first satellite dedicated to studying the ocean surface using microwave sensors such as the radar altimeter (ALT). In the same year France, Belgium and Sweden started to operate SPOT satellites in a commercial way. Monitoring of both water and land features (i.e. ice, agriculture, geology, hydrology and forestry) are also sensed by satellites such as Canadian RADARSAT and the Japanese JERS 1 (Japanese Earth Resources Satellite). The data provided from this satellite are useful for monitoring changes in different wetlands, especially as applied to wetland trees. Resource management will be one of the Indian remote sensing satellite objectives (IRS-1A).

NASA is planning to launch the Sea-Viewing Wide-Field-of-View Space Sensor (SeaWiFS) as a replacement of the Coastal Zone Colour Scanner (CZCS) installed on Nimbus-7 to determine sea colour and complement the NOAA satellite series capabilities to sense the earth. In 1981, the AVHRR (Advanced Very High Resolution Radiometer) started to operate being of particular interest to scientists studying sea surface temperature and vegetation indexes. (Szekielda, 1988; Booth, 1991; UNEP/IOC, 1992; IOC-UNESCO, 1992; Sherman, 1992).

Sensors

Three major obstacles to carrying out useful measurements of the marine environment from space were sensor accuracy, views on surface and cloud cover, which have been largely overcome through mathematical and statistical procedures, as well as through the technological advances that occurred in these years. Nevertheless, the most common sensors used in the satellite science are;

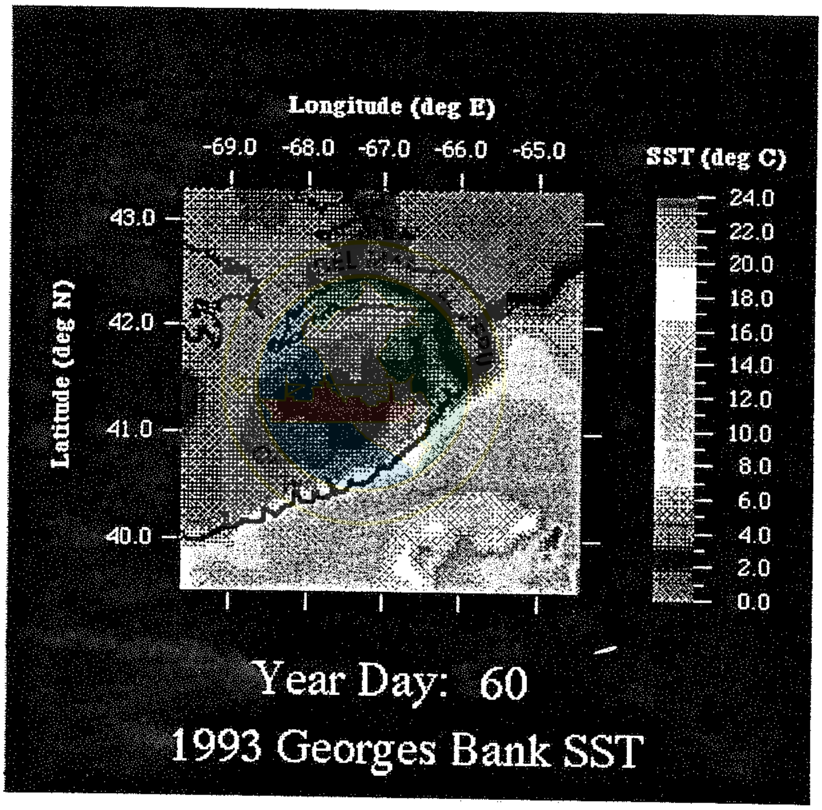
1. Thermal radiometers (Figure 2)

This type of sensor does not need solar illumination. The absorption in the sea is high for most of the electromagnetic spectrum. Moreover, by using microwave (near-infrared wavelength), the possibilities to detect thermal data is high, especially at night when optic sensors are limited.

There is a limitation in the information obtained by this sensor due to the fact that temperature value represents only a few centimetres in the water column. However, by using mathematical analysis and through previous knowledge of the physical processes in the ocean, it is possible to extrapolate and generalise, with a certain degree of accuracy and confidence, the temperature of the sea at greater depths within the uppermost ten meters of the water column.

Quoting Gallaudet & Simpson (1994, page 375) "The mean structure found in an image sequence describes the seasonal cycle in sea surface temperature (SST) and the large-scale, north-south, oceanic SST gradient of the region". The combination of satellite-based results and the shipboard observations indicates that satellite data can be used successfully to study other current systems (i.e., Peru Current), where in situ observations (ships, buoys) are less abundant.

Figure 2. Thermal image. Georges Bank SST 1992. (©NOAA, 1993)

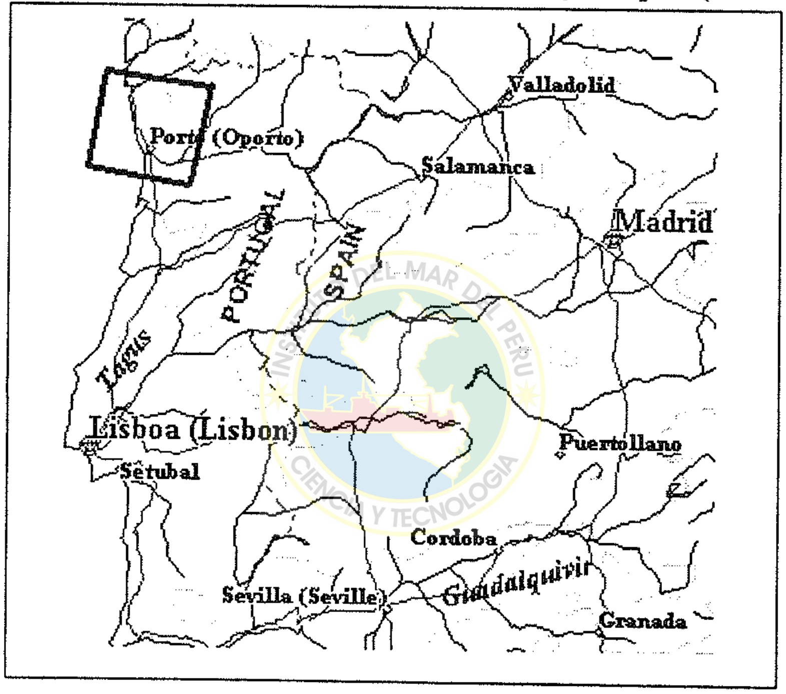


2. Microwave Radiometers & scanners (Figure 3 and 4)

Like the thermal infrared sensors this type of sensor does not need solar illumination. Microwave radar signals penetrate darkness, clouds and haze, providing imagery at any time of the day or night regardless of weather. (IOC-UNESCO, 1992; UNEP/IOC, 1992; Corbley, 1995).

The sensor can measure the sea surface height. One of the newer types is the Synthetic Aperture Radar (SAR), which uses the amplitude of the return signal as a measure of the radar reflectance of the sea surface. Ship wake, sea-surface contamination by hydrocarbons and floating debris can be detected by this technology. Other applications cover tides, horizontal thermal difference (fronts) and waves.

Figure 3. Map of the Portuguese area affected by oil spill. (©ESA, 1994)



The main types of microwave sensors are the radar altimeter (useful to measure the wave height at sea), scatterometer (use to measure wind speed at sea surface) and multi-scanners or scanning microwave multi-channel radiometer (it can calculate the current directions among other things). Table 4 (Source: UNEP/IOC) shows the different wavelengths used in the microwave spectrum.

Figure 4. Satellite image of oil pollution. (©ESA, 1994)

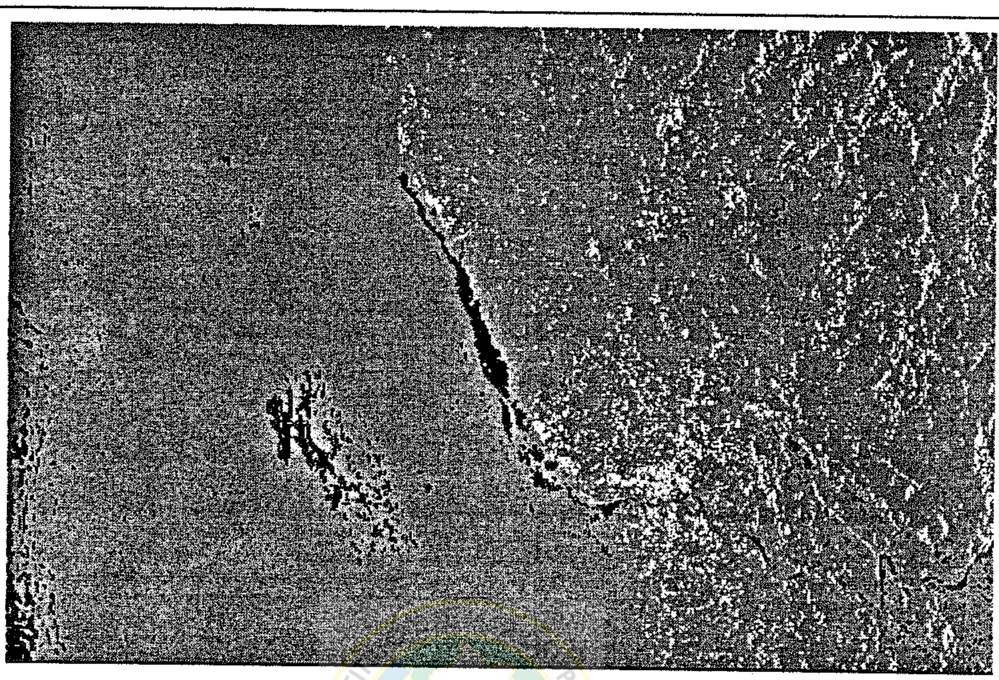


Table 4. Band uses in microwave applications

Band	**Wavelength**	**Band**	**Wavelength**
Ka:	0.75 - 1.10 cm.	C:	3.75 - 7.50 cm.
Kc:	1.10 - 1.67 cm.	S:	7.50 - 15.0 cm.
Ku:	1.67 - 2.40 cm.	L:	15.0 - 30.0 cm.
X:	2.40 - 3.75 cm.	P:	30.0 - 100 cm

For an Ocean and Coastal Zone manager using satellite infrastructure to detect problems of pollution or illegal fishing, it is recommended to review first, the parameters of the microwave sensor such as power, angle of incidence, frequency, polarisation and viewing angle, before taking a decision.

Multispectral scanners

Earlier sensors of this kind were used in airborne platforms; subsequently they were installed on satellite platforms. Later sensors such as imaging spectrometers (i.e.

CZCS, AVHRR, AIS, IRS, JERS, SISEX and HIRIS) are essentially multispectral scanners that employ many bands (a few hundred) and a very narrow segment of the wavelength. These types of sensors (Table 5) can be used to register and identify

- Bathymetry
- Bottom sediments
- Surface material such as oil slicks and other pollutants
- Short-wave radiant energy from the sun in ocean
- Superficial sea temperature and currents (see Figure 5)
- Vessels at the sea (open sea and inclusive in port)
- Phytoplankton activity

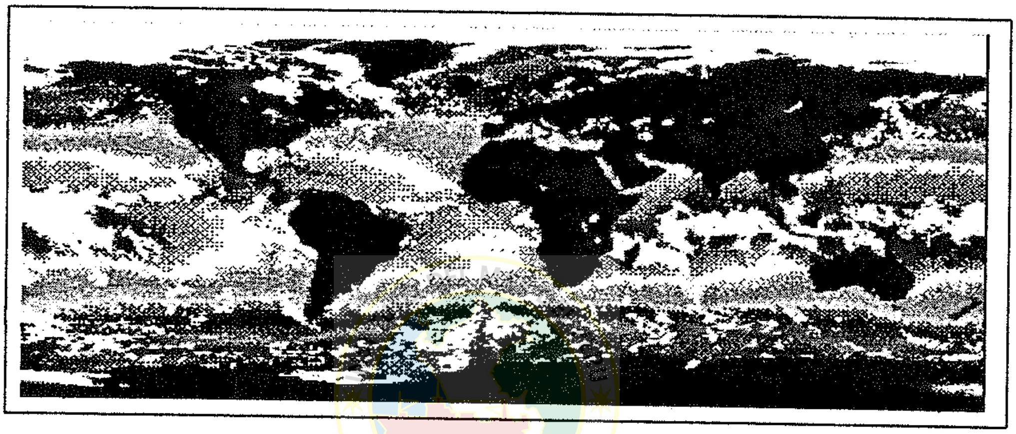
Table 5. Multispectral sensors

Multispectral sensor	Organisation, Programme or Institution
Landsat MSS and Thematic Mapper	Landsat Programme
Advanced Very High Resolution Radiometer (AVHRR)	NOAA
Multispectral Electro-optical Imaging Spectrometer (MEIS)	Canada Centre for Remote Sensing
The Compact Airborne Spectrographic Images (CASI)	Itres Research Ltd.

Type of bands, resolution and map scale used by sensors and satellites are shown in the Table 6 (Annex I). This information is useful when a manager should decide what kind of information and accuracy he or she wants. Depending on what information is required it is necessary to know what electromagnetic spectrum is the best to detect the resource in analysis. Besides resolution on the image or data to be used, it also depends on the resource to be managed or simply analysed.

For remote sensing, especially in disasters such as oil spills or the release of toxic fumes, low orbit satellites can give better degree of definition. One of these satellites is the Russian satellite network that recently entered the satellite image market. (Chem. Britain, 1994, page 18).

Figure 5. AVHRR satellite image. Monthly composition of the sea surface temperature from NOAA/NASA AVHRR Oceans pathfinders SST data set.



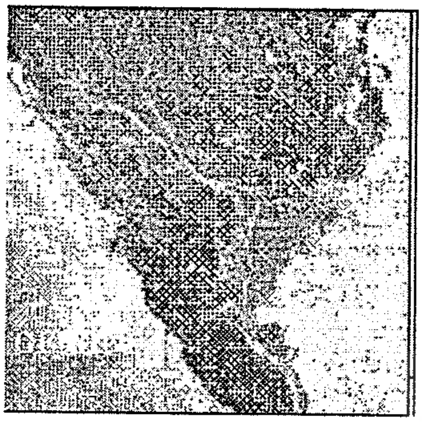
The ERS-1 satellite has an along-track scanning radiometer and microwave sounder (ATSR-M) which instruments combine infrared and microwave sensors for the measurement of sea surface temperature, cloud top temperature and cloud cover and atmospheric water vapour. Also by using a model the ERS-1 can measure wind speed to an accuracy of 2m/s in the range from 4m/s to 24m/s, although this last parameter was measured by the scatterometer sensor. Another capability in this satellite is the altimeter sensor that provides a precision of about 5 cm. (Masters, 1990; IOC-UNESCO, 1992).

Another multi-scanner is the SAR (Synthetic aperture radar) which includes sensors such as active microwave instrument (AMI), radar altimeter, scanning radiometer and ranging satellite position equipment.

3. Photographic(Figure 6.1, 6.2 and 7) and Non-photographic

These kinds of sensors are unique remote-sensing devices, which respond directly to conditions in the upper part of the water column. Other wavelength sensors can only reveal conditions at the surface or within a depth of less than a millimetre.

Figure 6.1 Satellite photography



Gemini sample

Figure 6.2 Satellite photography

SKYLAB sample

Photographic information (Figure 7) can be used to detect oil pollution. Subsequent measures of reflectance characteristics can help to determine suspended solids, chlorophyll, algae, etc. Since the firsts satellites started to operate, the main objective was to obtain information from the earth or other space objets (transmission of that data is inherent in the process). Technology has evolved and new aspects of remote sensing has appeared. The main types of sensors used in this activity are thermal radiometers, microwave radiometers and scanners, and photographic and non-photographic instruments (optic sensors). Pollution activities, resource distribution and non-licensed fishing vessel activities can be monitored using these sensors available in satellite networks already in use.

Figure 7. Aerial photograph. Berkeley image.

3.3 Types of satellites

After a brief presentation of the different sensors used in the marine and maritime field, and earth studies, it is necessary to have a vision of what kind of satellites are currently being used. Furthermore, a knowledge of the main characteristics of these satellites in the space environment is important and will be addressed in the following paragraphs: A primary characteristic of satellite orbits is the altitude, which is chosen on the basis of both physical and geometric considerations. Low Earth Orbit (LEO), Medium Earth Orbit (MEO), geostationary orbit (GEO) and highly elliptical orbit (HEO) are the main divisions.

The altitude of a satellite can vary from 500km above the equator to 36,000km or beyond that (Table 7). Orbital inclination is defined as a function of the global coverage requirement, the level of coverage and the minimum angle of elevation and the third important orbital parameter is the eccentricity, which determines the orbit shape.

Table 7. Satellite orbit types

ORBIT TYPE	ALTITUDE (km)	PERIOD OF REVOLUTION
LEO	500 - 1,500	100 minutes
MEO	5,000 - 15,000	6 to 8 hours
GEO	35,786	23.934 hours
HEO	1,000 - 70,500	24 hours

3.3.1 Polar satellites

Polar orbiting satellites circle the earth in low (altitudes between 800 and 1000 km) north-south orbits. These satellites cross the equator at the same time each day, providing continuos, detailed data sampling. Polar orbiting satellites provide visible and infrared radiometer data which are used for imaging purposes, radiation measurements and vertical temperature profiles. The satellite sensor also helps calculate water vapour content at several atmospheric levels. (UNEP/IOC, 1992; Chien, 1994; Corbley, 1995). Some of these satellites are indicated in the following lines:

- *Nimbus and TOMS (Total Ozone Measuring Spectrometer)* are used to detect the changes occurring in the stratospheric ozone levels over Antarctica by industrial activities in the earth.

- *TIROS (Television and Infrared Observation Satellite) and ITOS (Improved TOS)* have the following instruments: the High Resolution Infrared Radiation Sounder, the Stratosphere Sounding Unit and the Microwave Sounding Unit (which together comprise the TIROS Operational Vertical Sounder), the Advanced Very High Resolution Radiometer; the Space Environment Monitor; the Data Collection System; and the Search and Rescue payload. Environmental monitoring is one of their applications. (Szekielda, 1988).

- *The NOAA Satellites* are used to determine the weather conditions and subsequently to sense the whole earth.

- *Other Polar Satellites*:
  a) Meteor polar weather satellites were launched by the former Soviet Union. The Meteor spacecraft carries television cameras to observe clouds, an infrared imaging device for day or night cloud patterns, a visible image from daytime clouds, and an infrared sounder for vertical temperature measurements. (Chien, 1994, page 24).
  b) China has launched two Feng Yun polar satellites that produced reliable data, but failed prematurely. (Chien, 1994, page 24).

c) The European Space Agency plan to launch its own polar low earth orbiting weather satellites, the Meteorological Polar Platform (METOP), by the end of the decade. (Chien, 1994; Corbley, 1995).

3.3.2 Geostationary satellites

These satellites are into orbits above the equator at such a height (about 36,000 km) that it takes precisely 24 hours to complete one orbit and thus matches exactly the rotation rate of the earth. Meteorologists use geostationary satellites to be able to see an entire hemisphere at once and provide information on large weather patterns. Geostationary satellites, however, do not diminish the need for their polar counterparts, which provide finer-resolution images, which are important for studying details (UNEP/IOC, 1992; Chien, 1994; Corbley, 1995). Although geostationary satellites have limited spatial capabilities, its temporal capabilities are better than polar satellites but with low temporal sampling frequencies.

<u>1. and 2. NOAA's GOES East at 75°W and GOES West at 135°W</u>.

The first dedicated geosynchronous weather satellite was the Synchronous Meteorological Satellite (SMS). SMS A and B were prototypes, becoming SMS C the first operational geosynchronous weather satellite. SMS C was renamed GOES A. The next-generation of GOES spacecraft will have as new feature a High Resolution Radiometer, which will provide more clarity in the images produced. The new image will be able to view cloud patterns over an entire hemisphere, or zoom in to produce more precise observations of a storm region. Other instruments include a sounder that can plot temperature profiles, and a space Environment Monitor, which measures the earth's magnetic field and solar disturbances affecting the weather. GOES Next will be capable of using the sounder and radiometer simultaneously, a feature not available in previous spacecraft. (Szekielda, 1988; Chien, 1994; Corbley , 1995).

3. EAS's Meteosat at 0°E/W.

Europe's first Meteosat spacecraft was launched in 1977, so far five Meteosat spacecraft have been launched. These spacecraft carry UHF and S-band transponders; these satellites have a nominal lifetime of five years. Their primary sensor was an imaging radiometer in visible and IR wavelengths. A set of three images, was sent once every 30 minutes. (UNEP/IOC, 1992; Chien, 1994).

4. India's Insat at 74°E.

India's contribution to the world-wide meteorological network consists of the Very High Resolution Radiometer: a two-channel visible and IR instrument on its Insat communications satellites. (UNEP/IOC, 1992; Chien, 1994; Corbley, 1995).

5. Japan's GMS at 140°E.

The GMS satellites are similar to the existing GOES satellites. (Chien, 1994; Corbley, 1995).

These five satellites provide continuous coverage of the entire world, except for the Arctic regions. However, old TV satellites have been moved from their original position to provide a connection network with this region. Both polar and geostationary satellites are indispensable for environmental monitoring and control of activities that can affect coastal and ocean regions. International efforts for understanding the environment and each single element of it have generated the requirement for having several instruments that can measure the changes and different activities of those elements, as can be observed in the increasing production of satellites and sensors in Japan, EU, Canada, USA, India and China.

3.4 Communications Satellite

In the present document, communications satellites are considered as a separate section due to their importance in safety at sea. Besides, these satellite networks can be better and quicker transmitters of information (voice and data) compared with marine band radio communications. Taking Christensen's (1994, page 40) idea, the ultimate goal in the provision of telecommunications services is the ability to communicate anywhere, at any time, with anyone or anything according to each individual's needs. Communications networks have increase dramatically in recent years. The necessity of communication appears in all the regions of the earth. It is said that whoever manages information has to manage communication, and that is true. Information is needed, but if there is no communications infrastructure, the main goal of obtaining information is slow and sometimes incomplete.

Table 8. Frequency bands in communications satellite

Band	From	To
L	390 MHz	1550 MHz
S	1.55 GHz	5.2 GHz
C	4.2 GHz	6.2 GHz
K	10.9 GHz	36.0 GHz
Q	16.0 GHz	46.0 GHz
V	46.0 GHz	56.0 GHz
W	56.0 GHz	100.0 GHz

Travelling wave tube amplifiers (TWTA) are the heart of a communications satellite system, providing amplification of RF signals for transmission back to the ground. They are still the primary equipment used for RF amplification onboard satellites. (Shimamoto, 1994, page 19). Radio frequency used by communications satellites vary from 390 MHz to 100 GHz (see Table 8).

Satellite communications systems have several unique properties that distinguish them from terrestrial communications systems. The main ones are:

- the broadcast property,
- geographical property,
- distance-independent cost of provision,
- high transmission capacity, and
- the significant round-trip propagation delay time and the echo effect.

Advantages of satellite communications:

- Ubiquity. Satellites, particularly those with powerful and flexible spotbeams, can provide cost-effective, point-to-multipoint distribution across widely dispersed geographical areas;
- Mobility. On land (particularly in remote areas), at sea and in air, satellites are the only means to provide reliable communications.
- Distance insensitivity. Unlike all terrestrial modes of communications, the cost of satellite communication is relatively insensitive to whether a transmission is local, regional or international.
- Resiliency. Communications satellites are relatively insensitive to natural catastrophes (e.g., hurricanes, earthquakes) or manmade disasters (e.g., war, environmental destruction)

(Dalbello, 1994, page 50).

Mobile satellite services represent one of the fastest growing segments of the satellite industry. Geostationary satellite systems currently provide voice and data communications for a variety of land-, maritime- and aeronautical-based applications. (Bryant, 1993, page 49).

In relation to the International Telecommunications Union's Radio Regulations (ITU), Peru is in the region 2 with 500 MHz of bandwidth, 11.7 - 12.2 GHz in downlink and 12.7 - 12.75 GHz in uplink. (Christensen, 1994, page 56). So far, the communications network in Peru is a mix of satellite technology, earth stations, and UHF/VHF radio relay links for rural communications. The satellite communications are managed by ENTEL (National Telecommunications Enterprise). INTELSAT has been used by ENTEL to perform the communications necessary for the Peruvian population.

Communication through satellite started in the maritime field as a necessity to have a quick and confident procedure to help vessels in distress or in an unsafe situation. INMARSAT has been a key for this development, but new companies that can provide global communications have appeared causing a reduction in cost and an increase in new services in the communications industry.

3.4.1 INMARSAT Satellite

The 1980's saw the use of INMARSAT (International Maritime Satellite Organisation), with communications by telex, telephone and facsimile. The use of a satellite meant that ship-to-shore communications were no longer affected by atmospheric conditions (Taylor, 1995). INMARSAT was created to improve communications and provide better options in maritime safety and distress systems. The Global Maritime Distress and Safety System (GMDSS) was established by the SOLAS Convention as a requirement to be implemented in the international maritime industry fleet before 1999. However, this system is not compulsory for fishing vessels.

INMARSAT-C utilises the Global Positioning System and the INMARSAT-C communications system. The GPS unit is integrated with the INMARSAT-C equipment in the same casing. INMARSAT transceiver is used for normal communications by the vessel operator and for distress signalling. This two-way communications system permits remote operators to send messages to a mobile station and it is designed as relatively low-cost, low volume technology.

INMARSAT-C services are operating in all ocean regions, providing two way, store-and-forward, message or text communications at a data rate of 600 bits per seconds. The transmission frequencies are 1626.5 - 1645.5 MHz and receive frequencies are 1530.0 - 1545.0 MHz.

3.4.2 Argos Satellite

Argos involves the transmission of a very simple identification message by radio every 100 seconds. Two TIROS orbiting satellites receive these transmissions and, using Doppler effect, calculate the location of the transmitter. Accuracy is in the order of ±350 metres. This system provides between 12 and 16 positions for each vessel each day and is a one-way communications channel, vessel to satellite, to earth station.

The Argos shipboard equipment consists of a small transmitter mounted outside the pilot house or on a mast, this transmitter broadcasts about every two minutes, and these signals are picked up by the two National Oceanic and Atmospheric Administration (NOAA) polar-orbiting TIROS-N satellites.

3.4.3 Other Satellite Networks

In addition to INMARSAT and Argos constellations, there are other telecommunications systems, such as: Volna and Marafon, Russian systems that use L-band in the communicating process. Optus (Australian satellite) and AMS/TMI (American satellite), share the same L-band in the communications. (Christensen, 1994). The meteorological and scientific satellites can also be employed in the communication network if it is necessary.

3.5 Global Position System (GPS) and Global Navigation Satellite System (GLONASS)

Both GPS and GLONASS are satellite networks that provide the position of any vehicle at sea or land through triangulation. For this process is necessary that the vehicle has a receptor-transmitter for the satellite signal. Then the GPS or GLONASS equipment onboard captures signals from different satellites and compares these signals and gives the position as a function of the satellite position in space. Thus, GPS and GLONASS are a helpful tool to locate vehicles or any mobile object on the earth, being one of the most useful satellite applications today.

Global Position System (GPS) normally has an inaccuracy in the altitude reading of ±125 -130 m is due to selective availability (SA), required by the US government so that the receiver could not serve any military function. Initially the accuracy on the horizontal plane was only within 100 m.

GLONASS has completed its 24 satellite constellation now being able to bring its services all around the world. A study to compare the rms value of the user range error (URE) for GLONASS is about 10m compared with the 25m for the GPS with SA active. (Navigation News, 1996).

However the differential GPS (DGPS) has a differential accuracy of 1 - 3 meters rms (PDOP $\leq$ 4) (Long, 1990; Nelson, 1995).

To conclude this chapter a satellite is a combination between computers and a variety of sensors (reception and transmission) working in a different environment such as space. In simple words the different sensors on board the satellites provide a powerful instrument to monitor human activities at sea (i.e. fisheries and maritime transport).

Time past! Wake up!
(McAuley, P., "Red Dust", 1993)

4. CONCEPTS IN DATA PROCESSING AND INTERPRETATION

Technologic advances have permitted improvements in information management, where data processing and interpretation play an important role. Satellite sensors are useless if the data are not analysed. Therefore, this chapter presents concepts of data management that will be used in the process of analysing the data provided by the satellites.

With the introduction of machine processing of remotely sensed data, the actual boundaries between the processing of data and the interpretation of that data have become more diffused, because in recent data processing systems the processing of data from tape to the image or finished product is already part of the interpretation whereby resources specialists extract specific features from the original data. (Szekielda, 1988).

Information requirements have improved with the advances in technology, i.e. new ships have computerised engines, multiples sensors and advance equipment. For instance, weather information would become more accurate if ships masters were able to transmit information on their local conditions for inclusion in later forecasts. These data can be sent and received by shore-bases and later transmitted to the fleet in a few seconds using satellites and advanced compressed programs.

4.1 General Considerations

First, data can be primary (raw data from remote sensors), processed data (a product resulting from the processing of the primary data to make such data available) and analysed information (resulting from the interpretation of processed data). (Szekielda, 1988). In other words data is any information to be used in an analysis process.

Any kind of media can be digitised, and subsequently used as data. The process of getting, sending and again capturing this data for subsequent analysis depends mainly on the instruments used for that purpose. For data applications the instrument must be designed in relation to radiometric resolution, spatial resolution and spectral resolution. Radiometric fidelity is better when the energy received is higher. Thus, energy received provides the instruments with the information related to the conditions or resources present in that period of time, making it possible for the user or analyst to look at any natural phenomenon, or human activities, far away in time and distance. Of course, there are technical aspects, such as the level of radiation captured, noise included in the process of capture, electromagnetic effects (external and internal) and human error (interpretation).

4.2 Data Transmission

Characteristics about the space and satellite environment have been outlined in the chapter before. Further, there was an added description of the different types of sensors used to watch the earth through a process currently called remote sensing. The satellite networks currently employed for communications were also addressed. However, the key point is how to obtain and transmit the data captured by those sensors. This point is developed in following paragraphs.

Data is usually transmitted between points on a communication link in what is called "bit-serial" fashion. Most applications up to 1200 bps transmit bits in what is called the "asynchronous" modes. In this mode, the data bits of each character are preceded and followed by special start and stop bit sequences. "Synchronous" transmission, on the other hand, is usually employed for applications involving speeds of 2000 bps and higher. Here, a constant rate clock determines the exact time instant at which bits are sent and received, eliminating the need for the special start and stop bit sequences associated with asynchronous transmission. Synchronous transmission is thus more efficient in utilising a given amount of available line capacity. (Dickson & Wetherbe, 1985, page 246).

Data transmission, accuracy, time of process and range of analysis of sensors or instruments carried by the satellite are the main issues that must be addressed when the information is captured by the satellite sensors and processed by the ground laboratories. However, one problem still remains and that is to take account of "propagation delay", which can produce data transmission errors as Nelson (1995) pointed out.

As Wout (1985) wrote, fishing communications themselves can be divided into three roles, although the same rules apply to other kind of vessels:

1. The first is ship-to-ship communication by VHF or SSB. There may be no role for satcoms here except with those large company vessels wishing to have uninhibited discussion in total security.
2. The second, that of ship-to-shore dialogue, covers aspects of vessel management, market communications and other matters. Here there is obviously no privacy at present, using conventional radio.
3. The third role covers those relatively new technologies, which are those involving integrated vessel management. While many skippers will feel justified in fitting a satellite communications terminal, or ship earth station (SES), purely for straight

communications and the benefits of privacy, it is this third aspect which offers the greatest justification for fitting and everyday use of satellite communications.

Thus Commercially operated communications can be divided in the following networks (Table 9):

Table 9. Types of satellite communications networks

Network	Involves
VHF/UHF	communications (data and voice)
INMARSAT	safety at sea, communications (data and voice)
Argos	scientific research and data communication
Remote sensing networks	remote sensing and data communication

Starting with VHF, satellite link provides a high capacity, real-time and multi-user data transmission. It can also operate in duplex mode. Development and implementation of data links using satellite communications systems now provide facilities for sea level data transmission in near real-time on a global scale. (Palin & Rae, 1986, page 2).

INMARSAT satellite network provide high data capacity with good coverage, but scientific applications are costly to set up and operate. INMARSAT-3s will have 10 times more capacity than the INMARSAT-2s. Spot-beam operations will increase the system capacity as the more powerful, focused antennas on the INMARSAT-3s will result in more effective use of satellite resources. INMARSAT-3s will effectively halve the space segment resources utilisation per minute of voice call, leading to a reduction in costs. (Palin & Rae, 1986; Asker, 1996).

Furthermore, some INMARSAT coast earth stations (CES) now offer electronic mail services that can also handle ship-to-shore fax, telex and X.400 messaging. The usual data speed is 9600 bits per second (bps) but speeds up to 16800 bps are becoming widely available. All messages are deposited and collected from password protected mailboxes located in the CES. (Asian Shipping, 1996, page 30). However, INMARSAT-C has only a communication speed of 600 bps.

The ARGOS system using polar orbiting satellite provides a world-wide position fixing capability and also has a data transmission capacity of 250 bits per messages. (Palin & Rae, 1986).

As part of the remote sensing satellite networks METEOSAT covers meteorological studies and data transmission although in a narrow band channel. It has fixed time slots for data collection and is limited to 650 bytes of data during a 2-minute message. (Palin & Rae, 1986, page 2). Systems developed by METEOSAT comprise DATAFLOW, DATARING and DATASAT.

Within this satellite network information can be shared among scientists through two channels; first, real-time T-S data are transmitted over the Global Telecommunications System (GTS), which was originally established to disseminate weather data internationally. Second, the same observations are also recorded on computer tapes or diskettes on ship and later sent as "delayed mode" data to national data centres in many countries of the world. (Hamilton, 1992). Delayed mode data is usually higher in quality and resolution than the same observations that were sent previously in real-time. Nations manage the sharing of real-time data through the Integrated Global Ocean Services System (IGOSS) and the delayed mode data through the Committee on International Oceanographic Data Exchange (IODE).

4.2.1 Internet

It is impossible to obviate the latest advance in sharing information and data transmission, the Internet or WEB. This is actually the largest way to receive and send information. Transmission of information through Internet is easy and quick, moreover cheap. However, there are certain problems regarding privacy; various solutions have appeared and the availability of this tool to different users is world-wide due to the use of satellite communications networks in the process of transmitting information from one user to another in different parts of the world.

ISO defines Internet as a network of networks that joins together to form a huge network enabling thousands of computers to share services and communicate directly with millions of users from all over the globe. On a typical day, more than 20 million people now use it to send and receive information. The services include electronic mail, interactive conferencing, file transfer and numerous new services.

Jones (1995) considered that the improvement in data transmission will make possible the updating of electronic chart databases in real time, and increase capabilities onboard for developing a shore-to-ship video conference. Furthermore, it is possible to reduce the communication costs by using data compression techniques. Maybe Internet might play an important role in this development. So far, it is widely expected that electronic mail, or 'e-mail' will have an even stronger impact than the fax and that the ongoing introduction will continue to accelerate and become 'the' business tool for communication during the 1990s, as a report in Asian Shipping (1996, page 30) predicts.

Sorocco (1995, page 12) indicated that the World Wide Web (WWW) sites provide access to environmental satellite-related products and information, being used frequently in the areas of broadcast schedules, coverage, and navigation. Today, it is possible to use on-line satellite catalogues provided by NOAA as a way to increase the level of accessibility of satellite data in the scientific community. A data catalogue has been documented using AVHRR, TOVS, SSM/I and CZCS instruments. (Metcalf, 1993, page 9). Some interesting home pages are presented in Table 10 (Annex I).

4.2.2 E-mail

E-mail is already used for internal and external communication by a growing number of both 'high-tech' as well as economically minded ship operators. It provides means of transmitting messages quickly and easily between personal computers (PCs) which can be virtually anywhere in the world as long as they are connected to a telephone line or an INMARSAT ship earth station. (Asian Shipping, 1996, page 30). However, fishing fleets seem to be slow in this process of high-tech transference. Most commercial fishing companies in Peru operate within 60 nautical miles of the shore; thus, not necessitating any further advances in communications systems than HF or SSB. Nevertheless, data compression in radio bands appears to be an interesting means to reduce administrative costs (i.e., reports, time saving, data security).

Use of radio-telephones are common in the fleet of the Peruvian anchovy industry, but satellite communications equipment is strange in this industry. However, the recent increase in fisheries activities out to 100 miles, looking for sub-exploited species such as Mackerel (**Trachurus murphii**) has created a necessity for better communications both for the fishing companies and for the Ministry of Fisheries to control this industry.

The main problem lies in the level of education of the fishermen. Within 5 to 10 years these men might be able to operate computers and understand them. But, currently this is possible in less than 5% of the fishermen groups. However, it is a responsibility of the company to improve the level of its human resources, and the present paper may be useful for the manager who will be dedicated to providing this capacity to the human resources in the fishing industry.

Data communications and messaging systems should decrease operation costs. High speed condensed transmission (shore-ship), standard electronic forms and e-mail desk to desk transfer will improve the level of savings in data communications. In conclusion, equipment requirements for data transmission are related to the level of information required by the company (the user). The quality of data is important for the analysis, but if there is a lack of equipment to deal with the transmission of this data, the whole process will fail. Currently the use of satellite communications networks seems to be the best way to send and receive information from any place in the world.

4.2.3 Electronic Chart Display and Information Systems (ECDIS)

Electronic chart display and information systems (ECDIS), provide a framework in the monitoring arena, or it is better said in auto-monitoring. Data interchange among electronic instruments onboard can establish complete support to deal with the sea. IMO is still studying the uses of ECDIS in the maritime world to define the requirements. (Bianchetti, 1995, page 23).

ECDIS of various types have been around for some time, but until recently these were only used by pleasure craft due to the lack of detail on the charts, with the paper chart still referred to for actual navigation. More recently there have been significant improvements in the way electronic charts are produced, resulting in both raster scanned and vectored charts being displayed as exact replicas of the original paper chart. (Douglas, 1995, page 34).

The hydrographic community has also been developing a standard format for chart data to use internationally between hydrographers, known as DX90/SP57. The IMO and IHO, observing the diverging market identified the Hydrographic Office standard as a basis for electronic chart systems for commercial use, based on approved standard data. The IMO/IHO harmonised group on ECDIS (HGE) has prepared a draft standard for ECDIS, and this with minor amendments was 'approved' by the 1993 IMO Safety of Navigation meeting (NAV39). (Ryle, 1994; Douglas, 1995).

4.2.4 Electronic Chart Systems (ECS)

The largest area of development is in non ECDIS chart systems known as ECS (Electronic Chart Systems) which will cover less stringent requirements, particularly relating to the use of non-approved charts. These charts may be of an excellent source but if not approved by the Hydrographic Offices they will still be classed as non-approved and will therefore never legally replace paper charts. The ECS is not intended to comply with up-to-date chart requirements of V/20 of SOLAS of 1974. ECS is considered a supplement to a paper chart and should be used with an up-to-date chart from a government authorised hydrographic office. The ECS, like the ECDIS, is capable of displaying all relevant nautical chart data from the charts used. (Ryle, 1993; Douglas, 1995).

Data transmission is done through digital procedures. High volume of data, such as satellite images take advantages of this technology. Thus, the digital image is transmitted in compressed blocks to be analysed later, but how this process is done, will be explained in the next section.

4.3 Digital Image Processing

The reflection of the energy emitted from any physical body (or structure) is detected by the sensors (Figure 8); each reflected wavelength creates a "spectral" signature that is used as basis to process the image. Digital data is easy to manipulate, enhance and process by computers — the other branch of this new technology. A digital process is used to quantify the information of any image or data from satellite systems. Currently it is a very useful process because it is possible to extract additional information about surface features

Digital data should be sent to a ground station to be processed and analysed in order to be useful in the decision making, but there are some problems such as noise, distance and other interferences, which can cause delay of information or worse loss of it. Transmission itself is not a problem due to the advanced capabilities of data transmission instruments currently employed on satellites. The real problem in satellite data transmission (remote sensing and communications) is the low signal propagation delay and the limitations on gain and power of the earth terminal. The operation process of transmitting and receiving is shown in the figure below, where TX and RX mean transmission and reception respectively.

Figure 8. Process of information reception and transmission

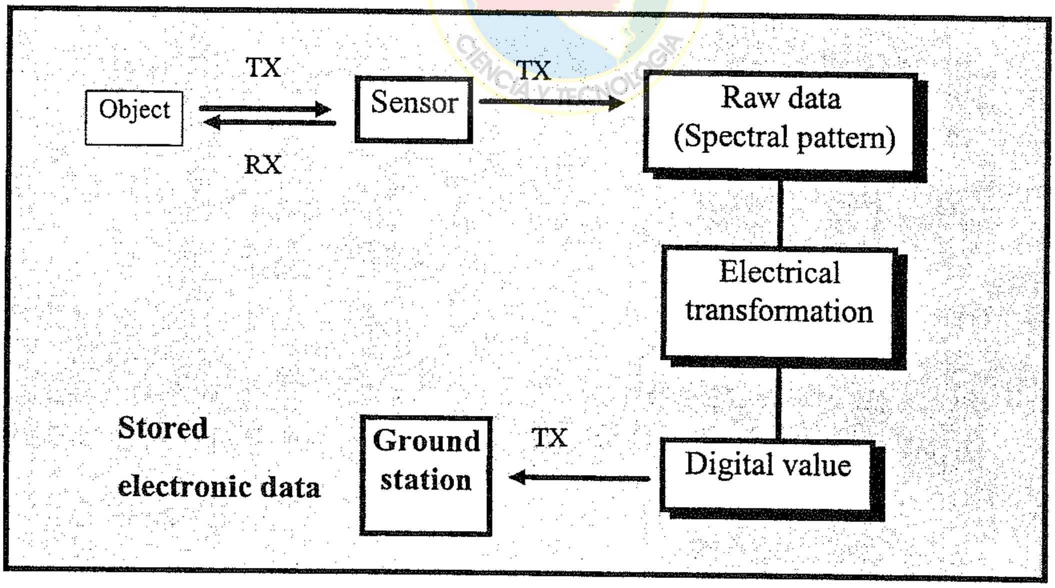


Image is one form of data group that can be analysed by colour and size compared with the real object. Szekielda (1988) and Oxford Reference (1991, 1991a) have defined image as a copy in memory (human or machine) of data that exists elsewhere. Thus, Image processing is (in principle) a special form of two-dimensional, and sometimes three-dimensional, signal processing of scenes collected by sensors in cameras or sensing devices. But, how is this process done, and how can the information be analysed? These topics will be presented in the following section.

In the process of image transformation to digital data, this data is stored in computers and image processors in bits (0 or 1). As more bits are added, the level of information increases. As an example, a 6-bit data will provide 2^6 or 64 densities (for this case, satellite images 64 grey levels, ranging from 0 or black up to 63 or white). Colour images are simply an image where a colour is assigned to a grey level.

To analyse this data (image), the best way to do it, is to digitise the picture or image. The original picture may be a drawing, photograph or scene which can be stored in a two-dimensional array of data. As a basic element of the array, a pixel provides enough data relative to the whole picture. So the process of image digitisation starts through this pixel. However, it is necessary to remember that the number of bits in a given pixel determines the number of unique grey values or colours available. Spectrum signature is established by the spectrum reflectance and the image characters. The last one can be an analysis in function of parallax, tone, landscape position, patterns, texture, association, shape and size. Figure 8 shows a methodology overview of this process from the time the image has been captured by a sensor onboard of a satellite until the user receives the processed image.

Based on aerial photography the accuracy comparison with satellite images can improve substantially, although any kind of comparison should be made with the actual physical features of the land. On the basis of ground information the level of satellite sensor accuracy can be quantified and be used as background to correct probable errors. Thus, the data acquired should be evaluated for its accuracy by determining

- correlation with ground reference information relative to pixel size and concentration of specie represented by pixel.
- and how well the instantaneous data captured by the satellite represents the physical properties that may change overtime.

To conclude this section, it can be said that the advances in digital and satellite science have given better options to analyse an image, even though there are some problems regarding the level of noise and external interference. Today it is possible to detect a vessel in port or sailing. Moreover, there will be some improvements in the sensor capabilities that will make it possible to identify the type of vessel, which is useful information if the ocean and coastal manager will have to deal with fishing vessels and other types of vessels. Monitoring procedures can be created in function of this technology tool.

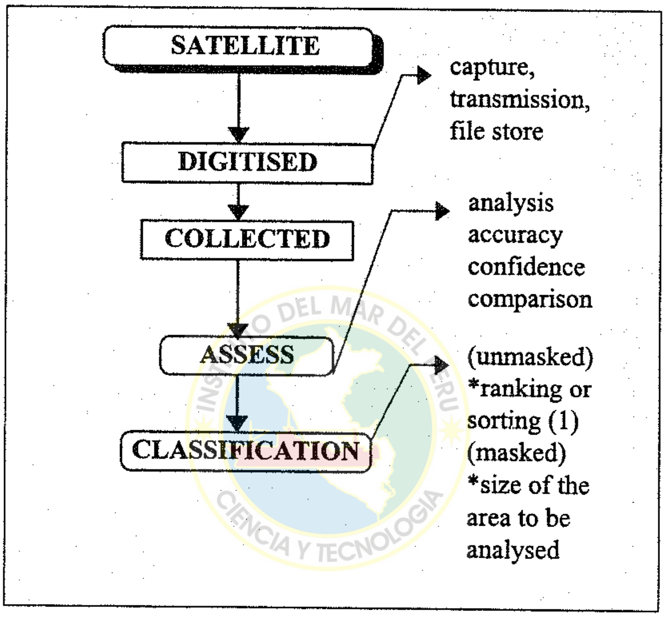
4.3.1 Interpretation of Satellite Images

The identification of objects in remote sensing photography is usually performed visually without the use of computers, since human judgement is extensively required (UNEP/IOC, 1992). However, computers are used in the interpretation process because the information obtained is usually digitised. This is due to the fact that digital data has certain advantages in time, scale, and quantity of information likely to be managed.

In the interpretation process of thermal images, it is considered that emissivities of different objects should be constant (not wavelength dependent). However, complications may arise from atmospheric conditions although various methods to overcome this problem have been created.

The normal processes of data capture (Figure 9) from a satellite and its subsequent analysis and interpretation is shown in the figure below. Here unmasked images are defined as satellite images than have not been modified with any kind of information on the other hand are the masked images that have been changed or include more information, such as the country grid.

Figure 9. Data recording from a satellite sensor



(1) Nagel (1995) modification

Interpretation of radar images is similar to photo interpretation, although the illumination coming from the side of the scene creates a viewing direction from above the image at right angles to the transmitted microwave energy. (Szekielda, 1988, page 145). Thus, the parameters to take into consideration are radar beam, radar-image plane, roughness of the surface and slope.

Geographic information systems (GIS) are currently used to create an integral spatial and temporal database of any area or zone. Mapping has become easy to develop if the convenient data and GIS are employed. Remote sensing has a high volume of data in tempo and space, thus using GIS as a tool to locate determinate points of the remote sensing which will be useful for the decision maker. Furthermore, GESAMP (1990) considers the integrated environmental databases, such as GIS useful for long-term coastal zone management.

Recent use of satellite sensors has provided an alternative in Coastal Zone Management. However, before studies conducted by the University of Wisconsin-Madison concluded that thematic mapper (TM) imaginary was not ideal for the classification of wetlands. Nagel (1995) applied a new methodology to increase the classification accuracy of this TM imaginary, getting 95% accuracy, to separate uplands of wetlands (see Figure 9). In addition to this study other studies have appeared providing the satellite image with capabilities, better accuracy combining satellite data with field data.

In conclusion, the utilisation of data communication processes has as a function of technological advances, such as geographic information systems combined with geo-referenced satellite data. Today, it is possible to observe the evolution of anthropogenic activities in a specific area due to these technology advances. However, it still is a responsibility of the human being (i.e. manager) to judge the information provided by different types of sensors analyse the impact of this information for his or her present and future.

"First there was the race for manned space flight, then satellite communications and now remote sensing"
(Antenucci, Plan-Graphics Cia.)

5. CASE STUDIES IN PERUVIAN OCZM

Peruvian legislation has clearly defined that natural resources within the 200-nautical miles of the territorial sea must carefully and efficiently be used in benefit of the Peruvian population.

Satellite technology appears as an interesting tool to be used for controlling and monitoring fisheries and other activities such as oil exploitation on the north coast of the country. The following lines will discuss the satellite application on the Ocean and Coastal Zone.

Although the bathymetric study is chiefly used in oil pipelines, the fishing industry can use this information in near-shore areas where the fishing stocks are larger, thus improving the possibilities to fish in larger fishing grounds, due to the known tendency of these fish stocks to be in a place where they can find shelter and food.

Distribution of the resource is in function of several variables, such as depth, type of bottom, sea surface temperature, salinity and others. However, by studying one parameter such as sea surface temperature it is possible to determine the most likely area of fishing. This information is also useful for the institutions or organisations in charge of the control and monitoring of the fishing activities such as IMARPE (Peruvian Institute of the Sea) and the Ministry of Fisheries in Peru because they can improve the ability to quantify the most vulnerable areas and also calculate the effort over a determined fishery.

Another procedure to deal with the effort over the fisheries is to use a vessel monitoring system, which is extensively discussed in section 5.3. An interesting point to take into consideration is that this satellite application can be used in any type of vessel monitoring.

The application of remote sensing should always be complemented by reference data for the analysis and interpretation of remotely sensed data. A large number of measurements are required for the monitoring of water quality of an area during a reasonable period. Remote sensing is an attractive alternative for the efficient monitoring of large areas.

Earlier efforts in researching have provided that application of remote sensing has a relative medium accuracy useful in quick decision making because its large capability to catch a huge amount of data in a wide area.

Main strength of remote sensing

- Capability to provide synoptic images of large area
- Time-serve
- Reasonable cost (to be discussed later)

Main weakness

- It can only provide information for water quality parameters near the water surface.
- It is an indirect means for measurement. It only records a particular kind of information.

Kunte & Wagle (1994) demonstrated the utility of extracted coastal information to coastal zone management. One of the most useful pieces of information to manage the coastal zone comes from the SPOT image and aerial photographs that can recognise fluvial, marsh, marine, vegetation and near-shore features. Besides, as Shears (1992) indicates, remote sensing data has been used for modelling surface water pollution.

Various authors have written that any project of research and development must focus on exploiting existing and planned remote and in situ sensed data to extract information, such as navigation hazards, water depth, bottom configuration, sea surface temperature, etc. (Graham, 1995, page 7).

A quick access of data is necessary to take better decisions and to improve company or institutional performance. Therefore, an optimisation of data technology and data access seems as the better solution. An essential feedback is obligatory to take a decision. Communications satellites are playing an essential role. By the turn of the century, information will be the most important global currency. It will create new jobs and new markets; it will assist in the development of nations; it will empower consumers; it can help to create a healthier and more secure world. (Dalbello, 1994).

To achieve cost-effective data collection and assessment, users and their requirements need to be more clearly identified. In addition, ways of transforming existing information into forms more useful for decision-making are essential, together with targeting the information at different user groups. (UNEP, 1993).

Recent advances in data acquisition, mass storage, and communications technologies, coupled with more powerful analysis methods, indicate that the role of satellites and environmental oceanography will expand considerably in the future. (Simpson, 1994, page 743).

The next table presents the potential contribution of satellites to marine applications. The author has chosen three (underlined), which will be developed in this chapter.

Table 11. Potential marine application of satellite technology

Application	Relevant satellite products
Marine resources	
• Offshore oil and gas	• Wind and waves (real time and archive)
• Fisheries and mariculture	• Temperature, colour
• Renewable energy	• Wind and waves, tides
Marine Transportation	
• Ship traffic control	• Fine resolution imagery (radar and visible), satellite communications and satellite geo-positioning constellations
• Optimum ship routing	• Wind, waves and currents
Marine Pollution	
• Spillage at sea	• Radar imagery, currents, colour
• River effluents	• Radar imagery, colour, temperature
Marine meteorology	
• Improved weather forecast	• Wind and waves
• Long term trends	• Statistics on wind, waves, currents
Marine science	
• Physical, biological, chemical and geological	• All products - temperature, colour, waves, winds, radar imagery
Global warming	Sea level, temperature and other products

Source: (IOC-UNESCO, 1992)

5.1 Bathymetry

To initiate the following section, it is necessary to have a clear idea of what bathymetry is. Thus, bathymetry is the science of measuring ocean depth in order to determine the sea floor topography. Bathymetric studies are mainly done by echosounding surveys; however, microwave signals sensed by remote instruments can be used to model the form of the bottom of a body of water. Uses of bathymetry involve sea mining, pipeline routes (oil or fishing industry) and navigation. The latter is the most widely used in the maritime field. For example nautical charts have been developed based on this science where the level of accuracy is less than 20 cm. The sea mining industry requires the information of depth and type of bottom to determine the richest areas in minerals. In this way the industry will reduce cost of searching.

Pipeline routes in the oil industry are one of the alternatives to reduce oil transportation cost, as is shown in the following lines. It is also used in the fish-meal industry to transport the fish catch from the vessel as the "chata" or "pontoon-pump" is the interface between the vessel and the factory. The pipeline route from the pontoon-pump to the factory must be carefully chosen; therefore, information of isobaths (a contour of equal depth in a body of water) is useful. Because, in a homogenous type of bottom the pipeline installation will be less expensive and with less technical complications. Thus, information of the bottom geography would make it possible to find the most appropriate route for the installation of any pipeline (for the oil or fishing industry).

5.1.1 Traditional method

The oldest way to determine the bottom structure was using a simple echosounder. In those days the accuracy was not so good, however, this information was used for navigation.

Acoustic surveys have appeared after the First World War, and have been used since those days world-wide for the drawing of nautical charts. Moreover, this data can be used for the installation of undersea buildings or structures.

With traditional methods, the first step is to study admiralty charts, which give a rough estimate of the bottom topography, but they usually underestimate depths and — for nautical reasons — ignore local details. Then, it must be sent out to a ship to confirm or update this information by performing echosoundings for the exact depth at every location in order to choose the most promising track. (Wagner, 1995).

For the present paper, the traditional method is considered by using echosounding instruments. Thus, there are two ways of getting bathymetric data a) oceanographic vessels and b) non-scientific vessels.

a) Oceanographic vessels data

The "Dirección General de Hidrografía del Perú" provides adequate oceanographic surveys to be used in creating or up-dating nautical charts. The instruments used in these surveys are carefully calibrated and employed because these previous measures depend on the accuracy of the data obtained.

The development of a powerful database such as the GIS makes it possible nowadays to have a better mapping of the bottom of the sea. For example, the Ocean Mappings Section of the National Ocean Services's (NOS) Coast and Geodesic Survey is producing gridded data sets of multibeam bathymetry in the US Exclusive Economic Zone. (Earth System Monitor, 1993, page 11).

The normal process of bathymetry on an oceanographic vessel is using the echosounder which is very accurate; however, it is also very time-consuming and expensive because a ship can only cover a limited width on each survey line. Next is the route survey where additional tracks are also surveyed a few hundred meters on either side of the proposed route (Figure 10).

The experience developed by The Delft Hydraulic for the oil pipeline industry shows that the total width of the surveyed corridor is usually around 1000 meters and the required depth accuracy is about 20 centimetres. Subsequently, surveyors optimise the pipeline tracks because, based on these two previous surveys, the final pipe route is established. (Wagner, 1995). In order to plan an undersea pipeline route normally takes a number of different surveys, such as reconnaissance, route, prelay, and as-laid or as-built are needed. The cost involved seems to be high.

b) Non-scientific vessel data

An alternative way to get more information is using fishing and trade vessels. However, the instruments used to detect the bottom (variable: depth) are not so accurate for precise bathymetric studies. Nevertheless, the information possible to get from these vessels is larger than from normal oceanographic surveys, but the accuracy of the information varies widely. Therefore, this information has so far been considered as inaccurate information.

Not only satellite science has developed in recent years, but also the acoustic science has improved in accuracy and confidence. Most fishing vessels are using accurate sonar and echosounders for locating the fish grounds and the type of bottom although these acoustic instruments are not so accurate as the oceanographic science requests but useful enough for the fishing industry. The author has always considered the data from vessels a good source of information for analysis in the marine environment, but there is always the requirement of accuracy and confidence of this information. The way the author deals with those issues are shown in the following.

The methodology used to graph the bathymetry of a defined area is the following:

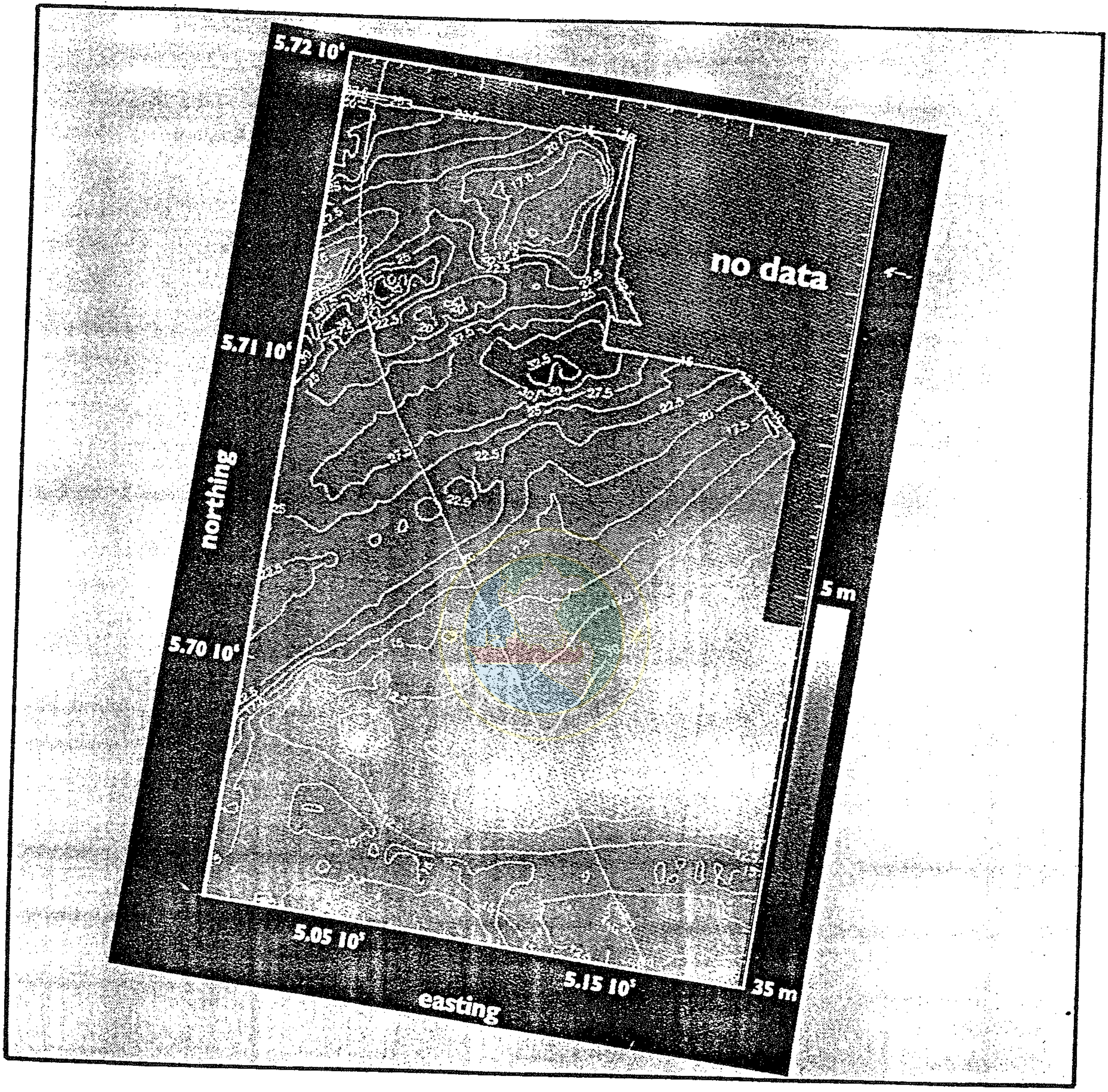


Figure 10. Isobaths using acoustic information

- Data compilation
- Transference of information
- Data processing
- Information distribution

This methodology was developed at the SIPESA fishing fleet, which has echosounders as the first instrument to be used in the process of locating and catching the fish.

A fishing report that should be submitted daily to the local fishing fleet department and weekly to the headquarters in Lima was created. Then, these fishing reports were reviewed carefully and compared with the catching radial information that was also submitted daily from every local fishing fleet department. How to fill the fishing reports was a timely process of training. As the author was in charge of that task, he went to each vessel belonging to the company to educate the fishermen in the correct use of the equipment and to improve the level of confidence in the information that the fishermen would later submmit. Lack of data and non-consistency was later shown to the fishermen that produced the information, including in this way a feed-back procedure.

The data obtained using the reports were digitised in a computer database, then processed with the software Surfer Access System (version 4.10) to obtain graphs of bathymetric, resource distribution and sea surface temperature. The technique was used to generate a gridded graph from the data available, such as bathymetric information. It was the "Minimum Curve", where different values of data are used to generate lines of the same value in function of geometrical distance to a point related to another.

The following figures show the isobath calculated by Surfer using the minimum curve method. As can be seen the confidence of this information is less than 80% because this was the first year of implanting the fishing report, and most of the people were not completely able to give the data required. However, 80% of confidence is an average from 4 different fleets within the company as the company operated on the entire coast of Peru in 4 different regions in that year.

Figure 11 shows the isobaths calculated from 1496 samples for 1993, which is very few, if considering the area analysed. In this case it is completely clear that the map shows a large piece of information of the isobath distribution. Besides, due to the operation conditions of the software used, some data appear inconsistent, especially close to zero isoline.

The following figure (Fig. 12) shows a smaller area in the region of Pisco, between 12°00 S and 16°00 S, where the bathymetric information seems to be more useful because the confidence of the data and the consistence (accuracy) of the same data. It is important to point out that better software can produce better visual results, which can be used in bathymetric surveys or in fishing research.

5.1.2 Satellite application

Due to the cost involved in an oceanographic survey and the limited area covered, the availability of other sources of data with sufficient accuracy and more frequency and volume of data would be an interesting alternative to be developed.

Satellite sensors such as the Synthetic Aperture Radar has the ability to do so because the SAR can obtain digital images of large areas of the earth in all weather conditions. (University of Zurich, 1996). However, microwaves do not penetrate water bodies so it may seem hard to believe that an underwater topographic map could be produced from this kind of sensor. Imaging radar is sensitive to changes in

Figure 11. ISOBATHS (Peru - 1993)

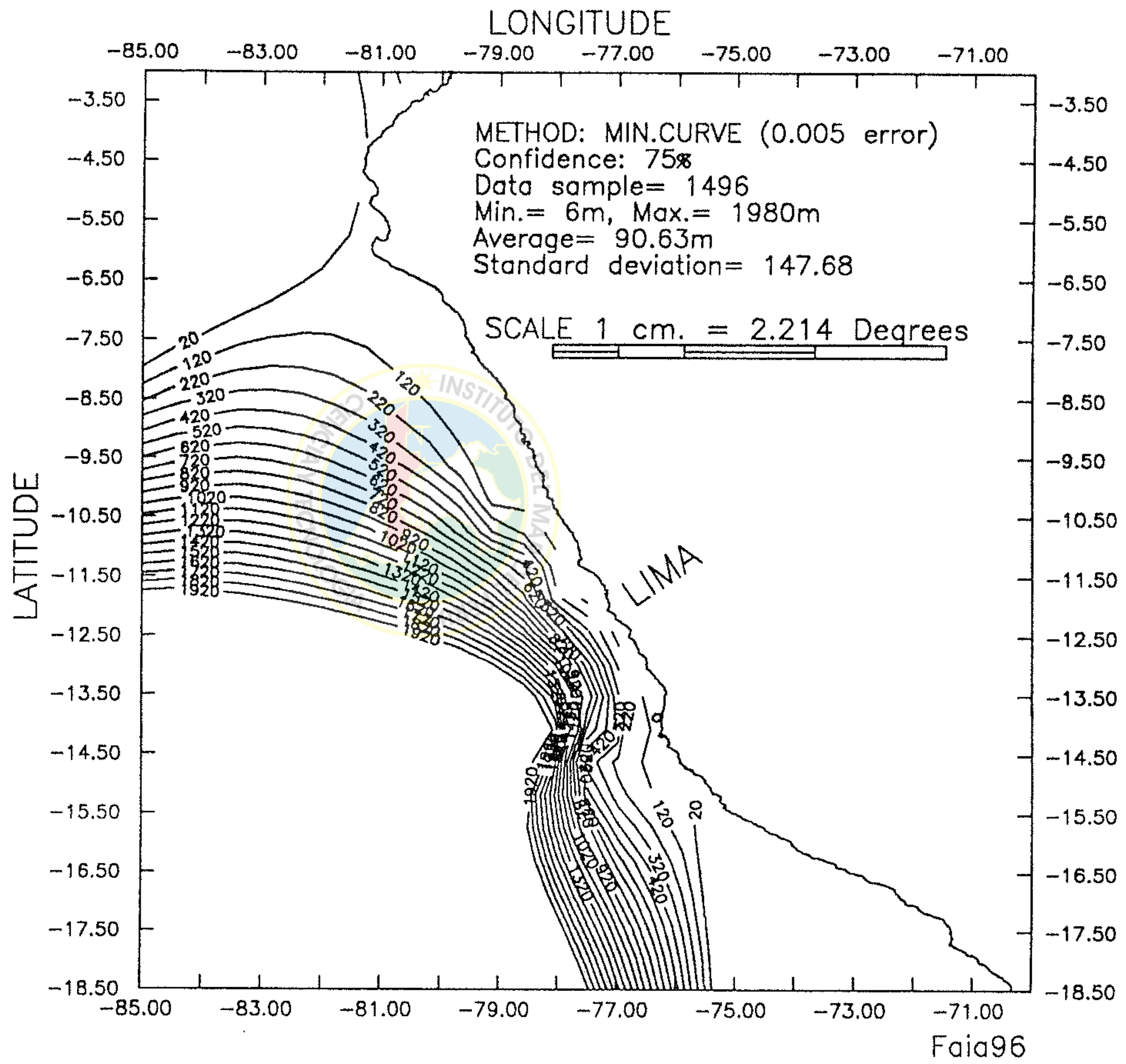
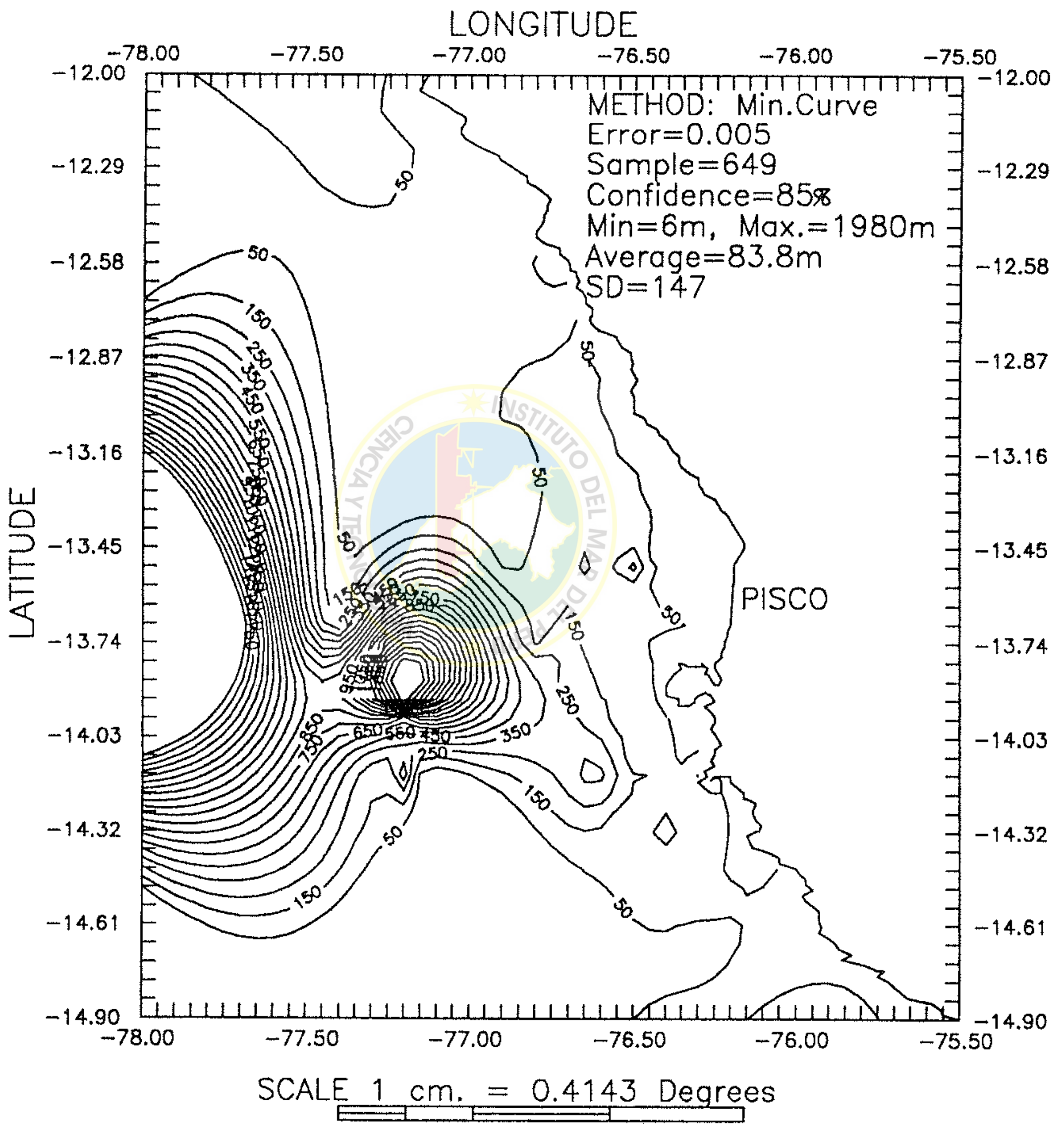


Figure 12. ISOBATHS (Pisco–Peru 1993)



sea surface roughness, which can be related to sea surface winds, ocean surface waves, bathymetry, internal waves, and oceanic eddies. Delft Hydraulics in Netherlands developed a model that can detect this surface roughening, and given known conditions of current and wind flow can indicate where underwater features lie by showing changes in depth. However, the SAR does require moderate winds and normal tidal currents in order to acquire good-quality bottom topography of shadow water. (Wagner, 1995, page 14).

Extracting other lines from Wagner (1995), she said that

> *The basic idea of the system is this: normally, four surveys are required. But with BAS, the first three can be done faster with adequate accuracy. Starting again from an admiralty chart, ERS-1 data are obtained and calibrated with the average depth of the chart, creating a more accurate map with which to propose a pipeline route. To check this route feasibility, echosounding are still taken. Then a single sounding along the proposed track is made during the route survey and the SAR data are used to interpolate the bottom topography over a 200-meter-wide route corridor. The route is then refined. For the next phase, pre-lay, two further soundings along the borders of the corridor are used to interpolate between them, producing a final depth map.*

Butler (1989) and Charvis & Royer (1991) also presented studies regarding bathymetry using a combined technique between satellite altimeter and acoustic information. On the basis of the data brought by this sensor, a mathematic model was applied to calculate the isobaths in the area in study (Figure 13).

All these studies are based on the close correlation between the satellite information and the ocean surface topography established by oceanographic surveys. Some studies were presented by IOC-UNESCO (1991), which shows an analysis of the Seasat and Geosat altimeter records that revealed strong correlation between the fine

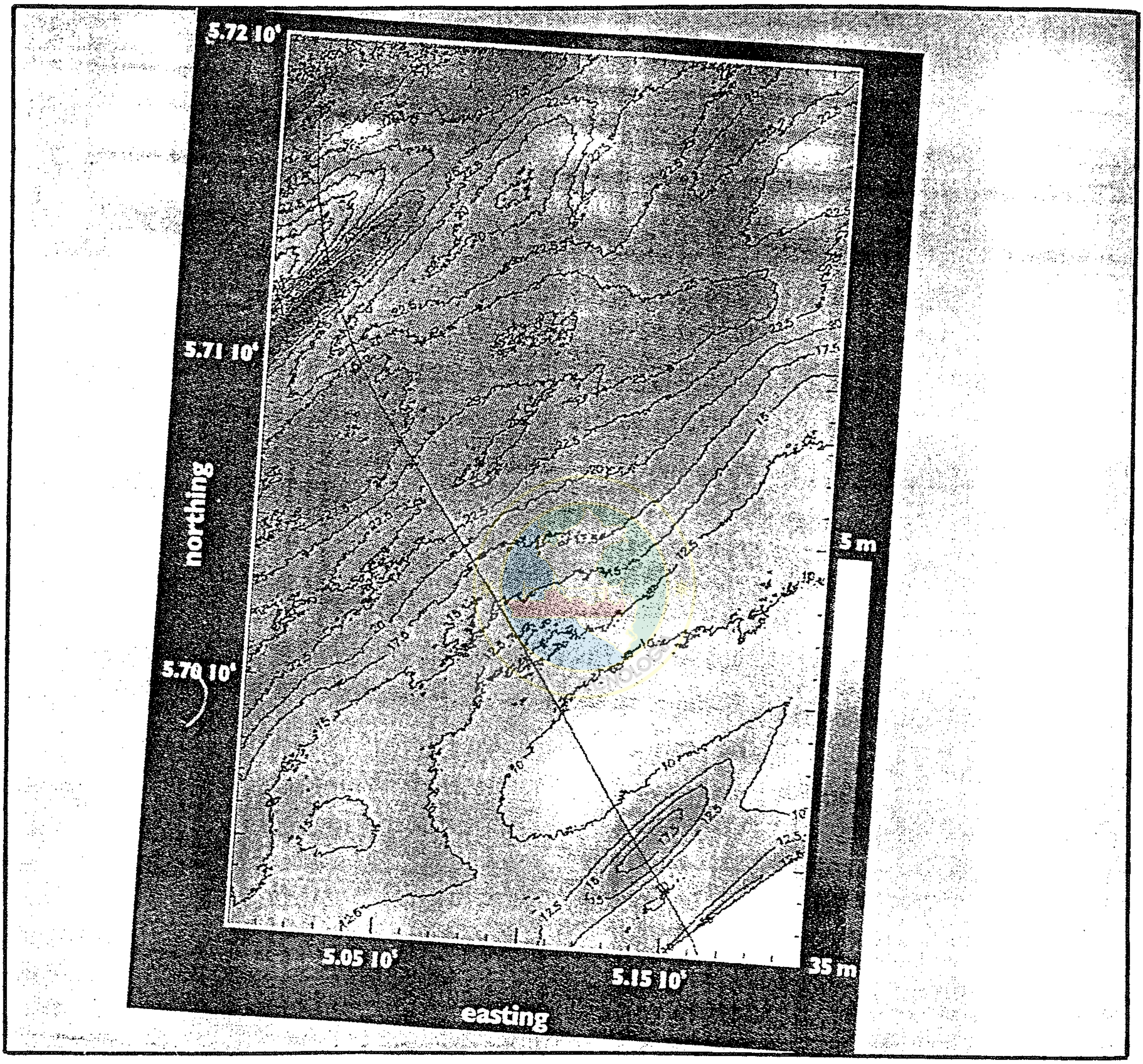


Figure 13. Isobaths using SAR image

detail of ocean surface topography and the structure of the underlying sea floor. The maps produced from radar altimeter record bear a striking resemblance to physiographic maps showing tectonic patterns of the sea-floor, constructed from many years of ship surveys.

EROS data centre provides a world map where the Latitudes and Longitudes are indicated on the sides of the image. The green lines indicate the nadir swaths of Space Shuttle SIR-C/X-SAR data that have been survey processed. Data at other locations are still being processed and analysed by scientists. When they become available, they will be added to this data base. However, not all the data processed will be made into publicly released images (The Remote Sensing Society, 1995). One of these areas in analysis is the South Pacific coast, specially the Peruvian area. Here, is the previous idea of using the available sources of information such as fishing and trade vessels until the satellite sensors information will be available.

Industry necessity of that information can accelerate the availability of the data to be analysed locally (in Peru). However, it will also be necessary to have a trained group able to process the data provided for the satellite instruments.

To summarise, the microwave signals used in radar sensors can be used as a data source for calculating the bathymetry of the area covered by the satellite sensor used. The time-saving in the process seems to be less (than 4 times), as Wagner (1995) pointed out, because of the volume of data involved and also because of the area covered for the analysis. Furthermore, it is said that it is a money-saving procedure (this will be discussed in the following chapter).

5.2 Resource distribution

This section will analyse the application of satellite sensors in the fisheries. Though, the traditional methods used to determine the probable distribution of the fishing resource exploited by the fish-meal industry (i.e. sardine and anchovy), will be shown first, other fishing industries apply the same methodologies.

Fish aggregations may be associated with spawning, feeding, or migration. Some oceanographic factors that tend to produce aggregation are temperature, coastal and bathymetric boundaries, currents, and salinity. As the sea surface temperature is the parameter most used in the determination of the most probable area of resource distribution, all species are bound for a temperature range. Thus, fish often aggregate near oceanic fronts; that is, at boundaries between water types and currents. Satellite data (i.e. infrared and radar imaging) and modern methods of digital image analyse permit detecting the near-surface expression of these boundaries, following their evolution or movements in space and time, and to determine the velocity and current shears associated with them. Advances in communications technology make such information available in near-real time to help optimise fishing operations (Simpson, 1994).

This study considers that satellite sensor can provide useful information for the management of the living resources within the EEZ and also beyond this boundary, but it is also indicated that ground-data must be compared and inclusive it is used to calibrate the satellite information. Furthermore, it is known that the actual technology in satellite sensors can provide accurate data for the purpose of the fishing industry or the governmental manager. In addition to 1- and 3-meter-resolution, customers can soon expect their images to be delivered via computer modem to their desktop. And in a few more years, private dishes will receive imagery directly from satellites. (Corbley, 1994, page 51).

5.2.1 Traditional methods

For this study traditional methods mean methodologies applied for oceanographic and biologic sciences to determine or predict the distribution of a living resource at sea. Procedures of these different methodologies used are shown in the following lines.

a) Oceanographic and biologic surveys

In Peru, biologic surveys directed by IMARPE have been frequently used to quantify the biomass of resources available in an area and during a determined period. There were several EUREKA surveys when the fishing industry together with the government employed their vessels in a specific time of the year on whole Peruvian coast.

However, this method has a disadvantage, the period used to study the species present in the Peruvian waters was short; on the other hand, the availability of data in that short period of compilation was high and not expensive, because the industry covered the operation cost of the program. While the fishing industry was good, this program was available, but after 1975 these programs started to disappear because the fishing industry was not able to continue financing these programs and the government did not have sufficient funds.

The principal techniques to calculate the biomass and the distributions of a resource at sea are

- Acoustic (echo-integration surveys)
- Un-loading catch in ports (port reports)
- Catch reports (vessel surveys using trawler or seine nets)
- Eggs and larves distribution (biological survey)

Both acoustic and catch reports are complementary because the acoustic method will only confirm the present biomass. However, to identity the resource can this only be done by catching. Although, the acoustic technique is one of the quickest ways to calculate biomass and determine the distribution of these resources, the biases of these techniques are related to the random process used to obtain the samples regarding the resource in study. Further, modern techniques can provide a pattern to identify the detected species underwater, but it is still necessary to do a biological calibration. In other words to catch some species and calibrate the instruments (echosounders or sonars) with the echo-registers given by this sample. Statistical samples will appear in the process, but scientists or researchers will be more confident in the data obtained by this equipment.

Most of the techniques used in fisheries management complement one another. Thus, the oceanographic and biologic surveys use all of them for the study of the resources at sea. Moreover, the fishing vessels are able to get useful information about the condition and distribution of the resources, due to the fact that they are continuously going to fish (almost daily in Perú). One experience used years ago was EUREKA programs (as has been described before), including information of the whole year.

In Peru, oceanographic and biologic surveys in recent years have been reduced, due to the costs involved in the process (i.e. personnel, equipment, vessels and time analysing). The research institutes saw the necessity to find other techniques that made it possible to compile data in a less expensive way. Options such as EUREKA programs seem to be interesting (Industry and government integration is looked at by everybody), but this has its advantages and disadvantages as will be shown later in this dissertation.

An interesting experience was realised by Iriarte (1992) in the central area of Perú showing that simple echosounders can provide very good information to calculate the relative abundance in the area. However, as been indicated before the integration between industry and government is required for a good data collection (confidence of the data) and good analysis (accuracy of the results).

Recompilation of data using satellite has appeared with strong interest these last 5 years. However, there are some doubts regarding both accuracy and confidence (this will be discussed later).

b) Fishing vessel reports

A fisherman knows well that the location of fish is determined not geographically but by variable parameters of water temperature, salinity, air pressure and other factors. Although well aware of all this, fishermen have always had to rely on personal experience and empirical judgement to gauge their prospects. However, most technical fishing methods have been developed with a focus on temperature giving the fish-hunting an impressive result. (Hela and Laevaestu, 1970; Wout, 1985; Laevaestu and Bax, 1989).

The author's point of view regarding fishing vessel information (using catch reports) is that this information is useful to determine better fishing areas (prediction process), fishing resources condition and biomass. Confidence and accuracy of the data compiled for the fishing industry can be discussed. However, human resource education and calibrated equipment can provide a high level of confidence and accuracy. Of course, costs in equipment will increase, but the fishing industry has always looked at the fishing efficiency and effectively, giving a better chance to the manager in charge of fishing activities to equip the fishing company vessels.

The following table (Table 12) shows the level of accuracy of the sea temperature sensors used by SIPESA. Also Table 13 shows the accuracy and resolution of the GPSs employed by the same company in 1994 and 1996.

Table 12. Temperature sensor accuracy

	Model	Accuracy	Resolution
Furuno	T-2000	± 0.2°C	0.1°C
Muruyama	DS-2	± 0.2°C	0.1°C

The requirements of temperature sensors in the Peruvian fishing fleet and specially in the SIPESA fleet started from early 1993. That can be shown in the number of equipment bough for these fleets in those years (see chapter 6).

Nowadays, there are two ways to reach the aims of high efficiency and effectively, these are technology and technologic training. Better and accurate equipment has recently been bought for the Peruvian fishing industry such as GPS with electronic charts, sonars and radars, and also sea temperature sensors (further discussion in chapter 6).

Table 13. GPS accuracy

	Model	Accuracy	Resolution
Furuno	GP 300	300 meters	Without chart
Furuno	GP 1250	50 meters	640 x 480 pixels
Koden	GTD 07	15 meters	640 x 480 pixels
Garmin	MAP 200	15 meters	512 x 672 pixels

Data obtained from 43 SIPESA fishing vessels during 1993 provided enough information to analyse the resource distribution of anchovy in the Peruvian waters. To predict this distribution the author used the Kringing method.

This method is a classical grid algorithmic interpolation, a procedure in which a variogram is estimated for the species and is used to define the distance-covariance relationship for the smooth. In theory, the Kriging should provide a more accurate surface than a procedure such as inverse distancing, which never uses information from the data to adjust the weighting. Kriging is a model-based estimation procedure, and if the model is appropriate for the data confidence intervals can be put on the resulting surface. As Cressie (1993, page 106) pointed out, Kriging is a minimum-mean-square-error method of spatial prediction that (usually) depends on the second-order properties of the process Z(•).

The procedure to obtain the data useful for this analysis involves the following steps:

1. Data compilation by the fishermen in the fishing report (SIPESA).
2. Compilation of fishing reports by fleets.
3. Compilation of fishing reports produced by all the vessels.
4. Codification of caugh species and vessels.
5. Digitisation and codification of fishing reports into a database in the microcomputer of the company.
6. Production of manager reports to quantify the efficiency and effectiveness of vessels and fleet. Besides, to calculate the relative abundance of the resource in function of the Effort Unit per Catch (EUPC) and the area covered by these fleets or these vessels.
7. Data analysis of the sea surface temperature and catch using the Minimum Curve and Kriging methods to predict the availability of the resources in the area analysed for the next month in function of the previous data and the temporal analysis of the graphs. (Prediction could only be done for one month because the limit of the data analysed and because the human resources were not completely familiar with the fishing reports).
8. Print of graph informs.
9. Distribution of summary reports to every factory.

The limits used to calculate the isotherms are presented in Table 14. In the same way for the isolines of catch Table 15 shows the size and limits of that grid.

Table 14. Characteristic of the ISOTHERMS graph by Surfer software

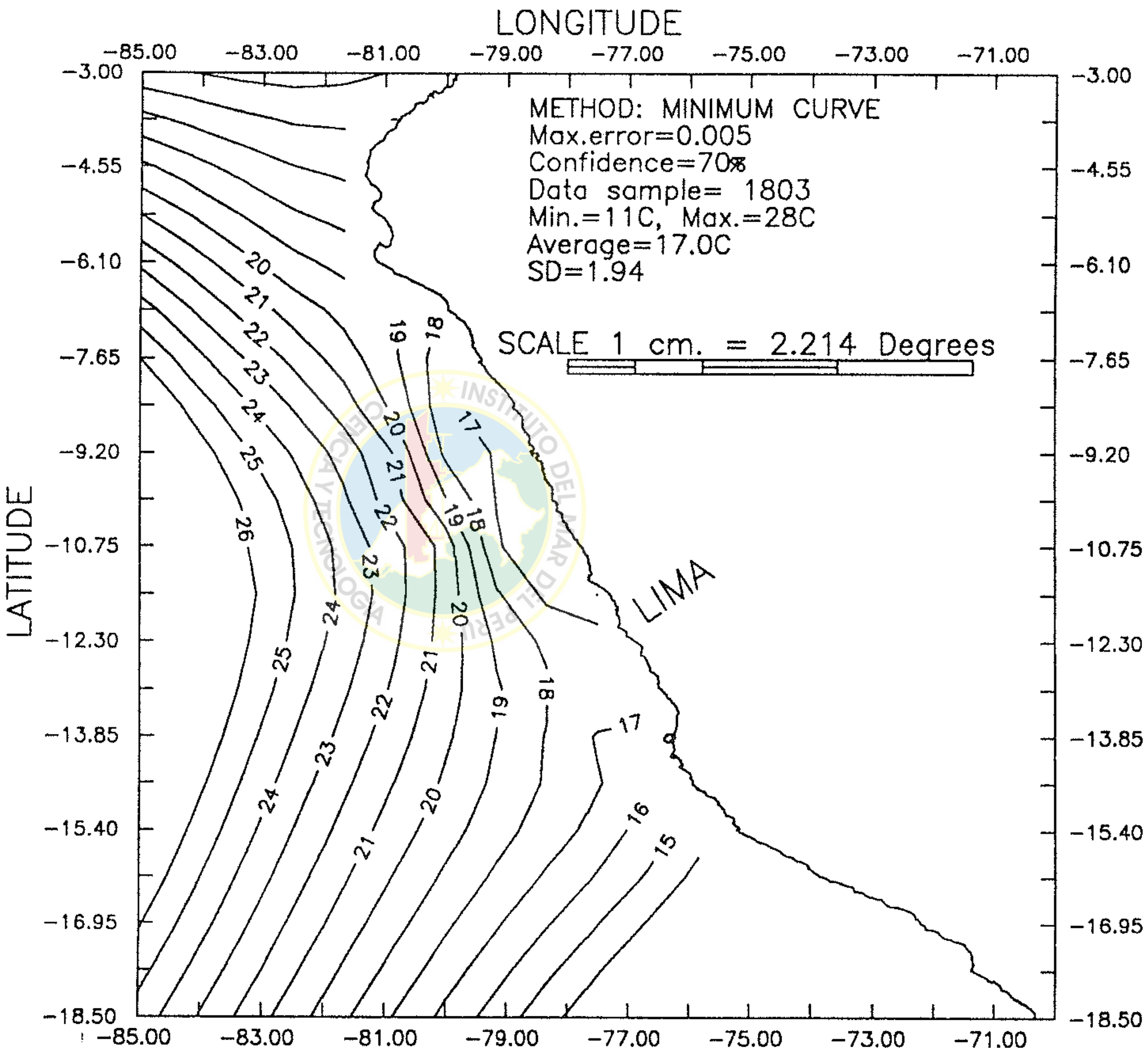
File: ISOTERMA.DAT		
Limit of grid	85°00W, 18°30'S 85°00W, 03°00'S	70°00W,18°30'S 70°00W, 03°00'S
Method : Minimum curve	max. error =0.005	

Table 15. Characteristic of the ISOLINES OF CATCH graph by Surfer software

File: ISOCAP.DAT		
Limit of grid	85°00W, 18°30'S 85°00W, 03°00'S	70°00W, 18°30'S 70°00W, 03°00'S
Method : Kriging	Search radius in X data: 15.48004 minutes of degree	number of nearest points : 20

Figure 15 shows the average isotherm distribution in the Peruvian waters giving an idea of the upwelling process in front of Trujillo (08°30'S) and Lima (12°00'S). However, an intrusion of cold waters in the South did not change the patterns of warm waters bounding and closing the cold waters near to shore, where the resource (mainly anchovy and small sardine) could search for their environmental conditions of living. This gave advantages to the commercial fishing industry which had at that moment a close and large resource; thus the fuel and time used to catch the resource was less than normal.

Figure 14. ISOTHERMS. Peru 1993



Besides this graph, are shown the isolines of catch (Figure 16 and 17), which complement and confirm the previous analysis. It can be seen that the better fish congregations or schools appear close to shore. Taking a look in the north area close to Lima (12°00'S), the average catch was around 200 tonnes, with the average time of catching less than 2 hours. Areas with less than 50 tonnes can be considered to have had a disperse resource during this period. Data to the South from 14°00'S in the year 1993 was null, because at that moment the company (SIPESA) did not have any operating fleet in that area.

c) Air-craft survey

Air-craft (aeroplane or helicopter) are also included as instruments to detect fishing grounds. The results of several aircraft programs have demonstrated that water temperature information can be derived from passive microwave measurements with an accuracy that satisfies most user applications (UNEP/IOC, 1992).

These air-craft employ similar equipment to the satellite, for remote sensing of water and land resources, i.e. fisheries monitoring. However, this equipment is very expensive, therefore there are few countries that have especially designed and equipped air-craft for that purpose. Moreover, the fishing industries do not use the complete capability of the air-craft for economical reasons. For example in the tuna fishery, the air-craft are used in the day-light to detect the fishing-grounds without employing any equipment that can increase the efficiency of their searching.

The use of airplanes to detect fishing grounds in Peru has not been applied in the past, due to the easy accessibility to the resource in coastal areas. However, five years ago in Chimbote-Peru a company started to provide services to detect the distribution of the sardine. It was a successful business, due to the fact that the sardine was very, widely dispersed in the area, providing in this case a time and fuel-saving service to the fishing companies who paid for that information.

Figure 15. CATCH ISOLINES. Peru 1993

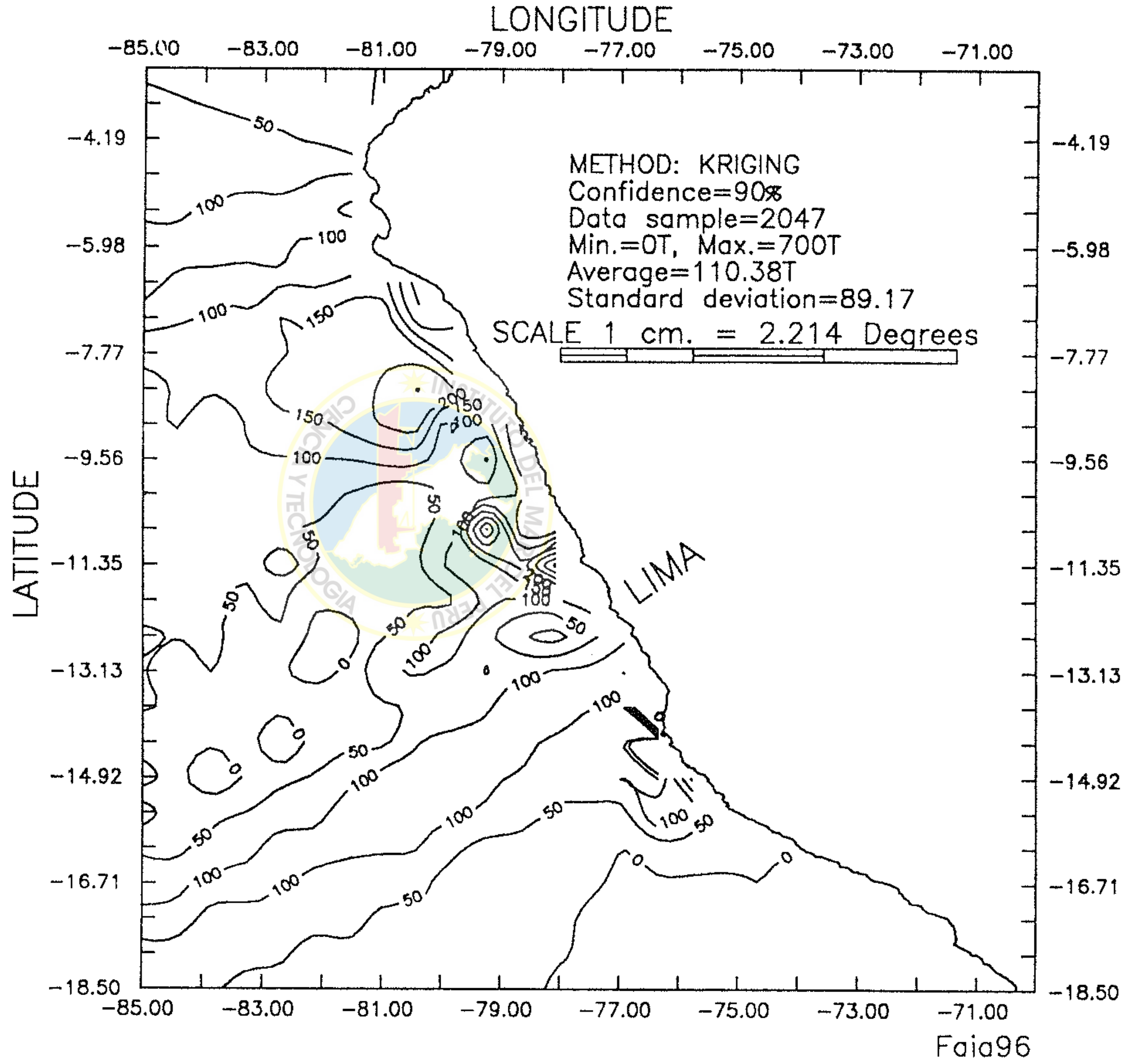


Figure 16. CATCH ISOLINES. July 1993

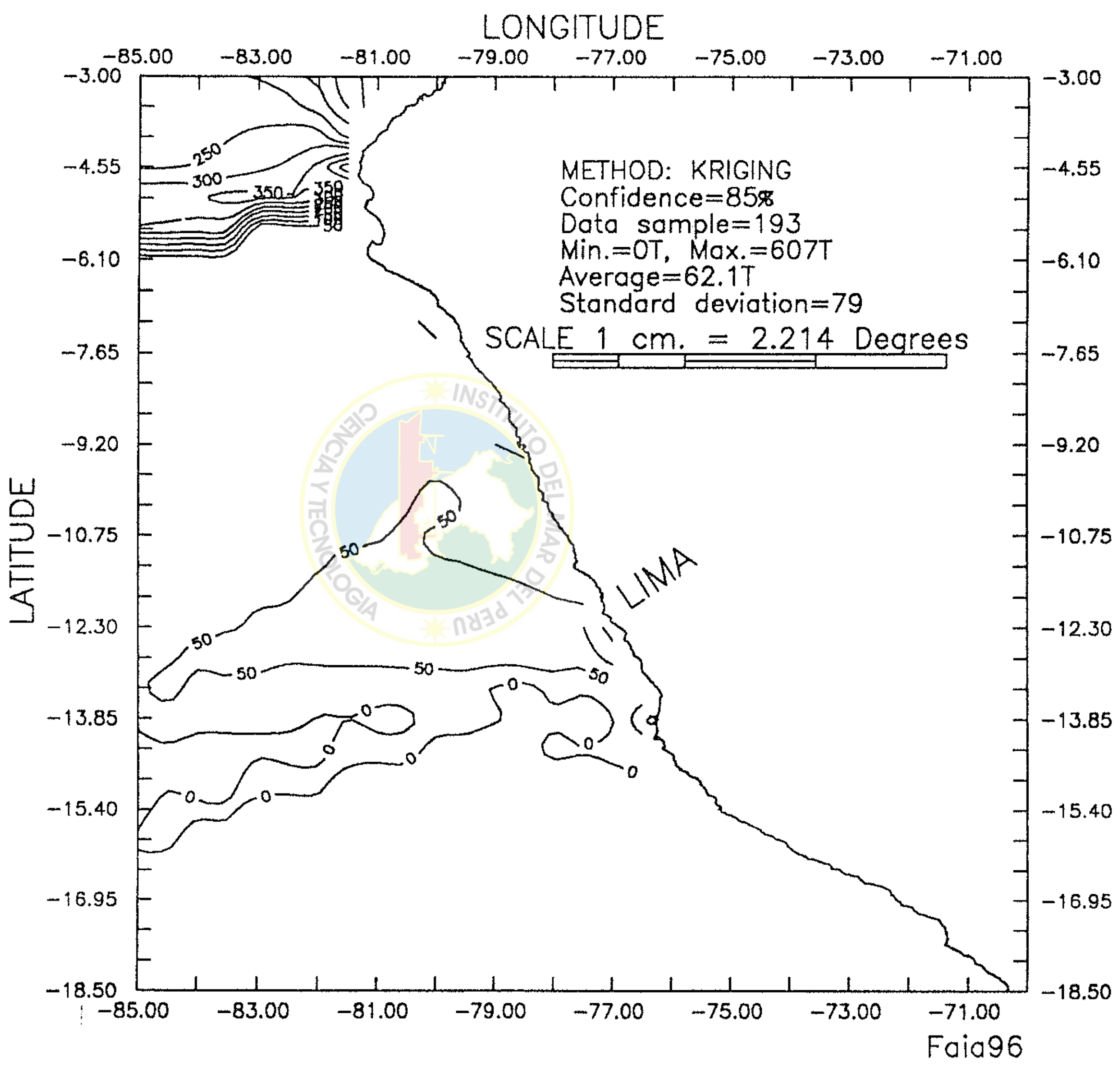
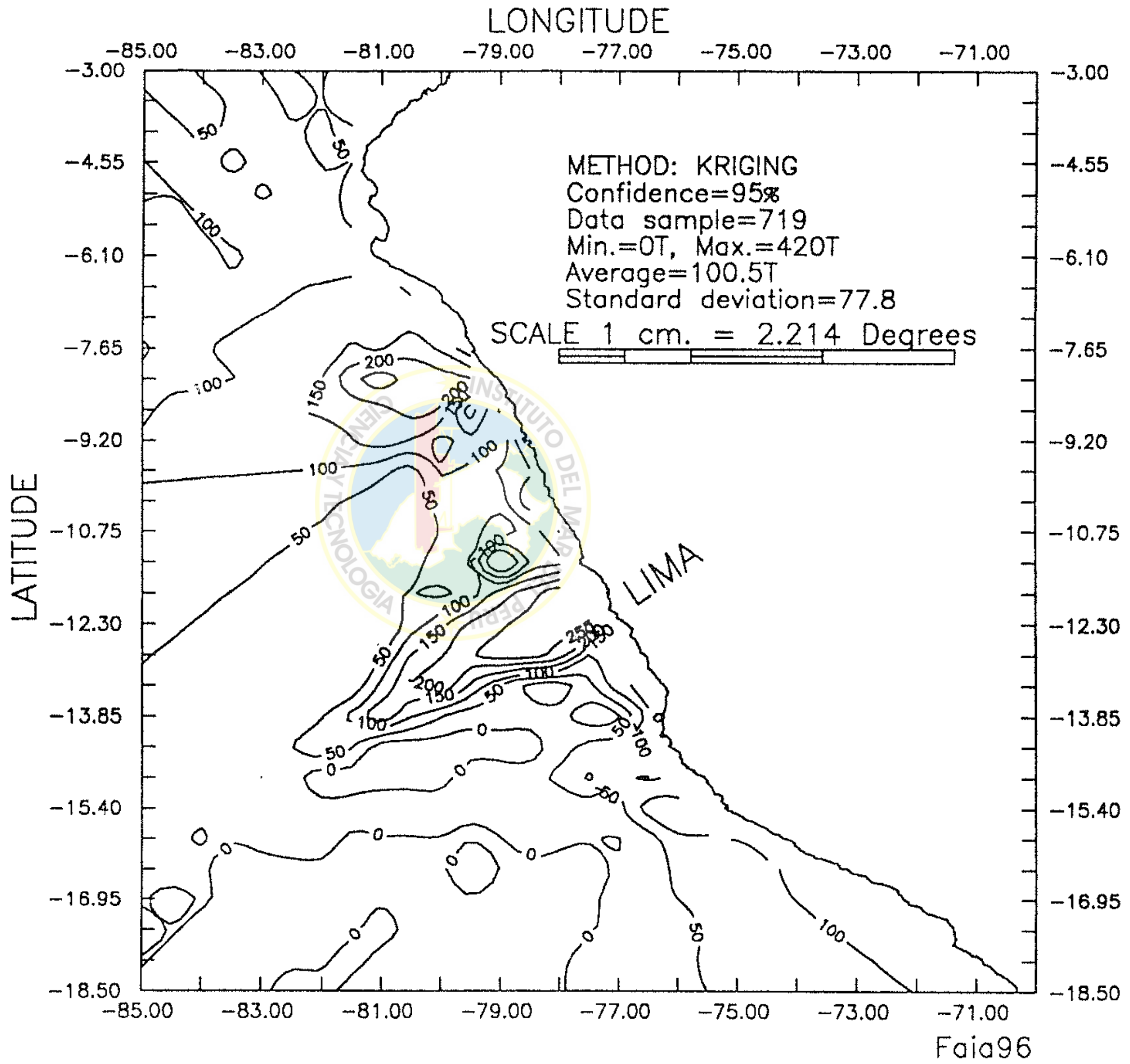


Figure 17. CATCH ISOLINES. December 1993



This experience is shown in the following steps:

1. Planning of aeroplane survey based in the previous vessel and aircraft information.
2. Aeroplane surveys over the most likely areas of fishing resource distribution.
3. Radial communication to the fleet manager of the company that is paying for the services or to its vessels about the location of the largest fishing schools observed.
4. Daily, weekly and monthly transmission of printing report by fax to the fishing company regarding to the distribution of the observed resources and theirs probably migration pattern.
5. Sailing of the vessels to the most likely area of fishing in function of the aircraft information.

This method has the advantage of provide real time information (through radial communication) to the fleet manager for the decision to send the fleet to the best fishing areas improving the efficiency and effectiveness of the fleet. Furthermore, the ocean and coastal zone manager can also have complementary information to decide if the fishing season is still open or not. This should be carefully considered in function of more scientific data. However, the aircraft surveys can give the basis to determine what area is more disperse in resources than other.

A momentary disadvantage of this process is that most of the fishermen are not familiar with the use of co-ordinates to arrive at a fishing area; however, that is changing in Perú at least due to the new trend of the fleet managers for training programs, besides the new maritime regulations regarding fishing captain and fishermen certificates. The most complex disadvantage of this method is the number and level of trained pilots (aircraft) skilled in the detection of fishing grounds from the air and the capital required to cover the cost of an aeroplane operation. While the fishing industry is good and strong, this method may have prevalence over others in the searching of resources to fish, except from the author's point of view when this method is compared with the satellite sensing method.

5.2.2 Satellite application

Remotely sensed data, visual and thermal imagery is playing an important role for the future. Gathering of resource distribution (land and water) and environmental information has become practical and economically viable due to the use of satellites. Thus, this part of the document will show how the satellite has increased this practical and economical goal of any production activity such as fishing.

IOC-UNESCO (1992) and Meltzer (1994) indicate that with the assistance of remote sensing, satellite imagery and more sophisticated scientific understanding of fish movements, the relationship of living resources to a variety of oceanographic phenomena is becoming evident. Ocean current water temperature, eddies, spirals and gyres, and sea-mounts are all determinate of fish migration patterns.

As Chien (1994, page 28) pointed the spacecraft can pinpoint different temperature boundaries in ocean surface areas, giving commercial fishermen vital clues to the whereabouts of different fishing species. Satellite maps can indicate up-welling and current convergence. Experience of the Japanese and Korean squid fleet in Peruvian waters seems to be broad in the satellite data (SST) to locate the most probably zones of fishing. Moreover, the Japanese fleet provide feedback information from their on sensors (such as echosounders and sea-surface temperature sensor, and sometimes bathy-thermographs) complementing information from ground side which is indispensable to reach the goal of effectiveness. But satellite information is global giving better vision of the phenomenon in process, as Ferrer (1995, page 396) said although the data "in situ" has provided good information about the oceanographic process. Satellite prospection is not replaceable, because it is the only method that can provide a global vision, besides its possibilities to transmit in real-time and using computerised data directly.

Other countries such as Canada and Australia have also used satellite information to predict better fishing areas and weather conditions to be distributed and employed in their fisheries.

Temperature data obtained by satellites have been used by the Laboratory of Systems at the Compostela University (Spain), Universidad Catolica de Valparaiso (Chile), Vega Group PLC of Harpender (UK), Roffer's Ocean Fishing Forecasting Service, Inc. of Miami (USA), among other research institutions and enterprises. They have analysed and processed satellite and ground data to obtain marine charts, where the isotherms and the fishing fronts appear using the relation fish-sea temperature to locate the most probably fishing zone. The information is regularly sent out via INMARSAT or Argos system to vessels to aid in the search for commercially viable concentrations of fish stocks. (Davidson, 1990; Barbieri et al., 1991; Fishing News International, 1995; World Fishing, 1995). Sea Technology (1992) indicates that Argos system together with RS/GIS technology have been used to locate albacore in the Northeast Atlantic and to study shrimp on the shelf off French Guyana, making the fishing effort more efficient through time and fuel saved while they are using these technologies.

An alternate source of remotely sensed information can be obtained by satellites such as Landsat TM and SPOT HRV, where the data is routinely incorporated into GIS for land-use mapping. Further, satellite remote sensing is widely considered to provide a cost-effectiveness which has clearly been demonstrated in economic terms. (Mumby et al., 1995).

The main disadvantage of using satellite sensors is the interference of clouds. To overcome such difficulty the use of 10 cm to 30 cm wavelength can be useful. Thus currently, it is possible to detect and evaluate sea surface temperature and salinity information in coastal and estuarine areas. (UNEP/IOC, 1992).

The monitoring of sea-surface temperature (SST) from earth-orbiting infrared radiometers is the technique of marine remote sensing which has had the widest impact on oceanographic science. The principal source of infrared data for sea-surface temperature measurement is the TIROS/NOAA series of polar-orbiting meteorological satellites. (Robinson, 1985, page 194). Once infrared radiometer data has been atmospherically corrected, there is no doubt interpreting it in terms of an ocean parameter.

The temperature measured from space is a skin temperature, and its usefulness in contributing to oceanography in wider perspective depends on being able to interpret it in terms of the underlying temperature of the top metre or so of the ocean. (Robinson, 1985, page 207).

The principal advantage of satellite remote sensing over aerial photography, ground surveys, and nautical charts is that information can be collected uniformly in both time and space. It also offers a non-intrusive, repeatable solution to mapping large areas of marine features, given suitably clear water and little atmospheric interference. With the current spectral and spatial resolution of satellite sensors, the major limitation of remote sensing is perhaps the difficulty of spectrally separating biological communities rather than geomorphologic zones. (Mumby et al., 1995).

As can be seen satellite uses are varied and global. Satellite application in resource distribution can be direct detecting from low orbit satellite the fishing grounds, but there is a disadvantage. This satellite is a long term cycle not to be recommended in the case of small and very fast species. The indirect way of using the information of satellite sensors to determine the distribution of a fishing resource is getting oceanographic information. Thus, in function of the relationship species-habitat the coastal and ocean zone manager (government) or the fleet manager (private company) can deduct the richest areas of fishing grounds or determine which areas are null in resources giving in this way a powerful tool for the decision-making whether the resources should be affected by a seasonal restriction of fishing (governmental decision) or direct the fishing fleet to the best fishing areas (fleet manager decision).

In any case, an integration is necessary between companies and government for the main goal of the nation, maximising the fishing effort within a sustainable principle. Because, these new tools can provide the fishermen with a global vision in real time of the resource distribution, it means better possibilities of fishing (increase of effectiveness). Furthermore, if this effort is not controlled, the resources will disappear in the process, it will be overfished causing the loss of jobs (fishery collapse) and loss of a specie and probably of other related species (biodiversity reduction). A very good example of this last effect is the 1970 Peruvian anchovy industry collapse due to overfishing and oceanographic adverse conditions.

5.3 Fleet Monitoring

This section will deal with the monitoring of vessels (fishing fleet) based on GPS and data communication through satellite network. Advantages and disadvantages of using this process will be discussed. Moreover, the traditional ways of vessel monitoring will be shown and compared with the satellite application on monitoring.

Monitoring is a centuries-old activity but in recent years it has assumed a more rigorous form. This has been partly in response to an increasing demand for data on which to base regulation and control measures (legal requirements) for pollution and illegal fishing. In addition there is the need of any company for having constant information from their vessels. This growth in monitoring demand has followed closely the rapid development of sophisticated technology. (Hood et al., 1989; McIntyre, 1995).

A precautionary fisheries management policy may combine a variety of approaches and regulatory tools. One of these approaches is **strengthening monitoring, control and surveillance,** while raising penalties to deterrent levels.

Countries should research and apply mechanisms for monitoring and controlling high seas fishing activities and, to the extent possible, co-operate on reciprocal and joint surveillance and enforcement, as the articles 116 - 119 of LOSC suggest.

Krawetz et al. (1987), assumes that effective monitoring consists of three factors:

- Developing a monitoring plan. Scoping, data collection, analysis interpretation and feedback (user-oriented).
- Managing the monitoring process. Analysis, organisational arrangement, participation of the parties-at-interest.
- Achieving the monitoring objectives. Activities depend on the objective for which monitoring is undertaken.

There is a growing need in the fisheries field for accurate and timely information for monitoring, control, and surveillance measures, as well as conservation measures. Such measures have been initiated by several countries. Considering fishing vessel monitoring (FVM) programmes, countries such as Argentina, Australia, Canada, Chile, Morocco, New Zealand, Peru, and the USA have systems either operational or at an advanced planning stage. Also the EU countries have developed a FVM programme for their own waters. These programmes are used to conserve and manage rationally the natural resources within their EEZ. (Meltzer, 1994; Gallagher, 1995).

For fishing and sea-trade companies, either governmental or private, the process of monitoring is, as Gallagher (1987) pointed out, part of a long trend to enhance competitiveness on the part of shippers by reducing the size of crew necessary to operate a vessel (fishing or sea-trade).

For any company in the marine environment, the monitoring objective will have an impact on management and on the prediction (short-term forecasting) process. In the specific case of the fishery industry, better and quicker data communications mean more accurate predictions of resource distribution at sea, as well as information on market prices and market demand that will allow the company to obtain better profits.

Thus, satellite-based systems are becoming an increasingly popular way to offer low-cost communications over large areas. Providing the necessary mechanism for monitoring and controlling vessels that now are less-expensive and faster. (Harrison, 1993).

5.3.1 Fishing Industry

In the words of Simpson (1994, page 744) the fishing industry's primary concern should be to harvest economically a given resource from the sea in such a way as to insure its continued, long-term use. Thus, the fishing industry should constantly try to optimise catch per unit of effort without jeopardising the fecundity of the stock. Unfortunately, this has not always been the case.

The data analysed in this document has been provided by a fish-meal company (SIPESA) which had in 1993 four factories, distributed close to Paita, Chimbote, Huacho and Pisco. Their 43 vessels were distributed in 4 sub-fleets one for each factory. Their fishing operations covering 4/5 of the coastal areas but less than 2/5 of the ocean zones in Peruvian waters.

These vessels are the main providers of the raw-material (anchovy and sardine) for the fish-meal factories, which produce, on average, 500 tonnes of fish-meal per day. The transformation relationship from raw fish to fish-meal may be taken to be roughly 1:5. Thus, the maximum tonnes per day discharged in the SIPESA factories could be 10,000 tonnes per day (500 t of fish-meal/day * 4 factories * 5 tonnes of fish tonnes /tonnes of fish-meal). As can be seen in Table 16 (Annex I) these vessels vary from 80 to 450 m^3 of hold (*bodega*) capacity; most of them (98 %) are less than 10 years old and are well maintained.

Fleet management

Fleet management systems require inventory information, maintenance routines and access to all equipment information. This will improve the confidence of the equipment, its performance and the safety of the vessel. In addition to the technical aspect of information, it is necessary to take into consideration the education of the personnel, because they will be the people who will use the equipment and who will take decisions in order to provide data for the system.

As Simpson (1994) indicated, the fishing industry is looking for a constant improving of its benefits. In Perú, the fishing companies have discovered the best way to arrive at that aim is through technology. Powerful, long distance, high resolution and more accurate sonars, echosondes, radars and GPS have been bought for that purpose.

Technology transference is also an important item. SIPESA training programmes have been improved since 1992. However, this is not an isolated case, most of the fishing companies in Perú are trying to get qualified people and also include updated courses for their fishermen.

As Fay (1995, page 22) suggested, planning and managing a voyage require collecting, processing, integrating and the displaying of a wide range of data. Monitoring and managing the movements of many vessels requires the same discipline.

It can be said that SIPESA followed this idea, because in 1993 the company created a procedure to collect and process information obtained from the fleet in the different areas of operation (Paita, Chimbote, Huacho and Pisco). The company also used the available information in its computer networks about fish-meal processing to compare and calibrate the data compiled from the fishing reports. After that, the process of feedback assured the confidence of the data.

To complement and fix the training programme, developed from November 1992 to November 1994, and aid the process of data collection, the company published an electronic equipment guideline (Iriarte, 1995).

Data integration and information analysis were done in the headquarters (Lima) by the Fleet Management Department together with the Computing and Systems Department. Later, engineering, administrative and management reports were produced (SIPESA Informs: "INFORME 102-FLO94"), ensuring that this data provided the necessary information to support the decision processes, such as maintenance programmes (engineering), cost-saving or cutting-cost (administrative) and fleet direction or FVM (fleet management).

5.3.2 Description of a monitoring requirements

It is the user who will take the decisions on the basis of this information to control or initiate prevention measures for cases of pollution or accidents at sea. In other cases the information may be simply used to monitor the fishing fleet in order to control the effort over the resource. However, what are the costs involved? One of them is the cost of maintenance services for data communication equipment located both on land and at the vessels. These costs can vary depending on the market competitiveness and the advances in technology.

What type of information is the company or the government interested in taking into consideration? The main parameters to be transmitted and used by the administration or the fleet manager are the following:

- Location of the catch (location of cargo discharges)
- Volume of catch
- Species represented
- Temperature of the sea surface
- Fishing time (i.e. start-end, period delay)
- Bathymetric information

Besides these parameters, other information is needed such as:

- EEZ or territorial sea (i.e Peruvian waters) limits

- SOS transmission
- Port location
- Indication of the nationality of the zone
- Sailing to the fishing area; this also includes searching for the resources in areas of widely dispersed fishing grounds

However, before receiving all this information, the manager should take into consideration that any communications system has to deal with the

- human - machine interface,
- data storing process,
- backup procedures, and
- statistical management of the information.

The monitoring process can be operative if this information is complemented with a graphic display in the office (government or private) to be able to follow the fleet. To support this need, a periodic transmission is an important issue, depending on the company or government policy regarding the monitoring process and the sending time of the requested information. As Sainsel (1994) indicated, the data transmission periods can be

1. each 24 hours
2. each 12 hours
3. each 6 hours
4. each 1 hour, or
5. As a function of the users requirements

After the information is sent to the user, it should be possible to calculate and produce statistical reports of vessels, ports or discharged factories, vessel-owners, gross tonnages or catch volume:

- Total days in port (weekly, monthly and periodical reports can also be available),

- Total sailing days (weekly, monthly and periodical reports can also be available),
- Total fishing days by fishing areas
- Port of entering and departing
- Vessel types
- Species captured by area and total
- Time of fishing by area and total
- Status of fishing (i.e. fishing or not)

The nautical charts can also be used in the computerised system of monitoring to be able to determine the local port, fishing area, restricted areas and the complete nautical chart of the country. Further, parameters such as, isobaths and signals (lights) can also be useful for normal navigation.

5.3.3 Traditional methods

a) Aerial surveillance

This method is rather difficult to follow and implement, if a country has limited economic and manning resources. Further, the extent of the area to be searched is limited by the type of vehicle to be used. It is a complex and very difficult operation to follow several vessels in different directions for a long time because of the need for many air-crafts and, high associated costs.

The most clear example of this technology application on monitoring can be the adoption of airborne surveillance and other methods to be used in identifying offenders by "The North Sea Conference". It seems to be a good idea to be implemented in other areas in the world. However, the North Sea is an area comparatively more amenable to monitoring by airborne platforms than the West Pacific Ocean (i.e. Chile, Perú, Ecuador, Colombia). The technology and budget available for the northern countries are better and larger than the South American countries. Airborne surveillance may provide more accurate information, but the costs involved in equipment and operation of these air-craft are not affordable by developing countries.

The most useful application area for aircraft monitoring programmes is for detecting pollution activities either from fishing or commercial fleets at sea, though this process is expensive and time consuming. This process can be described as follows:

1. Advises by fishing or commercial vessels or aircrafts. Probable information related to pollution activity within the national water and inclusive international waters (radial or satellite communication).
2. Air-craft survey over that location indicated by the adviser. These also include the random surveys that normally effect these air-craft if no advice has been provided.
3. Identifying of the offenders.
4. Radial communication to the Coast Guard or the in charge entity.

At this point, it is also important to create a database that compiles all this information for future use in comparative analyse and in the enforcemnet of national regulations related to control of the vessels calling at the ports of a country.

Due to the reasons presented, the viability of using air-craft for FVM, or any kind of vessels monitoring, seems rather limited. However, it can be useful to confirm previous information provided by vessels, other air-craft or satellite remote sensing.

It can be said that combining aerial surveillance with satellite applications would be useful. Such suggestion has been already made by NOAA (Hamilton, 1990). NOAA ocean data are derived from a complex global network of satellites and an ocean based observation system is used for monitoring pollution activities from sea-trade and fishing vessels. A procedure of combining both air-craft and satellite data could produce a reduction in operation costs and more confidence in data management. This means a better chance of determining the extent of illegal fishing actions or

This means a better chance of determining the extent of illegal fishing actions or pollution activity. A good example is the South-African experience in monitoring foreign vessels in their waters.

b) Vessel surveillance

Gallagher (1987) considers that monitoring is performed best by using sensors to collect data about the state of a ship or its cargo. Once collected, these data can then be organised in formats designed to make them easy to use for on-board personnel, as well as to be transmitted to the ship's operator for use in fleet management and planning. Most monitoring is still undertaken manually. A crew member reads instruments in various shipboard locations, logs them, perhaps in an on-board computer, and transmits them to the ship's operator in accordance with prior arrangements. More advanced systems permit the interrogation of these computers from shore.

SIPESA has always considered that confident information is indispensable if the company wants to improve its administrative and productive efficiency. For that reason, the company created a daily fishing report, which was a simplified version of EUREKA's reports, which included a series of fishing, biological and oceanographic reports. These were used years before, when the fishing industry was directed by governmental organisations. This report can be taken as a kind of fishing log that normally has not been carried on board since EUREKA programmes stopped. This could be because of lack of enforcement by the government, lack of interest by the companies, or because of lack of interest by the fishermen as well.

That was the reality the author found in 1992. Therefore it was necessary to create a long-term and time consuming training programme whereby the fishermen were trained on board or on land during breaks in the fishing season.

The information, as Gallagher (1987) reported, is usually transmitted through radial signals or even brought by a fisherman to the office on land (factory) for later mailing to the headquarters. This is a very slow process for monitoring a fleet. However, this process formed the "start point".

Today, the high-frequency radio can be used in connection with computers, permitting data transference making a monitoring process easier. However, the latest advance in satellite communication gives this radial technology few opportunities for improving in the market. Nevertheless, it seems that for companies with installed radio communication infrastructure in local areas, it is appropriate until they change technology or while they wait for other technology alternatives.

Radio frequencies have been successfully used in fishing and shipping industries for monitoring their activities; such is the case indicated by Arthus (1994) and MER (1995) where the coastguard and port authorities routinely track and make radio calls to large ships carrying hazardous cargoes as they pass through busy shipping lines. However, by the end of the decade, the job could be done automatically using tamper-proof transponders on each ship.

If monitoring will be carried on, this system will require satellite data (i.e vessel location through GPS or GLONASS). The transponder would automatically respond by radio to inquire about received data from the shore or other ships. In other words, combined methods can also work and can be more effective if in the process the company reduces operation costs. In this context the LORAN system is also used to calculate or obtain vessel position; however, the LORAN system is not available world-wide, at least it does not operate in Perú.

5.3.4 Satellite applications

This system clearly has potential as a highly efficient method of monitoring fishing effort, as the time a vessel's gear is fishing can be tracked virtually to the nearest minute. This new system could permit authorities to distinguish between fishing and steaming time, providing greater flexibility for fishermen, i.e. in choosing where to land their catches. In addition, through the use of this system, engine efficiency can be monitored very closely, with all of the potential benefits possible in terms of reduced engine repair costs (World Fishing, 1995, page 15). The monitoring processes provide cost benefits by controlling fishing vessels, improving the catch report and controlling fishing activities to arrive at sustainable management of the resources

Satellite methods can provide a tool to enforce MARPOL in difficult areas to monitor; arriving at one of IMO's goals: clean seas. Satellites could play an important role as an 'eye-in-the-sky', assisting authorities to detect intruders or polluters, but this would require the force of international law to place identification transponders on every ship. (IOC-UNESCO, 1992).

The companies that can support the monitoring system by satellite constellation are the French ARGOS system, which is based on polar-orbiting satellites; and Euteltracs, a Ku-Band system originally designed in the USA for mobile land applications, in addition to INMARSAT-C. (Gallagher, 1995, page 22). Besides, Radarsat should be considered because it provides satellite image and data with high resolution, making the monitoring of vessels possible.

Hardware such as INMARSAT or Argos equipment or a simple computer complemented with radar or ARPA radar, ECDIS or ECS and GPS provide the most interesting advanced tools in the monitoring infrastructure. However, it is worth noting that GIS software can provide the integral vision for management of wider areas such as the Ocean and Coastal Zone. Thus, for example, the fishing vessel data can be displayed in a number of ways using Windows monitoring software. The geographic information system (GIS), which has been developed especially to work with electronic chart systems, displays the vessel's position by combining digital reproduction of admiralty paper charts through grid overlay techniques. This facility allows the monitoring authority to follow the progress of a fishing vessel very closely, with the capability of zooming the graphic location to a high level of magnification or providing the catching performance by a vessel or company. (World Fishing, 1995).

Therefore, the hardware and software configuration to be used should be

1. X.25 or X.400 communications system and two modems.
2. Workstation (can be also an intelligent terminal in a network).
3. Printer or Plotter.
4. GIS software.
5. INMARSAT-C or ARGOS equipment.

The following points should be covered:

- An interface to the Comms Handler to pick up the satellite position data
- The resolution of vessel identification (ID) from various 'alias'
- Vessel Registry: The registration/de-registration of Vessels/ALCs; the "type"of vessel it is; the "performance" characteristics and general physical data such as length.
- A means of entering other positions or vessel sighting information
- A database of positions over time
- Analysis of positions information
- Reporting forms in function of the user management requirements
- A data feed from the Vessel Possition System (VPS) database to the Geographical Display of vessel positions

The fact that satellite communications will enable an owner to question the skipper without doing so at a critical time is a great asset. Better still is the ability of such a system to provide answering data automatically. Log books are something of a sour joke with fleet managers, especially those books related to engineering. They are expensive, either too superficial or over-detailed and rarely filled in adequately. This task can be successfully accomplished by engine-room monitoring systems capable of reporting back to base, automatically or on request, via satellite.

Besides, governmental organisations in charge of monitoring vessels (in this case fishing vessels) know that most of the information in the report is not accurate, especially if there has not been a previous period of training in the human group working in the fisheries. Moreover, this process is expensive in terms of both time and money.

To be aware of what costs are involved in vessel tracking (later discussed in chapter 6), it is necessary to visualise what systems and equipment should be used. Thus, the following provides a brief report of them.

Argos

The data can be transmitted at a rate of 10 times per day. The information sent by the transmitter is stored in the satellites until they pass over an earth data station. The data are then transmitted to the earth station where the signal is converted into readable position information. After that the user can access this information through the Argos processing centre. The data are then manipulated, printed and/or displayed on mapping software. A mapping/tracking software package is used to monitor vessel positions on the computer screen.

Argos is a satellite data transmission and tracking system that uses the HRPT capabilities of National Oceanic & Atmospheric Administration weather satellites. Its satellite-based data serve a variety of applications within the marine community such as the collection of offshore weather data, the study of major oceanographic features affecting global change, fleet tracking in fishing, hazardous material transportation, and the tracking of marine animals. (Davidson, 1990; Wingenroth, 1993).

A joint study project in co-operation with Japan and the UK, France is proposing a more advanced type based on the Argos satellite system that would operate in line-of-sight as well as via satellites. Signals would be picked up by shore stations, other ships and by satellites. (Lloyd's of London Press Ltd., 1995).

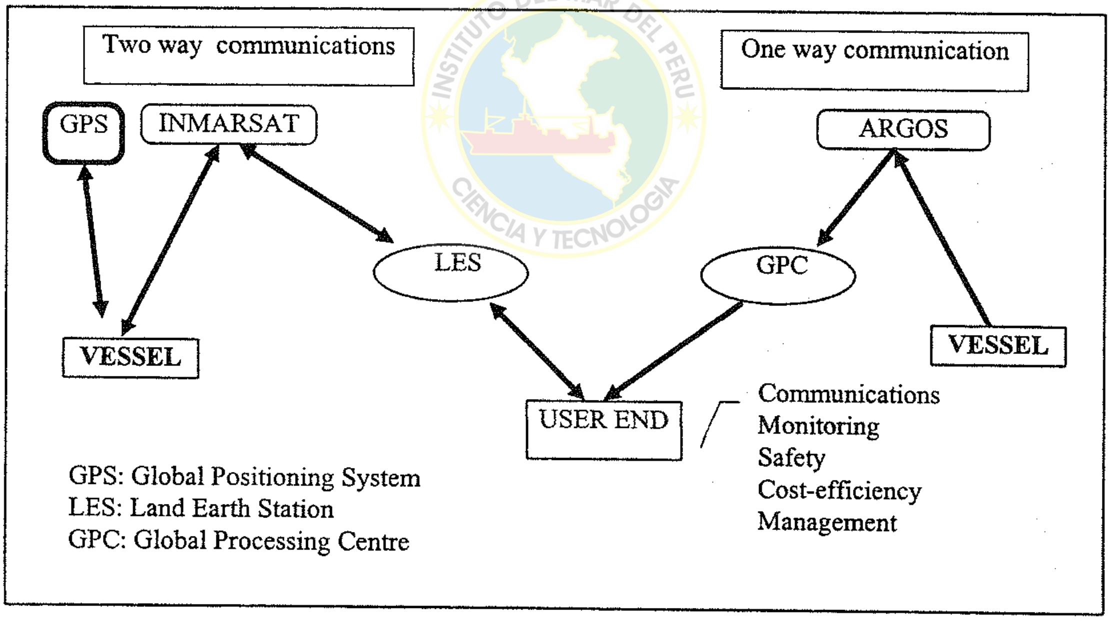
INMARSAT C

INMARSAT-C appears to be flexible, functional and of value for money. Further, it provides the capability to obtain data in quasi real-time with convenient accuracy. INMARSAT- C applied in monitoring has been used in the USA, Argentina, Chile, Peru, New Zealand, Morocco, Australia and EU. If the text messages are compared with voice radio phone, the former is extremely attractive to cut eavesdropping, which appears in normal radiophone communication. In addition, the total cost of communication is much less for text messages than is radio telephone.

High speed transmission of data will be available by INMARSAT A, B, C and/or M, P. The best way to move data from ship to shore seems to be the e-mail system, which reduces communication costs by almost 60%. Another advantage exists in the compacting of the data which in some cases appears to be a terrific technology alternative. However, all the data is still transmitted by satellite connection. Table 17 (Annex I) gives a better idea of how much INMARSAT-C can improve the communication rate.

INMARSAT has reported an increase in the number of ships using satcom installations for monitoring, principally for engine performance and weather and cargo conditions. Though most of these vessels transfer data to shore manually, systems that permit direct polling are becoming more common. Even more automation is inevitable in the future (Gallagher, 1987, page 13). For the shipowner, Starec (Status Recording) gives the ability to monitor safe operation of ships and present this information graphically. For the flag or port state it gives the capability to conduct random checks on the operation of ships within their jurisdiction; and in the event of a disaster, it provides a way to retrieve key data on ship status in the immediate aftermath of the accident, while search and rescue operations are still under way, without having to spend valuable time and resources recovering a 'black box'.

Figure 18. Monitoring system comparison (one and two way communications)



Fax-mail and e-mail open new alternatives in the technology evolution of data communication (transmission and reception) also giving the possibilities to reduce the costs involved in this process. The system operates in conjunction with an INMARSAT-C terminal of the kind that is coming into widespread use with fishing vessels in European waters. Linked to the satellite communications terminal is BPI's

Terminus SCADA (Supervisory Control and Data Acquisition) system, which collates information from an array of sensors fitted to the vessel, controls the transceiver, allows polling and sends information to a shore based terminal equipped with BPI's C-Trak software. Also, the Enhanced Group Call (EGC) facility will allow messages to be sent to multiple vessels selected in predetermined groups, or located in specified geographical areas. A likely application of this function in fisheries would be the transmission of environmental guidance products (weather, ice or temperature maps for instance) to the entire fleet of vessels operated by a particular company (Davidson, 1990; MER, 1995; INMARSAT, 1995; World Fishing, 1995; INMARSAT, 1996).

Radarsat

The images brought from this sensor are not attenuated by the clouds or rain. Furthermore this sensor has a resolution of 100 to 10 meters which is appropriate for the detection of vessels (i.e. fishing vessels close to shore or merchant ships in the open sea).

The next Radarsat "ScanSAR-N" will be able to detect vessels smaller than 100 meters. In this way, the monitoring process will become as easy as watching a monitor and determining which vessels are within the EEZ, or which vessels are in dangerous areas. Action for the Coast Guard or the in charge agency or organisation will be time and cost efficient. Ships can be plotted using SAR images from Seasat and also using SPOT images but here the detection is limited to daytime operations.

In conclusion, of these three alternative systems, INMARSAT and Argos seem to be easier to install and operate for vessel monitoring systems due to

- Reception of a variety of types of information (i.e. engine operating characteristics, cargo conditions, fishing reports), which an image satellite would not be able to transmit.

- Tracking period. Radarsat or other satellites that provide images are restricted by their orbit and period of rotation around the earth. Instead, INMARSAT (together with GPS) or Argos cover the earth 24 hours a day.
- Information analysis. The data provided by INMARSAT or Argos can be used directly to determine the position of a vessel. In case of Radarsat, the digital image should be processed and after that the position of a vessel determined using GIS.

Therefore, in the opinion of the author, it is recommended to make use of either INMARSAT or Argos for vessel monitoring. Which of these two is better? It depends on the data requirements (i.e. time transmission, volume of data) and the cost involved (i.e. installation, services).

Regarding time transmission, volume of data, transmission processes and other services (i.e. voice, e-mail), INMARSAT (Table 17 and Figure 18) is suggested as the alternative of choice. However, both systems can be used in a fishing vessel monitoring system. Moreover, both systems have been on trial in several countries to determine which one was the best for their requirements. As an example, Perú in 1992 decided to initiate a foreign fishing vessel monitoring capability with the Argos system. Another example is New Zealand where it has been decided to use INMARSAT for the same purpose, including the monitoring of their own national fishing fleet.

These technologies provide a potent instrument for fleet owners, operators, and in some cases, governments, to manage their ships. (Springer, 1993)

6. COST COMPARISON BETWEEN TRADITIONAL METHODS AND SATELLITE APPLICATIONS

Costs have always been the first issue looked at by managers in the development of any project. Thus, this section will discuss the viability of satellite uses in the ocean and coastal zone from this point of view. Traditional cost methods will be included as a comparison to establish the economic advantages or disadvantages of these newer methods.

In every contract to be negotiated there are some costs called, in economic terms, "transactional costs". These costs involve:

- Cost for the time devoted to search for information.
- Cost of sending a letter or fax to give or obtain information.
- Cost of data acquisition.

Can satellite applications substantially reduce these costs? Following the previous definition, the advantages of an automated information system, will be not repeating data entry, avoidance of introducing errors or omissions, cost reduction and increase of speed in the procedures.

6.1 Bathymetry

6.1.1 Traditional methods

Estimating the project cost is, of course, subject to the dimensions of the area of interest. Cost of a bathymethic survey is high — roughly $1 million per survey. According to Wagner (1995, page 17), "assuming a track length of 30 kilometres. Applying traditional methods for a 200-meter corridor will run up a bill of $248,000 — that is just for the first three surveys. The ship will also have to perform 15 survey lines. Deriving the bottom topography and planning a pipeline route for the same area with the BAS will cost about $60,000. Only two calibration surveys are required" (See Table 18).

This method involves several surveys in order to define the topography of the area in analysis. In addition, the time involved in the process is one of the most important parameters in some projects for the decision of what kind of methodology will be used.

6.1.2 Satellite applications

An oil company would only have to pay out $200,000 (the cost of SAR imagery acquisition, processing reporting, and calibration surveys by vessels) in comparison to $675,000 that oceanographic vessels surveys have to pay to obtain the bathymetry information to route a pipeline. (Wagner, 1995, page 17).

INMARSAT-C equipment can cost around $10,000 dollars, as INMARSAT-C is easy to install and use, although Argos can be used, too. Even yachts as small as 30ft have been fitted and used INMARSAT without problems. The system allows text messages to be sent and received at low data rates making it ideal for routine communications between a ship and its base office on shore.

The following table gives a clear idea of how much a satellite application on bathymetry can reduce the cost. As Wagner (1995) indicated, by using bathymetry assessment systems (BAS) — which combines ERS-1 synthetic aperture radar (SAR) data with in-situ observations — the users (research, company private or governmental) reduce labour time by a factor of four, and consequently, spend five to ten times less money than would be necessary to do it the old, long way. The conclusion is that clearly time and money can be saved through satellite application for this purpose.

Table 18. Cost (US$) and accuracy of bathymetric data

	Traditional Method	**Traditional Method costs**	**BAS Method**	**BAS Method costs**
Information	Admiralty chart	$40	Admiralty chart + ERS-1	$30,000
RMS accuracy (cm)	214	----------	135	----------
Reconnaissance survey	single track (20 tracks)	$15,000	single track (26 tracks)	$15,000
Route survey, borders of corridor	2 tracks (20 tracks)	$30,000	2 tracks (26 tracks)	$15,000
Pre-lay survey in 200 m corridor	15 tracks	$200,000	----------	-----------
TOTAL		$245,040		$60,000

Source: (Wagner, 1995, page 14)

6.2 Resource distribution

6.2.1 Traditional methods

Regarding oceanographic and fishery surveys, the Argentinean oceanographic vessel (OCA-BALDA) with a total cost of $6,000 per day can be taken as an example. This total cost includes personnel, voyage, equipment and normal vessel operating expenses. Usually the oceanographic and marine resource surveys should be done between 2 to 4 times per year considering 20 to 35 days per voyage. The cost of these surveys could be $240,000 as a minimum or $840,000 as a maximum (Table 20, Annex I).

The cost per day can vary depending on the size of the vessel and the equipment installed on it; such costs per day can be around $40,000, i.e. $1,600,000 to $5,600,000 for a complete oceanographic programme. It is worth mentioning that this is the price for oceanographic surveys only (Table 24, Annex I).

For SIPESA in 1993, the process of data transference regarding fleet monitoring meant a cost of around $10,000 dollars, due to the complex processing of fishing reports, which involved normal mail, their own transport, administrative costs and maintenance of the equipment used. Compared with radio communication of vessel location, this method of monitoring was and still is expensive. However, the amount of information obtained through the reports is useful for fishing resource research and engineering maintenance, which radio communications do not provide. Moreover, the costs of personnel, equipment, software and time were around $40,000. Furthermore, the cost of training programmes to educate the human resource involved with this monitoring system was estimated at $10,000 for that year (Table 24, Annex I). It is worth noting that the vessel operation cost is not considered in this analysis. As a reference the operation cost for the whole SIPESA fleet was around 10,447,884 nuevos soles ($4,619,009.52) in 1993.

The average cost of aircraft surveys was $208,000 considering an average of 5 flights per week for 8 months (the average time of the fishing season for the sardine and the anchovy in Perú), in addition to the personnel, paperwork and administrative costs. Further, these costs vary regarding air-craft availability and the price of the fuel. Moreover, the value of the skilled pilots was a critical factor to quantify.

6.2.2 Satellite application

The main cost is concerned with the satellite image that will be used (Table 19) to better forecast fishing areas or fishing periods. Another inherent cost is the specialised personnel who will manage the information provided by the satellite.

Table 19. Cost of satellite image by distribution company.

Company	Image	Cost	Resolution
Eosat	• 2,500 mile^2 or less • 2,500 to 11,000 mile^2 • Greater than 11,000 mile^2 • Others	• $495 • $995 • $1,495 • $4,000	Depending on the satellite sensor employed can vary from 3 m to 1 km.
Eurimage	Scales can vary from 1:500000 to 1:1000000	less than $2,300	From 30 m (TM sensor) to 1 km (AVHRR sensor)
Radarsat	1,400 mile^2	$2,500 to $4,700	It can vary from 10 to 100m depending on user requirements

Thus the cost for a satellite application on resource distribution involves

- Satellite image receptor or PC plus modem with Internet connection
- Fax machine in each factory or place where the fleet is located plus telephone or other types of communication.
- Trained personnel

Although, satellite images appear expensive compared with other methods (Table 20 and 24, Annex I), the benefits of using satellite image are large, if comparison is based on data transmission time and volume of data (accurate and confident).

6.3 Fleet Monitoring

6.3.1 Traditional method

The way of getting information for fleet monitoring can be done by aircraft surveillance, vessel reports and radio reports (Tables 23 and 25, Annex I). Although aircraft surveillance is too expensive for developing countries, it has been considered in the comparison cost. Thus the discussion will focus on vessel reports through radio or paper and satellite communications.

Regarding vessel reports in the case of SIPESA the cost was the same as in the previous study (*Resource distribution*) because this information was used for both applications. Furthermore, radio communications are the normal way of getting in contact with the fleet. Thus, the cost of buying the radio telephone (HF) equipment (FURUNO 1502) for the whole fleet was approximately $129,000 ($3,000 each plus installation on each vessel). Further, one additional equipment installation in the factory or in the headquarters was considered. Other types of equipment needed were GPS (cost of $2,000 for each). Personnel cost was also included in this analysis. Thus, if SIPESA had bought all the radios required for its vessels, it would have spent around $243,000 plus additional costs for maintenance of the equipment, which was almost $4,500 for all the equipment in that year (1993). However, most of the vessels had at that moment their own radio-telephones and 1/3 of the fleet had GPS. These meant only an investment of $57,333 in equipment.

Regarding aircraft surveillance, the cost was extrapolated by taking the Norwegian experience in that field. The Norwegian survey is done twice (2) times a week; an average of 100 surveys a year (the aircraft type is a Fairchild Merling 3B with a range of action of 2000 nm). The costs involved in this surveillance vary between $772,000 and $1,544,000 dollars a year.

6.3.2 Satellite application

There are new opportunities in the satellite market, which will provide increased numbers of customers, who will in turn cause a cost reduction for equipment in the future due to the free market in this industry. However, procedures to manage the amount of information available need to be established to develop a cost-effective use of the data. So far, the cost of a single report (including latitude, longitude, speed and course) is roughly $0.10 (Gallagher, 1995).

Sainsel of Spain presented a proposal for Fishing Vessel Monitoring to the Peruvian Authorities (Fisheries Ministry) in 1994. In the present paper, this proposal is used as basis for the costs calculation of FVM.

Eurimage is using SAR images from the satellites ERS-1 and 2 for data collection of weather and light conditions. Further, it uses the TIROS/AVHRR and the Landsat configurations to detect fire and oil spills. Other satellite images from SPOT, IRS, RESURS and MIR are used, too.

Prices of Satellite Image Maps by Eurimage depend on the data source, the size of the area and the scale required, i.e. the higher the mapping scale required, the higher the price. For example: for a 50 x 50 km at a scale of 1:25,000, SPOT plus Multi-spectral merge, the price is ECU 33,000 ($41,863). And for a 500 x 500 km at a scale of 1:1,000,000, RESURS, the price is ECU 10,750 ($13,637). (Eurimage, 1996).

Conventional monitoring systems are expensive. As a sample there was a case in West Africa (Argos, 1995), where a plane cost several million dollars, with $1,000 - $2,000 per flying hour. Included in this cost were trained inspector's salary, plus expenses, an office, a car, uniforms, inspection equipment and paperwork giving a cost of about $50 a day, or for an observer about $25. On the other hand, a satellite-based monitoring system (Argos system), which can track vessels continuously, costs less than $20 per vessel per day.

As can be seen aeroplanes and ships will always be needed, but satellites give a wide range of information in space and time. Satellite information provides the inspectors with a useful tool to develop their work faster and more effectively.

The INMARSAT-C coast earth station available for South America is Tangua (ID 114) in Brazil, being the company EMBRATEL the service provider.

Due to the introduction of INMARSAT B and M, the average price of overall INMARSAT voice services has fallen by more than 20% in the last 12 months. INMARSAT off-peak or reduced calling periods have been extended to 10 hours by many CES operators. The most competitive CES operators are now offering INMARSAT voice services at well below $5.00 per minute at standard rates and around $3.00 per minute during off-peak periods. (INMARSAT, 1996).

The INMARSAT equipment prices are summarised in the following table:

Table 21. INMARSAT equipment prices (1996)

Equipment (SES) Cost (US$)	INMARSAT A	INMARSAT B	INMARSAT C	INMARSAT M
From	20,000	20,000	7,000	10,000
To	30,000	35,000	10,000	20,000

To gain maximum savings, messages should be sent as e-mail or EDI wherever possible. The cost of sending a 1000-character message from a vessel via e-mail would be approximately $1.40 and via INMARSAT telex approximately $16.80. E-mail is the cheapest method of global communication available today (Slesinger, 1996). For example, to send a 1000-character message from Hong Kong to Norway the cost via Hong Kong Telecom would be $5.2, via Comtext telex $2.33, and by AT&T e-mail just $2.50. User charges are considered as follows:

Table 22. Cost per minute by type of transmission equipment

User charges	per minute	per minute	per kilobit	per minute
Telephone	$ 3.50 - 8	$ 2-7	N/A	$ 3 - 6
Telex	$ 2 - 4	$ 2-4	US$1 - 1.50	N/A
Facsimile	as telephone	as telephone	N/A	as telephone
Data	as telephone	as telephone	as telephone	as telephone

To calculate the communications costs it is necessary to consider the following:

1. Satellite communication costs

   The service costs vary between $50 to $500 (SAINSEL, 1994), depending on the number of the vessels, number of messages, and length of those messages.

   The cost for 10 vessels transmitting 1 message of 4 blocks per day during 264 days is approximately $27,000 (SAINSEL, 1994).

2. Communication on X.25 costs.

   Communication on X.25 costs depend on the national and international telephone prices and also on the free market competition among the telephone companies. However, for the present case the cost can arrive at $ 6 per day or according to SAINSEL at around $16,000 per year.

3. Telephone costs

   These costs were almost $ 11,000 per year (SAINSEL, 1994).

In total a yearly monitoring system of 10 vessels with 1 message of 4 blocks daily, the cost can be around $45,000 (Tables 23 and 25, Annex I). However, it is important to include that the technology has been improved, as there are now better protocols for communications such as X.400.

In 1988, the USA started fishing vessel monitoring (FVM) to get more cost-effective monitoring, control and surveillance (enforcement) of high-seas fisheries conservation and management measures (Springer, 1993). The USA developed a satellite monitoring method involving mainly foreign vessels; the same project was developed later in 1992 for foreign vessels in Peruvian waters.

Usage costs make INMARSAT-C more worthwhile than HF or Morse telegraphy. Sending an average 80-word message every day for a month using telex via INMARSAT-C costs about $60 as compared to more than $1,000 using telegraphy. (Shankar, 1995, page 113). Data compression can provide a 50% reduction in communication costs.

The cost of transmitting an e-mail containing the same amount of information is only a fraction compared to telex or fax. The method of message transfer is also much less sensitive to interference, avoiding the need to re-send, for instance fax messages. (Asian Shipping, 1995, page 30).

Substantial cost savings, as high as 70 per cent, when compared with telex, have been achieved by the use of high-speed data transmissions over an INMARSAT voice channel. (Howes, 1994; Taylor, 1995). Small messages are cheaper in satellite than in radio communications, depending mainly on the company that provides the services.

SafetyNET and FleetNET are special services which enable messages to be addressed simultaneously to a large number of users (INMARSAT, 1995). The inherent costs are as follows:

- INMARSAT-C mobile equipment cost in the range of $3,000 to $12,000 dollars.
- User cost: $1 per kilobit of information (about 20 words) transmitted; some operators offer prices based on message length or transmission time.

But intelligence can find solutions where there are none. Psychologists once locked an ape in a room, for which they had arranged only four ways of escaping. Then they spied on him to see which of the four he would find.
-The ape escaped a fifth way-.
(Heinlein, 1976, Tunnel in the sky)

7. CONCLUSIONS AND RECOMMENDATIONS

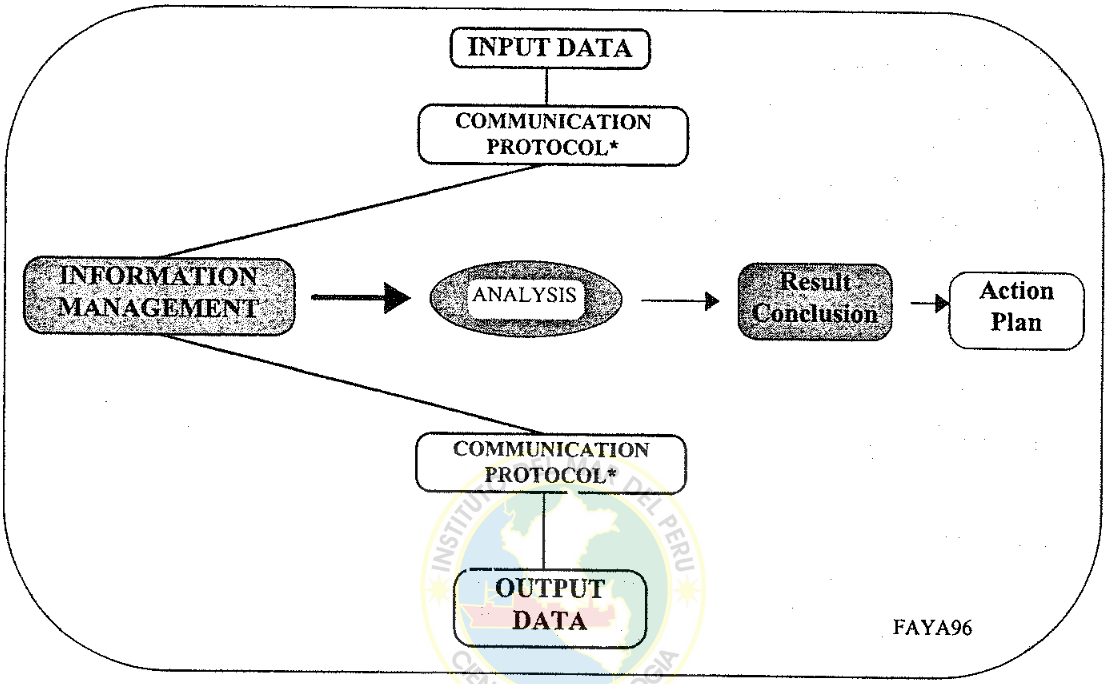
Satellite information is generally global, being useful to see the big picture of oceanographic processes or monitoring of resource conditions and fleet activities. To complement this wide picture, vessel-data which is ideal, provides a way to control and calibrate the satellite data. New advances in technology provide better and more accurate instruments that can give more precise information on small or local areas.

Information is a product likely to sell/buy or interchange, so the output data can be used in the following:
A) Interchanging research of data.
B) Monitoring, oceanographic, biological and fisheries processes.
C) Management (i.e. decision making).

Further, as Kunte & Wagle (1994, page 198) said, the synoptic view of space images provides an opportunity to study integrated coastal areas. Remote sensing with spatial, spectral, and temporal capabilities produces quick, reliable and accurate information on coastal and near-shore processes. Such information can be of vital importance to coastal zone planners in managing the coastal zone.

To conclude, management of information passes through an analysis, providing results and conclusions and ends in an action plan. The communication protocol is managed by the networks (LANs, & WANs) permitting the manager to obtain the information that is required. A simple portrayal of this process is given in Figure 19.

Figure 19. Information management process



* Supplied by Networks (LANs & WANs)

7.1 Bathymetry

Satellite sensors can provide

- enough information to determine the depth of the sea at least in shallow waters
- the tools to reduce cost of bathymetric surveys
- enough information to increase the bathymetry data of the area in analysis
- the way to decrease the labour time for bathymetric observations.

7.2 Resource distribution

Remote sensing gives information regarding the superficial temperature of the sea used as a tool to detect fishing grounds. Benefits coming from this information management can be indicated as:

1. Decreasing searching time and sailing distance to find fishing schools.
2. Decreasing fuel costs.
3. Making alternative searching zones possible to fish quickly and identifying new future fishing zones.
4. Augmenting fishing efficiency

However, remote sensing by satellite is not a panacea, but must be complemented by field data. These linked data will be useful to understand several processes in the sea. Further, adoption of GIS, as the basis for information management and storage, allows managers and planners to have permanent monitoring data, making the synthesis of management plans possible and also improving the quality of the overall database and, thereby, the quality of decision making.

As Davidson (1990) said, the inevitable conclusion is that the successful fishery information services of the future will be characterised by high information content, by timely, error free and secure delivery, and by reasonable communications costs.

7.3 Fleet monitoring

Vessel tracking and communications through satellites permits control of excessive exploitation of fishing fleets over a determined species. It is becoming a new tool for conservation and management of living marine resources.

Monitoring systems can give sufficient data about vessel movements allowing:

- improvement in the efficiency of fishing and the efficiency of the vessel operations.
- control over illegal activities (e.g. illegal fishing).
- control over pollution by vessels, and vessels.
- management of the fishing resources for a sustainable exploitation

Monitoring of fleets has already started in a number of countries. Also, private companies have started to use this new technology with high levels of benefits.

To many nations, whose resources in terms of research vessels or moored buoys are limited, satellites offer the only realistic means of providing regular monitoring of storm surges, potential pollutants, plankton blooms, anomalous temperatures, fronts, and ship traffic within their economic zone.

Fleet monitoring can be useful, especially for fishing for the following reasons:

- Improving the efficiency of fisheries monitoring by identifying potential violations of certain fishing regulations, thereby enabling fishery enforcement officials to analyse relevant details in order to deploy vessels and aircraft to respond directly to specific areas and use vessels in a more efficient manner.
- Increasing fishermen's compliance, including voluntary compliance, with quota, time and area restrictions through enhanced communications and monitoring.
- Improving interjurisdictional fisheries management through improved compliance with established boundaries.
- Reducing the paperwork burdens associated with some current vessel reporting requirements.
- Improving conservation and enhancing ability to achieve Fishery Management Plan goals and objectives by focusing in greater detail on time and area management techniques.

- Increasing vessel safety through special distress signalling capabilities that would alert the Coast Guard and other vessels of an emergency under the Global Maritime Distress Safety System (GMDSS).
- Providing improved fleet management by vessel owners who, with FVM data, would know exactly where their vessels are and the amount of their catches on a real-time basis.
- Enhancing global climate and environmental monitoring activities by voluntary reporting of certain environmental data over a FVM.

Further, a vessel monitoring system contributes significantly to cost-effective enforcement of high-seas fisheries conservation and management measures. Whether implementation occurs through regulation or voluntary participation, it is expected that the fishing industry will see the benefits of improved fisheries management, increased safety, enhanced fleet management, communication cost savings, and in some cases, obtaining a competitive edge.

7.4 Recommendations

The final recommendations can be summarised as follows:

- Fishing Vessel Monitoring should be employed in both national and foreign fishing fleets to control the effort over the resources in order to provide for sustainable exploitation.
- New applications of information management through satellite networks should be investigated.
- The technology gap should be reduced through education. Training programmes in satellite technologies or new technologies must be available for all countries.

In conclusion, this dissertation has analysed three applications of satellite technology in the marine environment. The main aim of this was to look at the advantages and disadvantages of applying these technologies in developing countries (essentially Perú). Throughout this study of the applications of satellite technology the cost of the satellite alternative was found consistently to be comparatively cheaper for the cases studied (*bathymetry and fishing vessel monitoring*) when compared with the use of traditional methods. Only the case of *resource distribution,* was an exception. However, the need and demand for this technology will promote the production of cheaper equipment and procedures in the near future. For example, the satellite image can be actually obtained through the Internet; new software to analyse data are becoming more powerful and easy to use. Thus, the total cost of satellite imagery use can be reduced.

One of the most interesting results of this analysis was that a single satellite can provide more useful information for Ocean and Coastal Zone Management than that available from several vessel or air-craft surveys. However, these traditional methods are still useful for the calibration process.

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ANNEX I. Tables

Table 6. Spatial sampling capabilities of sensors

SATELLITE	SENSOR	Resolution (m)	Bands
SPOT	Multispectral	20	• Visible red • Visible green • Near infrared
RADARSAT	Microwave	10 100	• C-band (5.3 GHz)
RESOURS F	Panchromatic	2-3 5 8 20 2-3 5-10	• Visible
JERS 1	Microwave	18	• L-band
ERS 1	Microwave	25	• C-band
SPOT	Panchromatic	10	• Visible • Near infrared
IRS 1B	LISS 1 & 2	72.5 & 36.5	• Visible red • Visible green • Visible blue • Near infrared
NIMBUS 7	CZCS	825	• Near infrared
LANDSAT	MSS	80 80 80	• visible red • visible blue • near infrared
LANDSAT	TM	30 30 30 30 120	• visible red • visible green • visible blue • near infrared • Mid-infrared

Table 10. List of useful WEB pages for satellite information.

Organisation	Home page
NOAA	http://www.noaa.gov/
ESA	http://www.esrin.esa.it/
EOSAT	http://www.eosat.com:80/index.html
EURIMAGE	http://www.eurimage.it/
NESDIS	http://ns.noaa.gov/NESDIS/NESDIS_Home.html
SeaWiFS	http://seawifs.gsfc.nasa.gov/SEAWIFS.html
INMARSAT	http://www.inmarsat.org
ARGOS	http://www.argosinc.com
METEOSAT	http://neonet.nlr.nl/ceos/METEOSAT_2.html
SAR	http://axp10.iend.wau.nl/sar/sig/sar_reso.htm
NIMBUS-7/TOMS	http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/OZONE.html
Swedish Space Corporation	http://www.ssc.se/
RADARSAT	http://radarsat.space.gc.ca
SPOT Image Corporation	http://www.spot.com

Table 16. SIPESA vessel by age and tonnage

Sindicato Pesquero del Peru S.A. Fleet Department (1993)					
Fishing vessel	Hold capacity	Building year	Re-building year	Number of Register	Operative unit. (Sub-Fleet)
AMAZONAS 2	180	1967	1988	CE-2462 PM	001-PAITA
ASIA 1	200	1968	1987	CE-1137 PM	031-CHIMBOTE
ASIA 3	200	1970	1987	CE-1245 PM	031-CHIMBOTE
CAJAMARCA 9	350	1971	1989	CE-0947 PM	031-CHIMBOTE
CAPLINA 8	180	1966	1987	CE-2466 PM	001-PAITA
EL SOL	180	1963	1990	CE-4520 PM	031-CHIMBOTE
ESTRELLA	420	1992		PS-10414 PM	061-PISCO
FERROL	320	1990		CE-6144 PM	061-PISCO
FLAMINGO	270	1991		PS-6579 PM	041-VEGUETA
GUAÑAPE 9	200	1968	1985	CE-2453 PM	031-CHIMBOTE

HUANDOY	320	1988	1991	CE-6559 PM	031-CHIMBOTE
HUASCARAN	320	1988	1991	PS-6512 PM	041-VEGUETA
IKA 1	200	1967	1987	CE-2478 PM	031-CHIMBOTE
INANSA	400	1993		CE-11079-PM	061-PISCO
INDEPEND. 1	420	1992		CE-10851 PM	041-VEGUETA
INDEPEND. 2	420	1992		PS-10933 PM	031-CHIMBOTE
INMAR 7	150	1965	1987	CE-2464 PM	001-PAITA
ITJ 1	340	1970	1988	CE-2027 PM	041-VEGUETA
JAYANCA	320	1990		PS-6531 PM	031-CHIMBOTE
JEQUE 6	180	1965	1988	CE-2479 PM	041-VEGUETA
JUNIN 8	350	1969	1989	CE-1732 PM	001-PAITA
MANU 7	180	1966	1989	IO-0827 PE	041-VEGUETA
MISTI 1	320	1988	1991	CE-6527 PM	061-PISCO
NAPO 3	180	1963	1988	CE-2469 PM	031-CHIMBOTE
OLMOS	320	1990		CE-6141 PM	061-PISCO
OLMOS 2	420	1992		CE-10850 PM	061-PISCO
PIZARRO 10	260	1968	1988	CE-2461 PM	001-PAITA
PROGRESO 2	100	1962	1988	CE-5043 CM	001-PAITA
PROGRESO 3	100	1963	1989	CE-5044 CM	001-PAITA
RIMAC 2	180	1967	1988	CE-2467 PM	041-VEGUETA
RIMAC 9	180	1966	1987	CE-0196 PM	041-VEGUETA
ROMINA 1	350	1970	1980	HO-4667 PM	041-VEGUETA
SALKANTAY	400	1993		HO-10722 PM	031-CHIMBOTE
SAN GALLAN 4	200	1965	1987	CO-2658 PM	041-VEGUETA
SECHIN	320	1990		CE-6143 PM	061-PISCO
SECHIN 2	420	1992		PS-10061 PM	041-VEGUETA
SIPAN	400	1993		CE-11080-PM	031-CHIMBOTE
TALARA 6	340	1971	1988	CE-2477 PM	041-VEGUETA
TARATA 2	320	1969	1989	MO-4442 PM	061-PISCO
TARATA 3	320	1969		CE-4830 PM	031-CHIMBOTE
VEGUETA	320	1991		PS-6243 PM	061-PISCO
YUTTA 13	150	1965	1987	CE-2463 PM	001-PAITA
ZAÑA	320	1991		HO-6173 PM	061-PISCO

Table 17.

COMPARISON OF MESSAGE SIZES AND TRANSMISSION TIMES

	MESSAGE SIZE			MF/HF		INMARSAT-A							INMARSAT-C		
				MORSE	TELEX	TELEX	FAX	DATA					TELEX	DATA	
							O'head 15s	2400 bits/s (O'head 10s)		9600 bits/sec (O'head 22s)				600 bits/sec	
								No Comp.	50% Comp.	No Comp.	50% Comp.			No Comp.	50% Comp.
	CHARS	MINS TELEX	KBITS	WORDS	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN	MINS INCR. 0.1 MIN		kbits Incr. 0.25kbit	kbits Incr. 0.25kbit	kbits Incr. 0.25kbit
AVERAGE SIZE TELEGRAM	100	0.25	0.78	20	0.3	0.3	0.6	0.2	0.2	0.5	0.5		1	1	0.5
AVERAGE SIZE TELEX	400	1	3.13	80	1	1	0.8	0.3	0.2	0.5	0.5		3.25	3.25	1.75
1 AVERAGE A4 PAGE	2500	6.25	19.53	500	6.3	6.3	1	0.4	0.3	0.6	0.5		19.75	19.75	10
5 AVERAGE A4 PAGES	12500	31.25	97.66	2500	31.3	31.3	4	1.1	0.7	0.8	0.6		97.75	97.75	49
MAX INM-C MESSAGE (32 KBYTES)	32768	81.92	256	6550	82	82	10	2.5	1.4	1.2	0.9		256	256	128

NOTES: Relationships between message sizes (Characters per page, characters per word etc.) are typical approximations and may vary depending on message contents. Transmission times are considered to be valid under normal conditions. Considerable variations may occur, especially for Inmarsat-A fax and data. For unit charges please contact your service provider(s) or your Radio Traffic Accounting Authority.

Table 20. Cost comparison between traditional methods and satellite application on resource distribution

Method	Cost	Data	Observation
Traditional methods			
• Oceanograhic and biologic surveys	$240,000 to $840,000	• Sea surface temperature and salinity • Water column temperature and salinity • Other oceanographic parameters • Resource distribution	• It is done two or four times in a year • It is a slow process for analysis and reporting results
• Fishing vessel reports (SIPESA)	$60,000 per year	• Sea surface temperature • Temporal distribution of the fishing resources	• High volume of data • It is a slow process of analysis producing a management report after a week of received data
• Aircraft surveillances	$208,000	• Sea surface temperature • Surface distribution of the resources	• No specific species • It is a quick process of obtaining data
Satellite application			
• Image satellite	It can vary from $300 to $3,000 per image. If it is considered 1	• Sea surface temperature	• It is an indirect method to determine the

	image per day for a year the cost can be $109,500 as minimun or $1,095,000as maximum.		distribution of the marine resources • It can cover a wide area • It is a very fast way of getting information of the sea conditions

Table 23. Cost distribution by methodology applied

	Equipment per vessels	Equipment on land	Cost	Observations
Vessel reports	GPS.	Computer	$179,251.81	• Daily reports • Information analysis after a week
Aerial surveillance	Aeroplane radar and radio	Computer, radio	$772,000 to $1,544,000	• The aircraft cost was not considered • Flight period of 6 hours per day for 2 to 3 times per week for a year • Information can be analysed in quasi-real time
Satellite connection	• INMARSAT + GPS or Glonass • Argos system	• Computer • Computer	$40,000 to $80,000	• Dialy vessel monitoring • Consideration of 10 vessel s during a fishing year sending 10 parameters per time of contact

Table 24. Cost (US$) comparison for resource distribution

	Traditional Method (1)	Traditional Method (2)	Traditional Method (3)	Satellite method costs
A. Data transference costs	--------------	$10,000	-------------	summarised in D
B. Personnel, equipment and maintenance costs	--------------	$40,000	$48,000	summarised in D
C. Training programmes cost	--------------	$10,000	-------------	-----------------
D. Operation costs	$240,000 include B	$107,418.81 for one vessel	$160,000 include A	min. $109,500 max. $1,095,000
TOTAL	**$240,000**	**$167,418.81**	**$208,000**	**$1,095,000***

(1) Oceanographic and biologic surveys

(2) Fishing vessel reports

(3) Aircraft surveillance

*** For this comparison the maximum value for satellite method costs has been considered**

Table 25. Cost (US$) comparison for fishing fleet monitoring

	Traditional Method (1)	Traditional Method (2)	Satellite method costs
A. Data transference costs	--------------	$10,000	summarised in C
B. Equipment and maintenance costs	--------------	$57,333 new equipment $ 4,500 maintenance. = $61,833	summarised in C
C. Operation costs	min. $772,000 max. $1,544,000	$107,418.81 for one vessel	min. $40,000 max. $80,000
TOTAL	$772,000	$179,251.81	$80,000*

(1) Aircraft surveillance

(2) Fishing vessel reports

*** For this comparison the maximum value for satellite method costs has been considered**

ANNEX II. Operational Satellite Programmes (UNEP/IOC, 1992)

1. - Landsat Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Band	Wavelength (µm)
Landsat-4 Landsat-5	1982 1984	705km	16	MSS, res.80m	1 2 3 4	0.5 -0-6 0.6 - 0.7 0.7 - 0.8 0.8 - 1.0
Landsat-4 Landsat -5	1982 1984	705km	16	TM res.30m; res.120m (band 6)	• 1 • 2 • 3 • 4 • 5 • 6 • 7	• 0.45 - 0.52 • 0.52 - 0.60 • 0.63 - 0.69 • 0.76 - 0.90 • 1.55 - 1.75 • 10.40 - 12.50 • 2.08 - 2.35
Landsat-6	1991	705km	16	ETM res.15m	• 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8	• 0.45 - 0.52 • 0.52 - 0.60 • 0.63 - 0.69 • 0.76 - 0.90 • 1.55 - 1.75 • 10.40 - 12.50 • 2.08 - 2.35 • 0.50 - 0.90
Landsat-7	near future	705km	16	ETM-TIR res.15-120m.	1 2 3 4 5 6 7 Pan	0.45 - 0.525 res.30 0.515 - 0.60 res.30 0.63 - 0.69 res.30 0.75 - 0.90 res.30 1.55 - 1.75 res.30 10.4 - 12.5 res.60 2.09 -2.35 res.30 10.40 - 12.5 res.60
Landsat-7	near future	705km	16	SeaWiFS res.1.13 - 4.5 Km	1 2 3	0.443 - 0.453 0.490 - 0.510 0.555 - 0.575

					4 5 6 7 8	0.655 - 0.675 0.745 - 0.785 0.843 - 0.887 10.5 - 11.5 11.5 - 12.5
Landsat-7	near future	705km	16	MSA (ALS) res.10 - 20 m.	32 bands	visible, near-IR, mid-IR

2. SPOT Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Wavelength (µm)
SPOT-1 SPOT-2 SPOT-3	1986 1990 1993	830Km	26 (3 or 4)	HRV res.10 - 20m.	0.51 - 0.73 0.50 - 0.59 0.61 - 0.68 0.79 - 0.89
SPOT-4 SPOT-5	1995 in 1999	830Km	26 (3 or 4)	HRVIR res.20m	HRV + 0.61 - 0.68 1.58 - 1.75
SPOT-4 SPOT-5	1995 in 1999	830Km	26 (3 or 4)	VGT res.1 - 4 Km	HRV bands + 0.43 - 0.47

3. NOAA Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (µm)
NOAA-9 NOAA-11	1984 1988	833-870Km	11	AVHRR res.1.1 Km	1 2 3 4 5	0.58 - 0.68 0.72 - 1.18 3.55 - 3.93 10.3 - 11.3 11.5 - 12.5
NOAA-9 NOAA-11	1984 1988	833-870Km	11	HIRS res.17.4 Km	1-5 6-7 8	14.95 -13.97 13.64 -13.35 11.11

					9 10-12 13-17 18-20	9.71 8.16 - 6.72 4.57 - 4.24 4.00 - 0.069
NOAA-K NOAA-L NOAA-M	1995			minor changes	1 2 3A 3B 4 5	0.58 - 0.68 0.72 - 1.00 1.58 - 1.64 3.55 - 3.93 10.3 - 11.3 11.5 - 12.5

4. TIROS-N Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor
TIROS-N	1978	850Km	11	AVHRR, HIRS

5. NIMBUS Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (μm)
NIMBUS-7	1978	955Km	6	CZCS res.800m	1 2 3 4 5 6	0.43 - 0.45 0.51 - 0.53 0.54 - 0.56 0.66 - 0.68 0.70 - 0.80 10.5 - 12.5

6. Canadian Radarsat Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (μm)
RADARSAT	1994	793-821 Km	1	SAR res.28m	C-band	5.7 cm

7. METEOSAT and MOP Programmes

Satellite	Orbit (year)	Altitude	Sensor	Channel	Wavelength (μm)
METEOSAT-1 METEOSAT-2 METEOSAT-3	1977 1981 1988	34,913 - 35,692	MSS res.2.5 - 5 Km	1 2 3	0.4 - 1.1 5.7 - 7.1 10.0 - 12.5

8. ERS Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (μm)
ERS-1 ERS-2	1991 1993	800Km	3, 35 and 176	ATSR res.1 - 50 Km	infrared micro-wave	1.6, 3.7, 11 and 12 0.82 and 1.26
ERS-1 ERS-2	1991 1993	800Km	3, 35 and 176	AMI res.50 - 100 Km	C-band	5.6cm

9. JERS Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (μm)
JERS-1	1992	570Km	44	OPS res. 8x14m	1 2 3 4 5 6 7 8	0.52 - 0.60 0.63 - 0.69 0.76 - 0.86 0.76 - 0.86 1.60 - 1.71 2.01 - 2.12 2.13 - 2.25 2.27 - 2.40
JERS-1	1992	570 Km	44	SAR	L-band	23.5cm

10. MOS programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor
MOS-1 MOS-1B	1987	909Km	17	MESS, VTIR and MSR

11. ADEOS Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (µm)
ADEOS	1993	800 Km	41	OCTS	1	0.402 - 0.422
				res.700 m.	2	0.433 - 0.453
					3	0.480 - 0.500
					4	0.510 - 0.530
					5	0.555 - 0.575
					6	0.655 - 0.675
					7	0.745 - 0.785
					8	0.845 - 0.885
					9	3.550 - 3.850
					10	8.250 - 8.750
					11	10.50 - 11.50
					12	11.50 - 12.50
ADEOS	1993	800 Km	41	AVNIR	1	0.42 - 0.50
				res.8 - 16	2	0.52 - 0.60
				m.	3	0.61 - 0.69
					4	0.76 - 0.89
					5	0.52 - 0.69

12. Resurs-O and Resurs-F Programmes

Satellite	Orbit (year)	Altitude	Sensor	Wavelength (μm)
Resurs-F	1990	260 - 275 Km	KFA-1000 camera res.5 - 10m.	
Resurs-O	1988	650Km	MESS res.45 m	0.50 - 0.60 0.60 - 0.70 0.70 - 0.80 0.80 - 0.90
Resurs-O	1988	650Km	MCSS res.150 - 600m.	0.50 - 0.60 0.60 - 0.70 0.70 - 0.80 0.80 -1.10 10.5 - 12.5

13. Okean Programme

Satellite	Orbit (year)	Altitude	Sensor	Wavelength (μm)
Okean-1	1988	650Km	SLR res.1.5 Km	3.15cm
Okean-1	1988	650Km	SHF res.200m.	0.8 cm
Okean-1	1988	650Km	MSU-M res.1500 m.	0.55 - 0.70 0.70 - 1.00

14. IRS Programme

Satellite	Orbit (year)	Altitude	Cycle (days)	Sensor	Channel	Wavelength (μm)
IRS-1A	1988	904Km	22	LISS-I and LISS-II res.72.5 and 36.25 m.	4 bands	0.45 - 0.86