PROJECT COMPLETION REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: Identification of Important Marine Habitat

PROJECT PERIOD: July 1, 1987 to September 30, 1987

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This project was financed in part with federal Coastal Zone Management funds administered through the Oregon Department of Land Conservation and Development.

ABSTRACT

In response to ocean resource planning needs, we are designing a long term program to combine environmental and biological data to identify discrete habitats in the ocean. The long term program, called Ocean Habitat Analysis and Mapping (OHAM) is intended to help define areas of special biological significance and understand how fishery resources respond to changes in environmental variables. The Ocean Habitat Analysis and Mapping system will include economic data to improve fisheries management and to help us respond to resource use conflicts.

This report describes the Ocean Habitat Analysis and Mapping system and a fish catch mapping pilot project. The pilot project's primary goal was to show how a comprehensive data analysis and mapping system could be used to describe ocean habitats. For the pilot project we set the structural framework for storing and analyzing different types of data bases, and compiled three years of fishery data to show how different data sets fit into the long term OHAM system. Additionally, we mapped the fishery data, comprised of commercial pink shrimp and groundfish catch data. The maps, stored at the Oregon Department of Fish and Wildlife's Marine Region and at the Department of Land Conservation and Development Salem office, are examples of the type of data display that the Ocean Habitat Analysis and Mapping system is expected to produce.

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INTRODUCTION

The continental shelf and slope contain critical habitats for fish and shellfish species that provide social and economic benefits to Pacific Northwest residents. The species caught provide recreational, economic, and nutritional benefits to residents of other parts of the United States as well. Current national efforts to extract oil and precious metals from the continental shelf could threaten these valuable fishery resources if the impending development activities are not carefully planned.

In response to the need for information on ocean resources, we designed a pilot project to show how commercial fishery data could fit into a long term program intended to link environmental and biological data. By combining environmental and biological data we expect to be able to identify discrete habitats in the ocean. The long term program, called Ocean Habitat Analysis and Mapping (OHAM) is intended to help define areas of special biological significance and understand how fishery resources respond to changes in environmental variables. The OHAM system will include economic data to improve fisheries management and to help us respond to resource use conflicts.

The primary goal of the pilot project described in this report was to set up the structural framework for storing and analyzing different types of data bases. We developed the computer programs and techniques needed to analyze and map fishery logbook data. An auxillary goal was to enter test data sets of commercial pink shrimp and groundfish fishery information to show how existing fishery catch records fit into the long term OHAM system.

The test data enabled us to produce a mapped summary of Oregon's commercial trawl catch in approximately five mile by five mile increments off the coast of Oregon for a three year period. A map of bottom sediments accompanied the fishery data to show how physical oceanographic information can be used with fishery information to identify important marine habitats. The maps, stored at the Oregon Department of Fish and Wildlife's (ODFW) Marine Region and at the Department of Land Conservation and Development (DLCD) Salem office, are examples of one type of data display that the Ocean Habitat Analysis and Mapping system is expected to produce.

Background

The U.S. Department of the Interior, through the Minerals Management Service (MMS), recently began a five year process leading up to the sale of lease areas for the purpose of extracting oil and gas from the continental shelf off Washington, Oregon, and Northern California (Risotto and Rudolph 1986). Additionally, mineral, sand, and gravel mining is expected to occur sooner than oil extraction in this area (Good and Hildreth 1985).

The exploration and development of oil, gas, minerals, sand, and gravel deposits will create environmental and resource use conflicts in the Pacific Northwest. State governments are concerned that the exploitation of the non-renewable resources will be detrimental to the renewable fishery resources and thus negatively impact the fishery and tourism base of coastal economies. The states understand that the stability of coastal economies is dependent upon the long term availability of renewable fishery resources, and desire to participate in coastal zone planning to ensure that offshore development is compatible with the long term use of fishery resources.

Existing biological and fishery resource inventories are too general for use in reviewing specific development proposals. The Oceanographic Institute of Washington (1977), Stander and Holton (1978), and Parmenter and Bailey (1985) provided general descriptions of the fishery resources in the coastal zone, but these inventories are too general for use in responding to specific development proposals. The fishery resource agencies of each state provide summaries of the distribution and rate of catch of commercial species, but the data are processed and reported in much larger units than is useful for evaluating offshore development proposals (PACFIN, PMFC).

There have been many studies describing the distribution and relative abundance of fish in small areas. Harvey and Stein (1986) recently completed a summary of knowledge of the distribution and relative abundance of the nekton in the Pacific Northwest. Although their work was primarily confined to the small Gorda Ridge study area, it did point out the overall lack of information about the distribution or relative abundance of commercial species. We need more specific information about fishing locations and the distribution of fishery resources to objectively identify impacts of specific development activities and suggest ways to minimize adverse impacts on ocean resources and fisheries.

In response to the need for more specific fishery information we started designing the OHAM system as a direction we could move in to more adequately define ocean habitats. The completion of the OHAM system will take a large expenditure of time and money. The fisheries catch mapping (FISHMAP) techniques developed in this project, however, represent a large step forward in our ability to define, locate, and analyze ocean habitats.

OCEAN HABITAT ANALYSIS AND MAPPING SYSTEM

We designed a long term data acquisition and analysis plan in response to the need for more precise biological information. The goal of the long term plan is to create a comprehensive set of data bases of physical, biological, and economic information for resource managers and researchers. The comprehensive data bases should help resource managers identify resource use conflict areas, environmental effects of development, impacts of harvest activities, areas of special biological significance, and the relative values of species harvested from specific areas. It will also help researchers propose and test hypotheses of physical and biological interactions. The data bases will be standardized to make different types of information as comparable as possible. In that way, quantitative comparisons will be possible with dissimilar data sets.

Many different types of biological, physical, and economic data sets exist. Some are long term data series and very complete; others are sporadic or contain few observations. Researchers and managers would benefit by the combined knowledge of results of work conducted in the different disciplines, but many of the data sets are inconvenient to use or inaccessible. Our plan is to bring several different types of data together and develop a way of comparing the data in order to learn more about the location and nature of fishery resources and the environmental factors influencing the distribution of those resources.

Figure 1 generally outlines the components of the Ocean Habitat Analysis and Mapping system we are constructing. Obviously, an important component of the system is the acquisition of data sets. Various types of existing data bases need to be identified and acquired. Existing types of data bases include:

Physical Data Bases:

- Bottom topography
- Sediments
- Subsurface geology
- Sea surface temperatures
- Pressure gradients
- Wind field measurements
- Current measurements
- Chlorophyll A concentrations
- Miscellaneous physical measurements

Biological Data Bases:

- Fisheries logbooks
- Official landing records
- Biological samples of commercial catch
- National Marine Fisheries Service (NMFS) groundfish triannual research cruises
- Other non-periodic research cruises

Economic Data Bases:

- Official landing records
- Data in Fisheries Economic Assessment Model (Jensen and Radtke 1987)

Some of the data bases listed above are on computer disk, some are in digital form but not currently in easily

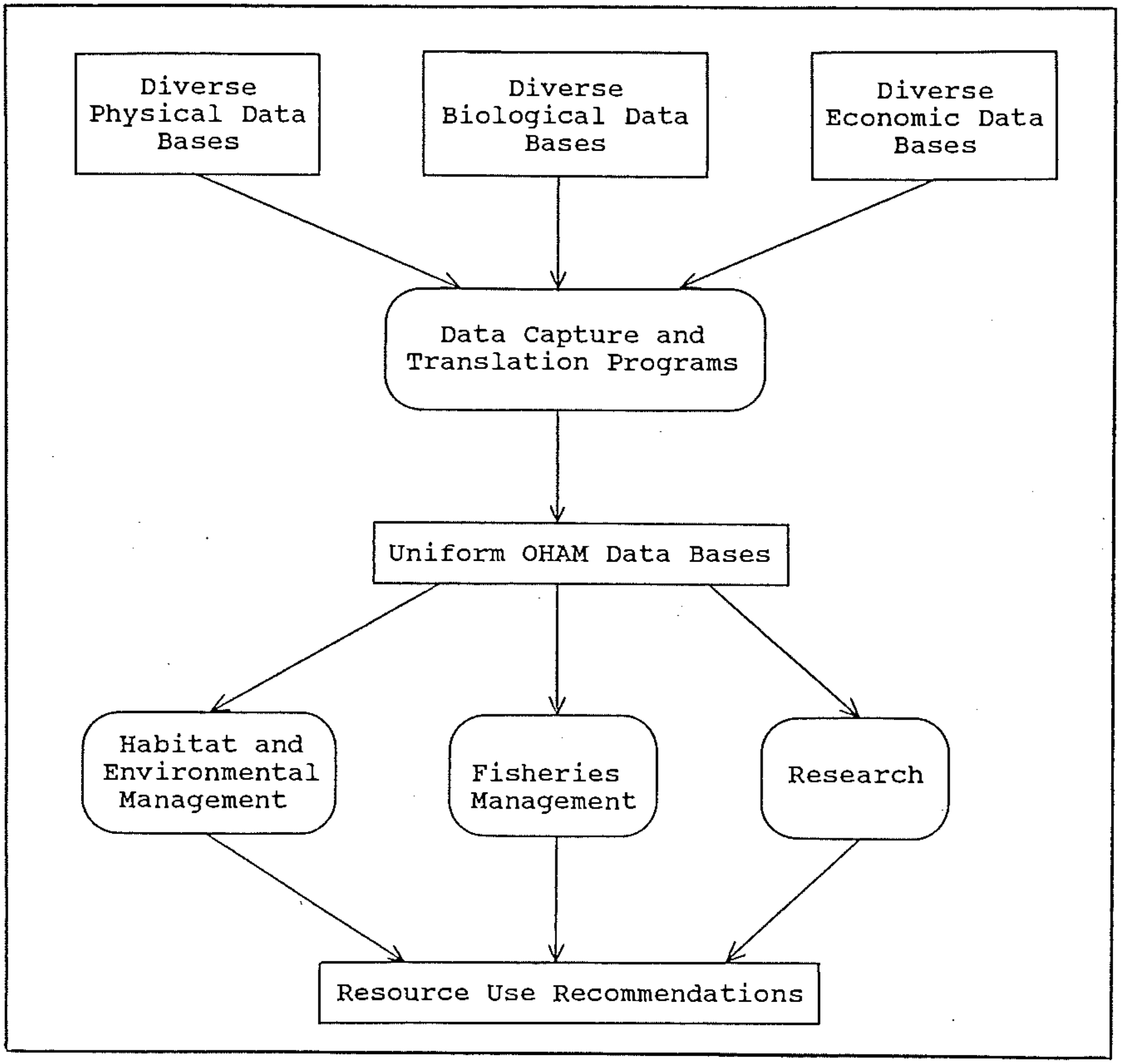


Figure 1. Generalized structure of Ocean Habitat and Mapping system.

accessible formats (such as satellite data), and some currently exist in handwritten form only. In general, the long term physical data sets occur in National Oceanographic and Atmospheric (NOAA) and US Geological Survey records, and the long term biological and economic data occur in Washington Department of Fisheries (WDF), Oregon Department of Fish and Wildlife (ODFW), California Department of Fish and Game (CFG), and International Pacific Halibut Commission files.

A big challenge in our work was to design a data storage system that enabled all the data bases to be entered into a computer and summarized in a consistent format. We accomplished that objective by selecting a geographic coordinate system as the primary reference criterion. By using coordinates of latitude and longitude, and entering data as a point in time and space, we could readily compare all data types. Data comparisons were enhanced by recording the time of day and date of observation of the variable entered, and by standardizing units between data bases.

A large task yet ahead of us is to locate and acquire the data bases that currently exist, and eventually to add new data to the system. Once the data bases are acquired and standardized, combinations of data types can be used for environmental management, fisheries management, and fisheries research.

The most obvious use of the OHAM system in environmental management will be to identify locations of resource use conflicts and impacts of development (Fig. 2). The intersection of development proposal areas and areas of special biological significance will be readily apparent using the OHAM system. We have already observed the utility of this system. Although the system was expected to be used first to evaluate offshore oil and gas lease sales, we have used the data to help evaluate a proposed artificial reef off the mouth of the Siuslaw River. By knowing the location of the proposed reef and the pounds of groundfish landed from the immediate area, we were able to quantify the impacts of the artificial reef on the commercial catch of groundfish. The system will work even better for this purpose when our groundfish data set is stored by catch of individual species. Also, with the addition of the economic data set we would be able to identify the economic tradeoffs between the loss of commercial catch of specific groundfish species and the projected revenues generated by anticipated sport catches of rockfish.

The OHAM system will be very useful for fisheries management issues as well. The system will help more precisely define the locations of catch of specific species, and describe the relationships between habitats and species. With this information and population dynamics models we will more accurately predict the biological impact of different

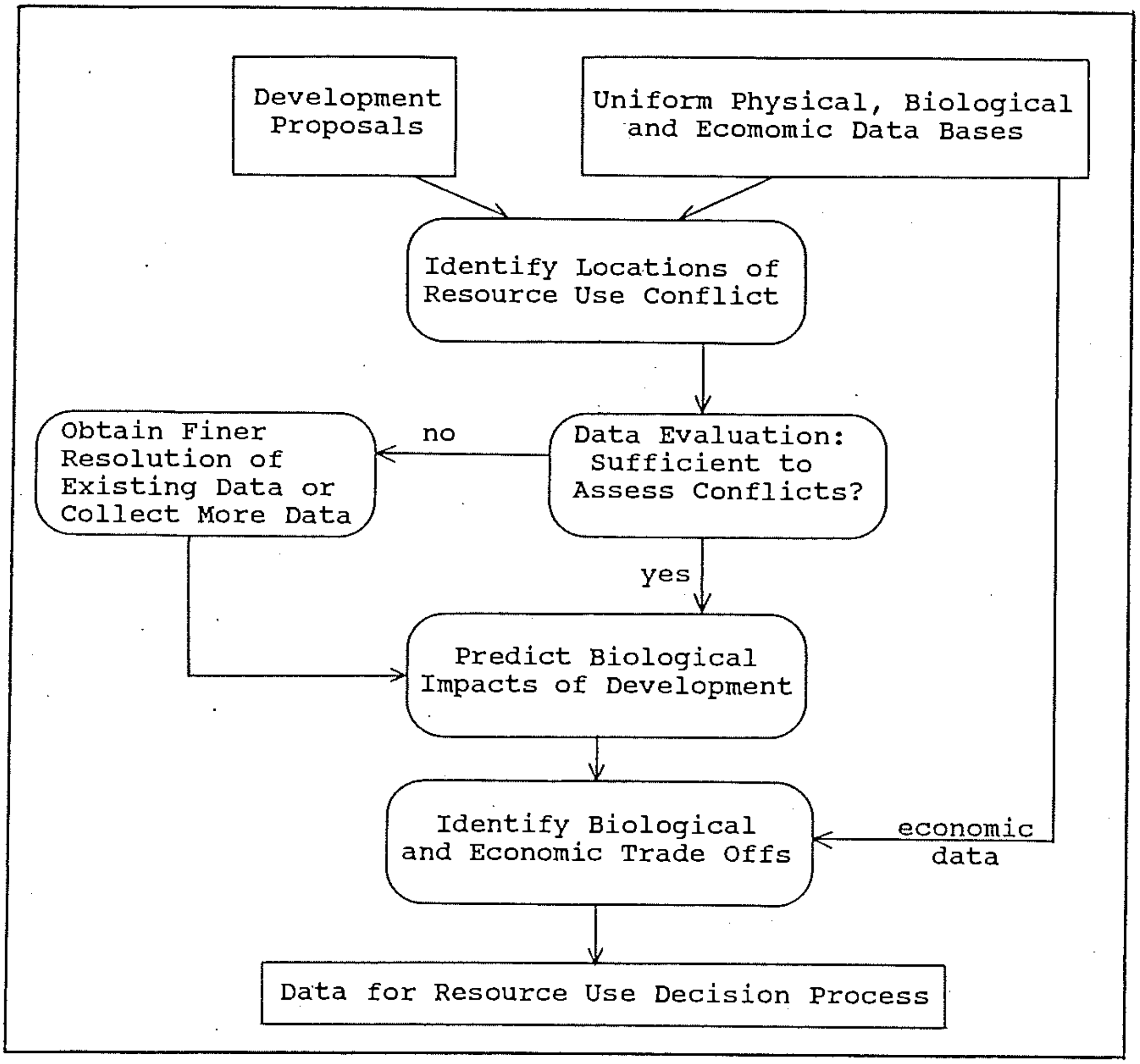


Figure 2. Habitat and enviromental management uses of Ocean Habitat Analysis and Mapping system.

management strategies. Again, by including economic data sets we will also be able to identify the economic tradeoffs of different management strategies.

For large areas that type of fisheries management analysis already occurs. The OHAM system will allow us to conduct detailed biologic and economic analyses for small areas as well (Fig. 3). For example, the OHAM system would have been useful in April 1987 when the WDF, to protect soft-shelled crab, proposed a summer closure of the commercial trawl fishery in water from 6 to 20 fathoms deep along the coast of Washington. The proposed closure included the "bar tow" at the mouth of the Columbia River, an area traditionally used by the Oregon trawl fleet for sand sole fishing. If the test data set of groundfish catch had been summarized by species, we would have been able to describe the average landings of sand sole in the summer months from that area for a period of years. With specific catch information, and the corresponding economic data, we would have been able to quantify the biological and economic tradeoffs related to the proposal to close the "bar tow" to trawlers.

The OHAM system will be extremely valuable for fisheries research. It will enable scientists to graphically view the relationship between a larger number of variables than currently possible. It will also allow us to

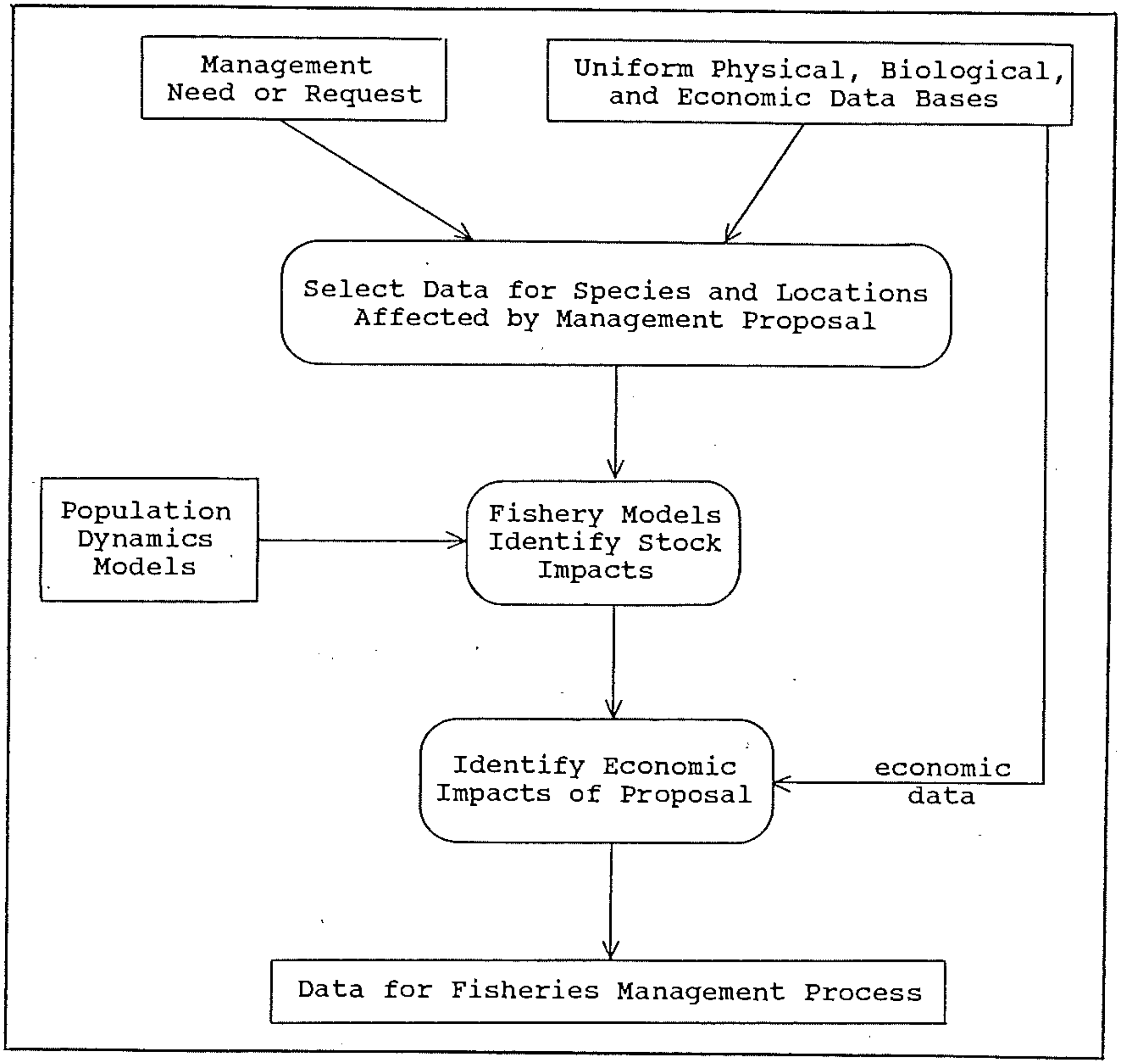


Figure 3. Fisheries management uses of Ocean Habitat Analysis and Mapping system.

combine physical and biological data sets in an infinite number of ways, and promote the formation and testing of research hypotheses. The use of a computerized geographic information system (GIS) for the hypothesis testing will enable us to rapidly evaluate numerous combinations of large data sets. With the juxtaposition of physical and biological data sets we expect to be able to identify and define important spawning and rearing grounds for a large number of species. We also expect the data to shed light on the variables influencing the catchability of commercially and recreationally important species.

The physical and biological data will be keyed to geographic location, date, and time of day. We designed the data base system that way to enable us, with the proper computer equipment, to graphically portray biological changes in time and space. The graphic display we envision is an animated view of environmental changes and corresponding changes in fish distribution. We expect to learn a great deal about the factors influencing changes in fish distribution by rapidly portraying combinations of different data sets displayed in a time sequence. We envision a computer simulation similar to the nightly weather forecast on television, in which the viewer sees an animated time series of satellite photographs.

OHAM PILOT PROJECT

The long term habitat analysis program we are designing can be divided into a number of sequential tasks (Table 1). The pilot project described in this report allowed ODFW to begin work on ocean habitat analysis and provide preliminary results to show how the OHAM system could be used in ocean resource planning. Because this project was a pilot project, we did not complete all 17 tasks outlined in Table 1. Instead, we selected tasks that would provide the best indication of how the long term OHAM system could be used for ocean resource planning and management.

We chose to work on tasks numbers 1 through 5, 8, 9, 11, and 14. Tasks 1 through 5 were necessary so the OHAM system would have shape and substance. After selecting the data base environment to work with and the size of the coordinate grid, we worked on programs to convert various data formats into a uniform data base format. We then entered and summarized a small data set of pink shrimp fishery information to show how raw logbook data could be entered into the system.

Computer System

Several criteria influenced our choice of a computer system. Sufficient data storage was a major consideration. From the birth of this project it was known that an extremely large amount of data would be utilized, and that these data would require a large degree of repetitive processing. In addition, since this project was by design a development exercise for using a computer to map fishery catch data, we

Table 1. Tasks required to complete the long term OHAM program.

1. Select and design a suitable data base environment.
2. Define, in parallels of latitude and meridians of longitude, a grid to serve as a reference base for oceanographic data.
3. Develop translational programs to convert long range navigation (LORAN) information into coordinates of latitude and longitude.
4. Develop computer programs to standardize units of measure and to delineate individual species caught. Design the programs to be able to summarize the data by time of day and date.
5. Develop computer programs to merge catch data with official landing records to translate estimated catch to actual pounds caught and to identify the ex-vessel value of each species caught.
6. Develop computer programs to merge fishery catch information with biological market sample data such as length, weight, sex, and maturity stage of individuals collected in the fishery.
7. Develop programs to import existing biological, physical, and economic data bases and transform them into the OHAM format.
8. Develop programs for computer entry of unprocessed fishery logbook and market sample data.
9. Enter fishery logbook data collected for the last 10 to 15 yr.
10. Enter biological market sample data for years with corresponding catch data.
11. Import the official landing records and ex-vessel value data that match fishery logbook data.
12. Import or enter biological research data from NMFS groundfish surveys and other approptiate research projects.

Table 1. Continued.

13. Import appropriate physical data bases from NOAA satellite data collection programs.
14. Import or enter data from appropriate bottom topography and sediment surveys, wave and current studies, and other sources of physical oceanographic information.
15. Develop computer capability to allow graphic display of data intersections to identify resource use conflict areas.
16. Develop computer capability to allow multiple correlations of data and the use of specialized interactive models for statistical analysis.
17. Develop computer animation capability to display data in a time series progression, either as raw data or in simulation models.

wanted the system to be flexible enough to allow us to be creative. We also wanted the ability to display large amounts of summarized data on tables, graphs, and color maps. And finally, we wanted to keep the cost down as much as possible.

We elected to use a microcomputer as a host for the fisheries catch data mapping portion of the OHAM system. Our computer hardware consists of an AT compatible 80286 microcomputer with a 6 or 10 megahertz selectable clock. Internally this machine includes a 80287-8 coprocessor, one megabyte (mb) of Random Access Memory (RAM), a parallel port, two serial ports and an Enhanced Graphics Adapter video card. For data storage we selected one 360 kilobyte (K) and one 1.2 mb floppy disk drive, and a Bernoulli box. The Bernoulli box uses two removable cartridges which can each store 21.8 mb. A color monitor was selected for video display.

We knew from the beginning of this project that we would be dealing with large amounts of information, and that the software (operating system, data base, etc.) which we selected would have to be powerful and flexible enough to handle this information. Using the 1986 shrimp fishery as an example, we discovered that we would have approximately 2,775 official landing records. We collected about 60-70 % of the logbooks associated with those landings, and thus started with about 1,800 logbook landing records. Each of the logbook landings had an average of 15 tows per record, yielding 27,000 sub-records. A data handling requirement of this magnitude rules out many data base software environments. Many commercial data bases are limited in the number of records there can be in one file, the size of the record or file, the number of fields which can be used to sort, and so on. Since we wanted an environment which was powerful and flexible we chose Cosmos Inc's, Revelation (REV) data base management environment. Release G2B seemed at the start of this project to fulfill our needs. Revelation contains powerful data entry design, programming, text editing, and report modules. To date, as future projects are planned and dreamed, REV still seems to be the best data base environment for our needs.

FISHMAP

A primary goal of the OHAM pilot project was to develop techniques to analyze and map fisheries catch data. Fisheries catch data mapping (FISHMAP) is a large component of ocean habitat analysis. Many years of catch data exist in several different locations, and will provide tremendous insight into ocean habitats when all the data are accessed and summarized. Figure 4 provides an overview of the steps required to capture, translate, and map fishery catch data.

Reference Grid

In order to map anything we first needed a reference base to use for locating information on a map. Only then could we proceed with distributing information such as catch on a map. Fishery catch data are often mapped on a nautical chart, or some representation of one, showing pre-defined management or

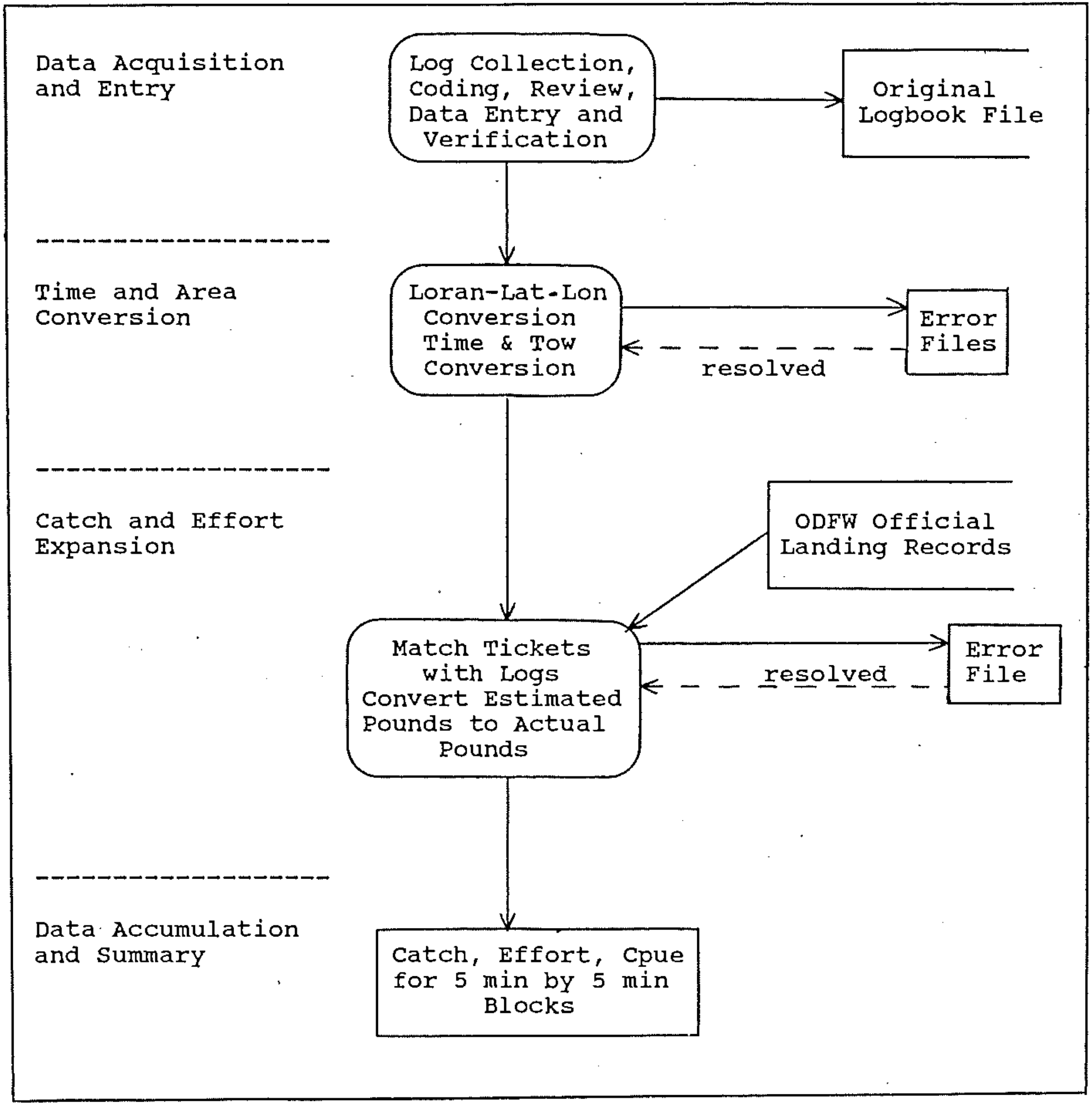


Figure 4. Schematic flowchart of FISHMAP process.

research areas. The traditional areas for managing Oregon's shrimp and groundfish fisheries have been State Statistical and Pacific Marine Fisheries Commission (PMFC) areas. In general these areas are defined by some geographic location along the coast, and extend westward as far as any Oregon fishery takes place. In this shape, State Statistical and PMFC areas cover 1,000 to 2,500 square miles of ocean.

The OHAM system requires a much finer resolution than this to effectively define habitats. We designed a reference grid system to work on point locations of latitude and longitude. This allows us to at any time modify the grid resolution to be fine enough to be used for the evaluation of specific development proposals such as may come from the mineral and oil industries.

Although the smallest possible grid seems preferable, the scale of the data limits the minimum size of the grid. For instance, the grid for FISHMAP must have a resolution somewhat larger than the length of a trawl tow, the item used to characterize the data. Since the primary data sets for FISHMAP come from trawl logbooks, we built the reference grid to a scale that fits the length of trawl tows. We also designed the reference grid to fit in with the existing Washington/Oregon/California uniform groundfish logbook blocks (Figure 5). These are 10 minutes of latitude by 10 minutes of longitude blocks established in the 1940's to study sardine populations, although they have been modified slightly to coincide with State Statistical Area boundaries established

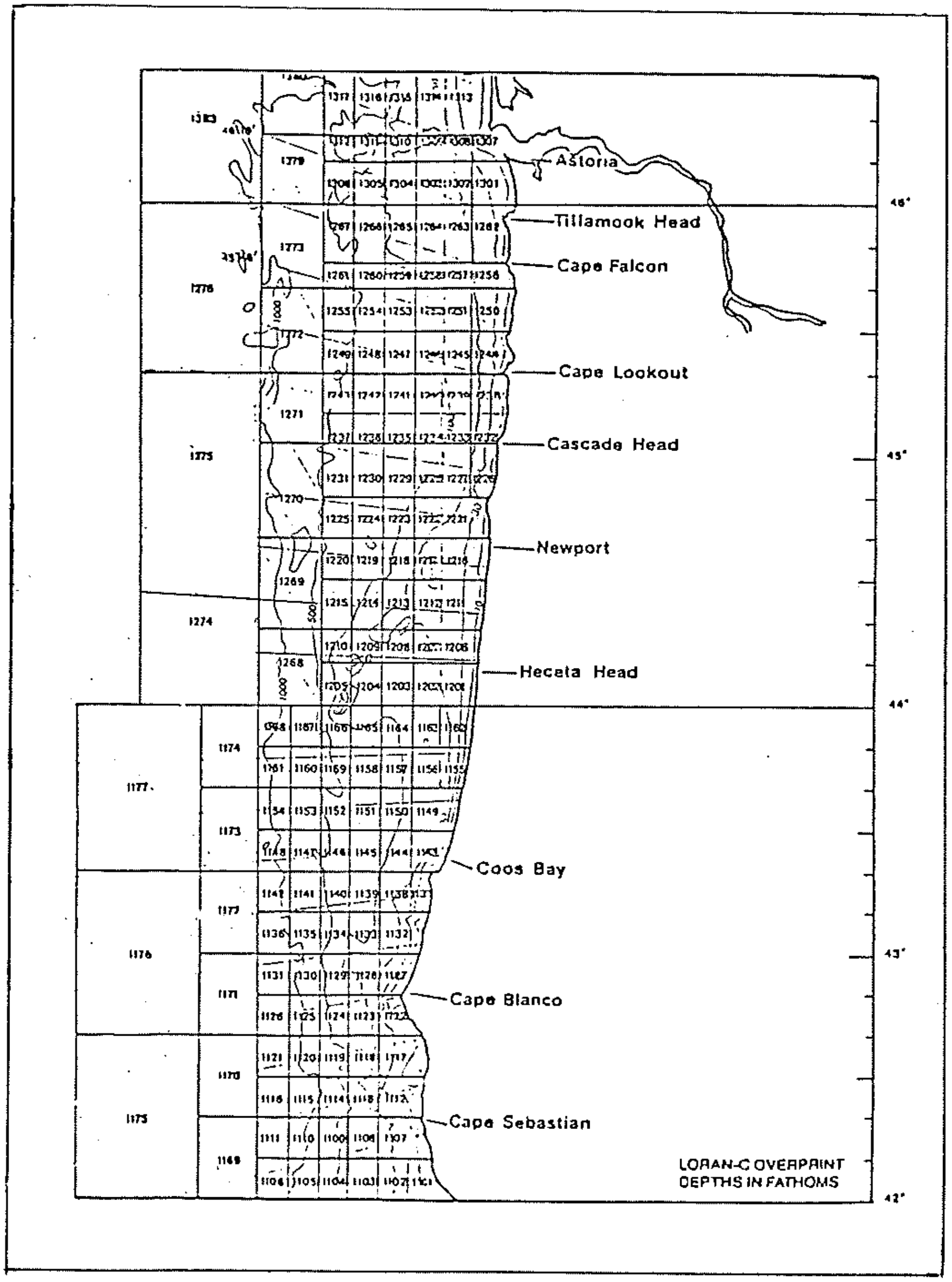


Figure 5. Coastwide uniform groundfish catch blocks.

since that time. We defined our grid by quartering the sardine blocks into 5 minute by 5 minute blocks.

The original sardine blocks were sometimes larger than 10 min square, particularly the furthest offshore blocks which are 40 min square. For this reason we had to develop a numbering scheme which would reference the original sardine block, and also identify the FISHMAP block. We added a two decimal suffix two each sardine block, and sequentially numbered each FISHMAP block from left to right, and top to bottom (Figure 6). Appendix A lists the FISHMAP block number, latitude and longitude point location (lower right hand corner of block), and a geographic reference for each of the blocks in the FISHMAP study area off Oregon.

Data Acquisition And Entry

The fishery data elements which we manipulated by computer are divided into two principle areas. These areas are: fishing vessel logbook records (logbooks) and fishing vessel delivery tickets (fishtickets). Logbook data come from vessels operating in Oregon that are required to keep a record of their fishing activity (Figure 7). Information such as where they fish, how long they fish, and how much they catch of various species are examples of the kind of information contained in logbooks. The shrimp and groundfish fisheries are two examples in which participating vessels are expected to keep a logbook.

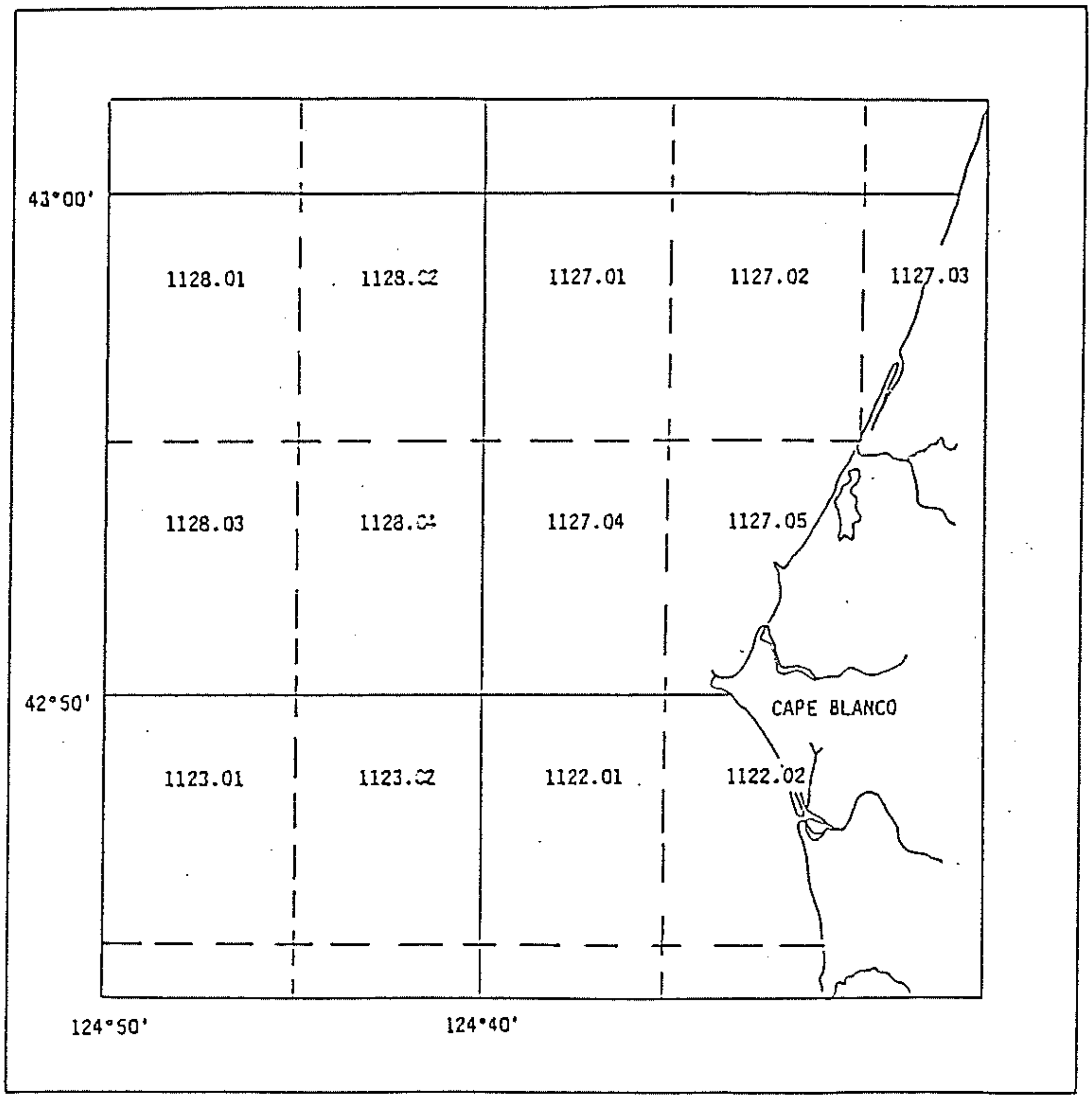
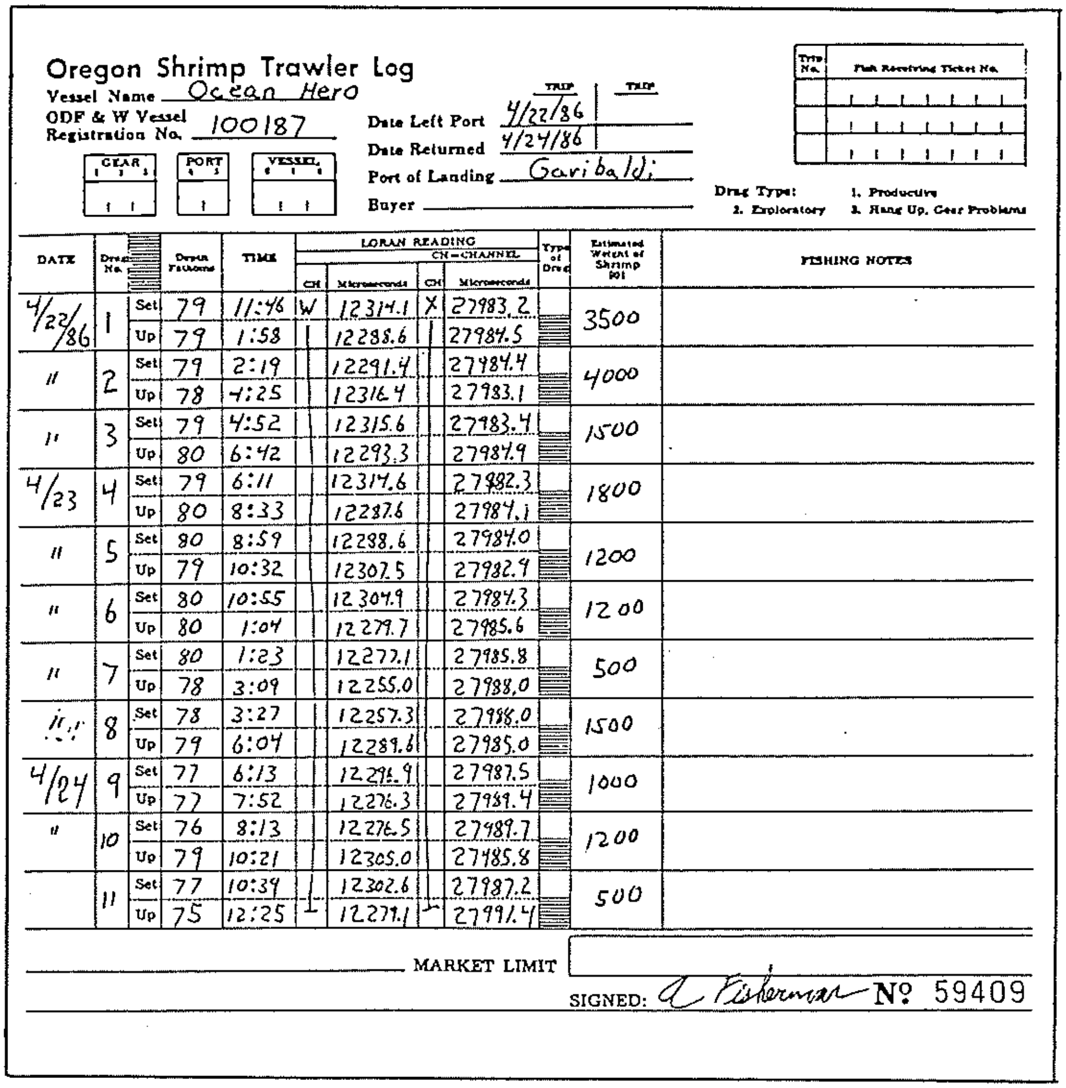


Figure 6. 5 by 5 min FISHMAP blocks obtained by division of coastwide uniform groundfish catch blocks.



Oregon Shrimp Trawler Log

Vessel Name Ocean Hero

ODF & W Vessel Registration No. 100187

GEAR	PORT	VESSEL

	TRIP	TRIP
Date Left Port	4/22/86	
Date Returned	4/24/86	

Port of Landing Garibaldi

Buyer

Trip No.	Fish Receiving Ticket No.

Drag Type: 1. Productive 2. Exploratory 3. Hang Up, Gear Problems

DATE	Drag No.		Depth Fathoms	TIME	LORAN READING CH	Microseconds	CH	Microseconds	Type of Drag	Estimated Weight of Shrimp (lb)	FISHING NOTES
4/22/86	1	Set	79	11:46	W	12314.1	X	27983.2		3500	
		Up	79	1:58		12288.6		27984.5			
"	2	Set	79	2:19		12291.4		27984.4		4000	
		Up	78	4:25		12316.4		27983.1			
"	3	Set	79	4:52		12315.6		27983.4		1500	
		Up	80	6:42		12293.3		27984.9			
4/23	4	Set	79	6:11		12314.6		27982.3		1800	
		Up	80	8:33		12287.6		27984.1			
"	5	Set	80	8:59		12288.6		27984.0		1200	
		Up	79	10:32		12307.5		27982.9			
"	6	Set	80	10:55		12304.9		27984.3		1200	
		Up	80	1:04		12279.7		27985.6			
"	7	Set	80	1:23		12277.1		27985.8		500	
		Up	78	3:09		12255.0		27988.0			
"	8	Set	78	3:27		12257.3		27988.0		1500	
		Up	79	6:04		12289.6		27985.0			
4/24	9	Set	77	6:13		12291.9		27987.5		1000	
		Up	77	7:52		12276.3		27989.4			
"	10	Set	76	8:13		12276.5		27989.7		1200	
		Up	79	10:21		12305.0		27485.8			
	11	Set	77	10:39		12302.6		27987.2		500	
		Up	75	12:25		12279.1		27991.4			

MARKET LIMIT

SIGNED: a Fisherman Nº 59409

Figure 7. Example of Oregon shrimp trawl logbook.

Fishtickets provide the state with offical landing records. When a vessel delivers catch to a buyer, the buyer is required to fill out a delivery ticket which tells who caught how much of what. The gear used and price paid to the fisherman is also recorded on fishtickets.

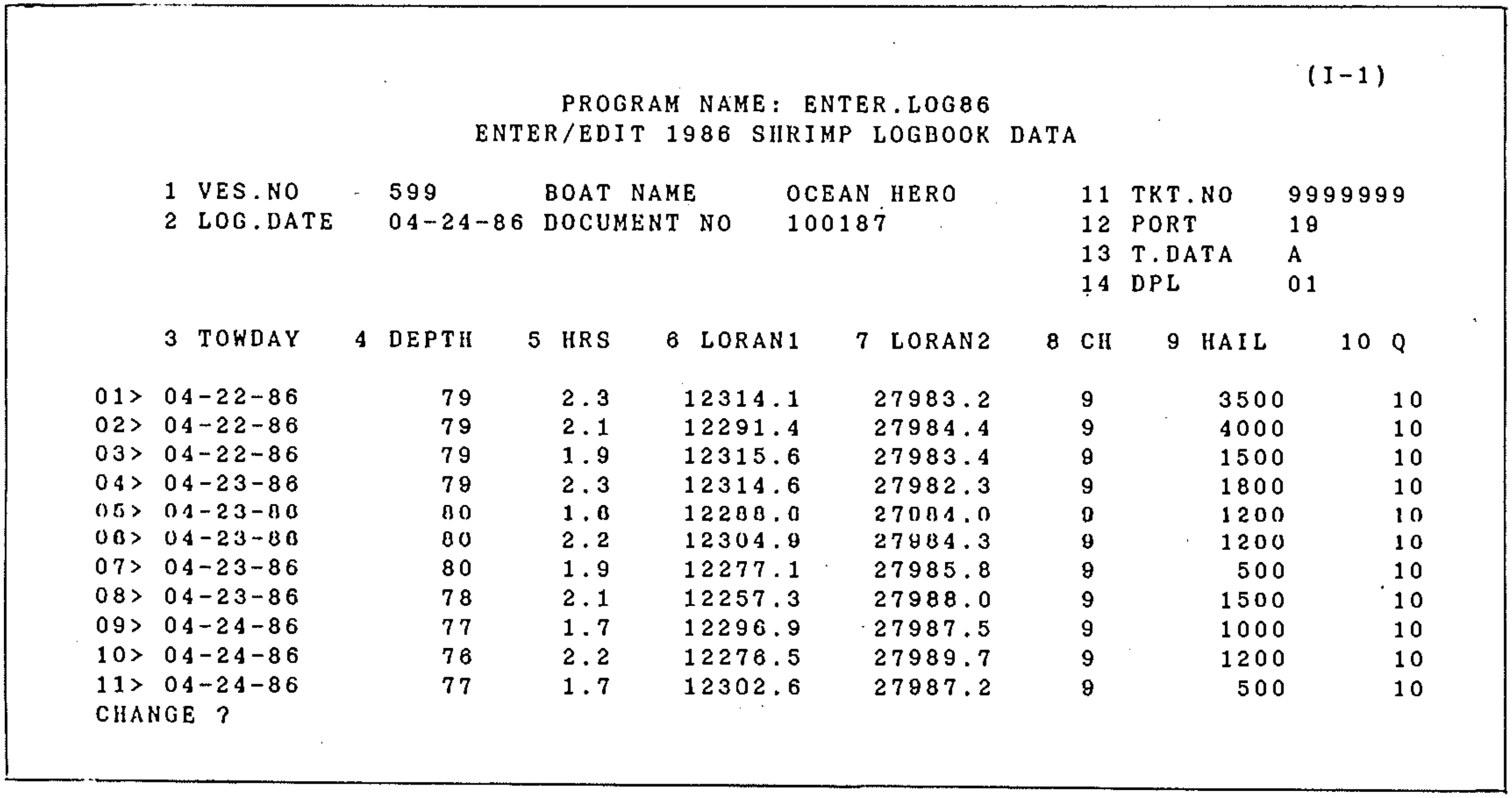
The collection, editing, coding and verification of logbook data is a role played by ODFW port biologists stationed at major ports along the Oregon coast. Port biologists typically tour their local waterfront each day to locate fishermen who have made deliveries of the species in which they are interested. The biologists collect the vessel logbook data, review it, and discuss any inaccuracy with the fishermen. Upon returning to the office with this information they code each trip with additional elements that our FISHMAP system requires. Finally, any unusual looking information is verified by using nautical charts, past history, experience, and sometimes even intuition.

Port biologists strive to collect logbook data for 100 % of the fishing trips occurring each month. Oregon Revised Statutes facilitates this collection by requiring that all vessels operating in the Oregon shrimp or groundfish fishery keep a vessel logbook, and that the logbook be available to officials of the state (ODFW staff) upon request. In practice it is extremely difficult to collect logbook data for every trip. Typically we achieve a 60 to 80 % rate of collection.

Collected logbooks are shipped to Newport for processing. The logbooks consist of vessel and other header information and data specific to individual tows. Most vessels operating in trawl fisheries have some sort of name. The name is used to identify vessel logbooks and fishtickets. While names are often interesting and somewhat descriptive of individual vessels it becomes difficult to distinguish between several vessels with the same name, or one vessel which over time has had several names. Since a name only will not always distinguish vessels we also use federal document number or state registration number for identification. Most trawl vessels weighing more than five tons carry a federal documentation number. This is a six-digit number which uniquely identifies each vessel. If the vessel is not large enough to qualify for documentation, then a state registration number is assigned as a record identification in lieu of the document number.

A tow is the process by which the crew of a trawl vessel releases or sets the fishing gear into the ocean, tows the net through the water for a given time, and then retrieves the gear (up or haul). For each tow, fishermen record the date, the set and haul depth in fathoms, the time of day, LORAN-C chain (west coast or Canadian) and LORAN-C locations (in microseconds), and the estimated weight for each target species caught during the tow. This estimated weight of catch is termed the hailed catch or simply the hail.

After the appropriate header information is coded by port biologists, we enter selected data from the logbooks (Figure 8). For each tow we enter only the set location information



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                                                                  (I-1)
                          PROGRAM NAME: ENTER.LOG86
                       ENTER/EDIT 1986 SHRIMP LOGBOOK DATA

     1 VES.NO     599       BOAT NAME     OCEAN HERO        11 TKT.NO     9999999
     2 LOG.DATE   04-24-86 DOCUMENT NO    100187            12 PORT       19
                                                            13 T.DATA     A
                                                            14 DPL        01

     3 TOWDAY    4 DEPTH    5 HRS    6 LORAN1    7 LORAN2    8 CH    9 HAIL     10 Q

 01> 04-22-86         79      2.3     12314.1     27983.2     9        3500        10
 02> 04-22-86         79      2.1     12291.4     27984.4     9        4000        10
 03> 04-22-86         79      1.9     12315.6     27983.4     9        1500        10
 04> 04-23-86         79      2.3     12314.6     27982.3     9        1800        10
 05> 04-23-86         80      1.6     12288.0     27984.0     9        1200        10
 06> 04-23-86         80      2.2     12304.9     27984.3     9        1200        10
 07> 04-23-86         80      1.9     12277.1     27985.8     9         500        10
 08> 04-23-86         78      2.1     12257.3     27988.0     9        1500        10
 09> 04-24-86         77      1.7     12296.9     27987.5     9        1000        10
 10> 04-24-86         76      2.2     12276.5     27989.7     9        1200        10
 11> 04-24-86         77      1.7     12302.6     27987.2     9         500        10
 CHANGE ?
```

Figure 8. Example of completed FISHMAP data entry sceen.

for depth, time, LORAN-C chain and readings, and the estimated catch. We thought about entering both the beginning and ending locations of a tow, but chose to use only the set location. Since the OHAM system we are setting up requires point locations of data, we needed to assign the catch from a tow to a single point. If we had chosen to enter both set and haul locations we would have had to obtain a single point estimate of catch by using the midpoint of the tow. We would identify the midpoint using an arithmetic average of the distance between set and up locations. In doing so, we would have assumed that the catch came from the middle of the tow, and that the vessel towed in a straight line. In reality, fishermen do not always tow in a straight line and it is not possible to determine where the majority of the catch occurred during the tow. Since assuming the hailed catch came from the midpoint of the tow may not be significantly more precise than assuming the catch came from the beginning of the tow, and since data entry time would be almost doubled by entering both set and haul data, we chose to enter only the set location information. Although we realize a point estimate of catch location introduces a bias, we believe it is very small because of the large number of tows used to characterize fish distribution.

Most of the logbook data elements discussed above are placed in a logbook file which is designed to hold data for a specific year and fishery. The final step in the data entry process is to visually verify the logbook data for keypunch errors, and possible data logic errors which were not discovered by the port biologists

Official fishery delivery records are kept at the head office of ODFW in Portland, Oregon. Oregon's fish buyers fill out a standard fishticket which reports on how much of each species a given vessel delivers into a given port on a given day. Our logbooks only give us the fisherman's estimate of catch; whereas, the fishtickets report the actual weight of each species caught and the ex-vessel value of the catch. Each of these tickets has a unique identifying number.

The fishticket files have the following data elements which are used in the FISHMAP system: fishticket number, date of delivery, port of delivery, federal document number, and fishing gear. A series of 12 species lines list a species code, pounds caught, and the price paid per pound; but, these elements are not used directly.

The first step in including fishticket information into our FISHMAP system is to download the tickets from the Portland computer to a REV file on our system. After doing this we create a file that contains landings with fishticket numbers that match the fishticket number entered into the logbook file.

Data Transformation

LORAN is a passive navigation system that employs land based transmitters and shipboard receivers. Pulses of radio waves are sent from different stations, and the difference in time of arrival of the pulses at the receiver are used to determine lines of position (LOP). It takes at least two LOP's to get a location fix. The older LORAN system (LORAN-A) could be utilized to get a location fix accurate to from 1.5 to 7 mi, depending upon the conditions under which it was operating. In 1979 and 1980 LORAN-C was introduced to the fishing fleet while Loran-A was gradually eliminated. LORAN-C provides location fixes accurate to within a quarter of a mile. On a navigation chart LORAN is viewed as a series of concentric arcs radiating out from a transmitter. There are three series of arcs for each of the LORAN-C chains used off our coast. The intersection of an arc from any two series provides a fix. Any two series from the same chain can be used to mathematically convert LORAN to latitude and longitude (Lat/Lon).

Initially we had hoped to keep the entire FISHMAP process within the Revelation operating environment. Unfortunately one of the key pieces to the system is the Loran-C to Lat/Lon conversion program called LORANC.BAS which was written in BASICA by Leonard A. Westbo, Jr., United States Coast Guard, assistant branch chief of electronics engineering. We tried to rewrite this program in R/BASIC, but due to the slight differences in how the trigonometric functions operated, slight variations were compounded throughout the algorithm and the resulting location was not accurate. We could not overcome this problem in an expedient manner so we opted to leave LORANC.BAS as a BASICA program. We wrote a modified version of this program (LORANC) to be a portion of our automated FISHMAP system. It allows for file input and output instead of keyboard input and screen output.

Because REV and DOS formats are not compatible we had to convert the logbook LORAN-C data entered in REV format to DOS format prior to making it available to the LORAN transformation program. After the LORAN transformation program creates a DOS file containing the resulting Lat/Lon locations we have to convert it back to REV format again. To help compensate for the time lost in converting the format back and forth we compiled the LORAN translation program so it would not have to run as an interpretative program.

Time And Area Conversion

At this point in the FISHMAP process we had collected a sizable amount of information telling where shrimp and groundfish vessels were operating, how much they were catching of what species, and how long it was taking them to do it. We also entered all of these data onto a computer system large enough to hold the data, and flexible enough to allow us to proceed with transforming the data into summaries and maps.

The next step of transforming the data (Figure 9) begins with a program that selects all of the logbook records (trips) for a given year of the fishery. The program then goes through each record and checks the LORAN-C readings for each tow to see if the values are in the range available for the

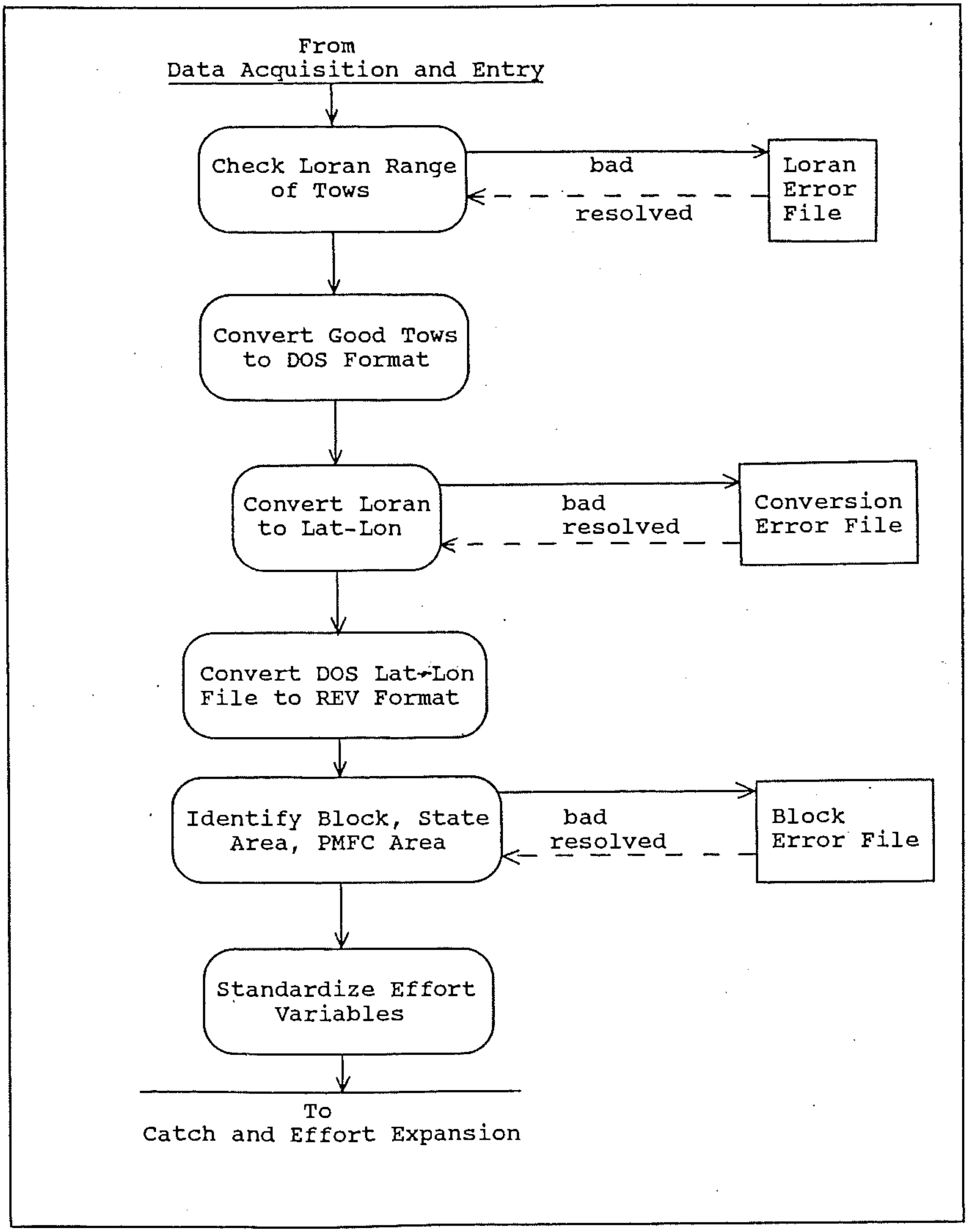


Figure 9. Schematic flowchart of FISHMAP time and area conversion procedure.

ocean area we are mapping (40° 30′ to 48° 50′ north latitude and 123° 55′ to 126° 20′ west longitude).

If any tow in a given record is out of range the entire record is skipped because the methods used to update and expand the catch and effort assumes that every tow in the trip is a valid location. A temporary error file is created which lists the Logbook ID, tow number and range problem for each bad tow. At any future time the bad tows can be reviewed and/or edited using the appropriate logbook enter/edit program. If the error is resolved the record can be re-selected for another try to pass through the system. All tows which do not encounter a LORAN range error are written to a temporary file in DOS format which is used as the input file for the LORAN-C to Lat/Lon conversion program.

We took advantage of the ability to convert LORAN-C to Lat/Lon because it more closely resembled the grid pattern of our blocks. After we converted LORAN location fixes to Lat/Lon, all that was left to do was to place the data point in the proper 5 min square block. We did this by building a look-up file containing all of our blocks. Each 5 min block is defined by the Lat/Lon coordinates of the lower right hand corner of the block. The look-up subroutine compares the coordinates of the tow in question to the coordinates of the grid in the look-up file and returns a block number. We designed the system to be flexible enough to enable us to change the grid system to any size we desire by simply changing the coordinates of the look-up file.

Effort Conversion

It was important to standardize efort variables as a last step before expanding catch and effort data. The shrimp fishery has vessels operating with two major types of gear. Vessels either tow one net (single-rigged) or two nets (double-rigged). To avoid having to run a parallel system (one for each gear) we decided to convert the effort variable from single-rigged (SRE) logbook records to a double-rigged equivalent (DRE).

Traditionally the shrimp management and assessment projects at ODFW have used SRE for shrimp trawl effort because historically the fishery was composed of mostly single-rigged shrimp vessels. Currently, most vessels are double-rigged, and as a result ODFW switched its standard shrimp effort unit to double-rigged equivalent trawl hours, or DRE. The ratio of single-rigged fishing efficency to double-rigged is 1.0:1.6. This means that, for the FISHMAP system all trawl hours are standardized to DRE by multiplying single-rigged trawl hours by a factor of 0.625.

Catch And Effort Accumulation And Expansion

If we had mapped the data at this point, using error free logbooks only, we would have had a distribution of catch by 5 min block which would be much more useful for the purposes of this study than the traditional manner of mapping catch by State or PMFC area. However, this map would show only the accumulation of estimated catch, and it would also only show catch for all trips that correspond to logbooks we collected. To increase the breadth of the data we converted estimated catch to actual catch using official landing records (Figure 10). The converted data were then summarized and distributed into the 5 min square blocks of our grid. This new catch distribution represented actual pounds caught in each block for fishtickets that have corresponding logbooks.

We also accounted for official landings that do not have corresponding logbooks. The general procedure was to derive the ratio of the catch occuring in each block to the total catch for fishtickets corresponding to logbooks. We then multiplied the sum of the landings without fishtickets (unknown catch) by the ratio for each block. This gave us a derived catch for each block. The final expanded catch figure for each block was obtained by adding the known catch for each block to the derived catch for each block.

More precisely, we accumulated all of the unknown landing data by month by port. We did this to avoid biasing the catch towards, or away from, any month or port which may have an unusually large or small collection of logbook data. Next, we ran a program which accumulated all of the known landing data by month by port by 5 min block. The program told us, based on our known landing data, how much catch and effort there was for each block, for each fishing period (month), and for each major fishing location (port). The expand program calculated the ratio of the known catch for a given block to the total

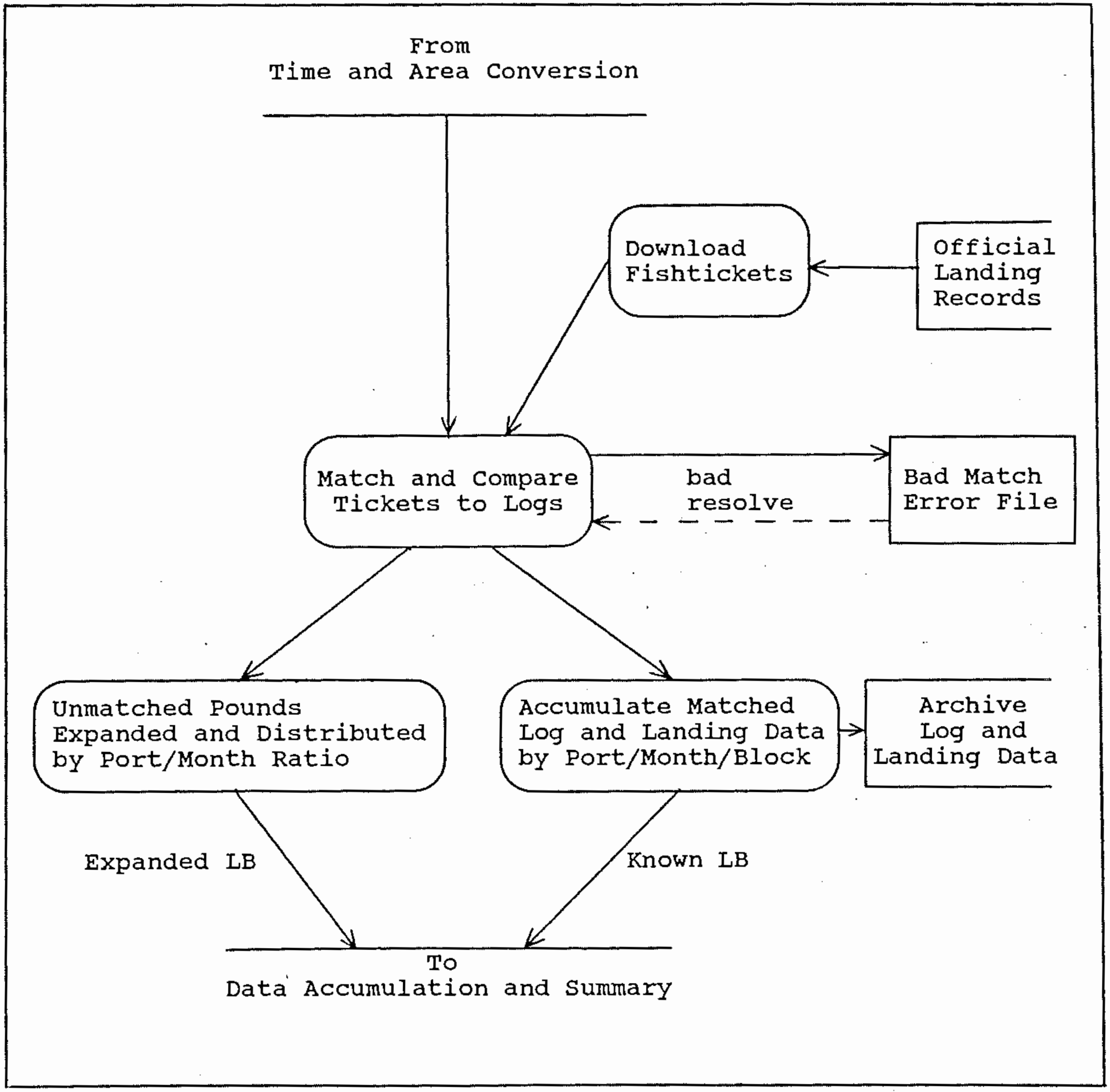


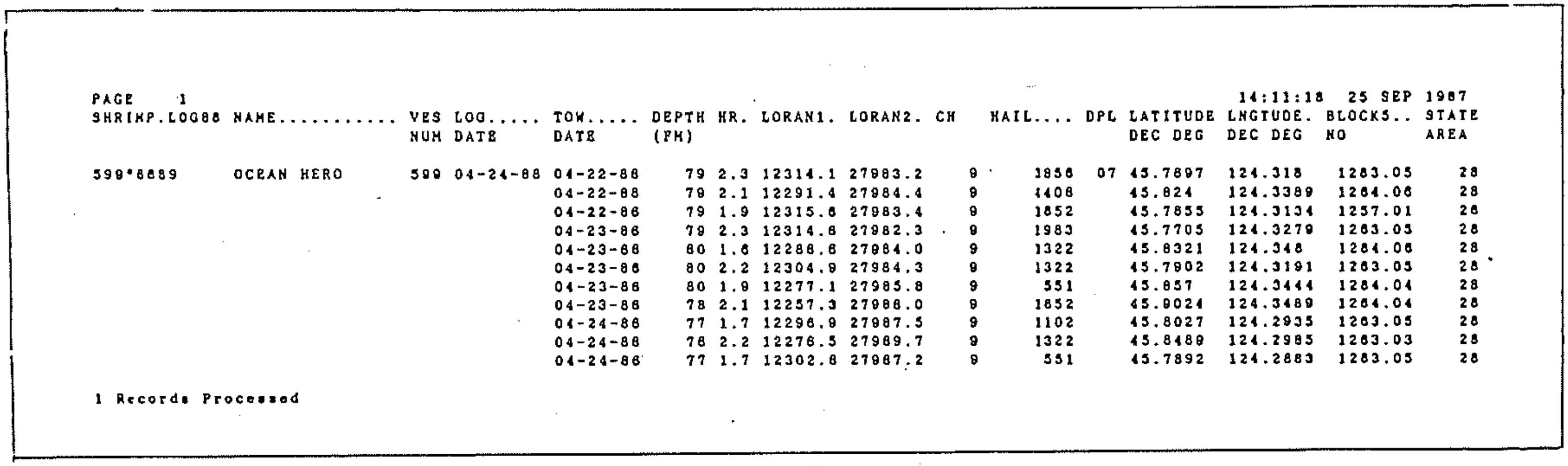
Figure 10. Schematic flowchart of FISHMAP catch and effort expansion procedure.

known catch for that month/port unit. This ratio was then multiplied by the total unknown catch for that month/port unit to give us a prorated amount of additional pounds which were probably caught in that block.

After that process, data was reduced to two forms. One segment was the error free logbook data (Figure 11) which contained actual catch (in lb) and the adjusted trawl hours (in DRE) distributed by 5 min block. These were labeled known landing data. The other segment was the portion of actual catch (lb from fishticket records) which was not matched to a logbook record (unknown landing data).

We also expanded effort variables before merging known and derived data. The pounds caught per trawl hour were calculated by dividing the known catch by the known effort (in DRE). Since the resulting value was a ratio (expressed as pounds of catch per double-rigged equivalent trawl hour (CPUE-DRE)), it would not change when additional unknown pounds were added. However, we did need to expand effort estimates. We accomplished this by dividing the additional unknown pounds by CPUE-DRE, and adding this additional effort to our known effort. By summing known and derived data we obtained expanded catch, effort, and CPUE-DRE by block for each port/month unit for a given year of the fishery.

The final processing step was handled by an R/BASIC program that accumulated all of the known and derived data available for a given 5 min block into a single record of a new file (Figure 12). This record represents all of the



```
PAGE    1                                                                                         14:11:18  25 SEP 1987
SHRIMP.LOG88 NAME........... VES LOG..... TOW..... DEPTH HR. LORAN1. LORAN2. CH   HAIL.... DPL LATITUDE LNGTUDE. BLOCKS.. STATE
                             NUM DATE     DATE     (FM)                                       DEC DEG  DEC DEG  NO       AREA

598*8889     OCEAN HERO      599 04-24-88 04-22-88    79 2.3 12314.1 27983.2     9     1856  07 45.7897  124.318   1283.05     28
                                          04-22-88    79 2.1 12291.4 27984.4     9     1408     45.824   124.3389  1284.06     28
                                          04-22-86    79 1.9 12315.6 27983.4     9     1852     45.7855  124.3134  1257.01     28
                                          04-23-86    79 2.3 12314.6 27982.3     9     1983     45.7705  124.3279  1283.05     28
                                          04-23-88    80 1.6 12288.6 27984.0     9     1322     45.8321  124.348   1284.06     28
                                          04-23-86    80 2.2 12304.9 27984.3     9     1322     45.7902  124.3191  1283.05     28
                                          04-23-86    80 1.9 12277.1 27985.8     9      551     45.857   124.3444  1284.04     28
                                          04-23-86    78 2.1 12257.3 27988.0     9     1852     45.9024  124.3489  1284.04     28
                                          04-24-86    77 1.7 12296.9 27987.5     9     1102     45.8027  124.2935  1283.05     28
                                          04-24-88    76 2.2 12276.5 27989.7     9     1322     45.8489  124.2985  1283.03     28
                                          04-24-86    77 1.7 12302.8 27987.2     9      551     45.7892  124.2883  1283.05     28

1 Records Processed
```

Figure 11.   Example data elements in the error free logbook data file.

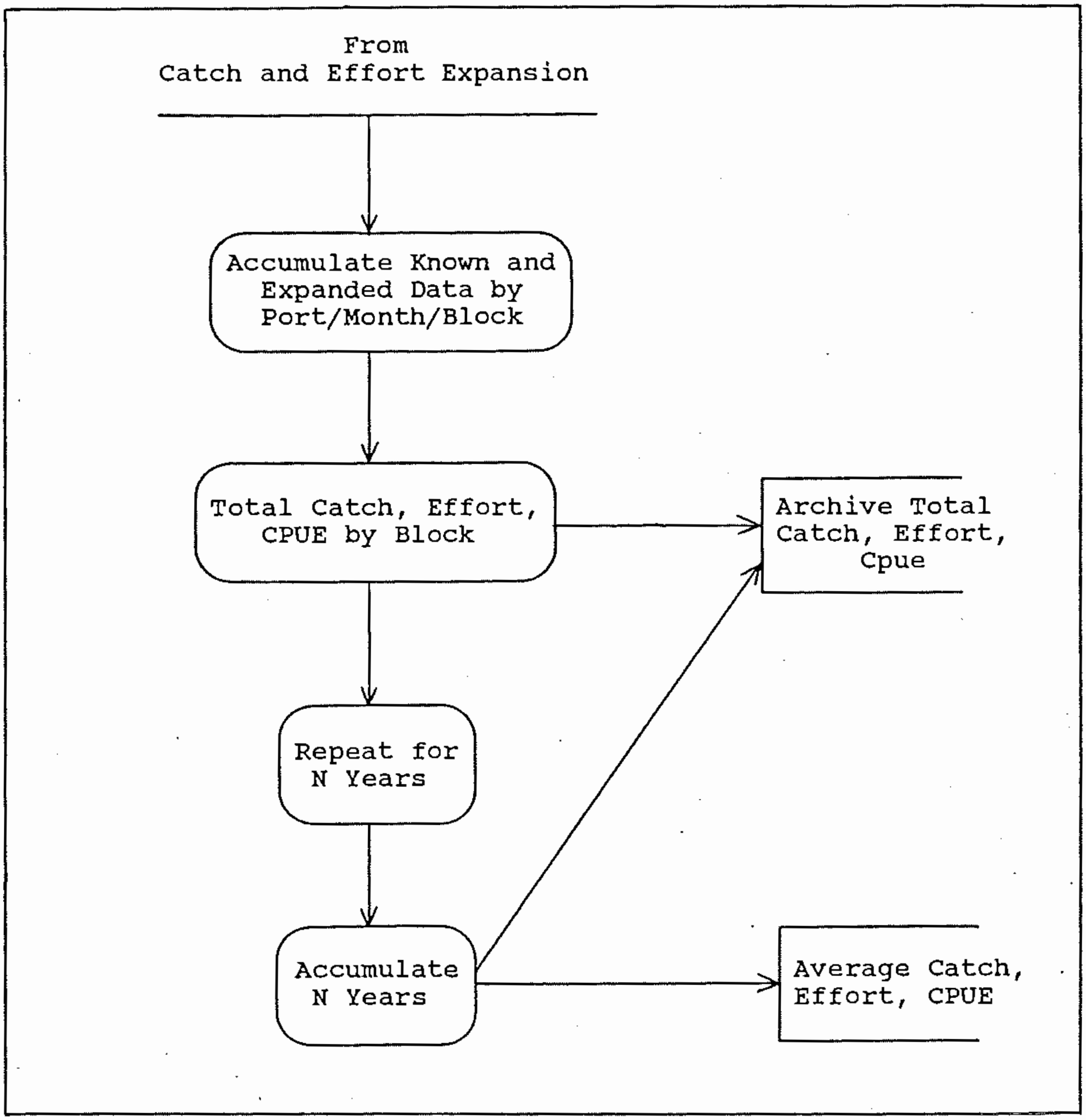


Figure 12. Schematic flowchart of FISHMAP data accumulation and summary procedure.

catch, effort, and CPUE data for a given 5 min block in the fishery during a given year. Data for several years were then easily summed and averaged.

GROUNDFISH PROCESSING

A secondary project objective was to show how external data from similarly managed fisheries could be easily incorporated into the FISHMAP system. We used the Oregon groundfish fishery to accomplish this objective.

ODFW has several years of groundfish logbook data which were originally entered and processed on the CYBER mainframe computer at Oregon State University. This information was stored on magnetic tape and consisted of most of the data elements discussed above. The position fix of each tow in these logbook records had already been converted to Lat/Lon, and the estimated catch of groundfish had been expanded to actual catch.

We electronically transferred three years of groundfish catch information into our system. First, the original data were modified slightly to fit the pattern of data elements we used in the shrimp FISHMAP process. Next, the data were converted into a DOS compatible format. We built a program that converted DOS files of groundfish logbook information into REV format.

Once the data were in REV format we utilized the same steps to summarize the data into 5 min blocks by time period. We thus completely satisfied ourselves that we could incorporate data from many fisheries, and probably from various types of computer formats, into FISHMAP and OHAM by simply writing head end routines to modify the format and structure of the data prior to exposing it to our system.

DATA SUMMARIES AND MAPS

The visual evidence of the progress we made using this system comes in two forms. First, we produced hardcopy data listing (one each for the shrimp and groundfish fishery) showing the average catch for each 5 min block off the coast of Oregon (Table 2). This catch was divided into five ranges, and a level number from 1 (lowest average catch) through 5 (highest average catch) was assigned to each range. Table 3 describes the catch ranges.

Table 3. Range in average catch (lb) corresponding to catch levels described in Table 2.

Catch Level	Range (lb)
1	< 99
2	100 - 999
3	1,000 - 9,999
4	10,000 - 99,999
5	> 100,000

Second, we built color overlays maps of the average catch for each fishery. A base map showing the coast of Oregon and its prominent features is used to orient the viewer, and the overlay of choice is place over the base map. This overlay has five shades of a given color (red for average groundfish catch, and blue for average shrimp catch). A catch level is

Table 2. Example of average catch level by 5 min square block of Lat/Lon for the shrimp and groundfish fiseries.

BLOCK5.NO	CATCH LEVEL	BLOCK5.NO	CATCH LEVEL	BLOCK5.NO	CATCH LEVEL
1101.01	3	1114.04	3	1131.02	3
1101.02	4	1117.01	5	1131.03	2
1101.03	4	1117.02	4	1131.04	3
1101.04	4	1117.03	2	1132.01	4
1101.05	4	1117.05	4	1132.02	1
1101.06	2	1117.06	4	1132.03	3
1102.01	4	1117.07	3	1132.04	2
1102.02	4	1117.08	1	1132.05	4
1102.03	4	1118.01	3	1132.06	4
1102.04	5	1118.02	4	1132.07	4
1103.01	3	1118.03	4	1133.01	4
1103.02	4	1118.04	4	1133.02	4
1103.03	1	1119.01	3	1133.03	5
1103.04	4	1119.02	3	1133.04	4
1104.03	2	1119.03	1	1134.01	3
1104.04	3	1119.04	3	1134.02	5
1105.03	2	1120.02	2	1134.03	3
1106.04	2	1122.01	4	1134.04	5
1107.01	4	1122.02	3	1135.01	4
1107.02	4	1122.03	5	1135.02	2
1107.03	4	1122.04	4	1135.03	4
1107.04	1	1122.05	3	1135.04	3
1107.05	5	1123.01	5	1136.01	3
1107.06	4	1123.02	5	1136.02	3
1107.07	4	1123.03	3	1136.03	3
1107.08	3	1123.04	5	1136.04	2
1108.01	4	1124.01	4	1137.01	3
1108.02	4	1124.02	5	1137.02	3
1108.03	3	1124.04	4	1137.03	3
1108.04	4	1125.04	1	1137.04	3
1109.01	2	1126.04	2	1138.01	5
1109.02	3	1127.01	5	1138.02	3
1109.03	1	1127.02	4	1138.03	4
1109.04	3	1127.03	3	1138.04	2
1110.04	2	1127.04	4	1139.01	4
1112.01	4	1127.05	3	1139.02	5
1112.02	3	1128.01	5	1139.03	4
1112.03	2	1128.02	5	1139.04	5
1112.04	5	1128.03	5	1140.01	5
1112.05	4	1128.04	5	1140.02	5
1112.06	3	1129.01	4	1140.03	4
1113.01	4	1129.02	5	1140.04	5
1113.02	4	1129.03	4	1141.03	2
1113.03	4	1129.04	5	1142.01	1
1113.04	4	1130.02	3	1142.04	3
1114.01	2	1130.03	3	1143.01	4
1114.02	2	1130.04	3	1143.02	4

assigned to each shade. The result is a color graphic representation of the average catch of shrimp and groundfish off the coast ranging from very low (less than 100 lb/yr) to very high (greater than 100,000 lb/yr).

This type of information can be used to help establish the importance of a given location for a given fishery. The type of information we present here is only an example of the things which can be produced by our FISHMAP system. Along with the average catch data, we could just as easily produce summaries and maps of annual catch, effort, and catch per hour. Also with some additional data and programming we could convert catch data into economic value information.

SUMMARY AND
STATUS OF OCEAN HABITAT ANALYSIS
AND MAPPING SYSTEM

In response to ocean resource planning needs, we are designing a long term program to combine environmental and biological data to identify discrete habitats in the ocean. The long term program, called Ocean Habitat Analysis and Mapping (OHAM) is intended to help define areas of special biological significance and understand how fishery resources respond to changes in environmental variables. The Ocean Habitat Analysis and Mapping system will include economic data to improve fisheries management and to help us respond to resource use conflicts.

This report described the Ocean Habitat Analysis and Mapping system and used commercial fishery catch data as an example of how the system will work. After showing how commercial fishery logbook data could be manually entered, we chose to show how an existing data set could be electronically transferred into the OHAM system. We selected Oregon groundfish trawl logbook data that resided on files on the Oregon State University CDC CYBER mainframe computer. The data were transferred from the mainframe to the microcomputer system we used and then transformed into the OHAM system format. All groundfish species were aggregated for the pilot project; one of the next tasks to work on is the splitting of the aggregate groundfish data base into its constituent species.

Once three years of pink shrimp and aggregated groundfish catch data were entered, we apportioned the catch to individual blocks about five square miles in size and summarized the data by statistical block. The data were averaged over the three year period and intervals of catch were chosen. We selected five intervals ranging from extremely low to extremely high catch. The catch intervals were selected to show how the OHAM system could be used to highlight areas of special biological significance.

In the pilot project we used trawl catch to highlight important ocean areas. After more data are entered in the OHAM system, we would expect to delineate areas of special biological significance using other parameters as well. For example, we would expect areas of special biological significance to include blocks with high fish density (high catch per hour), high species diversity, or that contained a high proportion of gravid females or juvenile fish.

Finally, for the pilot project, we used existing bottom sediment data to show how biological and physical information could be combined to help identify ocean habitats. The catch data were displayed on mylar overlays that fit over a base map containing sediment types. The combination of catch data and sediment data helped highlight relationships between bottom sediments and species distribution. The maps, stored at the ODFW Marine Region and at the DLCD Salem offices, are examples of the type of data display that the Ocean Habitat Analysis and Mapping system is expected to produce.

ACKNOWLEDGEMENTS

Of the many people who have helped us, several deserve special recognition. Phil Flanders deserves credit for the selection of the Revelation data base and the design of many of the data translation programs. He continues to help us develop computer programs and resolve data transfer problems. Beyond this we want to express our gratitude for his continuing patience and tutoring in the fine art of computer programming. Clay Creech massaged the groundfish logbook data in the CYBER computer and helped transfer it to our microcomputer. We especially want to thank Susan Riemer who spent many long days coding, reviewing, and entering logbook data. Nancy Brown, Jean McCrae, Kathy Murphy, and Dave Smith also helped review the data. Susan Jurasz provided us with excellent service in drafting the maps associated with the data. Don Oswalt provided help in smoothing out the administrative kinks of this project.

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APPENDIX A

Example of a portion of the look-up table used to identify FISHMAP blocks, including coordinates of latitude and longitude (expressed in degrees and ten-thousandths of degrees) corresponding to the lower right corner of FISHMAP blocks.

DLCD BLOCK LIST
PAGE 1

BLOCK...... NUMBER	LAT.DEG.....	LON.DEG.....	LAND............... MARK
1101.01	42.0833	124.4167	CAPE FERRELO
1101.02	42.0833	124.3333	CAPE FERRELO
1101.03	42.0000	124.4167	CHETCO RIVER
1101.04	42.0000	124.3333	CHETCO RIVER
1101.05	42.0000	124.2500	CHETCO RIVER
1101.06	42.0000	124.1667	CHETCO RIVER
1102.01	42.0833	124.5833	CAPE FERRELO
1102.02	42.0833	124.5000	CAPE FERRELO
1102.03	42.0000	124.5833	CHETCO RIVER
1102.04	42.0000	124.5000	CHETCO RIVER
1103.01	42.0833	124.7500	CAPE FERRELO
1103.02	42.0833	124.6667	CAPE FERRELO
1103.03	42.0000	124.7500	CHETCO RIVER
1103.04	42.0000	124.6667	CHETCO RIVER
1104.01	42.0833	124.9167	CAPE FERRELO
1104.02	42.0833	124.8333	CAPE FERRELO
1104.03	42.0000	124.9167	CHETCO RIVER
1104.04	42.0000	124.8333	CHETCO RIVER
1105.01	42.0833	125.0833	CAPE FERRELO
1105.02	42.0833	125.0000	CAPE FERRELO
1105.03	42.0000	125.0833	CHETCO RIVER
1105.04	42.0000	125.0000	CHETCO RIVER
1106.01	42.0833	125.2500	CAPE FERRELO
1106.02	42.0833	125.1667	CAPE FERRELO
1106.03	42.0000	125.2500	CHETCO RIVER
1106.04	42.0000	125.1667	CHETCO RIVER
1107.01	42.2500	124.5833	CAPE SEBASTIAN
1107.02	42.2500	124.5000	CAPE SEBASTIAN
1107.03	42.2500	124.4167	CAPE SEBASTIAN
1107.04	42.2500	124.3333	CAPE SEBASTIAN
1107.05	42.1667	124.5833	MACK ARCHES
1107.06	42.1667	124.5000	MACK ARCHES
1107.07	42.1667	124.4167	MACK ARCHES
1107.08	42.1667	124.3333	MACK ARCHES
1108.01	42.2500	124.7500	CAPE SEBASTIAN
1108.02	42.2500	124.6667	CAPE SEBASTIAN
1108.03	42.1667	124.7500	MACK ARCHES
1108.04	42.1667	124.6667	MACK ARCHES
1109.01	42.2500	124.9167	CAPE SEBASTIAN
1109.02	42.2500	124.8333	CAPE SEBASTIAN
1109.03	42.1667	124.9167	MACK ARCHES
1109.04	42.1667	124.8333	MACK ARCHES
1110.01	42.2500	125.0833	CAPE SEBASTIAN
1110.02	42.2500	125.0000	CAPE SEBASTIAN
1110.03	42.1667	125.0833	MACK ARCHES
1110.04	42.1667	125.0000	MACK ARCHES
1111.01	42.2500	125.2500	CAPE SEBASTIAN