AN AUTOMATED DATA SYSTEM FOR STRATEGIC ASSESSMENT OF LIVING MARINE RESOURCES IN THE GULF OF MEXICO

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ABSTRACT

This paper briefly describes and illustrates the features of a computer-based data system designed to provide easy access, manipulation, retrieval, and display of information on the temporal and spatial distribution of living marine resources in the Gulf of Mexico. This data system is one component of a larger system being developed by the Office of Ocean Resources Coordination and Assessment (ORCA) of the National Oceanic and Atmospheric Administration (NOAA) to analyze the distribution of living marine resources in all U.S. coastal and ocean regions, excluding the Great Lakes.

INTRODUCTION

Development of the Automated Data System for Strategic Assessment of Living Marine Resources in the Gulf of Mexico is an integral part of ORCA's strategic assessment project for that region (ORCA, 1981). The overall Gulf of Mexico project, second of a series of five strategic assessments that will cover the entire "coastal zone" of the U.S.A., extending seaward to the 200-mile limit of the fishery conservation zone, was initiated in 1980. These assessments are described as "strategic" because they are carried out from a long-term and large-scale planning perspective intended to complement, not replace, the necessary detailed, site-specific or "tactical" analyses of specific ocean use proposals (Ehler and Basta, 1982).

The Gulf of Mexico strategic assessment project focuses on the entire Gulf, including the coastal and ocean waters of both the U.S.A. and Mexico. The project is developing data on the distribution of various characteristics of the region, including: 1) physical characteristics; 2) plants; 3) marine animals; 4) economic activities and their pollutant discharges; and 5) management jurisdictions. These data, in conjunction with analyses performed using pollutant transport models (Duke, et al., 1980, and ORCA, 1982), will be used as a basis for identifying and understanding better some of the relationships between and among economic activities, their pollutant discharges, and living marine resources in the Gulf of Mexico.

The system has two primary objectives: 1) to support the analyses of living marine resources conducted as part of ORCA's national Strategic Assessment Program; and 2) to provide a rapid-turnaround analytical tool to assist NOAA resource management and project review activities, such as those undertaken through its Office of Habitat Protection, Office of Marine Pollution Assessment, and ORCA. Upon completion of the first phase of the Strategic Assessment Program, the data system will combine in a single consistent data set information on the spatial and temporal distribution of important living marine species for all U.S. coastal and ocean waters.

THE SYSTEM

The Gulf of Mexico data system is comprised of life history and economic activity data for 73 species of marine fishes, invertebrates, mammals and reptiles (see Table 1). These data have been collected primarily from the literature by biologists of NOAA's National Marine Fisheries Service (NMFS).* Based on these data, NMFS biologists have prepared maps to illustrate the spatial and temporal characteristics of the life history, as well as important commercial and recreational fishing grounds, of each species.

Species	Scientific Name
INVERTEBRATES+	
Clam, Sunray Venus	Macrocallista nimbosa
Conch, Queen	Strombus gigas
$Crab, Blue	Callinectes sapidus
$Crab, Stone	Menippe mercenaria
$Lobster, Spiny	Panulirus argus
Octopus, Common	Octopus vulgaris
Octopus, Mexican Four-Eyed	Octopus maya
$Oyster, American	Crassostrea virginica
Scallop, Calico	Argopecten gibbus
Seabob	Xiphopenaeus kroyeri
$Shrimp, Brown	Penaeus aztecus
$Shrimp, Pink	Penaeus duorarum
Shrimp, Rock	Sicyonia brevirostris
Shrimp, Royal Red	Pleoticus robustus
$Shrimp, White	Penaeus setiferus
Squid, Long-finned	Loligo pealei
FISHES	
Amberjack, Greater	Seriola dumerili
Bluefish	Pomatomus saltatrix
Bonefish	Albula vulpes
Butterfish, Gulf	Peprilus burti
Cobia	Rachycentron canadum
Croaker, Atlantic	Micropogonias undulatus
Dolphin	Coryphaena hippurus
Drum, Black	Pogonias cromis
Drum, Red	Sciaenops ocellatus
Flounder, Dusky	Syacium papillosum
Flounder, Gulf	Paralichthys albigutta
Flounder, Southern	Paralichthys lethostigma
Grouper, Black	Mycteroperca bonaci
Grouper, Red	Epinephelus morio
Grunt, Tomtate	Haemulon aurolineatum
Herring, Atlantic Thread	Opisthonema oglinum
Herring, Round	Etrumeus teres
Jack, Crevalle	Caranx hippos
Mackerel, King	Scomberomorus cavalla
Mackerel, Spanish	Scomberomorus maculatus
Marlin, Blue	Makaira nigricans
Marlin, White	Tetrapturus albidus
Menhaden, Gulf	Brevoortia patronus
Mullet, Striped	Mugil cephalus
Pompano, Florida	Trachinotus carolinus
Porgy, Longspine	Stenotomus caprinus
Runner, Blue	Caranx crysos
FISHES (cont.)	
Sailfish	Istiophorus platypterus
Sardine, Spanish	Sardinella anchovia
Seatrout, Sand	Cynoscion arenarius
Seatrout, Spotted	Cynoscion nebulosus
Shark, Shortfin Mako	Isurus oxyrinchus
Shark, Scalloped Hammerhead	Sphyrna lewini
Snapper, Gray (Mangrove)	Lutjanus griseus
Snapper, Gulf Red	Lutjanus campechanus
Snapper, Lane	Lutjanus synagris
Snapper, Mutton	Lutjanus analis
Snapper, Vermilion	Lutjanus vivanus
Snapper, Yellowtail	Ocyurus chrysurus
Snook	Centropomus undecimalis
Spot	Leiostomus xanthurus
Swordfish	Xiphias gladius
Tarpon	Megalops atlanticus
Tilefish	Lopholatilus chaemaeleonticeps
Tuna, Blackfin	Thunnus atlanticus
Tuna, Bluefin	Thunnus thynnus
Tuna, Little Tunny	Euthynnus alletteratus
Tuna, Yellowfin	Thunnus albacares
REPTILES	
Alligator, American	Alligator mississippiensis
Crocodile, American	Crocodylus acutus
Crocodile, Morelet's	Crocodylus moreleti
Sea Turtle, Loggerhead	Caretta caretta
Sea Turtle, Kemp's Ridley	Lepidochelys kempi
MAMMALS	
Dolphin, Bottlenose	Tursiops truncatus
Dolphin, Spotted	Stenella plagiodon
Manatee, West Indian	Trichechus manatus
Whale, Fin	Balaenoptera physalus
Whale, Short-finned Pilot	Globicephala macrorhynchus

+ Preliminary tests run for invertebrates only.
$ Indicates major commercial invertebrate in U.S.A.

Table 1. Species included in Gulf of Mexico data system

At least four types of areas are identified on each species map:

1. Adult Area: An area in which sexually mature individuals of a species occur;

2. Reproductive Area: An area in which spawning (for fishes and invertebrates) or calving or

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* Life history data on Gulf of Mexico species were organized by the Panama City Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, located in Panama City, Florida.

pupping (for marine mammals) or nesting (for reptiles and birds) occurs;

3. Nursery Area: An area in which larvae, juveniles, or young stages of a species occur or concentrate for feeding or refuge; and

4. Exploitation Area: An area in which living marine resources are harvested for commercial, recreational, or subsistence purposes.

Draft maps were drawn at a scale of 1:2,000,000, or 1 inch = approximately 32 miles. This large scale was necessary to illustrate on a single map the spatial extent of marine species in the Gulf since many range throughout the entire Gulf. These maps will be reduced to a scale of 1:4,000,000 and published in a Gulf of Mexico Data Atlas (ORCA, 1981) being developed as part of the regional project.

The system converts data on the temporal and spatial distribution of the life history, as well as the commercial and recreational fishing grounds, of each species into a computerized 10-minute by 10-minute square (approximately 10-mile by 10-mile) grid system covering the entire Gulf of Mexico. The process of translating mapped data into digital data has been designed to provide, as closely as possible, a literal representation of each species map. Once coded, the data are stored in the automated data system and a map of each species can then be produced by the computer. Figure 1 illustrates a computer-generated map of brown shrimp adult areas throughout the year.

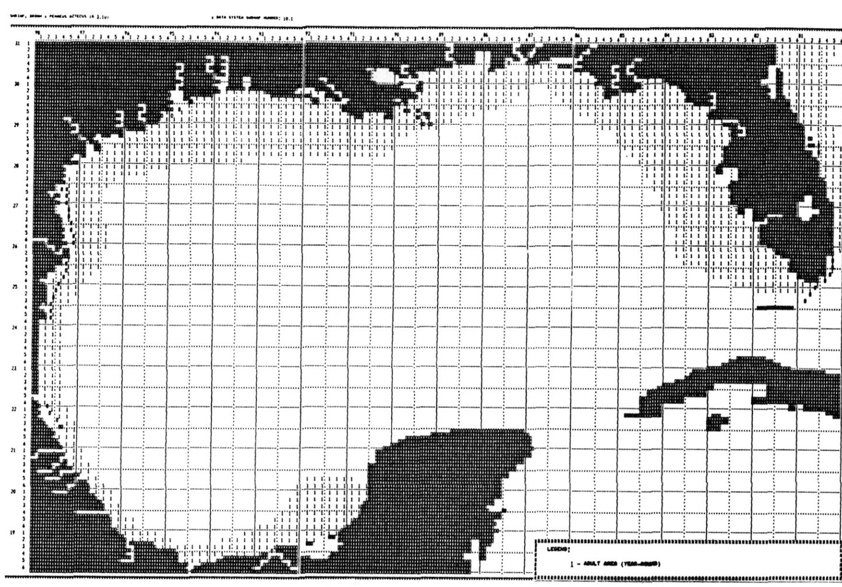

Figure 1. Computer-generated map of brown shrimp adult areas, year-round

A user can perform at least two relatively simple operations on the stored life history data: 1) composite mapping of the presence or absence of any combination of species, their life histories, or seasonality across the entire 10-minute square grid system or any portion of it; and 2) an examination and comparison of the presence or absence of species and life history for any season within any individual grid cell or set of cells. The composite mapping feature produces a schematic map showing numbers of types of species in each 10-minute cell, a simple measure of species diversity. Results can be displayed either as the total number of types of species or as shaded intervals. Since most of the detailed life history and seasonal information displayed on the hand-drawn maps is preserved in the system, a wide variety of composite maps can be developed. For example, maps can easily be made of the winter or summer distributions of the spawning areas of the top twenty commercial fish species, or for selected biological groupings of species (e.g., groups aggregated by tolerance to seasonal temperature changes), or for areas of adult concentrations of specified species groups during a particular season of the year.

The second operation enables the user to assess specific attributes of marine species within selected areas described by any combination of 10-minute square grid cells. For example, life history stages or fishing grounds of species found within 30 miles of proposed or active ocean dump sites or within estuaries in the Gulf of Mexico can be easily listed. For any specified area the system can provide a listing of the life history stages of each species found within the area, the seasonality of the individual life history stages, and the total number of 10-minute cells within the area occupied by each life history stage of each species for each season. In a manner similar to the composite mapping feature, this listing can incorporate all or any combination of marine species, life history stage, and season. The system can also compare areas. For example, the system could be used to compare the spatial and temporal distributions of living marine resoures in the U.S.A. fishery conservation zone and Mexican "exclusive economic zone" of the Gulf of Mexico, or the relative biological importance of existing or proposed offshore oil and gas exploration and production areas.

In conjunction with these basic operations, a number of criteria can be used to emphasize the relative importance of a particular species, group of species, life history stage, or other attribute. For example, commercial species can be weighted by their relative economic value, or by the spatial extent of areas in which a specified life history stage of a species takes place. The weighting scheme and individual weights that could be used depend on the specific problem context in which the data system is applied. Care is required in choosing a meaningful weighting scheme, regardless of the problem context.

TEST RUNS FOR INVERTEBRATES

Preliminary test runs of the data were made to illustrate the capabilitiy of the system. Invertebrates were arbitrarily chosen for this illustration for two reasons: 1) they are by far the most economically valuable group of marine species in the Gulf of Mexico*; and 2) only 16 invertebrates are included in the data system (compared to 48 fishes), making them much easier initilly to code, edit, and enter. Several combinations of invertebrate species, life history stage, exploitation activity, and season were selected. For each combination the system generated a computer map which aggregated data for each species according to the attributes specified. Several of these combinations are illustrated below.

Two types of criteria (weights) were applied to the species data used in these test runs: "areal extent" and "economic value." In the context of the weighting scheme used in these test runs, the term "areal extent" represents the spatial extent of an area or areas occuppied by a species during a particular life history stage and season. For example, if the spawning areas of a species were uniformly distributed throughout 250 cells (each 10 minutes by 10 minutes) within the Gulf during the spring, then the "areal extent" value for each cell would be 1/250; if a species was uniformly distributed throughout 10 cells, then each cell would have a value of 1/10.** Given a specified combination of species, life history stage, and season, the system sums the areal extent values in all cells and produces a shaded computer map which places the sum of values for each cell in intervals to highlight differences among areas. Those areas in the highest intervals, i.e., the darkest areas shown on each map, have the highest relative areal extent value and are candiates for additional analysis. Each of these areas should be reviewed in detail on a species-by-species basis before conclusions are drawn. An area can have a high areal extent value for several reasons. It could contain a few species with very high values, many species with moderate values, or combinations between.

The economic value weights used are based on the commercial value of catch in 1980 (NMFS, 1982). These weights have only been applied to the seven major commercial species: blue crab (Callinectes sapidus); stone crab (Menippe mercenaria); spiny lobster (Panulirus argus); American oyster (Crassostrea virginica); brown shrimp (Penaeus aztecus); pink shrimp (Penaeus duorarum); and white shrimp (Penaeus setiferus). A weight for economic value was computed for each species based on its percent of the total dollar value of invertebrate catch. These weights were then multiplied by the areal extent values for each species. Computer-generated maps where then produced as described above. Areas identified in the highest interval that are weighted by both areal extent and economic value provide an indication of areas

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* Seven of these 16 invertebrates account for approximately 75% of the total value of U.S. commerical fish catch in the Gulf of Mexico (NMFS, 1982).

** Computing values of "areal extent" in this manner assumes that species are uniformly distributed throughout a specified area. While this is admittedly an unrealistic assumption, it is a necessary one given limitations of existing knowledge and data about the distribution in space and time of most species' life histories. However, the ORCA data system is capable of differentiating values among individual cells, given the necessary data. For example, an experiment is currently underway to use the bottom trawl survey data of the Northeast Fisheries Center of the National Marine Fisheries Serive, NOAA, for exactly this purpose.

that may not only be biologically important, but could also produce the greatest economic loss due to adverse impacts.

Initial results of these first runs simply illustrate some of the features of the system. For example, when data are weighted only by areal extent (Figure 2), coastal waters off of southwestern Florida are in the highest interval. In fact, the areal extent values of cells in this area are by far the highest in the Gulf for nursery areas. Since values are also very high when only major commercial species are considered (Figure 3), this group probably dominates the areal extent value of the area. However, when the data are also weighted by economic value (Figure 4), the combined values in cells in this area decrease dramatically (although the area is still in the highest interval). This is primarily because of the relatively low economic value of blue crab and spiny lobster which dominate areal extent values in the area.

Another example can be illustrated by Figures 5 and 6. When summer spawning areas for major commercial species are weighted only by areal extent (Figure 5), no areas stand out as having very high areal extent values relative to other areas, although a few are slightly higher than others. This is because spawning areas for most of the major commercial species are generally in large offshore areas. Therefore, each species has a relatively low areal extent value. However, when the data are also weighted by economic value (Figure 6), one offshore area in the northern Gulf has very high combined values compared to others. The primary reason for this is the presence of both brown and white shrimp spawning in this area during the summer and the very high economic value of these species.

Although admittedly simplistic, these two examples provide an indication of some of the capabilities of the system. They show the potential of the system for relatively easy manipulation of information on life history stages, seasons, and commercial and recreational fishing grounds for a large number of important marine species within a consistant analytic framework. The maps shown above represent only one type of display and data aggregation that the system can produce. Various other displays, data aggregations, and weighting schemes will be used to analyze a number of problems related to conflicts between economic activities and living marine resources in the Gulf of Mexico. This capability is not a substitute for the judgments and interpretations of expert marine biologists. On the contrary, it is complementary and can enhance and expand the range of issues on which expert judgement can be made.

Development of this data system is a continuing process and is only one of several analytic methods and tools being developed as part of ORCA's Strategic Assessment Program. As additional and improved information becomes available, the data system will be upgraded. For example, the same formats will be used to display the spatial and temporal distribution of other physical characteristics of the region such as bathymetry, surface and bottom temperature, salinity, and sediment type, or economic data such as weight of fish catch. Use of this system in conjunction with other components of the program will provide a basis for understanding better the relationships between living marine resources and human activities in the Gulf of Mexico.

REFERENCES

1. Duke, J., et al., 1980, Development of a simple pollutant transport model for the Gulf of Mexico, Washington, DC, National Oceanic and Atmospheric Administration, Office of Ocean Resources Coordination and Assessment, 27 p. (mimeo).

2. Ehler, C. N., and D. J. Basta, 1982, Information for assessing the future use of ocean resources, Marine Pollution Bulletin (forthcoming).

3. National Marine Fisheries Service, Resource Statistics Division, 1982, Unpublished data.

4. Office of Ocean Resources Coordination and Assessment, 1981, Gulf of Mexico strategic assessment project, Washington, DC, National Oceanic and Atmospheric Administration, 11 p. (mimeo).

5. Office of Ocean Resources Coordination and Assessment, 1982, Predicting the surface transport of pollutants in the Gulf of Mexico: first results, Washington, DC, National Oceanic and Atmospheric Administration, 13 p. (mimeo).

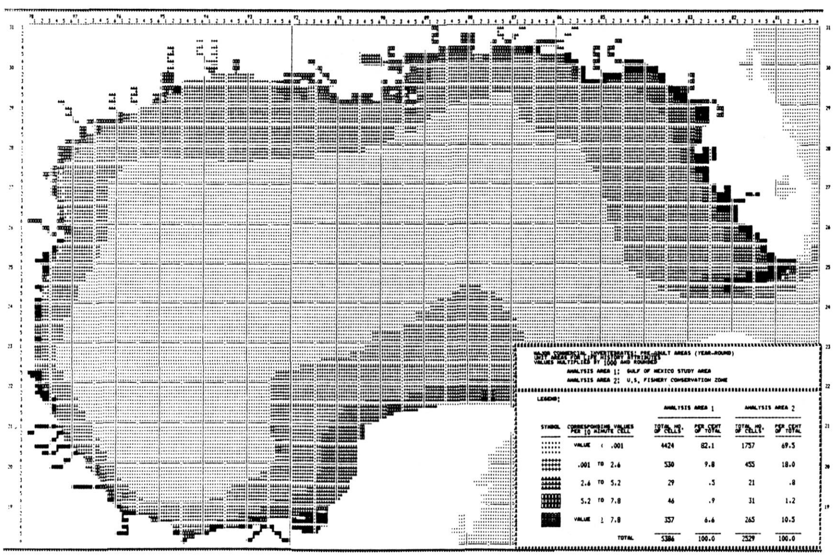

Figure 2. Computer-generated map of invertebrate nursery areas, year-round (weighted by areal extent)

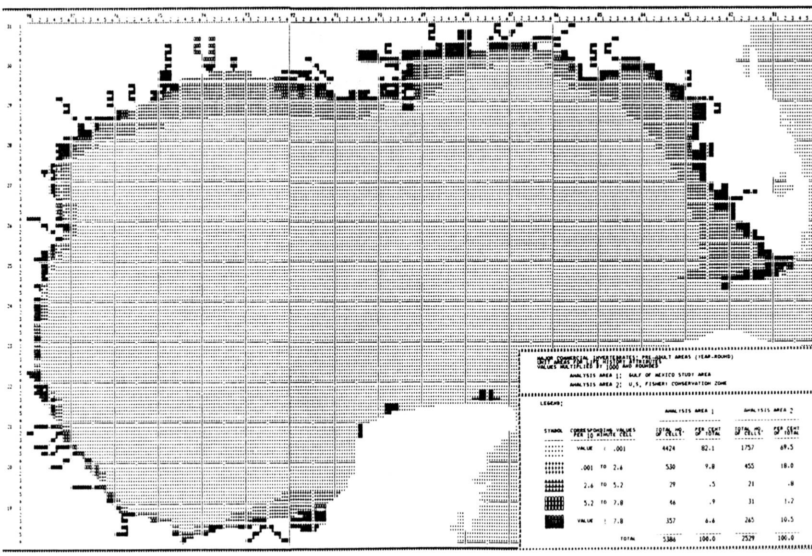

Figure 3. Computer-generated map of major commercial invertebrate nursery areas, year-round (weighted by areal extent)

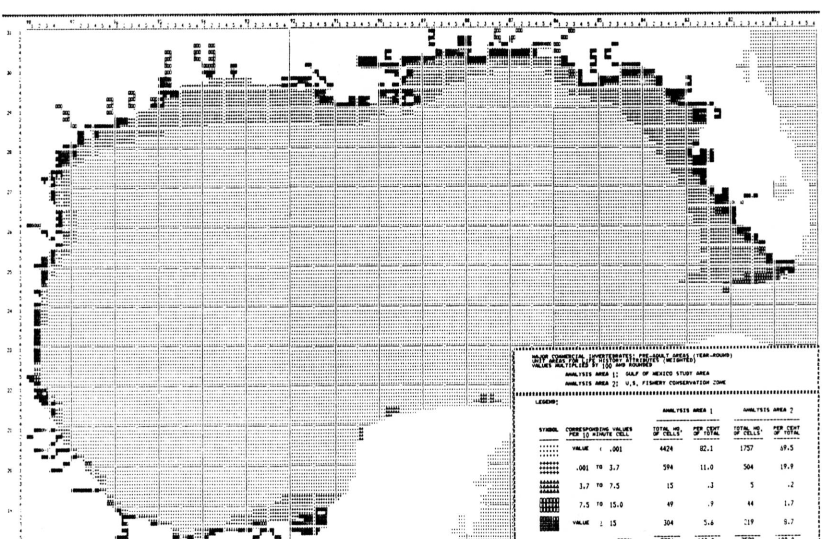

Figure 4. Computer-generated map of major commercial invertebrate nursery areas, year-round (weighted by areal extent and economic value)

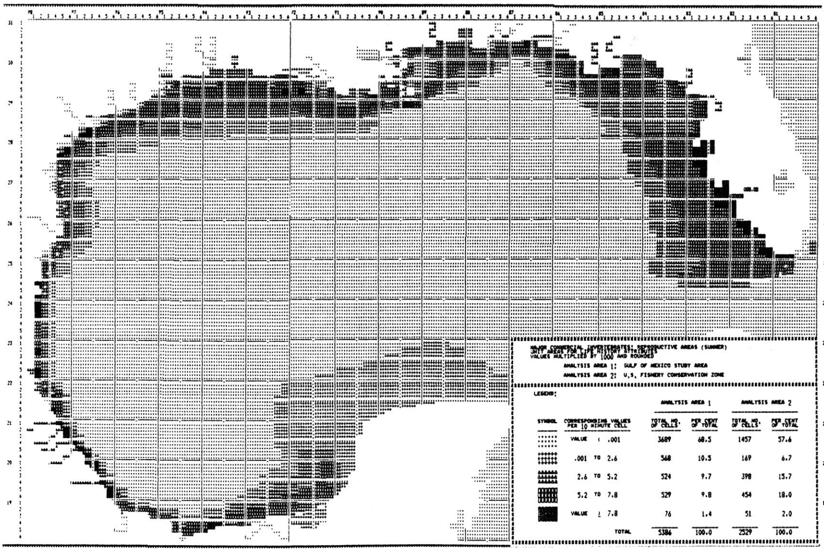

Figure 5. Computer-generated map of major commercial invertebrate spawning areas, summer (weighted by areal extent)

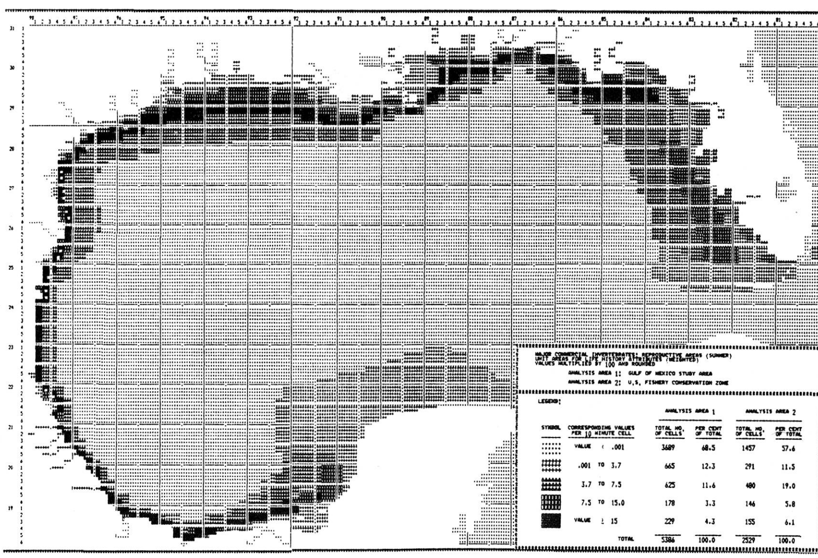

Figure 6. Computer-generated map of major commercial invertebrate spawning areas, summer (weighted by areal extent and economic value)