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Fishery Oceanography From Space

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FISHERY OCEANOGRAPHY FROM SPACE

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The exploration and utilization of world oceanic fishery resources have been limited in the past for lack of a technology which could provide the observations required for rapid assessment, real time intelligence, or the environmental monitoring necessary to determine the space time ecosystem relationships on which a predictive system could be based within usable time factors.

The space agency has undertaken an extensive study to determine if it would be economically feasible to develop a satellite system to survey the resources of the earth. This satellite would be equipped with various types of sensors which operate on the principle that each object on earth reflects, absorbs, or re-emits energy in a manner characteristic of the object's physical and molecular structure giving each its own spectral signature. The Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Pascagoula, Mississippi, in cooperation with the National Aeronautics Space Administration's Spacecraft Oceanography Project, is engaged in a program which seeks to apply existing remote sensing technology to the problems of fishery resource assessment, i.e., the location, identification, and quantification of surface and near-surface fish stocks. Several approaches are being taken in this effort. These include studies of the reflectance spectra of fish schools and associated surface fish oil films; the intensity and spectral emittance of bioluminescence associated with most schools, which may permit night-time detection of fish schools through the use of low-level light sensors; and the possible application of a pulsed laser system which may provide a means for locating fish schools at sub-surface depths. Results of studies conducted in these areas by the Bureau of Commercial Fisheries, Pascagoula Base, are the subject of this paper and are discussed in the following sections.

Spectro-Photographic Studies

Many species of pelagic fish can be distinguished on the basis of color by a qualified observer. These color differences are used by spotter pilots of the commercial fishing industry to locate and identify commercial fish stocks. The experienced spotter also uses a number of other features in addition to color, to locate and identify fish. These are the presence of fish-oil films, diving birds, ripples, and, in some cases, a churning of the waters. It is assumed, on the basis of these and other considerations, that present airborne and spaceborne sensors, which outperform the human eye in many important respects, may be used to locate and identify surface and near-surface fish stocks.

Our initial effort at Pascagoula was to determine the potential application of standard aerial photographic techniques as a means of obtaining quantitative and qualitative data on pelagic fish stocks. The field activities associated with this program were concluded in May of 1968 after more than 1,000 schools had been photographed using black and white, color, and color infrared films and filter combinations. Sixty-five of these schools were sampled in an effort to determine size and species composition. Simultaneous sonar soundings were also obtained of a number of schools in an effort to determine sub-surface configuration and school density. Preliminary results show that both the position and surface configuration of fish schools at or near the surface may be precisely determined from high altitude photography. An effort is now being made to correlate the photographic imagery with the "ground truth" data and sonar soundings obtained during the field operations. Upon completion, forty transparencies of fish schools of different species will be subjected to densitometric analyses. Transmissivity of the images will be measured in the red, green, and blue spectral regions, and with white light. These data will then be subjected to a statistical analysis to determine correlations between spectral transmissivity and species, surface area of schools and quantity of fish in school, and transmissivity of image and school size. It is believed that this study will serve to determine the potential application of the photographic techniques employed as a means of identifying and quantifying pelagic fish stocks.

The distinctive color of certain species suggests that measurements of the spectral energy distribution may reveal characteristic spectral signatures which may be used to locate and identify fish schools in their natural environment under certain conditions. During September 1968 the Pascagoula Base and TRW Systems obtained spectral reflectance measurements of fifteen schooling species in the northern Gulf of Mexico. Measurements were made on single fish, fish in small groups and fish in schools inside impoundments using a recently developed TRW Water-color Spectrometer.

This Spectrometer (figure 1) was designed for field use, is aircraft rated, and possesses the characteristics described in table 1. It receives incoming light focused by the objective lens on a narrow slit located at the focal plane of a parabolic mirror. Light which passes through the slit is reflected by the spherical mirror onto a reflection diffraction grating. The diffracted light reflected from the grating is reflected by the spherical mirror and focused on the base of the rotating disc located in the front of the sensitive end of a multiplier phototube. A slit in the rotating disc allows only a small portion of the spectrum to reach the face of the phototube and as the disc rotates the slit successively permits light from all portions of the spectrum to register on the face of the phototube. In this study, output from the tube was recorded on a paper strip chart recorder.

The observational program was conducted in the area extending from Cape San Blas westward to Mexico Beach, Florida. All data were acquired aboard a Bureau vessel and from "Stage II", a Texas type tower which was made available to the Bureau of Commercial Fisheries by the U. S. Navy Mine Defense Laboratory, Panama City, Florida. Thirty-three of approximately 120 spectra obtained during this period were analyzed by TRW. Examination of these data indicate that, in general, the reflectances are separable on a species basis and are different from sea-water reflectance. The results of this initial research effort prove the strong potential for application of remote spectral sensing for fishery resource assessment. It also appears that existing sensor technology is adequate in resolution and sensitivity to discern differentials and color spectra in a variety of pelagic schooling species. In this study, measurements were made on a relatively large variety of species in an effort to gain an impression of the range of signatures which might be available and the feasibility of detecting and classifying species by remote sensing. However, these data were acquired under laboratory-like conditions, and it must now be determined whether these techniques will achieve similar results when applied to schools of fish in the sea. The second phase of this research will be concerned with the reliability and application of these techniques in a field program. During the coming months, observations will be made of the reflectance spectra of a number of commercially important species in their natural environment. These observations will be made on captive schools under a wide range of known (monitored) environmental conditions of sea-state, lighting conditions, and water turbidity. It is anticipated that the results of these tests will determine the feasibility of an operational system which will provide a means for location and identification of fish school from observations of the spectral energy distribution.

Night-time Detection of Pelagic Fishes Through The Use of Airborne Low-Level Light Sensors

Another approach to the problem of locating and identifying pelagic fish stocks which shows great potential is the use of low-level light sensors such as image intensifiers to detect the bioluminescence, or "fire" as it is referred to by fishermen, associated with most schools. The Spanish mackerel fishery which yields an annual catch of 7 to 8 million pounds serves to illustrate the potential application of this method. In Florida this fishery is carried on chiefly with gill nets and haul seines at night. The fish are sighted by the "fire" in the water. This "fire" results from the movement of fish schools which cause luminescent organisms in the water to glow momentarily. The bodies of rapidly swimming fish are outlined with light and each leaves a trail of fire as it moves through the water (figure 2). Large schools of mackerel containing 5 to 10 tons are identified by individual flashes within a larger glowing sphere of bioluminescence. The "fire" can be seen best with the naked eye on moonless nights, however, fishing is also done on cloudy nights.

A search of the literature dealing with the spectral characteristics and geographical distribution of luminescing animals has revealed the following:

1. Bioluminescence is usually evident in the upper layers of the ocean usually within the Euphotic Zone or above the Thermocline.

2. Luminescent flashes may have an intensity as high as 10^{-2} microwatts per square centimeter and are well above the visual threshold of the human eye.

3. Four species of dinoflagellates were shown to have similar emission spectra with a spectral peak between 470 and 480 nm. The wavelength of maximum transmissivity in clear oceanic water.

4. Two types of bioluminescence are recognized, the steady glow and the flash. Both responses can be induced in Noctiluca miliaris by prolonged or sudden mechanical stimulation.

5. Dinoflagellates luminesce upon agitation by schooling fish which is observable from the air at night. Night aerial spotting operations have been conducted off southern California to locate sardine schools.

6. It appears that fish schools may be seen to a depth of 10 fathoms under certain conditions.

During the past four months a series of tests have been conducted by the Pascagoula Base from Coast Guard helicopters, fixed-wing aircraft, a stationary oceanographic platform, and surface vessels using a Plumbicon Television Image Intensifier system (figure 3). The image intensifiers, loaned to us by the Night Vision Laboratories, Fort Belvoir, Virginia, amplify the ambient light, or in this case the bioluminescence, 40,000 times. This amplification of the light is achieved through the use of a three-stage image intensifier tube. Each stage is composed of a photocathode at the forward end and a phosphor at the rear. When light enters the forward end of each stage, it activates an electron beam emission toward the phosphor end. On leaving the cathode, the electrons are accelerated by an electrostatic field and focused at the phosphor, which converts the kinetic energy of the electron beam into visible light. The three stages in each image intensifier tube are interfaced by fibre optics and a final, greatly intensified image is formed on the third phosphor and viewed through an eyepiece.

The Plumbicon Television, coupled to the three stage Image Intensifier, provides a highly sensitive system which combines the advantages of easy operation, high speed of response, and relatively good resolution. The Plumbicon is a 30-mm tube, compared with 25-mm for most vidicons. Lead oxide is used as a photoconductive surface which gives the Plumbicon the good qualities of both the Vidicon and the Image Orthicon.

This system has been used to observe fish schools, individual fish, SCUBA divers, and objects towed at sub-surface depths in water masses containing both low and high concentrations of luminescing organisms. In recent studies conducted off the west coast of Florida, imagery was obtained of thread herring schools at night from altitudes of 500 to 5000 feet. Results of these tests strongly suggest that low-level light sensors may be used effectively from high altitudes as a means for locating and possibly identifying pelagic fish stocks over large oceanic areas.

Application

The remote sensing system which is expected to evolve from this and other research will have both daytime and night-time sensing capabilities. It will scan wide areas of the ocean at high speeds and provide real time data on the location, quantity, and species of pelagic fish stocks in the area under surveillance with a high degree of accuracy. The fishery intelligence obtained would then be relayed immediately to commercial fishing vessels in the area and to receiving stations on shore which would disseminate the data to the commercial fishing industry. The impact of an airborne/spaceborne sensing system on the commercial fishing industry would be dramatic. It would result in large scale reductions in search time and, therefore, in operating costs per unit of catch. It may also make possible profitable fishing on stocks now impossible to locate with sufficient accuracy to permit economical operations. The synoptic data which could be obtained with such a system would enable us to determine the fishery potential of a particular area in terms of availability and degree of utilization. It would also permit systematic appraisals of the near surface fishery potential of wide oceanic areas. A possibly more significant use of the aircraft/satellite data would be in determining the movements and concentrations of fish over space and time, which would provide us with the ability to predict when and where various species of fish can be taken at lowest cost.

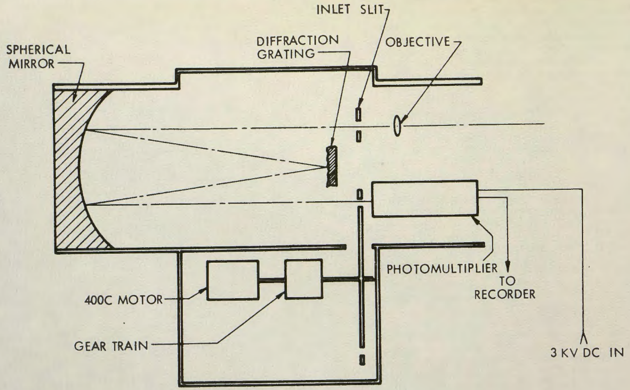

Figure 1 Water Color Spectrometer Schematic

Table 1
Water Color Spectrometer Parameters

Performance		Design	
Spectral range	4000 to 7500 Å	Type	Off-plane Elbert
Spectral resolution	50 Å (at central wavelengths)	Photomultiplier	RCA 7265 (S-20 response)
S/N at 3000 Å	800	Grating aperture	26 by 26 mm
S/N at 5000 Å	700	Grating line density	500 lines/mm
S/N at 6000 Å	300	Grating blaze	5600 Å
S/N at 7000 Å	110	Mirror focal length	9 inches
Scan time	1.2 seconds	Scanning slit dimensions	0.0185 by 0.10 inch
Instantaneous field	3° by 1/2°	System speed	f/8.8
Spectral calibration	Continuous identification	Recording	FM magnetic tape, or strip chart
		Weight sensor	25 pounds
		Weight electronics	20 pounds

FIGURE 2

BIOLUMINESCENT OUTLINE OF FISH AS SEEN WITH PLUMBICON TV IMAGE INTENSIFIER SYSTEM

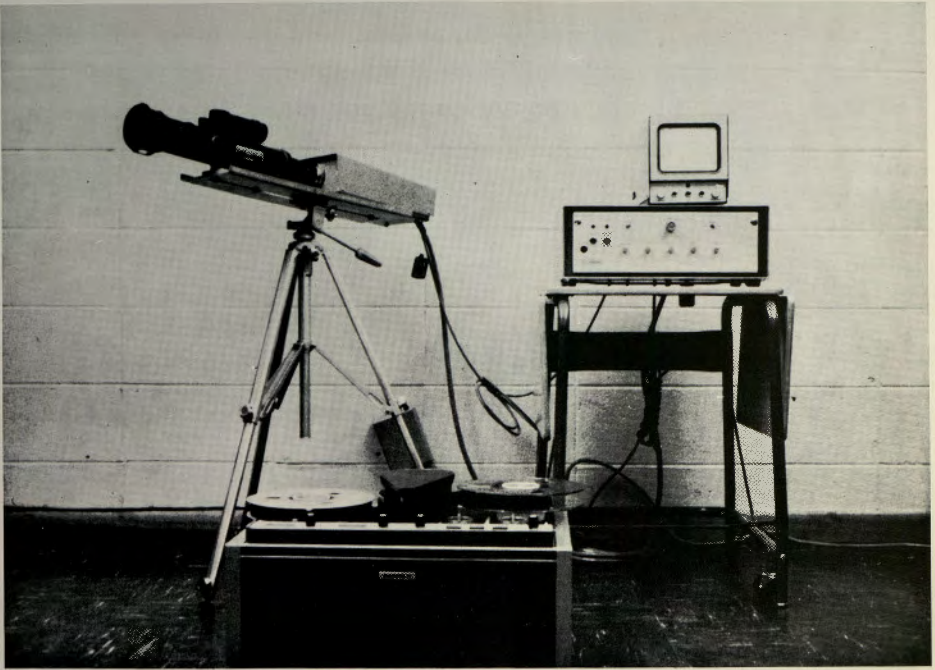

FIGURE 3

IMAGE INTENSIFIER (STARLIGHT SCOPE) COUPLED TO PLUMBICON TELEVISION SYSTEM