Remote Sensing and Extractable Biological Resources

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GLOSSARY

Several terms[1] merit definition or clarification as they are used in this consideration of the potential uses of remote sensing in relation to extractable biological resources of the Bay.

Remote sensing: Used to describe any non-contact reception of signals from the resource, with emphasis on long-distance sensing.

Extractable: Includes those organisms and materials now harvested and also those which are potentially useful.

Biological: Applies to both the organisms and their products.

Resources: Encompass those taken from the Bay for use and the organisms which are essential for the support of the harvested species.

RESOURCES

The extractable resources of the Bay have not been accurately measured. Those harvested for commercial sale are recorded with reasonable accuracy, but the recreational catch and the potentially useful species and quantities are not. It is possible, however, to make some pertinent summary statements about them.

Commercial Fisheries

These fisheries vary considerably from time to time in species composition, quantity landed, and value, but the summary by McHugh (ref. 1) provides useful data. I will blend those with my own impressions.

Recent catches landed in Chesapeake Bay ports have been about 500 million pounds per year. In 1967, these had a dockside or primary value of approximately $35 000 000, and retailed for a total at least three times that amount.

The oyster is the most valuable resource, producing about one-half of the dockside value, but only 5 to 10 percent of the weight landed. A benthic or bottom species, the oyster usually occurs only on the shoulders of the floor of the Bay where sediments are firmer and oxygen depletion is less likely than in deep waters. Most oysters are in less than 25 feet of water. They are semi-buried with the lip of the shell exposed to the water. Seed areas, producing a crop of small oysters which can be transplanted to other areas, are reasonably well identified. Many beds are self-sustaining while other oyster grounds are useful only for growing transplanted seed. Oysters have very great potentials for increased production since the Bay is exceptionally suitable and since they feed near the base of the food web where the quantities of available nutrition are greatest. These molluscs are intimately related to the environment and respond rapidly and measurably to improvement or degradation of the water around them. They are remarkable accumulators, and therefore provide useful information on heavy metals, pesticides, and other environmental contaminants.

Clams are also molluscs, and now contribute about 10 percent of the commercial value. Soft-shell clams are produced

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[1] Ref. No. 71-28, Natural Resources Institute.

almost entirely in Maryland, while the larger harvest of hard-shell clams is in Virginia. Both live in the bottom. The hard-shell clam digs to several inches below the sediment-water interface, and the soft-shell clam may be a foot or more in the bottom. Both extend dual tubes up to the water for intake and excurrent water flow.

The blue crab is the leading food species by weight, and 70 to 90 million pounds have been landed in recent years. It is so variable in abundance that crop prediction would be of exceptional value. Except during larval stages almost all of its life is spent on or near the bottom with semihibernation while slightly embedded in the sediments during the winter months. The life history of the blue crab involves the entire Bay system and emphasizes the biological unity of that system.

These benthic oysters, clams, and crabs provide about 75 percent of the total value of commercial fisheries of the Chesapeake Bay. Fish yield the remaining 25 percent of value although they involve about 80 percent of the weight landed.

The menhaden sometimes provide 300 to 400 millions of pounds of fish, dominating the weight of all commercial fisheries landed. The fish is used for fish meal, oil, and valuable secondary products. The catch has seriously declined in recent years, but there is some evidence of recovery. Menhaden are migratory and show a strong schooling pattern. One remote sensing system, visual sensing from a small plane, is extensively used by the industry with 18 to 20 planes in use along the Atlantic Coast and 32 to 35 along the Gulf (ref. 2). They locate schools from an altitude of 500 to 1000 feet by noting reddish-brown colored areas or a large abrasion on the surface. The pilot sometimes assists further by directing the set of the purse net around the school.

Alewives are herrings which live in the sea but, like other anadromous species, migrate annually back to fresh water for spawning. These, along with river herring and the hickory shad, contribute 30 to 40 million pounds of fish to the annual Bay catch. They are used as food for people and their pets and as bait. Demand is not high, and many biologists see substantial potentials for increased yield from this species.

The shad is also an anadromous species, but one which is declining in catch. Dams, pollution, and heavy fishing have all been charged with contributing to decline. Present demand is not great. Shad spawn in fresh water, spend their first summer in the Bay, and then go to sea. At about four years of age, they return to the Bay and successfully select the bay, river, and tributary of their origin. Their sensor and sorter systems for this remarkable sequential selection and response are not known.

The striped bass, locally called rock, is highly prized as food, and recent catches have ranged from 5 to 8 million pounds. The species uses the entire estuary, and a small percentage of the Chesapeake population spills out into the ocean to become a large percentage of the North Atlantic catch. Striped bass migrate to spawning areas near the fresh-salt water interface, and these areas are fairly well-identified. They are especially vulnerable to damage from pollution, especially from the many cities and towns located near the fall line at the upper end of easy navigation from the Bay.

Many other fish enter the commercial catch in smaller quantities including bluefish, gray sea trout, yellow and white perch, croaker, spot, sea bass, butterfish, flounders, swellfish, eels, carp, catfish, and others. For every useful species there is serious need for increased ability to measure abundance and track movements—both of which are susceptible to remote sensing.

Recreational Fisheries

Hundreds of thousands of people fish the Bay each year, and they catch millions of pounds of fish. Accurate statistics are not available, but careful estimates by experienced scientists suggest that sport catch of some species, like striped bass, equals or exceeds the commercial catch in weight and far exceeds it in value. Principal species also include white perch, bluefish, croaker, spot, sea trout, and flounders as well as crabs, clams and a few oysters. Recreational fishing, like other leisure-time activities, is rapidly increasing and the trend is most likely to continue.

Reptiles, Birds, and Mammals

The diamondback terrapin was long a gourmet species but is now in little demand. Abundant in many tributaries, they and other turtles live a semiaquatic life.

Since the Chesapeake lies on the eastern fly-way for migrating waterfowl, large populations visit the area for winter feeding. Native populations of black duck, mallard, and other species remain throughout the year. The total number of ducks, geese, swan, and related waterfowl in Maryland alone, as estimated by annual aerial survey, has ranged from 750 000 to 980 000 in the last five years.

Mammals abound in the large wetlands of the Bay region. Over 200 000 muskrats were caught in 1970, and mink, otter, fox, raccoon, and nutria are also of commercial value.

Potentials

Manyspecies are unused or underutilized in and around the Bay. Caution should be exercised in efforts to increase the extraction of proteins and other biological materials from the estuary, because present trophic relationships might be damaged or other undesirable effects might be achieved. Serious consideration could, however, be directed toward use of several large crops.

Marsh grasses of several types, rooted aquatic plants, and abundant macroscopic algae offer potentials. They make essential contributions to the nutritional cycles of the Bay, but there may be a surplus available for harvest.

Among fish, several herrings, the hogchoker, anchovies, silversides, and white perch all maintain large populations worth exploring for exploitation. Bloodworms and several small molluscs also may have use.

The plankton populations have never been used directly for human purposes. They contain large quantities of organic material, although it is pertinent to note that high total production is frequently achieved through rapid turnover rather than through huge standing crops. The total plankton contains egg and larval stages of almost all estuarine species, and due caution should be exercised in selecting areas and seasons for possible harvest.

Negative Resources

Sea nettles are sometimes abundant and can cause considerable personal annoyance and economic damage. Such species of plants as Eurasian water milfoil and water chestnut have invaded portions of the Bay and caused damage by crowding out other species, clogging waterways, increasing local sedimentation, deposition of injurious seedcases, and by other means. Surveys of these plants by low-flying airplanes have been of assistance to ground-level studies of distribution and abundance.

Supportive Resources

There is insufficient knowledge of the nutritional requirements of most Bay species to permit quantitative determination of the importance of various foods. Several biological resources are thought to be essential, however. The complex wetlands, for instance, act as giant factories of organic material as well as large areas of protective habitat for juvenile fish and other marine life. The phytoplankton and zooplankton populations must be available in suitable quantity and quality to feed the useful species. Small fish, especially the anchovy, silversides, and young menhaden, are consumed in large quantities by predacious fish, and their abundance may determine the availability of desired fish. Management efforts must take these factors into proper account if the extraction of biological resources is to be optimal.

REMOTE SENSING PRACTICE AND POSSIBILITIES

Reception of information which is useful in managing or harvesting resources can involve both direct observation of the organisms and indirect evidence obtained through associated events or biological products.

Sensing Organisms

Bottom species have always presented serious difficulties in surveying. These include oysters, clams, crabs, many benthic fish, and some plants. The oyster beds of the Bay were first surveyed early in the century by use of piano wire attached to a drag towed along the bottom. An experienced hand on the wire, roughly calibrated by scattered samples from the bottom, assisted in outlining the areas of useful oyster populations. Some of these outlines are still useful, and practicing oystermen still feel the dredge cable for information. More recently a first effort to apply high resolution sidelooking sonar as a scanning device was attempted by Westinghouse (ref. 3). Detection of shelled areas was possible, but discretion between shell and oysters was not.

At the Symposium on Remote Sensing in Marine Biology and Fishery Resources held in January at Texas A&M, Kelly reported considerable success in discerning, surveying, and predicting shallow-water (less than 4 meters) beds of edible mussels, eel grass, and green algae (ref. 4). Photography with Ektachrome and panchromatic film, with various filters, was of considerable value at altitudes of 3000 to 5000 feet. He suggests the many values such synoptic observation might serve. Higher altitudes are useful for obtaining patterns, but lower altitude observation appears to be essential for interpretation. He expressed the opinion that present satellite imagery probably does not provide sufficient resolution for use in such studies.

In the Chesapeake Bay, beds of vegetation are readily visible from planes, and species patterns are strongly suggested. About 5 to 7 years ago, serious consideration was given to the use of visual and photographic surveys for Eurasian milfoil, but experienced observers could not distinguish it from consorting species except at or near ground level. Turbidity is relatively high, but the annual period of minima in late winter may be useful, as might the exceptionally good visibility noted by skin divers in Eastern Bay and other specific regions.

Potentials appear to be seriously limited for obtaining information on oysters, clams, and crabs by remote sensing. There are serious difficulties involved in crossing air-water interface and penetrating the suspended material in Bay waters; the biological habits of these species are not helpful. Clams live in the bottom and are visibly detectable only by the small pits around their siphons. Oysters are difficult to discern for skin divers. Crabs work their way slightly into the bottom in winter and frequently crawl very close to it in summer. All do have shells much harder than the usual substrate, and this may offer opportunities for sensing. All of them might, however, carry small sensors to obtain in situ information on physiology and behavior.

Swimming species, including most fish, squid, and a few other forms, have also been sensed by various primitive and sophisticated techniques. Many species can be identified accurately by underwater acoustical sensors, and sometimes helpful information can be obtained on density. In a converse sense, fish can hear and respond to acoustic signals and that ability has been used through both primitive noise makers and more elaborate equipment for attracting and catching them.

Acoustic sensing is now a precise and valuable tool. Midttun (ref. 5) describes present echo-sounding and estimation techniques in Norway and other countries. They can assist in locating fish and estimating abundance, and they sometimes indicate the species. He provides comment on some of the pertinent limiting conditions and also suggests ways in which computer competence can improve the general method.

Implanted radio transmitters are already in use in the Bay and at other coastal sites. Carlson (ref. 6) used them to track the movements of shad transplanted above the Conowingo Dam on the Susquehanna River. J.A. Mihursky and T.S. Koo, at the Chesapeake Biological Laboratory, are employing them, respectively, to learn the response of striped bass to the intake and outfall conditions at power plants, and to learn the behavior of fish in the Chesapeake and Delaware Canal as it undergoes enlargement. As with salmon on the West Coast, these sensor systems have present value which can be enhanced by further miniaturization.

Spectrophotometric techniques may eventually be useful in relation to schooling fish like menhaden, striped bass, bluefish, and baitfish. Drennan (ref. 7) reported that the spectral reflectance of fifteen schooling species (in impoundments and held near the water surface) were separable by species and different from sea water. He calculated the expected reflectance curves obtained from a plane at 1000 feet with the fish at a depth of 50 centimeters, and estimated that fish could be detected if they occupied 10 percent of more of the area under the surface.

Drennan also discussed the embryonic possibilities of using a laser. Sensors of these coherent beams of monochromatic light are able to measure distance, and therefore to detect difference in distance, with fantastic precision. He cites airborne bathymetric sensing through water 250 feet or more in depth and measurement of wave height with accuracies in terms of inches. Further he noted that his spectrophotometric studies showed that the tested species of fish had a reflectance of 3 to 9 percent of the wavelength band of interest, while sea water varies from approximately 0.3 to 3 percent. Such laser equipment is apparently within the load capabilities of planes and satellites.

The surface manifestations of fish and other organisms have already been noted in part. Schools of menhaden and cow-nose rays can easily be seen from the air. Exceptionally dense and colorful plankton populations are highly visible in the form of red or mahogany tides of dinoflagellates and the paint-green surface populations of algae in the Potomac, below Washington, in summer. More subtle signatures of surface and near-surface populations are probably detectable.

The edge of the Bay, containing hundreds of thousands of acres of various types of marsh and wetlands, offers exceptional opportunities for advantageous use of remote sensing. Such techniques, from planes, have been used for specific areas for several years. As reported elsewhere in the Conference, Maryland is now surveying some of its wetland areas, and the Chesapeake Center for Field Biology of the Smithsonian Institution is making detailed analysis of photographic coverage of the Center by infrared and visible-light photographs. Richard Anderson at the American University and others are examining the possibilities of determining the species present, their distribution, relationships to various environmental parameters, and the changes which are occurring with time. Remote sensing at all levels from surface to satellite appears to have unique and high value for the definition, understanding, and management of such edges.

Aerial species, including ducks, geese, swan, and other birds, have been surveyed by eye from small planes to provide valuable population estimates. Efforts to utilize photographic surveys for this purpose have generally been disappointing. At least two other remote sensing uses are, however, quite promising.[2] Wild-fowl habitat information can be rapidly, accurately, and repetitively obtained. Attached radio transmitters have been essential in W.J. Sladen's efforts to track the movements of whistling swan during spring migrations. Other uses will probably emerge.

Sensing the Associated Environment

Meteorological information should have value to fishery biologists–else every fisherman is wrong in his legendary use of weather to predict catch. In the Bay, the specific effects of cloud cover, weather systems, and other patterns on fish distribution and behavior are not established. Perhaps they could be examined with profit.

Chemical features of the Bay of importance to biological events include salinity and the complex which is termed "water quality." Since the sensing of such features is discussed elsewhere, no further comment is appropriate here.

Physical circumstances which may be helpful in understanding, managing, and using biological crops include flow lines, eddies, depth, bottom contours, color, silt, temperature, surface abrasions, and emitted light. Only the last, which might not be treated by others at this conference, merits special comment.

At the Texas Symposium, Hornig (ref. 8) discussed the use of stimulated fluorescence in detecting and identifying fish oils. He used an arc lamp as a stimulant, and could distinguish the spectra emitted by a half dozen species of fish. He concludes that arc or laser stimulating of fluorescence provides a new and useful supplementary technique.

Drennan (ref. 7) considered some of the possibilities of using fish-stimulated bioluminescence to locate fish. In the Chesapeake Bay, bioluminescence occurs year-round from the comb-jellies or ctenophores, which are most noticeable in summer; from *Noctiluca* and other dinoflagellates; and from less obvious species. Drennan noted that the light reaching a sensor is affected by several important factors, but that present capabilities of intensifying images by a factor of up to 75 000 may provide a highly useful tool. It seems worth exploration in the Chesapeake Bay.

Secondary biological evidence on populations can frequently be obtained. The food of fish, such as plankton or prey fish, may be more easily detected that the predator. Birds wheeling over schools, frequently feeding on the small prey of larger carnivores, are valuable indicators and might be susceptible to scanning. We must beware, however, of the same birds wheeling over garbage. Finally, fish products–like oils from prey–may be useful as indirect evidence.

[2] Personal communication from Vernon D. Stotts, Maryland Waterfowl Project Leader.

POSSIBLE USES OF DATA FROM REMOTE SENSING

Research

(1) To locate and inventory species. Synoptic and repetitive samples are especially valuable for observing changes with time in the sessile species.

(2) To examine relationships of species to associated environmental events and alterations.

(3) To assist in learning the behavioral patterns, including seasonal movements, schooling behavior, diurnal and other short-term patterns, and responses to environmental circumstances.

(4) To search for new resources.

(5) To provide clues on the best design of many types of research.

(6) To assist research on the best possible uses of remote sensing.

Management

(1) To assist in continuing inventory.

(2) To help measure exploitation rates and distribution.

(3) To guide control efforts to enhance desired forms and reduce undesired organisms.

(4) To assist efforts to make optimal uses of wastes, especially of heat and nutrients.

(5) To monitor pollution and other unfavorable environmental circumstances.

Fishing

(1) To determine distribution and abundance of sessile target species.

(2) To locate mobile species, estimate yield potentials, and guide specific fishing activities.

(3) To assist in developing improved short-term and long-term forecasts of abundance and distribution.

OPERATION CHESAPEEK

From this brief review it is evident that there is urgent need for remotely sensed information about biological resources and that there are and will be valuable instruments, platforms, and techniques for obtaining such data. There are not, however, many present uses of such data. I suggest that a research and observational program be designed and completed for two purposes:

(1) To determine experimentally and from previous experience here and elsewhere the best possible application of the unique capabilities of remote sensing to Chesapeake Bay resource problems, with special attention to the uses of aerial surveys.

(2) To develop a long-term pattern for useful surveillance of Chesapeake resources.

The research phase will probably require at least two years of coordinated studies, including the following elements:

(1) Satellite observations by the widest possible variety of sensors.

(2) High- and low-level planes with selected sensors.

(3) Simultaneous ground truth for each type of aquatic, semi-aquatic, marginal, and terrestrial habitat which has been defined for this or other purposes, obtained at intervals corresponding to seasons or other biologically significant units of time.

(4) Testing of the greatest possible variety and combinations of sensors, films, filters, frequency of observation, and altitudes.

The observational phase will require:

(1) Regular repetition of selected coverage on defined schedule and use of defined elevations, sensors, films, filters, and other techniques.

(2) Availability of equipment and staff for supplemental, exceptional, and urgent observations.

(3) Wide distribution of films and other products to scientists, resource managers, and fishermen (as well as to planners and users in many other fields).

(4) Effective assistance in interpretation for all potential users.

(5) Maintenance of a continuing program of research to improve the design, quality, and use of remote sensing operations for Chesapeake Bay.

REFERENCES

1. McHugh, J.L.: Fisheries of Chesapeake Bay. Proc. Gov. Conf. Ches. Bay, 1969.
2. Maughan, P.M.; and Marmelstein, A.D.: Operational Use of Remote Sensors in Commercial Fishing. Proc. Symp. on Remote Sensing in Mar. Biol. and Fishery Resources. Texas A&M Univ., 1971, pp. 13-31.
3. Chesapeake Bay Bottom Survey Program Report. Westinghouse Electric Corp., 1969.
4. Kelly, M.G.: Studies of Benthic Cover in Near-Shore Temperate Waters using Aerial Photography. Proc. Symp. on Remote Sensing in Mar. Biol. and Fishery Resources. Texas A&M Univ., 1971, pp. 234-252.
5. Midttun, L.: Acoustic Methods for Estimation of Fish Abundance. Proc. Symp. on Remote Sensing in Mar. Biol. and Fishery Resources. Texas A&M Univ., 1971, pp. 228-233.
6. Carlson, F.T.: Suitability of the Susquehanna River for Restoration of Shad. U.S. Dept. of Interior, Md. Bd. Nat. Resources, N.Y. Conserv. Dept. and Pa. Fish Comm., 1968.
7. Drennan, K.L.: Some Potential Applications of Remote Sensing in Fisheries. Proc. Symp. on Remote Sensing in Mar. Biol. and Fishery Resources. Texas A&M Univ., 1971, pp. 32-72.
8. Hornig, A.W.: Remote Sensing of Marine and Fisheries Resources by Fluorescence Methods. Proc. Symp. on Remote Sensing in Mar. Biol. and Fishery Resources. Texas A&M Univ., 1971, pp. 136-167.