Stickney, R. R., and S. E. Shumway. 1974. Occurrence of cellulase activity in the stomachs of fishes. J. Fish. Biol. 6:779-790.
Yashouv, A. 1969. Mixed fish culture in ponds and the role of Tilapia in it. Bamidgeh, 21:75-92.
Yashouv, A., and J. Chervinski. 1960. Evaluation of the various food items in the diet of T. nilotica. Bamidgeh, 12:71-78.
Yashouv, A., and J. Chervinski. 1961. The food of *Tilapia nilotica* in ponds of the fish culture center at Dor. Bamidgeh, 13:33-39.
Yokoe, Y. 1960. The cellulase activity in gastric juice and hepatopancreas of crayfish. J. Fac. Sci., Tokoyo Univ. 4:31-38.
Yokoe, Y., and I. Yasumasu. 1964. The distribution of cellulase in invertebrates. Comp. Biochem. Physiol. 13:323-338.

AERIAL SURVEILLANCE TO MONITOR WATER QUALITY IN CATFISH PONDS

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ABSTRACT

Remotely sensed data and ground truth data were collected simultaneously from 16 experimental ponds during 6 days in June and July, 1974. Color infrared images were taken with hand-held 35mm cameras from single engine aircraft. Numerical color values for pond color were obtained by visually matching the pond color with a Munsell Color System chip which had a standardized numerical value assigned to it. Ground truth data involved the determination of 14 chemical, physical, and biological parameters. Regression analysis indicated a significant correlation ($P < .01$) existed only between total and inorganic solids and the Munsell Color System. There was evidence to suggest that the color—inorganic solid relationship was masked by the organic solids present.

INTRODUCTION

A new rapid technique for monitoring water quality is needed by fish culturists for two reasons; to monitor and maintain the new Environmental Protection Agency water quality standards and to be able to predict the onset of low oxygen conditions. The Federal Water Pollution Control Act Amendments of 1972 requires the states, beginning in 1975, to submit annual reports to the EPA which locate point sources of pollution, describe existing and anticipated water quality, and contain proposals for point and nonpoint source control. A small but vital part of the overall pollution problem will be fish culture systems as they will soon fall under EPA guidelines. The fish culturist will be responsible for monitoring and maintaining EPA standards for his particular systems effluent.

Secondly, thousands of acres are now in aquaculture production in the U. S. However, due to several high-risk problems, maximum growth of aquaculture systems has not been realized. One of the primary problems is maintaining water quality; namely, preventing oxygen depletions. At present, most fish farmers are not equipped to deal effectively with oxygen depletion because, more often than not, this problem is discovered too late to remedy. Since even seemingly identical ponds are seldom if ever identical in terms of water quality, the farmer cannot monitor one pond and expect it to be representative of every pond on his farm.

Clearly then, there is a need for a technique which will allow us to monitor water quality rapidly on a large scale. Such a technique might involve aerial surveillance, thus "remote sensing".

Most prediction techniques which utilize remotely sensed data collected during aerial surveillances involve the use of expensive instruments. In a study to determine various pollutants in lakes and streams, Scherz, Graff, and Boyle (1969) used a 35mm camera in conjunction with a microdensitometer to establish reflectance curves. Klooster and Scherz (1974) exploited a similar technique for determination of turbidity caused by paper mill wastes. Gramms and Boyle (1971) sought to establish the reflectance and transmittance characteristics of several species of blue and blue-green algae by spectral analysis. Scherz (1971), utilizing reflectance curves, concluded that photography and multispectral scanners can readily sense suspended solids in the water, but that dissolved oxygen, other gases, phosphates and nitrates can not be determined.

Unlike the above studies, our preliminary work indicated that the human eye might be capable of categorizing color differences on infrared photographs by means of the Munsell Color System. Researchers believed that a visual analysis technique might yield the information needed to predict water quality parameters.

The Departments of Forestry, Wildlife and Fisheries, and Agronomy at Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, in partial fulfillment of NASA contract NGL 25-001-054, were united in a multidisciplinary study to test the utility of visual interpretation of remotely sensed data in water quality surveillance.

The principal objective was to develop an operational and inexpensive technique to predict various water quality parameters.

MATERIALS AND METHODS

Description of the Study Area

The study area consisted of 16 experimental fish production ponds. Ponds 1-12 were .04 ha in area, while ponds 13-16 were 0.10 ha. Maximum and average depths of the ponds were 1.75m and 1.25m, respectively. The ponds were constructed on an area of slightly alkaline, sandy clay loam. The ponds are individually supplied with water from a deep well, and little run-off water enters the ponds.

During the data collection period all ponds contained one or more species of fish and were actively managed for fish production before and during sampling periods.

Ponds containing large concentrations of algae (usually *Anabaena*) were treated with a 0.1 ppm concentration of copper sulfate in an effort to prevent massive algal population buildups. If the dissolved oxygen concentration in a pond dropped to 3 ppm, fresh water was pumped onto a splash board and into the pond until the oxygen concentration began to increase.

Munsell Color System

The Munsell Color System is based on a three dimensional color solid. This spherical color solid is composed of three color variables which are hue, value and chroma. They correspond to the psychological characteristics of color, brightness, and saturation, respectively (Rib, 1968).

The solid may be compared to a grapefruit, with each section representing a different hue (Fig. 1). Hue is composed of five major divisions which have been assigned to names red (R), yellow (Y), green (G), blue (B), and purple (P). These sections are subdivided into the intermediate steps of YR, GY, BG, PB, and RP. Finally, each of the ten zones are divided so that the result is forty segments of hue with each section representing a 2.5 Munsell hue-step. Chroma, or saturation, is represented by a horizontal axis which contains equal steps numbering from zero to more than twenty. Value, or brightness, is divided into ten equal steps on the vertical axis with zero representing black and ten representing white.

Colors are given in the order of hue, value, and chroma. A Munsell chip designated as 2.5 BG 5/4 indicates a color of 2.5 BG hue, 5 value, and 4 chroma.

A numerical color value was obtained by assigning a numerical scale of 1-12 to the Munsell hue scale of 10 G — 7.5 PB (Table 1); value and chroma received the observed numerical designations.

Ground Truth Data

Dissolved oxygen concentrations and temperature were monitored 7-10cm below the pond surface with a Chemtrix Type 30 Dissolved Oxygen Meter. Secchi disk readings were taken. Water samples were also collected with a Van Dorn type sampler 7-8cm below the surface in the deep end of each pond, as well as a column of water removed by means of a sample tube for total, organic and inorganic solids analysis.

Nitrate, nitrite, orthophosphate concentrations and pH values were determined using a Hach Model DR 8103 B colorimeter. Free carbon dioxide and total alkalinity were determined titrametrically. The Hach Model NI-8 ammonium nitrogen tester was utilized to determine ammonium nitrogen concentrations. Chlorophyll concentrations were calculated from spectrometric analyses

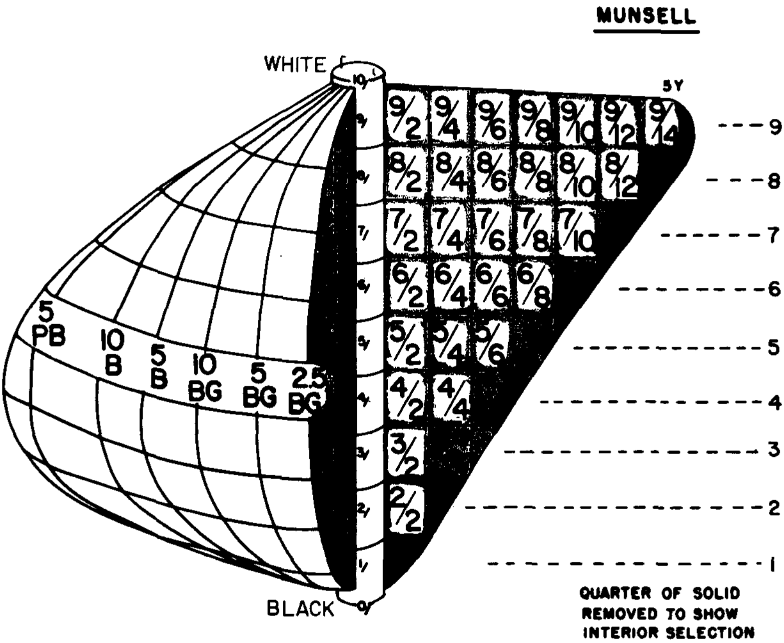

Figure 1. Schematic representation of the Munsell Color System (from Rib, 1968).

Table 1. Coding of Munsell hues for statistical analyses.

Hue	*Coded Value*	*Hue*	*Coded Value*
10 G	1	5 B	7
2.5 BG	2	7.5 B	8
5 BG	3	10 B	9
7.5 BG	4	2.5 PB	10
10 BG	5	5 PB	11
2.5 B	6	7.5 PB	12

after Yentsch (1969). Inorganic and organic suspensoids and plankton concentrations were determined after procedures outlined by the American Public Health Association (1971).

Remotely Sensed Data

Aerial data-collecting missions took place simultaneously with ground truth data collections at approximately 10:00 a.m. each sampling day. Three passes were made each sampling day in a small single engine aircraft from an approximate altitude of 525m. Researchers on board the aircraft took photographs with two hand-held 35mm Praktina FX-3 cameras. One camera contained Kodachrome X(ASA 64) film with a clear AV filter attached for true color, while the other camera contained Kodak Ektachrome infrared film with a Wratten 12 filter attached. The cameras were mounted side by side and were tripped simultaneously by a dual trigger mechanism.

Negatives were processed into 13cm by 18cm prints. A comparison of the color infrared (CIR) and true color prints showed that the CIR prints were superior to the true color prints in detail, clarity, and color quality. Therefore, CIR data was used exclusively in conjunction with Munsell color chips in an effort to predict parameter values. Three interpreters visually matched each pond on a CIR print with a Munsell color chip. The color chip that was selected by the majority of interpreters was chosen to represent pond color. The coded colors were utilized for regression analyses.

Due to the number of treatments of copper sulfate received by several ponds and their possible influence upon remotely sensed data, references will be made to "no treatment" or to "heavy treatment" ponds. No treatment ponds correspond to numbers 1, 2, 4, 6, and 12, while heavy treatment ponds are numbers 8, 9, and 10.

RESULTS AND DISCUSSION

Data collected on 6/26/74, 6/28/74-7/1/74, and 7/30/74 were included in regression analyses to determine if significant relationships might exist between water quality parameters and remotely sensed data. The regression equation $Y = b_0 + b_1 (\ln \text{Hue}) + b_2 (\text{Value}) + b_3 (\text{Value})^2$ was selected over many alternatives because of its superior predictive ability.

Chroma was initially used as an independent variable. However, statistical analysis indicated that chroma had only a minor effect on correlation with the dependent variables. Chroma is a blend of other color variables and apparently is not easily detected by interpreters. Therefore, it was deleted as an independent color variable.

Of all the parameters examined, significant correlations at the 0.01 level of probability were shown to exist only between total and inorganic solids and the Munsell Color System. A summary of the regression analyses is presented in Table 2. Figure 2 illustrates the predicted relationship between total suspended solids and hue in different treatment groups, with value held constant at 6.

As coded hue values increase, total solids concentration decreases, but total solids increase as value increases (Fig. 3). Relatively clear ponds appear dark on an infrared print while turbid ponds appear blue-green. Since low numbers on the hue scale represent light colors and high numbers represent dark colors, a hue of 7 indicates a higher solids concentration than a hue of 8 or more.

The relationship between inorganic solids and remotely sensed data (Fig. 4, 5) is similar to the relationship which exists between total suspended solids and remotely sensed data. Copper sulfate treatments probably affected the inorganic solid-color relationship. Ability to predict total and inorganic solid concentrations increased with increased use of copper sulfate. This was perhaps due to a masking of inorganic solids by organic solids which could not be predicted with this methodology.

Most parameters examined affected too subtle a change on CIR prints for detection by the human eye. However, it appears that the effects of total and inorganic suspended solids on infrared prints can be sufficiently decoded by visual analysis where a great degree of accuracy is not demanded. So far this method has not proven sufficiently sensitive to use as a dissolved oxygen detection system.

Table 2. Summary of regression analysis for total and inorganic solids for all treatment groups.

$$\text{MODEL } Y = b_0 + b_1 (\ln \text{HUE}) + b_2 \text{Value} + b_3 \text{Value}^2$$

Solids	*Treatment* ($CuSO_4$)	*N*	b_0	b_1	b_2	b_3	R^2 (%)	*F*	*df*	S[a]
TOTAL	Heavy	18	448.13	−59.72	−118.44	14.33	69	10.3**	3,14	22.57
	None	28	181.29	42.45	25.36	4.07	48	7.2**	3,24	24.15
	All Ponds	91	144.48	−39.94	−8.51	2.44	43	21.7**	3,87	24.12
INORGANIC	Heavy	18	334.47	−78.63	−67.31	8.90	88	33.1**	3,18	13.65
	None	28	151.30	−44.68	−16.38	2.66	54	9.4**	3,24	17.04
	All Ponds	91	155.40	−50.47	−12.72	2.52	61	45.2**	3,87	14.71

** Significant at .01 level of probability
[a] Standard Error.

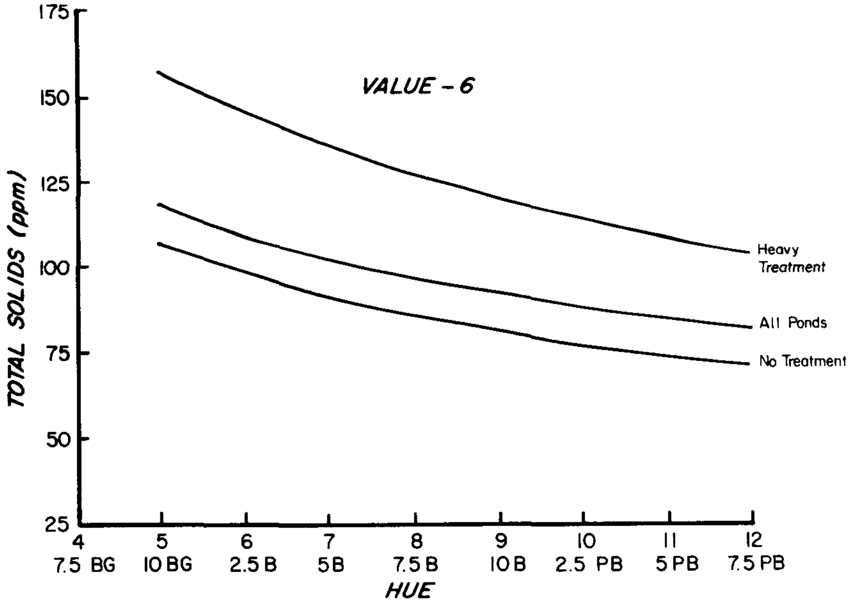

Figure 2. The relationship of total solids and Munsell colors for different treatment groups with value held constant at 6.

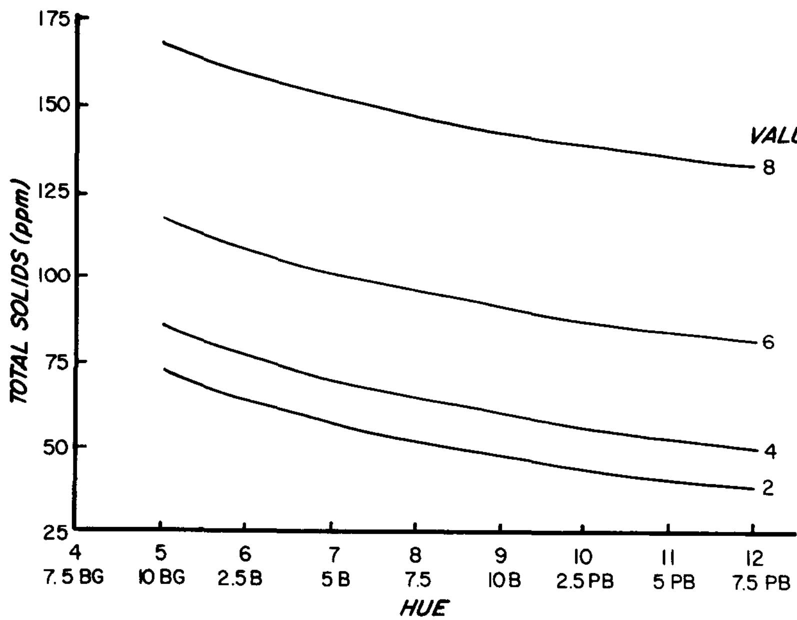

Figure 3. The relationship of total solids to hue and value for all ponds.

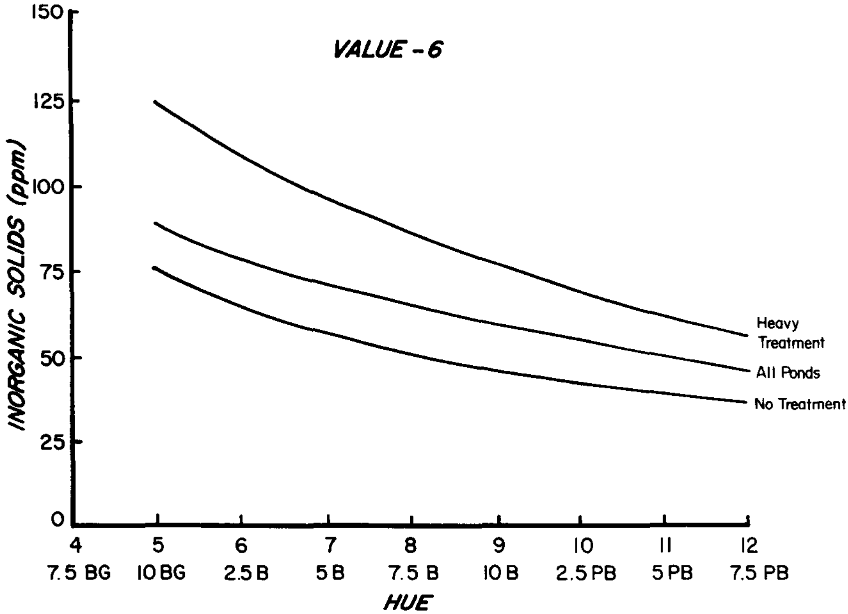

Figure 4. The relationship of inorganic solids and Munsell colors for different treatment groups with value held constant at 6.

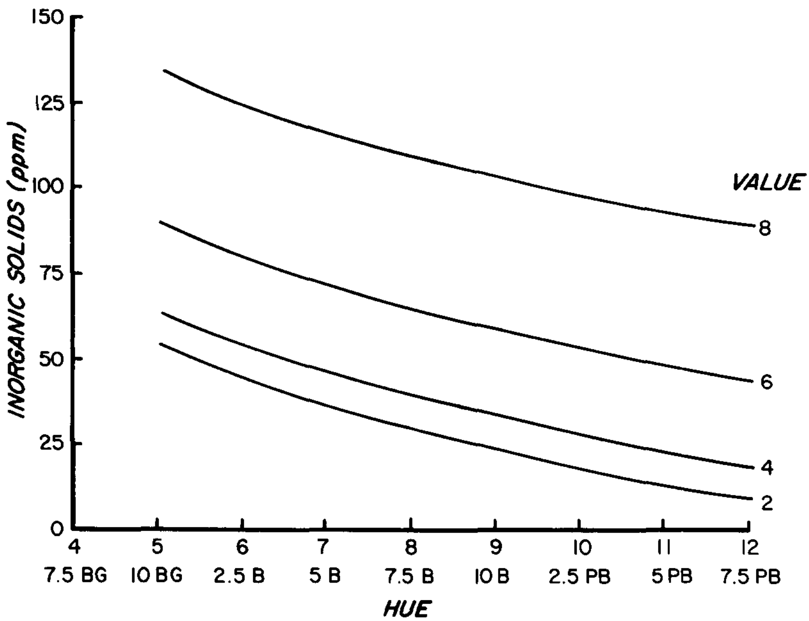

Figure 5. The relationship of inorganic solids to hue and value for all ponds.

LITERATURE CITED

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th Ed. New York, N. Y. 874 p.

Gramms, L. C. and W. C. Boyle. 1971. Reflectance and transmittance characteristics of several selected green and blue-green algae. Proc. Seventh International Symp. on Remote Sensing of Envir. Vol. 3:1627-1635.

Klooster, Steven A. and James P. Scherz. 1974. Water quality by photographic analysis. Photogrammetric Eng. 40(8):927-935.

Rib, Harold T. 1968. The Munsell color system. *In* J. T. Smith (ed) Manual of color aerial photography. American Society of Photogrammetry. Falls Church, Virginia. pp. 12-24.

Scherz, James P. 1971. Monitoring water pollution by remote sensing. J. Amer. Soc. of Civil Eng. Surveying and Mapping Div. 97 (2):307-320.

_______, Donald R. Graff, and W. C. Boyle. 1969. Photographic characteristics of water pollution. Photogrammetric Eng. 35 (1):38-43.

Yentsch, C. S. 1969. Determination of chlorophyll and phaeophytin. *In* H. L. Gotterman (ed) Methods for chemical analysis of fresh waters. IBP Handbook No. 8. Blackwell Scientific Publications. Oxford, England. pp. 116-120.

COST/BENEFIT ANALYSIS OF A CATCHABLE RAINBOW TROUT FISHERY IN TEXAS

by

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ABSTRACT

An evaluation of stocking catchable rainbow trout, *Salmo gairdneri*, in a section of the Brazos River was made in 1972-73 to determine if trout stocking is an economically and recreationally justifiable fishery management technique in Texas. A creel survey to measure fishing pressure and harvest, gross annual expenditures, and net economic value of the fishery was made before and after trout introduction. Benefits, in terms of increased harvest and utilization, were found to be substantially higher than the cost of stocking catchable rainbow trout.

INTRODUCTION

It is the responsibility of the Inland Fisheries Branch of the Texas Parks and Wildlife Department to manage all public freshwater fishery resources in Texas. Tailrace waters created by the construction of large multiple purpose dams represent an area suited to diversification of fishery management techniques. In 1966, a put-and-take trout fishery was established in the Guadalupe River below Canyon Reservoir in south-central Texas. The fishery met with good public response and a sufficiently high per cent of the stocked trout were harvested (White, 1968). The overall program was considered to be quite successful and it was recommended the put-and-take fishery be continued. Due to this success, additional tailrace waters were evaluated to determine if similar fisheries could be developed in other parts of the State. In 1972, a 20-mile section of the Brazos River below Possum Kingdom Reservoir was studied and suitable trout habitat was found in the first 4 miles of river below the dam (Forshage, 1972).

The Department felt before expanding its trout program an evaluation was necessary to determine if stocking catchable-size trout is an economically and recreationally sound fishery management technique. This study, through a creel survey designed to measure fishing pressure and harvest, gross annual expenditures, and net economic value of the fishery resource before and after the introduction of trout in the Brazos River, was initiated to determine the practicability of maintaining tailrace trout fisheries in Texas.

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