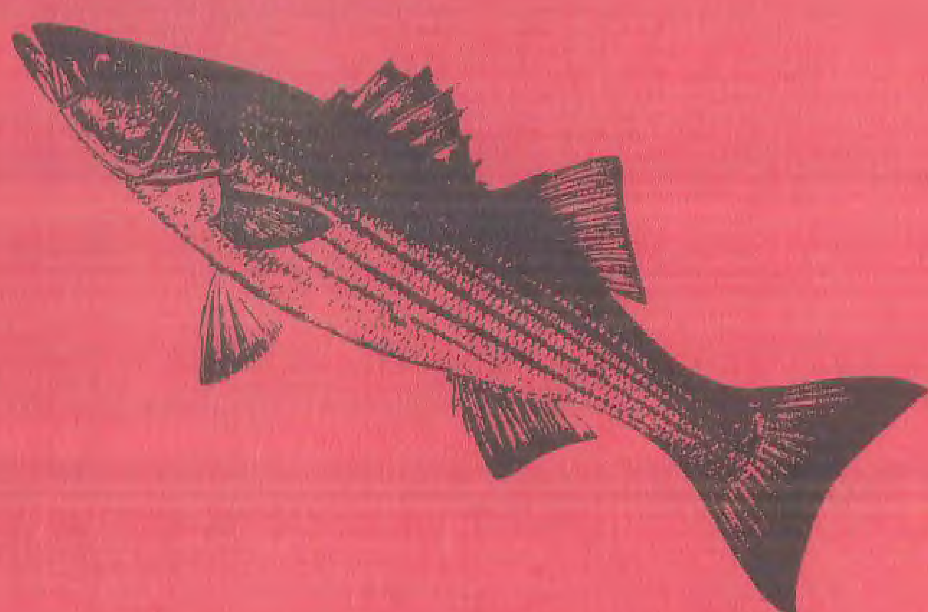
LOCATION AND IDENTIFICATION OF THERMAL REFUGES FOR STRIPED BASS ON THE APALACHICOLA RIVER, FLORIDA



Gulf States Marine Fisheries Commission
Special Report No. 7-WB

LOCATION AND IDENTIFICATION OF THERMAL REFUGES

FOR STRIPED BASS ON THE APALACHICOLA RIVER, FLORIDA

By

Ronald R. Lukens
Gulf States Marine Fisheries Commission

and

James M. Barkuloo
U.S. Fish and Wildlife Service

Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, MS 39564

This project was supported by the U.S. Fish and Wildlife Service Office of Fisheries Assistance under FWS Grant Agreement No. 14-16-0009-89-1202.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Ken Cashion and his staff at the Earth Resources Laboratory at the Stennis Space Center in Mississippi for the many hours of their time assisting in planning and implementing the remote sensing activities. Gratitude is also extended to the staff of the Panama City, Florida Field Office of the U.S. Fish and Wildlife Service. Thanks are due to Nancy Marcellus for her careful preparation of the manuscript.

GULF STATES MARINE FISHERIES COMMISSION

TCC Anadromous Fish Subcommittee

Richard Applegate
c/o San Marcos National Fish
Hatchery and Technology Center
Route 1, Box 159-D
San Marcos, TX 78666

James M. Barkuloo
U.S. Fish and Wildlife Service
1612 June Avenue
Panama City, FL 32405

I.B. "Buck" Byrd
National Marine Fisheries Service
Southeast Region
9450 Koger Boulevard
St. Petersburg, FL 33702

J. Alan Huff
Florida Marine Research Institute
100 Eighth Avenue, SE
St. Petersburg, FL 33701-5095

Vernon Minton
Alabama Department of Conservation
and Natural Resources
P.O. Drawer 458
Gulf Shores, AL 36547

Larry Nicholson
Gulf Coast Research Laboratory
P.O. Box 7000
Ocean Springs, MS 39564

Terry Stelly
Texas Parks and Wildlife Department
100 Navigation Circle
Rockport, TX 77640

Gary Tilyou
Louisiana Department of Wildlife
and Fisheries
P.O. Box 98000
Baton Rouge, LA 70898-9000

Forrest Ware
Florida Game and Freshwater
Fish Commission
620 South Meridian Street
Tallahassee, FL 32301

TABLE OF CONTENTS

Acknowledgements ii

GSMFC TCC Anadromous Fish Subcommittee iii

Introduction 1

Objective 2

Methods and Materials 2

Station Locations 2

TIMS Data Collection 2

Ground-truthing 4

Verification of Thermal Anomaly Locations 4

Results 7

TIMS Data 7

Ground-truthing 7

Verification of Thermal Anomaly Locations 7

Temperature Differential...15

Discussion 15

TIMS Data 15

Verification of Thermal Anomaly Locations 17

Conclusions 18

Literature Cited 20

INTRODUCTION

Striped bass have historically been prized by commercial and recreational fishermen on both the Atlantic and Gulf of Mexico coastlines (Coutant 1985). Evidence of striped bass stock declines on both coastlines has initiated considerable efforts on the part of state and federal agencies to restore stocks to historical levels and regulate the commercial and recreational fisheries so that healthy stocks can be maintained.

The Gulf States Marine Fisheries Commission (GSMFC) developed the Striped Bass Fishery Management Plan in 1986 (Nicholson et al.) to address striped bass problems in the Gulf of Mexico. As a result of the development of that plan, it was recognized that critical information relating to habitat requirements was insufficient to meet the needs of fishery managers. A project entitled "Habitat Criteria for Striped Bass Stocked in Tributaries of the Northern Gulf of Mexico" (Lukens 1988) was initiated by the GSMFC to address some of those data gaps. A result of that project was the recognition of thermal refuges as a significantly influential criterion for determining stocking success of striped bass in southeastern coastal streams. Thermal refuge is loosely defined as a distinct pocket of cool water (<60°C or 78°F) within a stream, lake, or reservoir system that maintains sufficient oxygen and temperature for survival of striped bass during the summer months (Ware 1987).

Current research has revealed that striped bass inhabiting coastal rivers and reservoirs in the southern United States exhibit preferences for cool water during summer months by seeking out microhabitats called thermal refuges (Waddle et al. 1980, Schaich and Coutant 1980, Cheek et al. 1983). Van Den Avyle and Evans (1984) studied temperature preferences of striped bass in the Apalachicola-Chattahoochee-Flint River System.

A lack of this cool water habitat has resulted in summer die-offs of striped bass in many southeastern reservoirs (Coutant 1978). It is generally accepted by striped bass researchers in the southeast that the amount of thermal refuge available during the summer months will dictate the numbers, size and condition of striped bass populations. Coutant (1985) suggests that knowledge of the extent of thermal refuges can be an important factor in guiding management measures to increase and support coastal populations of striped bass.

OBJECTIVE

The objectives of this project were to acquire thermal data from the Apalachicola River in northern Florida using the Thermal Infrared Multispectral Scanner (TIMS), and to determine if those data are suitable for locating thermal refuges for striped bass.

METHODS AND MATERIALS

Station Locations

Water temperature measurements were taken during the TIMS fly-over on November 29, 1988, and again on September 5, and 6, 1989. Stations were numbered as to the river mile (RM) descending from the Jim Woodruff Lock and Dam down river (Table 1).

TIMS Data Collection

The thermal data were collected using the TIMS mounted on a Lear jet. The TIMS is an experimental aircraft scanner which provides spectral capability in the thermal infrared region of the electromagnetic spectrum. Palluconi and Meeks (1985) provide a detailed description of how the TIMS functions. The aircraft on which the TIMS is mounted flew over the Apalachicola River from its mouth to the dam area of Lake Seminole covering approximately 110 miles of river. The Apalachicola River was used because it has a minimum of canopy cover and has an existing baseline of data on existing springs located throughout the river. Also, the Florida Game and Freshwater Fish Commission and U.S. Fish and Wildlife Service (FWS) are conducting ongoing striped bass research studies on that river.

Thermal refuges are utilized by striped bass during summer periods when ambient river water temperatures exceed 60°C or 78°F; however, the TIMS fly-over was conducted during the winter, specifically November 29, 1988 just prior to sunrise. The reason for this disparity is that ambient river water temperature is colder than the temperature of

Table 1. Station numbers, river mile (RM) and sampling date for temperature measurements.

Station Number	RM	Date
1	106.1	11/29/88
2	105.7	11/29/88
3	104.8	11/29/88
4	104.4	9/05/89
5	102.7	11/29/88
6	101.0-100.1	9/05/89
7	98.2	11/29/88
8	92.5	9/05/89
9	90.2	9/06/89
10	89.3-86.0	9/06/89
11	88.6	9/06/89
12	84.6-83.8	9/06/89
13	84.3	9/06/89
14	81.2-80.4	9/06/89

flowing springs and thus the warmer spring water rises to the surface. This is important because the TIMS only detects temperature differences which manifest at the surface. Also, river flow rates are minimal during the prescribed time period thus minimizing mixing of ambient and refuge waters. One other factor is that vegetative canopy is at a minimum because leaves are missing from the trees thus reducing interference with the thermal sensor.

Mean surface water temperatures plotted against time of year (Figure 1) provided a projected sampling period during which ambient river temperature would most likely be colder than the temperature of flowing springs, which is usually at 47°C or 65°F.

By plotting mean river gage reading at the Blountstown gage against time of year (Figure 2), a projected sampling period could be determined such that river volume would not be so great as to make location of springs impossible. Both factors indicated that a sampling period of mid to late November would provide optimum conditions for the TIMs fly-over.

Ground-truthing

In an effort to accurately interpret the remotely sensed TIMS data and to ground-truth instrument calibration, FWS personnel from the Panama City Field Office measured surface water temperatures from known flowing springs in the path of the TIMS fly-over at the exact time of the fly-over. Temperature data (°C) were collected using hand-held calibrated thermometers and Yellow Springs Instrument temperature meters.

Verification of Thermal Anomaly Locations

Based on areas indicated by the TIMS data, FWS personnel attempted to locate some of the more significant thermal anomalies. For the purpose of this study, the parameters investigated were the source of the thermal anomalies and the temperature differentials. Other parameters, outside the scope and appropriateness of this study, which may have management importance are volume of refuge discharge, oxygen content of refuge, water depth of refuge, and total refuge volume.

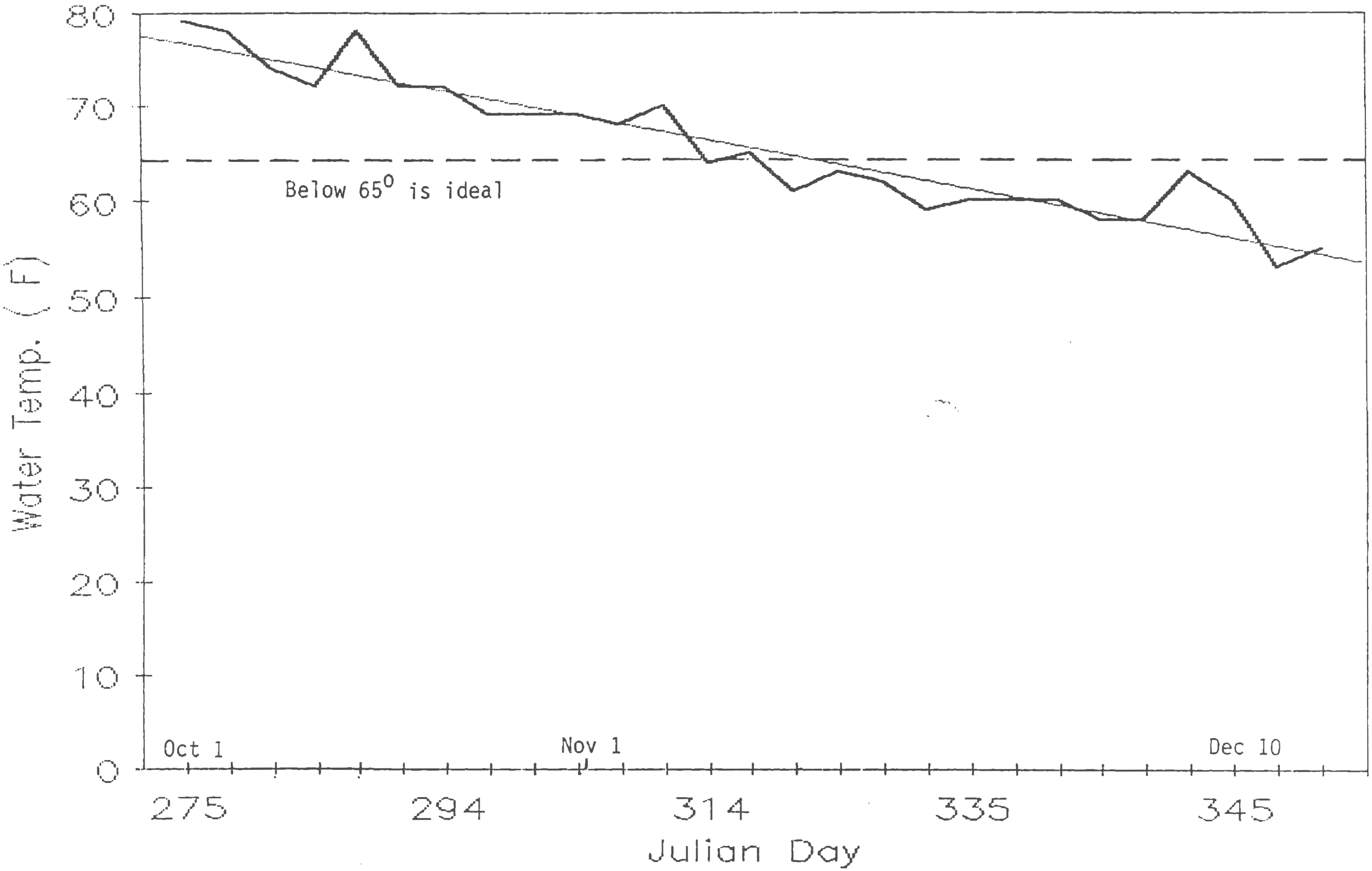


Figure 1. Mean surface water temperatures in the Apalachicola River below Lake Seminole from 1981-1987.

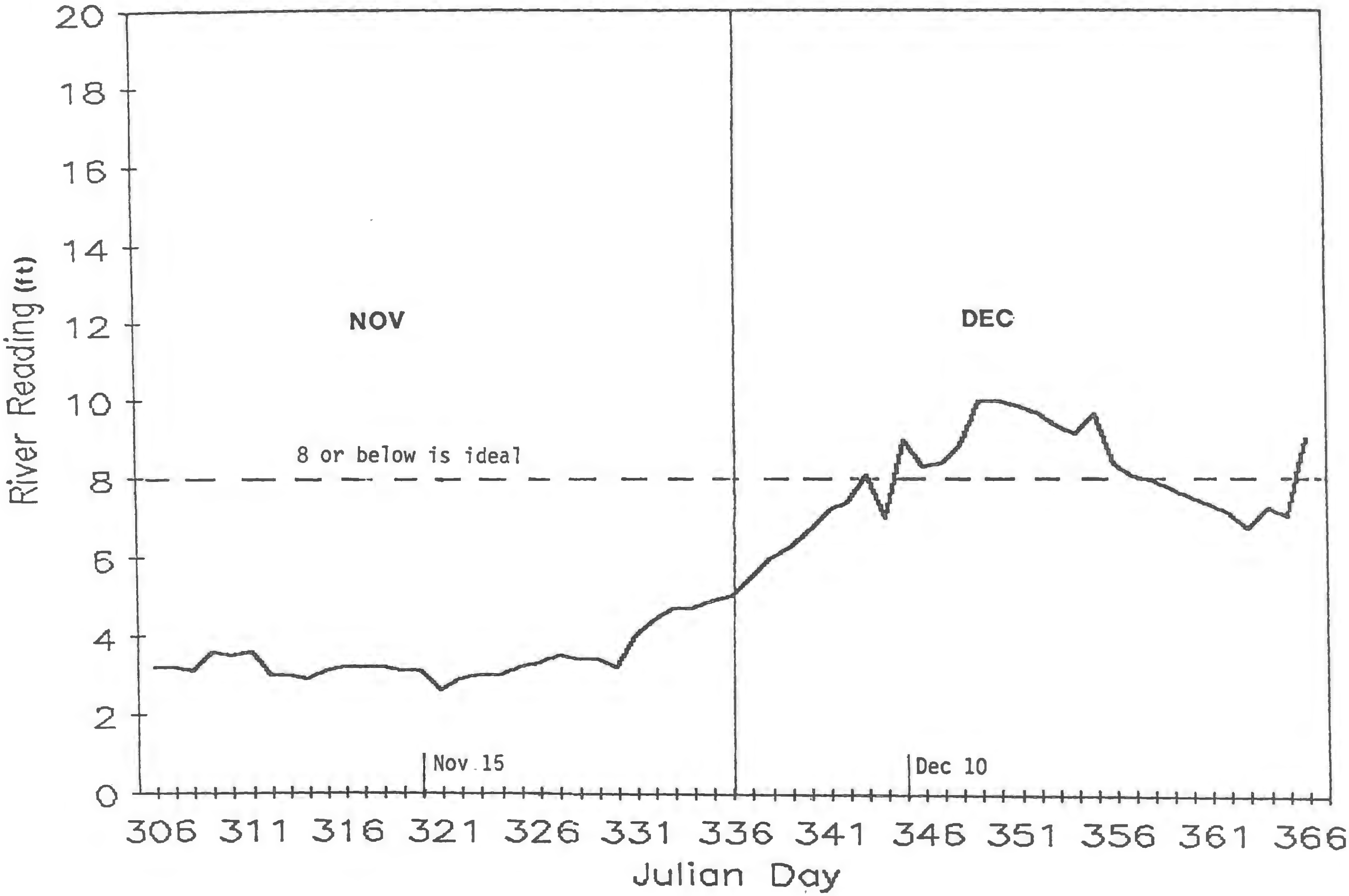


Figure 2. Mean river gage reading at Blountstown on the Apalachicola River below Lake Seminole from 1981-1987.

RESULTS

TIMS Data

Of the six known thermal refuges sampled, only stations 2 and 13 were identified in the TIMS data. Thermal imagery produced from the TIMS data are depicted in Figures 3 through 5. The bright white areas represent areas which are warmer than the surrounding background. Figure 6 is a computer enhanced picture of the thermal imagery in which specific thermal values were assigned and appear as red areas.

Stations 1 and 4 show no significant indication of thermal differences, while stations 2 and 3 indicate possible thermal anomalies (Figure 3). Station 4 is a spring creek which was dry at the time of the fly-over. Figure 4 indicates the distinctive thermal manifestation of the heated water discharge from the power plant at station 5. Station 8 shows no thermal anomaly in the river; however, the upland spring which is the source of the flow entering the river at station 8 shows a significant thermal difference with the ambient river water (Figure 5).

Ground-truthing

Ambient river temperatures ranged from 16.1°C to 16.7°C, while known thermal refuges ranged from 17.1°C to 18.1°C (Table 2). The temperature value of 23.9 was taken from the power plant discharge and does not represent a summer thermal refuge.

Verification of Thermal Anomaly Locations

Source of Thermal Anomaly - Six of the 14 stations sampled during the follow-up field work are known thermal refuges (Table 3). These are found in stations 1, 2, 4, 7, 11, and 13. In five of those cases, spring discharge is involved. At station 11, however, the thermal difference is attributable to vegetative overstory over a creek which enters the river.

At station 8, historical information (Barkuloo, personal communication, 1990) indicates spring seepage from the limestone substrate at that location. Investigations to date using temperature probes and Scuba have not revealed a thermal anomaly there. Station 5 revealed a significant thermal anomaly between ambient river

Figure 3. Thermal imagery of stations 1-4 on the Apalachicola River below Lake Seminole.

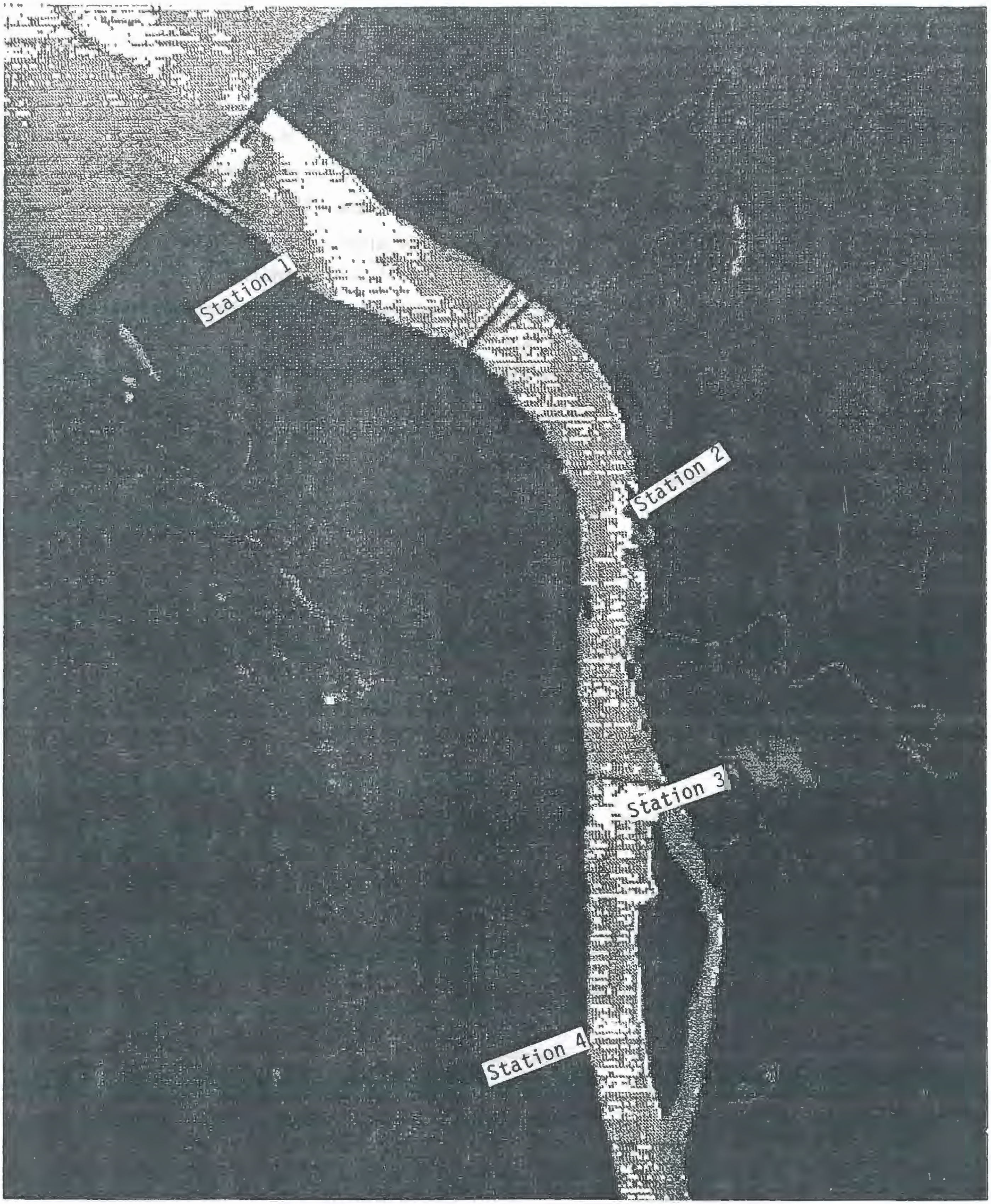


Figure 4. Thermal imagery of station 5, which is heated discharge from a local power plant on the Apalachicola River below Lake Seminole.

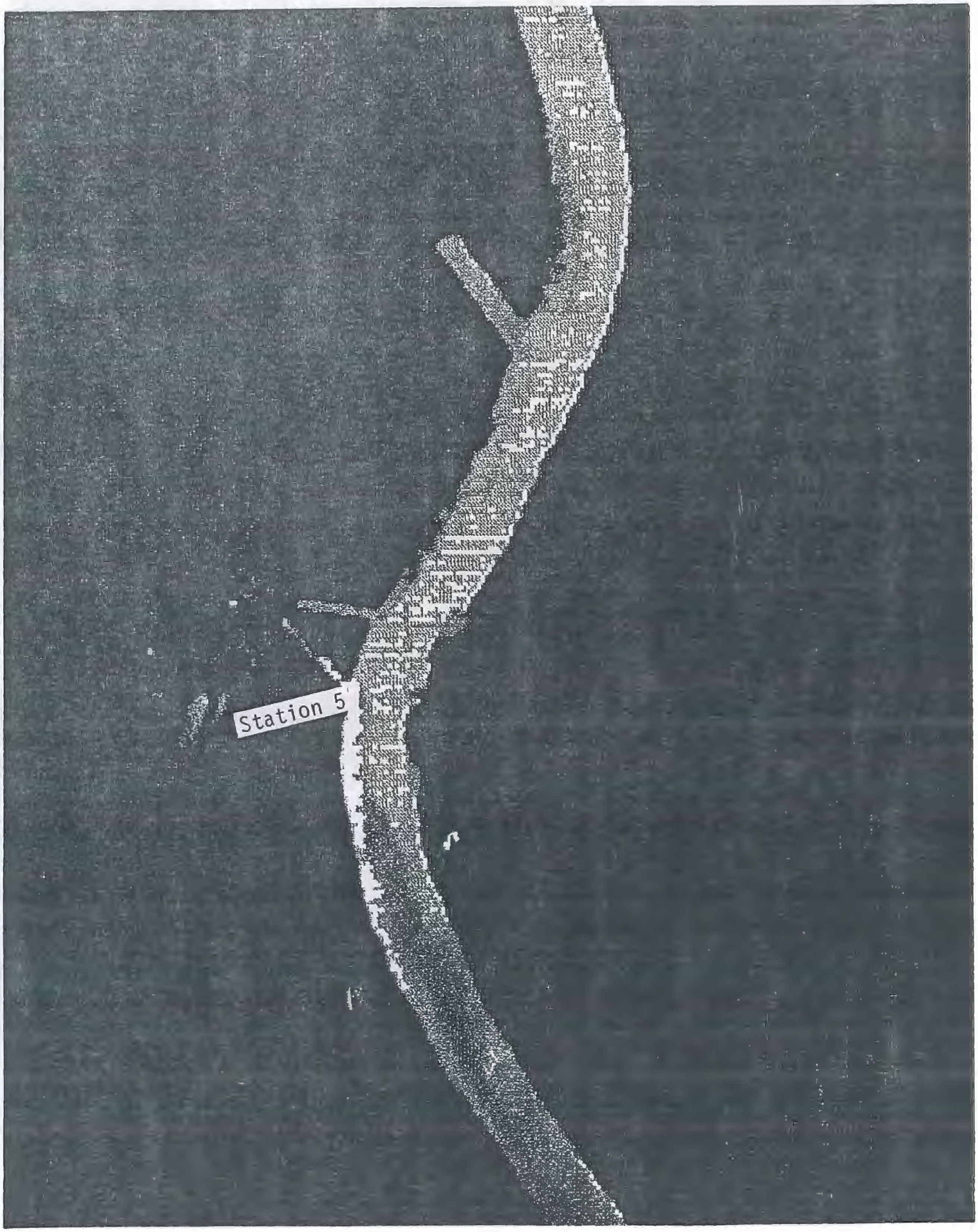


Figure 5. Thermal imagery of station 8 on the Apalachicola River below Lake Seminole.

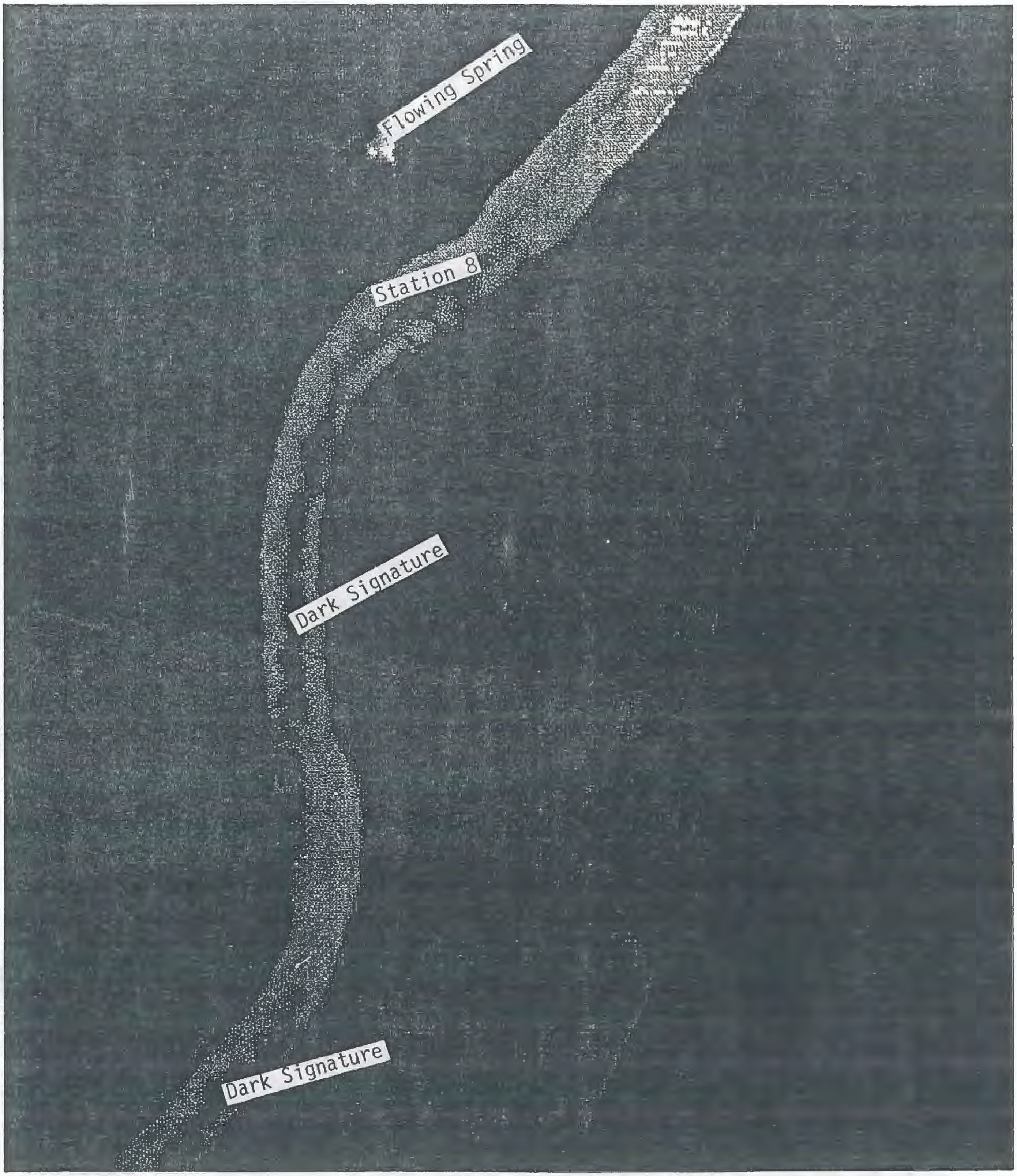


Figure 6. Computer enhanced thermal imagery of Figures 3 and 5 which depict stations 1, 2, 3, 4, and 8 on the Apalachicola River below Lake Seminole.


STA. 3
STA. 2
STA. 1
RANGE
N


COLD CREEK

Table 2. Station number, river mile (RM), mean ambient river temperature (°C), and mean temperature (°C) of known thermal refuges (T/R) on the Apalachicola River on November 29, 1988.

Station No.	RM	TEMPERATURE Ambient River	T/R	Diff.
1	106.1	16.1	17.5	+1.4
2	105.7	16.6	17.1	+0.5
3[1]	104.8	16.7	-	-
5[2]	102.7	-	23.9	-
7	98.2	16.7	18.1	+1.4

[1] No known thermal refuge. Ambient river temperature only.

[2] Power plant discharge. Not a thermal refuge.

Table 3. Station number, river mile (RM), source of thermal anomalies, and whether or not it is a known thermal refuge.

Station No.	RM	Source	Known Refuge
1	106.1	Spring	Yes
2	105.7	Spring	Yes
3	104.8	Unknown	No
4	104.4	Spring Creek	Yes
5		Power Plant Discharge	No
6	101.0-100.1	Unknown	No
7	98.2	Spring Creek	Yes
8	92.5	Spring Seepage	No
9	90.2	Unknown	No
10	89.3-86.0	Unknown	No
11	88.6	Vegetative Overstory Over a Creek	Yes
12	84.6-83.8	Unknown	No
13	84.3	Spring Creek	Yes
14	81.2-80.4	Unknown	No

temperatures and the discharge canal of the power plant. It does not provide a summer thermal refuge for striped bass; however, it does provide a "winter refuge" for striped bass and hybrid bass. The remaining six stations have no known source of thermal influence.

Temperature Differential - At two of the six known thermal refuges no temperature differential (+- 0.5°C) was noted. This was probably due to low ground water flow and slight differences between water and air temperatures. Table 4 provides temperature measurements taken at all stations sampled. In the case of stations 3, 6, 8, 9, 10, 12, and 14, the TIMS data indicated thermal anomalies; however, follow-up sampling revealed no temperature differences.

DISCUSSION

The primary objective of this study was to determine if thermal refuges for striped bass could be identified using TIMS technology. This application of such technology would minimize the amount of time and manpower required to investigate vast areas of coastal rivers for striped bass thermal refuges. Since thermal refuges play such an important role in striped bass survival in southeastern United States, refinement of a method to quantify available thermal refuge area would facilitate planning of restoration and stocking activities and could significantly enhance management practices used to regulate and protect striped bass.

TIMS Data

Of the six known thermal refuges included in the study area, only stations 2 and 13 were detected using the TIMS. No significant thermal signatures were observed at stations 1 and 4, even though both are spring-fed discharges. This is probably due mainly to three factors: 1) the ratio of spring water to river water was too low to be detected at the pixel resolution used in this study. This study was conducted at a time when the local area had experienced several months of below normal rainfall; therefore, some springs had stopped flowing and others probably had greatly reduced flows; 2) temperature differential between

Table 4. Station number, station date, river mile (RM), ambient river temperature (°C), anomaly temperature (°C), and temperature differential.

Station No.	Sampling Date	RM	TEMPERATURE Ambient River	TEMPERATURE Anomaly	TEMPERATURE Difference
1*	9/5/89	106.1	29.0	29.0	0
2*	9/5/89	105.7	29.0	29.0	0
3	9/5/89	104.8	29.0	29.0	0
4*	9/5/89	104.4	29.0	26.0	-3.0
5[1]	-	-	-	-	-
6	9/5/89	101.0-100.1	30.0	30.0	0
7*	9/5/89	98.2	30.0	23.0	-7.0
8	9/5/89	92.5	29.0	29.0	0
9	9/6/89	90.2	28.0	28.5	+0.5
10	9/6/89	89.3-86.0	28.0	28.0	0
11*	9/6/89	88.6	28.0	23.5	-6.5
12	9/6/89	84.6-83.8	29.0	29.0	0
13*	9/6/89	84.3	30.0	25.0	-5
14	9/6/89	81.2-80.4	29.0	29.0	0

* Known thermal refuge

[1] Power plant discharge was not sampled.

spring water and ambient river water was too low ($\leq 1.4^{o}C$ difference) to show a significant temperature change at the discharge site; and 3) the pixel size of the thermal sensor was too large (10 meters x 10 meters) for proper resolution of the water masses studied. A lower altitude flight could increase the resolution to 5 meters x 5 meters and could better detect temperature differences of these water masses. This is evidenced in figure 4 which depicts a large area of warm water discharge from the power plant at that location. Though that site is not a thermal refuge, because it is not a cool water source in the summer, it does point to the fact that the TIMS can detect temperature differences in rivers.

Weather conditions were near ideal during the TIMS fly-over for stations 1 through 5; however, dense fog was encountered just below station 5 and continued through station 8. Figure 5 shows a dark signature, indicating relatively colder temperature, which runs along the near center of the river. This phenomenon is consistent with the area in which the fog was encountered. The fog could have influenced the thermal signature of that portion of the river, although it did not appear to interfere with signatures of known groundwater discharges in the floodplain.

Verification of Thermal Anomaly Locations

The computer generated output of TIMS data depicts many thermal signatures, most of which cannot be explained. The stations used in this study were selected because they had a relatively large thermal signature and/or were located at or near areas which display conditions suitable for spring water discharge, such as station 8 at a rock bluff.

Of the 14 stations ground-truthed in this study, six were selected because they were known thermal refuges, seven were selected because of a thermal signature in the TIMS data, and one (station 8) was selected because it is a known warm water discharge. Ten of the stations (2, 3, 6, 8, 9, 10, 11, 12, 13, and 14) showed a thermal signature in the TIMS data; however, only two were later verified by field temperature measurements. Both are spring fed discharges.

Submerged springs at stations 1 and 2 have been verified by divers and utilized by radio-tagged striped bass (Barkuloo 1980 and 1981).

Station 1 did not appear in the TIMS data while station 2 did. Flow from these springs is relatively low and temperature differences were not detectable with temperature probes from the surface to the bottom during the September 1989 sampling.

It is not certain what caused the thermal signatures at stations which are not known thermal refuges. It is possible that some are sources of ground water discharge which were not verified due to low ground water conditions during the verifying field sampling. It is also possible that they resulted from some type of interference, such as fog.

CONCLUSIONS

TIMS technology was able to detect significantly large areas of temperature differences under optimum climate conditions; however, some small known refuges were not detected. Environmental conditions are critical to the success of such an effort, hence it is important to use historical rainfall and temperature data to predict possible fly-over dates. It is also necessary to closely track existing weather conditions as predicted fly-over dates arrive. Environmental conditions are also critical in the verification phase. River elevation, ground water discharge levels and vegetative canopy cover are particularly important.

Subsequent studies using the TIMS to locate thermal refuges should delay the fly-over until the temperature of the river is a minimum of 8°C colder than thermal refuge water. This would ensure a better chance of the temperature differences being detected by remote sensing. Also the fly-over should be conducted at a lower altitude thus increasing the resolution of the data. This would allow for detection of smaller areas of discharge. Regarding the verification phase, it is recommended that it be conducted during times when the spring to river volume ratio is fairly high.

The computer enhancement capabilities of the ELAS (Earth Resources Laboratory Application Software) program which is used to analyze TIMS data were utilized only to a minimal degree. It is felt that more time should be allotted to properly enhance data which are collected by the TIMS, which may result in more meaningful interpretation of the data.

The Anadromous Fish Subcommittee of the Gulf States Marine Fisheries Commission believes that the application of remote sensing technology (TIMS) has the potential to locate thermal refuges. The information resulting from this study should allow for a greater degree of success in subsequent studies. The Flint River in Georgia, which is a part of the Apalachicola River system, is recommended as a potential study area for using the TIMS because of several known springs which have large discharge rates and because of the importance of the river as striped bass habitat. Another significant area of interest for application of TIMS technology is the lower Mississippi River, which currently is known to harbor striped bass. The turbidity of the Mississippi River would introduce another variable, because it is not known how this would affect detection of surface temperatures; however, the importance of this area to striped bass justifies more intense study to determine the extent to which the river can support striped bass populations.

LITERATURE CITED

Barkuloo, J. M. 1980. Unpublished data. U.S. Fish and Wildlife Service. Panama City, Florida.

Barkuloo, J. M. 1981. Unpublished data. U.S. Fish and Wildlife Service. Panama City, Florida.

Cheek, T. E., M. J. Van Den Avyle, and C. C. Coutant. 1983. Distribution and habitat selection of adult striped bass, *Morone saxatilis* (Walbaum), in Watts Bar Reservoir, Tennessee. ORNL/TM-2029. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: A speculative hypothesis for environmental risk. Trans. Am. Fish. Soc. 114:31-61.

Lukens, R. R. 1988. Habitat criteria for striped bass stocked in rivers in the northern Gulf of Mexico. Special report. Gulf States Marine Fisheries Commission.

Nicholson, L. C., I. B. Byrd, E. Crateau, J. A. Huff, V. Minton, M. Powell, G. E. Saul, F. Ware, and A. Williams. 1986. Striped Bass Fishery Management Plan. Gulf States Marine Fisheries Commission. Publication No. 16.

Palluconi, F. D. and G. R. Meeks. 1985. Thermal Infrared Multispectral Scanner (TIMS): An Investigator's Guide to TIMS Data. NASA, JPL Publication 85-32.

Schaich, B. A. and C. C. Coutant. 1980. A biotelementry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. ORNL/TM-7127. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

Van Den Avyle, M. J. and J. W. Evans. 1984. Temperature preferences of adult striped bass in the Apalachicola River System. Progress Report, AFS-13, Georgia Cooperative Fish and Wildlife Research Unit, University of Georgia.

Waddle, H. R., C. C. Coutant, and J. L. Wilson. 1980. Summer habitat selection by striped bass, *Morone saxatilis*, in Cherokee Reservoir, Tennessee, 1977. ORNL/TM-6927, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

Ware, F. 1987. Personal Communication to R. R. Lukens.