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VERTEBRATE BEHAVIOR AND ECOLOGY

Progress Report
for Period July 1, 1975 - June 30, 1976

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Institution and Address:

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Project Titles:

Overall Project Title:

VERTEBRATE BEHAVIOR AND ECOLOGY

Subproject Titles:

(1) Engineering Design and Development

(2) Statistical Procedures and Quantitative Methods for Analysis of Ecological and Behavioral Data

(3) Coexistence and Population Dynamics of Selected Vertebrates

(4) Application of Radiotelemetry to Selected Problems in Vertebrate Censusing and Population Study

(5) Fish Response to Alterations in Water Quality Resulting from Power Production

(6) Seasonal Migrations and Habitat Selection of the Pronghorn Antelope

Contract Number:

E(11-1)-1332

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July, 1975 through June, 1976

Progress Report

Summary

Last year we reported progress under five subprojects, 1) Engineering design and development, 2) Statistical procedures and quantitative methods for analysis of ecological and behavioral data, 3) Coexistence and population dynamics of selected vertebrates, 4) Application of radio telemetry to selected problems in vertebrate censusing and population study, and 5) Fish response to alterations in water quality resulting from power production. This year we have added one new subproject to the above, Seasonal migrations and habitat selection of the pronghorn antelope (Antilocapra americana).

Under Subproject One, considerable effort was spent in the design and development of new data acquisition systems for biological information. The Nova 2/10 computer was installed at Cedar Creek along with supporting input/output devices to provide permanent processing of telemetry and weather data. A software system is completed and this system is operational; however, evaluation of the system limitations and verification of certain biological parameters are still being carried out. Considerable effort was spent on receiver design which resulted in a new receiver with a memory option. The basic receiver uses a frequency synthesizer where all channels are phase locked to a single crystal. Over 50 of these receivers are now in use in the field. Those with memory capability allow investigators in the field to select frequencies for certain animals. The receiver can then be programed to scan frequencies and record information from instrumented animals. Effort was spent on the design and construction of transmitters

for fish to relay information on temperature and depth. These transmitters have been used to monitor the response of fish to environmental factors such as thermal plumes near power plants or spillways. In both tags the pulse rates vary from 40 to 150 pulses per minute as a function of the parameter being measured. Pulse rate modulation makes the most efficient use of transmitter battery power and is easy to decode in the field. In addition to these major new developments, the Cedar Creek Bioelectronics Laboratory participated in the construction of equipment in support of biological programs. This Laboratory was fully responsible for all the electronic equipment needed in the subprojects of this proposal, and for equipment for several projects funded from other sources.

As previously mentioned, the Data General Nova 2/10 computer has been installed at Cedar Creek and preliminary tests and debugging for its data logging and preliminary processing capabilities are being carried out as part of Subproject Two. Some modifications of the electronic circuitry in the tracking system at Cedar Creek have been completed but further tests are needed before the modification can be finalized. Particular attention has been paid during the last year to updating and improving efficiency of the current software system for the analysis of tracking data. Since computer costs are climbing and the Nova 2/10 will increase our data handling requirements we feel that improved efficiency is an important area of consideration. A new program is now available which allows a fast determination of the habitat available to individual animals. This is possible through the use of an XY digitizer for storage of vegetation data and the subsequent combining of a home range definition with the vegetation matrix to identify habitat available. This program provides a rapid method for the determination of habitat preferences.

Studies under Subproject Three on coexistence and population dynamics of gray (Sciurus carolinensis), fox (S. niger), and red squirrels (Tamisciurus hudsonicus) were in the analysis stage during most of the report period. Data have been evaluated to assess effects of environmental conditions on activity rhythms of study animals. Pearson correlations and step wise regressions of six environmental factors were compared with total daily activity. Results of these analyses suggest that different weather variables influence squirrel activity at different times of the year. A total of 96 out of 151 months of data have been abstracted from microfilm records and is available for computer analysis. Computer analysis has been completed for home range and activity considerations for most of these data. Analysis of data on possible effects of the radio transmitter on the behavior and physiology of transmittered squirrels was completed. No differentiation in aggression or threat postures was observed between instrumented and control animals and the position of the squirrel in the social hierarchy was not affected by the radio transmitter. In general, comparison of transmittered and non-transmittered animals did not indicate any detrimental influences because of instrumentation.

Subproject Four concentrated on the development of long term studies on the sea otter (Enhydra lutris) population in Alaska and along the California coast. Work was carried out on Amchitka Island and Prince William Sound, Alaska, and in the Monterrey vicinity of California.

Primary attention was given to the development of radio attachment procedures for this species. Two types of attachments were tested: a neck collar mount and an ankle mount. Both methods gave variable results. The ankle mount on occasion caused swelling which was thought to be related to the stress in handling at time of attachment. Further work is indicated and tranquilizers will be administered to minimize stress during handling. Census data collected during the Amchitka studies indicated densities lower than those recorded in earlier investigations. While the counts made during these studies were of a very preliminary nature, they do indicate a decline in the population which perhaps should be investigated further. Skulls from dead animals found along the beach were examined for abnormalities and aged according to published criteria. In general these data indicated a higher percentage of adults in the natural mortality than that previously reported; however, these proportions could be a reflection of the time of year the skulls were collected.

Subproject Five concerns a cooperative investigation between the Ecosystems Department of Battelle Northwest Laboratories and the Department of Ecology and Behavioral Biology at the University of Minnesota. The effect of gas supersaturated water on the behavior of migratory salmon (Onchorhynchus tshawytscha) is being investigated through the use of pressure sensing transmitters. These transmitters were developed at the Cedar Creek Electronics Laboratory and, through changes in pulse rate, indicate depth where the salmon is located. Thirty chinook salmon were tagged with the pressure tags, released below Little Goose dam on the Snake River and monitored for position and depth. Problems were encountered in that instrumented fish did not cross the dam in the same pattern as control fish. A considerable amount of data was collected on the 24-hour depth profile pattern of fish in the vicinity of the spillways. Some difficulties developed because the pressure tag when released was not as stable as laboratory calibrations indicated. Thus, new calibration curves were required and the calibration problem is currently being evaluated to determine its effect on the data collected.

Subproject Six is concerned with seasonal migrations and habitat selection of pronghorn antelope at the Idaho National Engineering Laboratory Site. At this location antelope were herded into a corral trap with a helicopter, captured, sexed, aged, blood samples were taken and ear tags attached. Selected animals were fitted with radio transmitters operating in the 161-162 MHz range. Fifty-five adult antelope were instrumented with radio transmitters and 24 new-born pronghorn fawns were likewise instrumented. The new-born fawns were instrumented with expandable radio collars which will allow monitoring through the first year of life. Two of the fawns which were radio collared were fawns of radio collared does. About 600 telemetry locations on these instrumented animals have been recorded on their winter ranges. Monitoring was done primarily from aircraft with 77.3 hours of aerial tracking completed. Wide ranging movements were noted with a definite seasonal spring migration taking place. At the present time instrumented antelope are spread over a very large area in Idaho and Montana. Initial statistical analysis of blood data collected show significant differences between the three populations which are under study. A most interesting blood parameter is the blood urea nitrogen measure which is an indication of protein content of diet. These data indicate a significant difference among these populations with respect to their food intake over the several weeks prior to trapping.

SUBPROJECT ONE

ENGINEERING DESIGN AND DEVELOPMENT

A. Automatic Radio Tracking System

The original Cedar Creek telemetry system provided bearing and activity information on up to 52 animals every 45 seconds. Data are recorded on 16 mm microfilm via electro-optical readouts for later abstraction and decoding. Tabulated information is then punched, verified, and put on magnetic tape for data processing. Although the system has been reliable and given us good data for many years there is a considerable cost factor and time delay in getting the data from the 16 mm microfilm to the punch cards. To alleviate this problem a Data General Nova 2/10 computer was purchased with funds made available by the Field Biology Program, University of Minnesota.

The system was installed in December 1975 and is currently being debugged and field tested. A complete description of the hardware and software of the system has been completed in the form of an operations manual. Only a short summary of the operating characteristics and current status of the system will be included in this report.

A block diagram of the system is shown in Figure 1-1. Antenna signals are fed to a bank of receivers where a pair of receivers is tuned to each individual frequency, one receiver for each tower. The signal from the receiver is sent to an automatic gain control (AGC) device to keep the signal level in the 0 to 10 volt range required by the analog to digital converter (AD). The system is programmed to handle a group of 11 (22 analog channels) animals for each two rotations of the tower (1.5 minutes). The user can select the groups in any manner. For example, 11 animals can be tracked every two rotations or nine different groups can be set up tracking 99 animals approximately every 15 minutes. A primary limitation on the number of animals tracked simultaneously (group size) is memory capacity of the computer. Past experience indicates, however, that the present capacity will be more than adequate to track the number of animals we will be working with.

Bearing angle is determined by calculating the centroid of the three main lobes of the antenna pattern. A complete description and statistical evaluation of the algorithm is covered in Sanford (1973).

The calculated bearing is converted to X,Y coordinates and is recorded on magnetic tape. In addition to the X,Y coordinates the following information is recorded:

1. Date, time
2. Indication of whether errors in the digital data indicating tower bearing may have occurred.
3. Signal to noise ratios of the signal to give an indication of signal quality.
4. Signal discriptor indicating whether any of the main antenna lobes are missing and if so which one. This may occur on a very active animal and could cause error in the bearing indication.
5. Number of breaks in a signal and their relative intensity. This information is used in determining activity status.

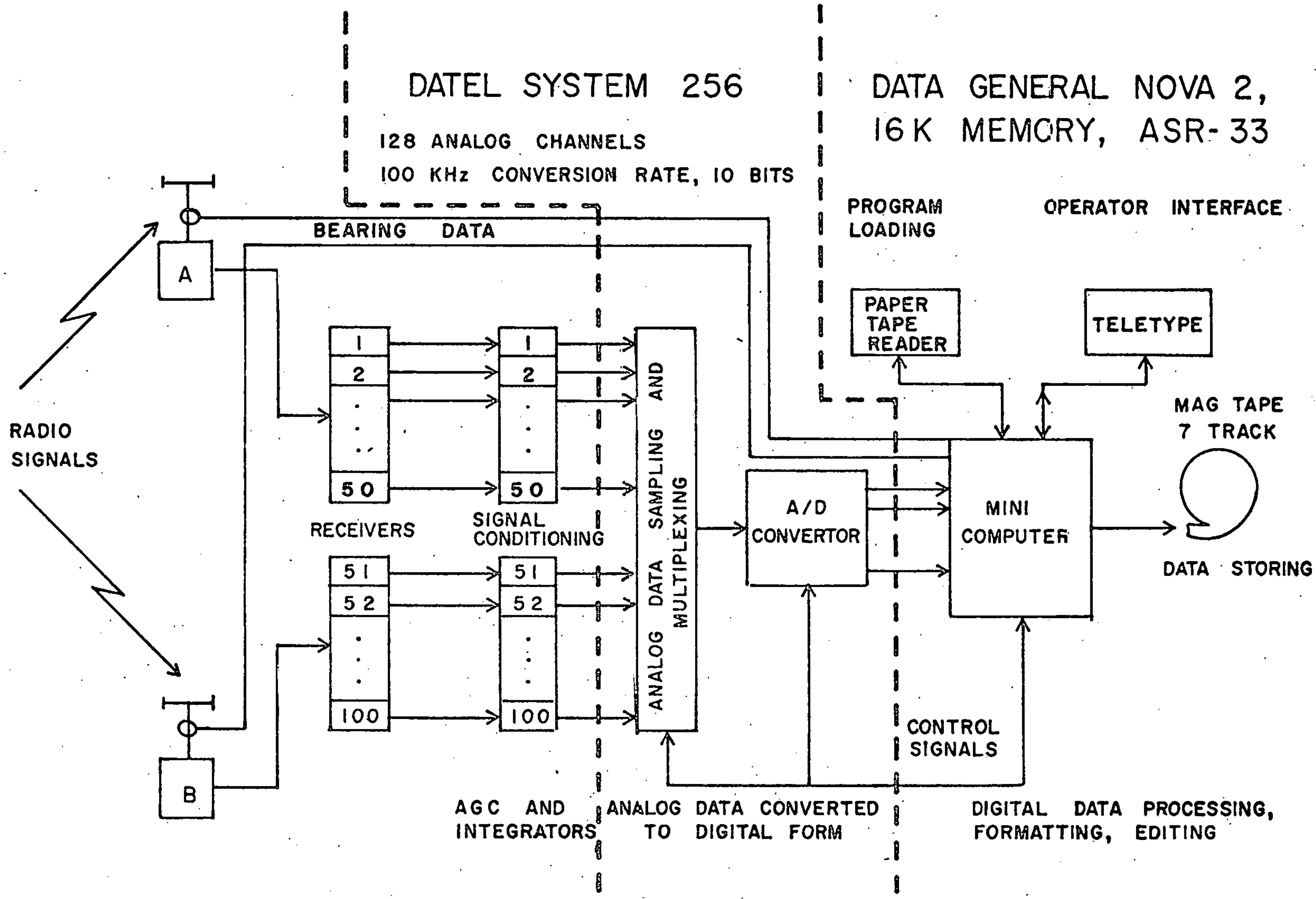


FIG I-I COMPUTERIZED DATA LOGGING SYSTEM

All of the systems are now operational; however, a great deal of evaluation must still be done to completely define what the system can do and what errors may be encountered under different operating conditions. An effort similar to that done for the accuracy determination in Cochran (1965) and Sargeant (1965) will have to be done to determine characteristics of the system under all conditions.

The system has been designed with enough capacity to include the logging of weather data automatically. This capability is not being used now because most of the present weather equipment at Cedar Creek does not have output characteristics compatible with a computer input. Weather data can now be inputed to the tape by means of a comment input to the keyboard.

B. Radio Receiver

Design on the standard receiver using a frequency synthesizer where all channels are phase-locked to a single crystal has been completed. Over 50 of these receivers are now in use in the field. We will continue to make improvements to correct any reliability problems that may occur and to make changes that will make the unit easier to construct and service. The receiver is designed so that the frequency range covered can be changed by changing the first converter. This allows use of the same basic design for every application without the need for a redesign for each frequency change.

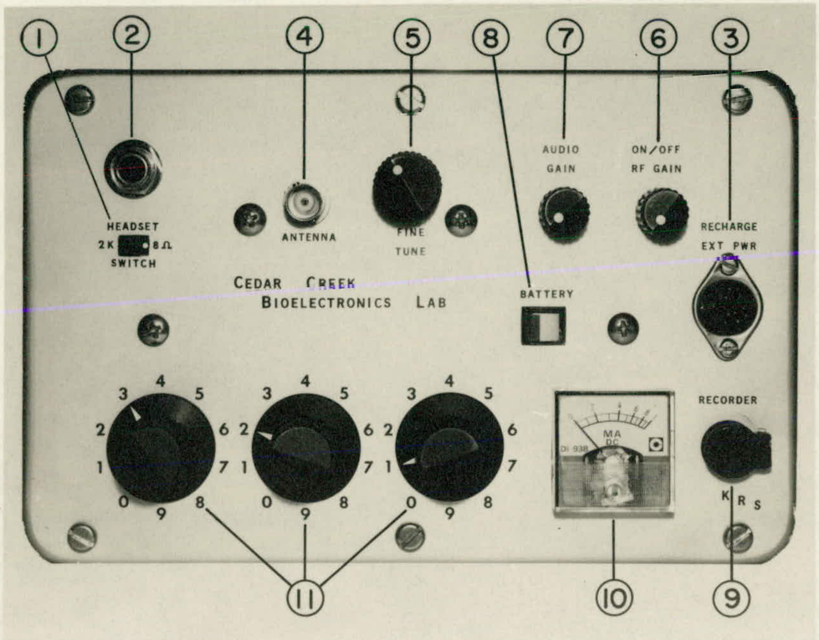
A second receiver has been designed which includes a memory option. The basic receiver design is the same; however, frequency can be selected by the three front panel frequency selectors or frequencies can be programmed into a memory and later recalled by means of a single selector or scanned automatically by an internal timer. This option has proven valuable in two applications. First, in tracking from an aircraft it is necessary to scan for a large number of animals in a short period. This can be done using the memory by means of a single switch. Since all channels are locked to a crystal there is no need to search around a frequency to make sure that a transmitter has not been missed. A second application, the one the memory was primarily designed for, is in unattended applications where the receiver can scan and record the signal from the frequencies that have been programmed into the memory. It has been used in such applications as recording activity data from a number of animals and to record data from temperature or pressure tags.

A brief description and circuit diagrams of the receiver have been excerpted from the operation manual to illustrate the function and design.

<u>Receiver specifications</u>:

Frequency range:	Any 1 MHz range as determined by the first converter.
Tuning method:	3 switch detent type.
Channel spacing:	1 KHz. Unit may be tuned more accurately by use of fine tune control.

Sensitivity:	Signal detectable aurally to -143 dbm.
I.F. band width:	1.2 KHz
Power supply:	Internal Ni-Cad, 8 hours min. use on full charge, or external 12 volt, negative ground.
Frequency drift:	0.01%.
Outputs:	0-1 ma signal indicator, output jack in series with meter for 0-1 ma recorder.
Output impedance:	2000 ohms or 8 ohms switch selectable, standard phone jack.
Dimensions:	21 cm x 13 cm x 17 cm high.
Weight:	1.8 kg.



FRONT PANEL CONTROLS, CONNECTORS AND INDICATORS

(1) Headset Impedance Selector

(2) Headset Jack

(3) Battery Charge/External Power/Auxiliary Output

(4) Antenna Input Connector

(5) Fine Tune Control

(6) On/Off RF Gain Control

(7) Audio Gain Control

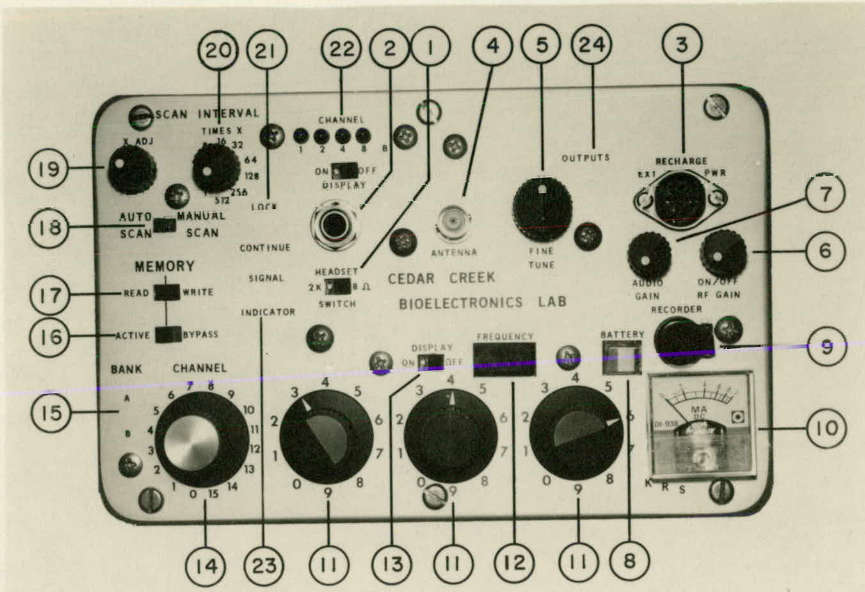
(8) Battery Status Indicator

(9) External 0-1 ma Recorder Jack

(10) Signal Level Meter

(11) Frequency Selector Switches

Figure 1-2. Telemetry Receiver



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(1) Headset Impedance Selector

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(7) Audio Gain Control

(8) Battery Status Indicator

(9) External 0-1 ma Recorder Jack

(10) Signal Level Meter

(11) Frequency Selector Switches

(12) Frequency Indicator

(13) Display On/Off Switch

(14) Memory Channel Selector

(15) Memory Bank Selector

(16) Memory Active/Bypass Selector

(17) Memory Read/Write Selector

(18) Memory Auto/Manual Selector

(19) (20) Memory Scan Interval Control

(21) Signal Search Control

(22) Auto Scan Channel Indicator

(23) Signal Indicator From Phase Lock Loop

(24) Auxiliary Outputs

Figure 1-3. Telemetry Receiver with Memory Option.

Function of Operator Controls

1. Headset Impedance Switch. This switch selects the best impedance match between the 2000 ohm Telex headsets which are normally used and the 8 ohm Koss headsets which are used if ambient or wind noise is a problem.

2. Headset Jack. Provides receptable for Headset or other listening device. Standard monouarl plug fits. Standard stereo plugs may be used if both head pieces are wired to the tip.

3. Battery Charge/External Power; Optional Input/Output. Provides receptable for input power to recharge internal batteries and to provide power from external 12 volt power supply. Extra pins may also be used as optional input/outputs.

4. Antenna Input. Female BNC connector to provide for 50 ohm antenna input.

5. Fine tune. Allows shifting the 1st converter crystal frequency to provide fine tuning between the 1 KHz increments of the frequency synthesizer. It allows the operator to tune to the frequency that can be heard best or is the most comfortable.

6. On/Off - R.F. Gain. Turns power on and off from internal batteries or external power supply. The variable resistance control varies the R.F. gain in the input pre-amplifier to prevent signal overload on strong signals. This prevents spurious signals from being generated by intermodulation and cross modulation. R.F. gain is maximum when the control is fully clockwise.

7. Audio Gain. Controls the audio level in the headset. This control has very little effect on detectability of a signal. Maximum signal level is with the control fully clockwise.

8. Battery Status Indicator. Indicates voltage level of internal rechargeable batteries or external power source. It should be in the white area for proper operation.

9. 0-1 ma External Recorder. Allows insertion of an external meter in series with the internal meter to record signal strength on an external paper recorder.

10. Signal Strength Meter. Provides an integrated indication of the audio signal level.

11. Frequency Selectors. The three switches select which frequencies are to be passed through the receiver and which are blocked. Frequency can be selected in 1 KHz increments over a 1 MHz range. The 1 MHz range is determined by selection of the preamp and first converter.

Function of Operator Controls - Supplement - Memory Receiver

12. Frequency Indicator: Three digit display of the frequency. In the manual mode the display will be the same as the frequency selector switches (11). When in the memory active mode it will display the frequency of the active channel.

13. Display on/off Switch: Turns off the display to save power when the display is not needed.

14. Memory Channel Selector: Sixteen position switch to address which channels is to be written or read into the frequency selector.

15. Memory Bank Selector: In 32 channels receiver the switch selects channels 0-15 in position (A) or 16-31 in position (B).

16. Memory Active/Bypass Selector: This switch determines whether the receiver frequency is selected by the memory (ACTIVE) or by the frequency selectors (11) on the front panel.

17. Memory Read/Write Selector: This switch is used to transfer a frequency selected by front panel switches (11) into the memory channel selected by (A).

18. Memory Auto Manual Selector: Selects whether the memory is to be scanned by means of the channel selector (14) or automatically by an internal timer.

19., 20. Memory Scan Interval Control: Controls the rate of the interval timer for the auto scan mode.

21. Signal Search Control: (Optional) With this signal in the lock mode the receiver will scan until a signal is found. It will then remain locked on that channel as long as a signal is present.

22. Auto Scan Channel Indicator: Lights indicate which channel is active in the auto scan mode. It is in binary code and can be converted to decimal by adding the number below the lights that are on.

23. Signal Indicator From Phase-locked-loop: Indicates a signal is present if the light is on.

24. Auxiliary Outputs:

Operating Procedure

Once the function of each control is understood, operating procedure follows quite easily.

(1)-(2) Headset Jack and Headset Impedance Switch:

The headset or other audio output device is plugged into the headset jack. The impedance switch is set to correspond to the impedance of the headset used; 8 ohms for the Koss or other stero types or 2 K for telex or similar 2000 ohm headsets. Headsets or audio devices of other impedance can be used with some loss in output level depending on the impedance mismatch and power required. For devices other than 8 or 2000 ohms the impedance switch should be set for the best output level.

(6) On/Off R.F. Gain. The on/off switch controls the power to all modules whether the receiver is operating on external batteries or is using an external power source.

The R.F. gain control should be rotated fully clockwise so the R.F. sections are operating at maximum gain to achieve maximum sensitivity. It should be left at maximum sensitivity until the transmitter or signal source can be heard. Once the signal is found, the gain should be reduced to achieve a signal level where differences in signal amplitudes can be easily detected. The gain should also be reduced as you move toward a signal source to prevent overload of the input stages. Although overload will cause no permanent damage to the receiver, it can cause spurious signals to be generated from cross or intermodulation. These spurious signals can cause confusion. Overload (spurious signals) can cause signals to appear on channel locations where no signal sources are supposed to be. This problem usually does not occur during normal operation with perhaps two exceptions. 1) When attempting to determine whether a transmitter is working on the test bench. Extraneous signals may be detected while switching to the correct channel. Confusion may also result while attempting to check out a number of transmitters for test purposes. 2) Occasionally problems will be encountered while trying to move in on a signal source. These can almost always be cleared up by making sure the channel setting is correct for the signal source being searched and reducing the signal level. The setting of the R.F. gain control is probably the most critical for accurate and efficient signal source location.

(7) Audio Gain. The audio gain should be set for a comfortable noise level in the headset. Setting of the audio gain does not affect sensitivity except as effects hearing sensitivity. The audio level does not affect signal to noise ratio. It does affect the meter indication.

(3) & (8) Battery charge/external power; Battery level indicator. The battery level indicator should be in the white region when the receiver is turned on. If it is in the red region the internal battery voltage is low and in need of

recharge or the voltage of the external power source is low. If an external power source is used, the receiver will switch automatically from internal to external power. The receiver is designed for a negative ground system. The positive supply line should be connected to pin 2 of the supply jack. If the polarities are reversed, a protective diode will block the current to prevent damage to the receiver. When external power is applied an audible click can be heard as the internal relay switches from internal to external power.

Operating Procedure - Memory Receiver Supplement

Frequency selection switches (11) control the frequency to which the receiver is tuned with the active-bypass switch (16) in the bypass position, or the read-write switch (17) in the write position. The receiver frequency will be displayed at (12) with the display switch (13) in the on position. The display draws approximately 40 ma or 1/3 of the current needed to operate the receiver. Power is saved with the display off.

The auto-manual scan switch (18) determined how the memory is addressed; by the channel switch (14) and bank switch (15), or the automatic scanning circuitry.

To program the memory, place the manual-auto scan switch (18) in the manual position. Set the channel (14) and bank (15) switches at the desired locations. Place the read-write switch (17) in the write position. Select the frequency desired with the frequency selector switches (11). Change the channel switch to the next location and select the next desired frequency. When through programming be sure the write switch (17) is set to read. With the read-write switch in the write position the memory will record the frequency of the selector switches at the channel addressed. Manually check the channels to be sure the desired frequencies have been programmed into the memory. To change a frequency on a given channel, address the channel, place read-write switch to write, select desired frequency on selectors and switch back to read.

The channels will be scanned automatically with the auto-manual scan switch (18) in the auto position. The lights (22) indicate which channel the scanning circuitry is addressing when the channel display switch (22) is ON. The time the receiver will remain on a channel is controlled by (19) and (20). The X adjust (19) controls the basic scanning rate while (20) selects a multiple of that rate. If X is adjusted to change channels every second, the multiplier (20) can change the rate up to 512 seconds. The scanning circuitry scans sequentially. The scanner does not stop scanning when the automanual switch is in the manual position, the memory, however, is addressed by the channel and bank switches.

The memory is kept alive when the receiver is off by a small internal power source. This power source should last at least one year.

RECEIVER FUNCTIONAL BLOCK DIAGRAM

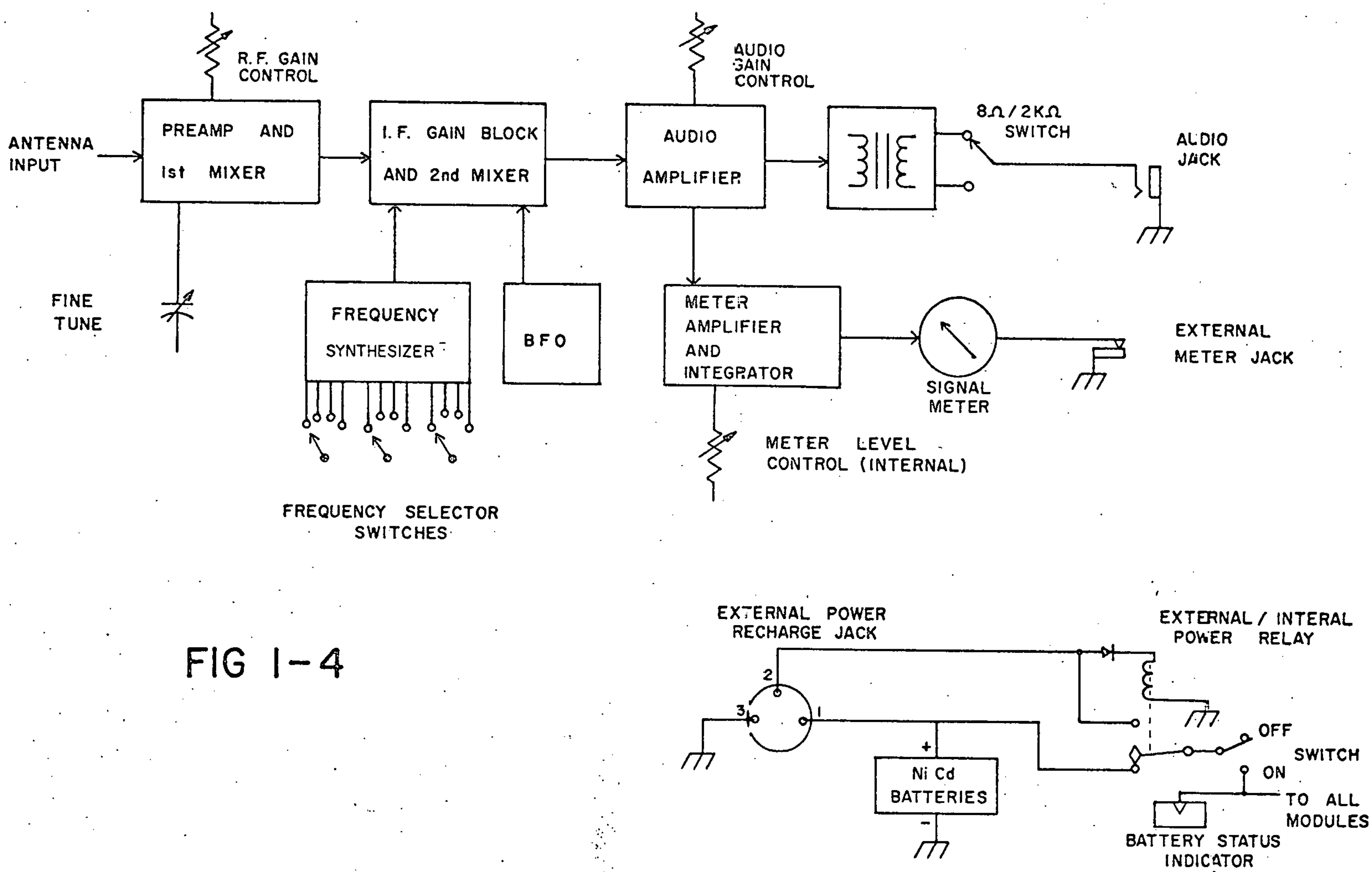


FIG 1-4

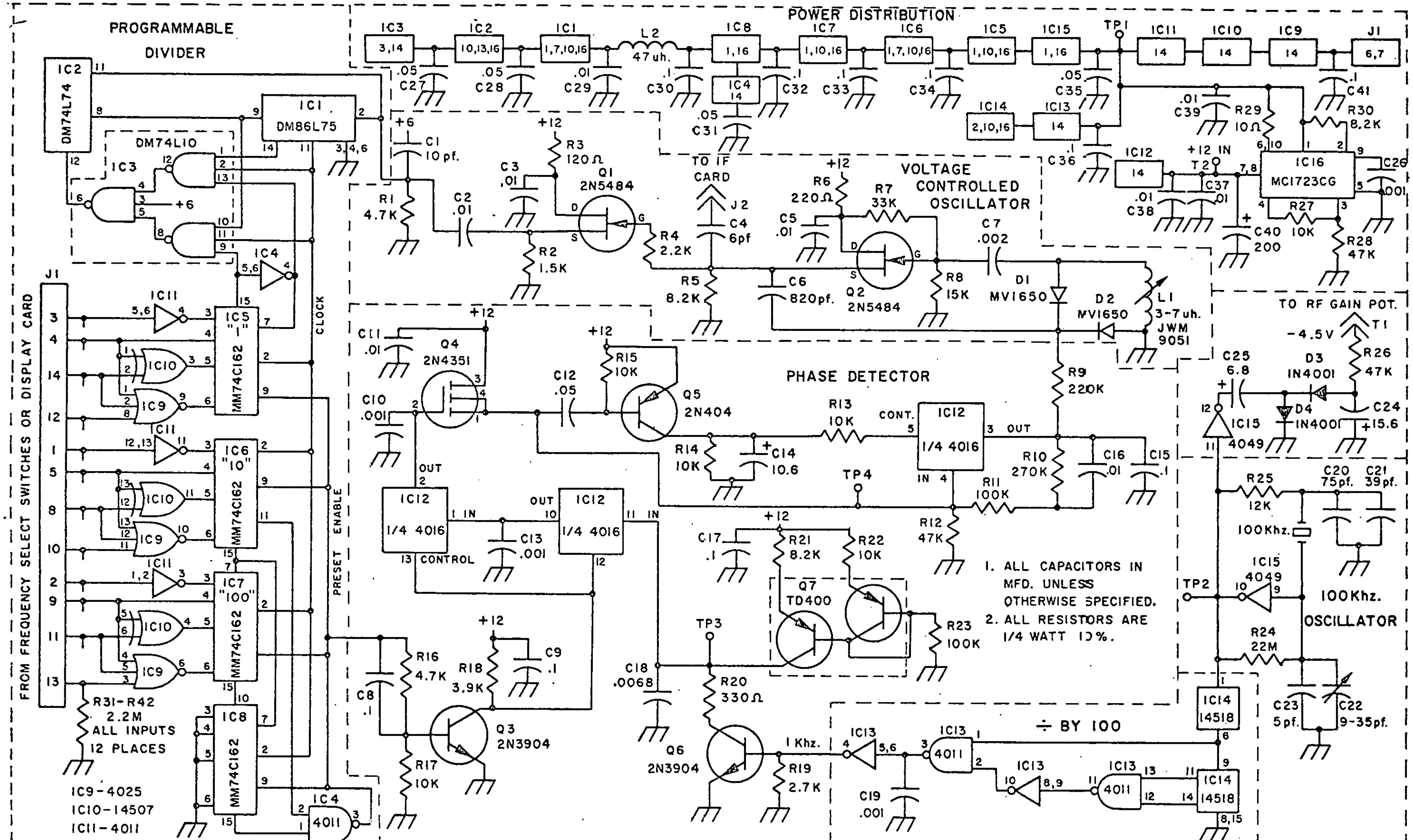


FIG 1-5 RECEIVER SYNTHESIZER BOARD

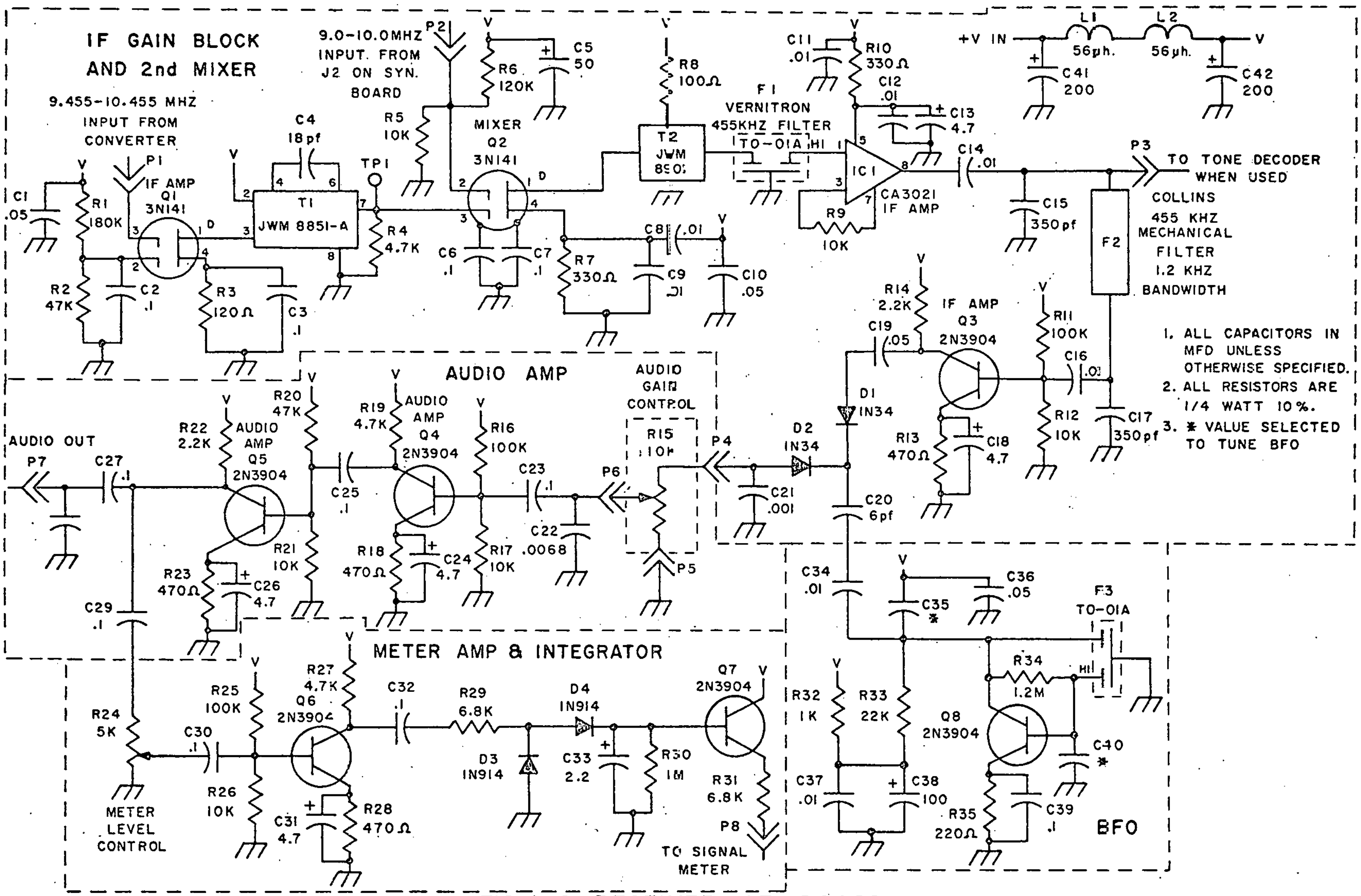


FIG 1-6 RECEIVER IF BOARD

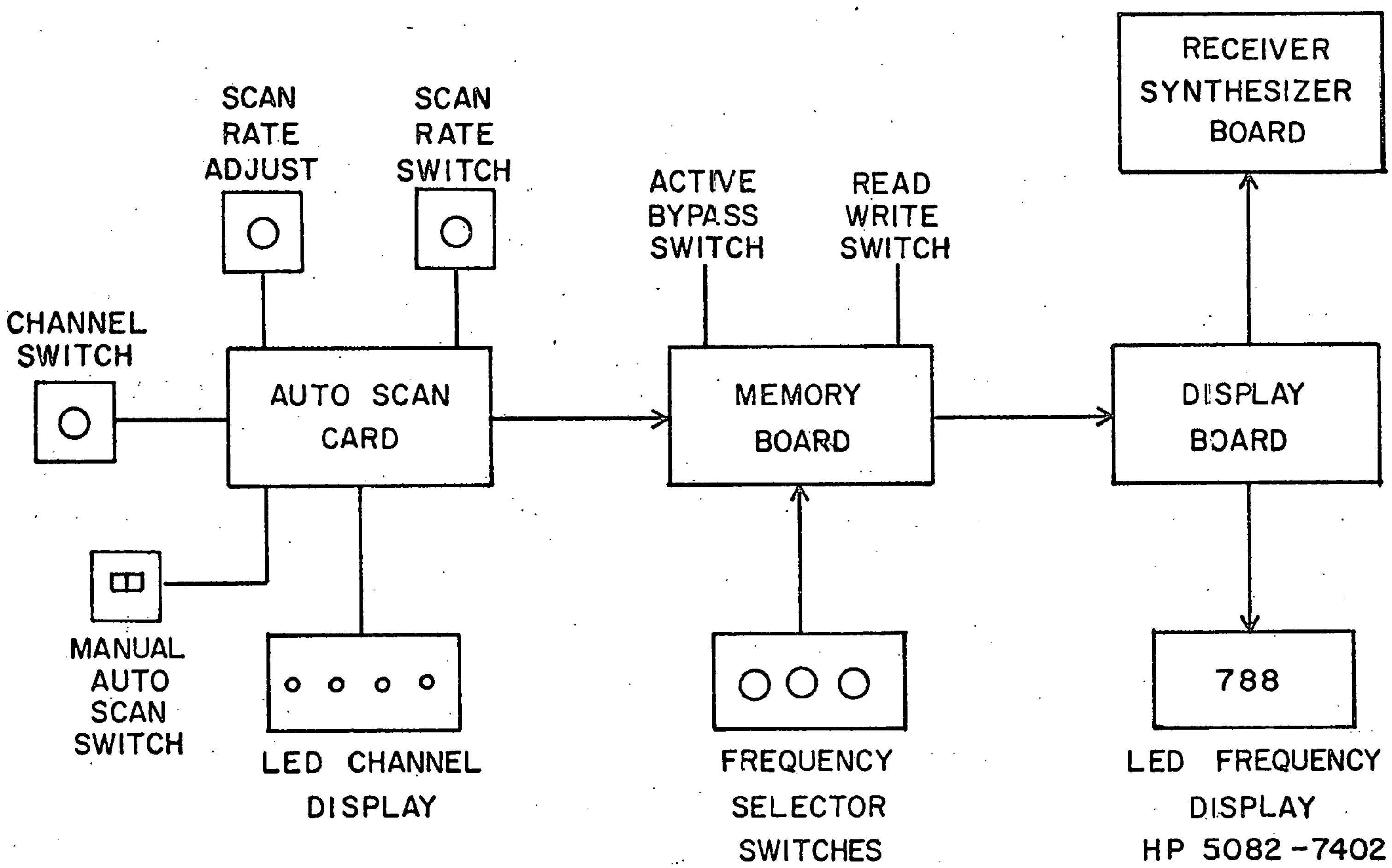


FIG 1-7 MEMORY BLOCK DIAGRAM

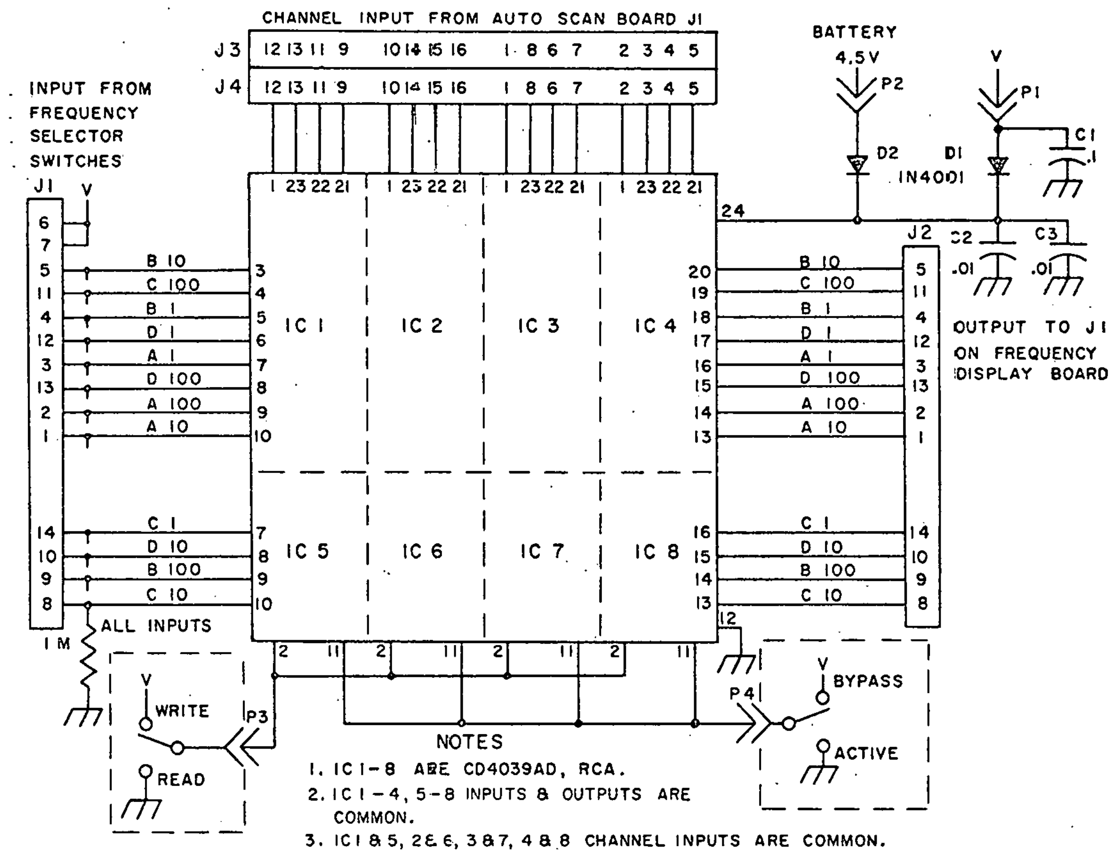


FIG 1-8 16 CHANNEL MEMORY BOARD

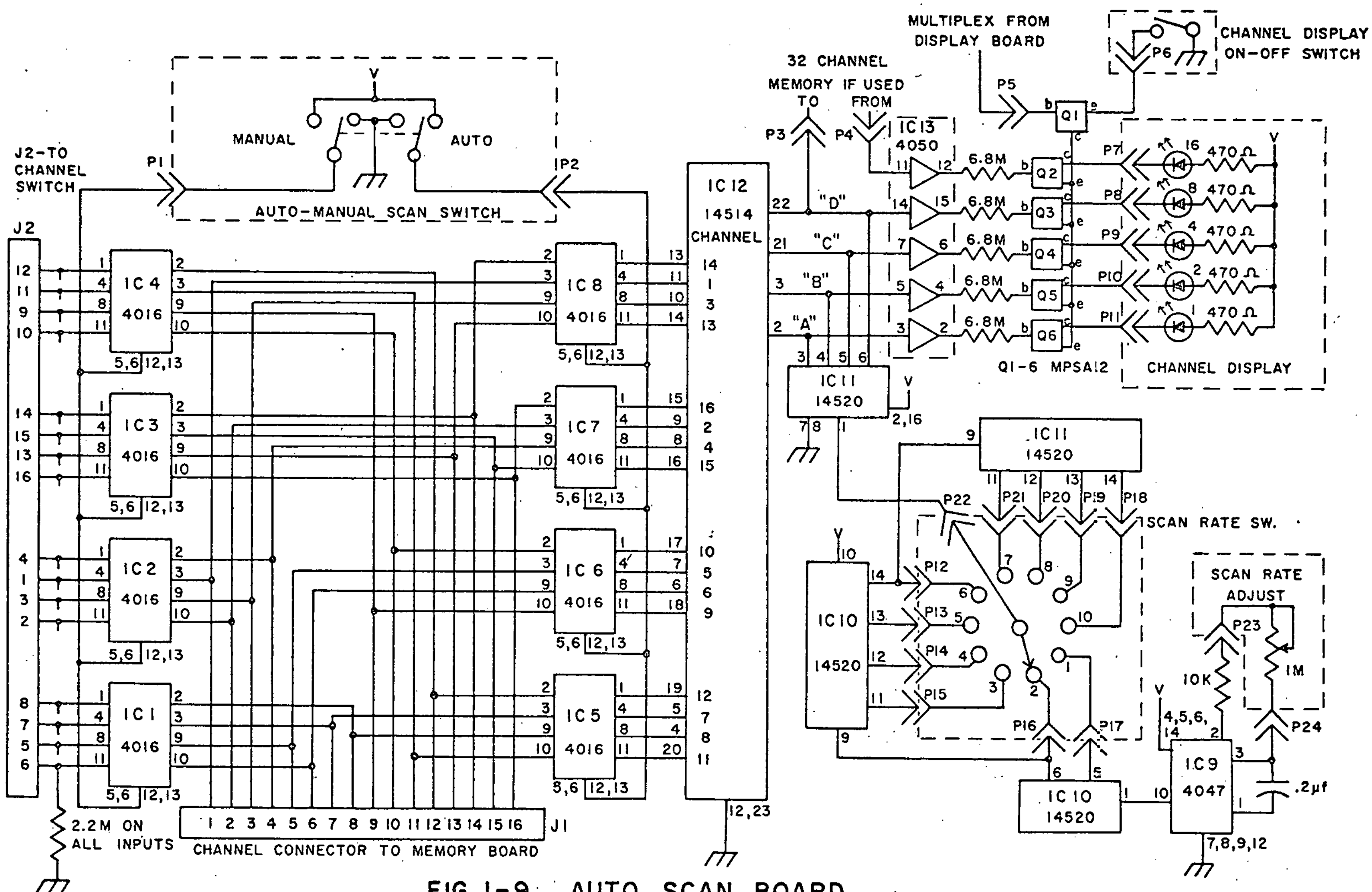
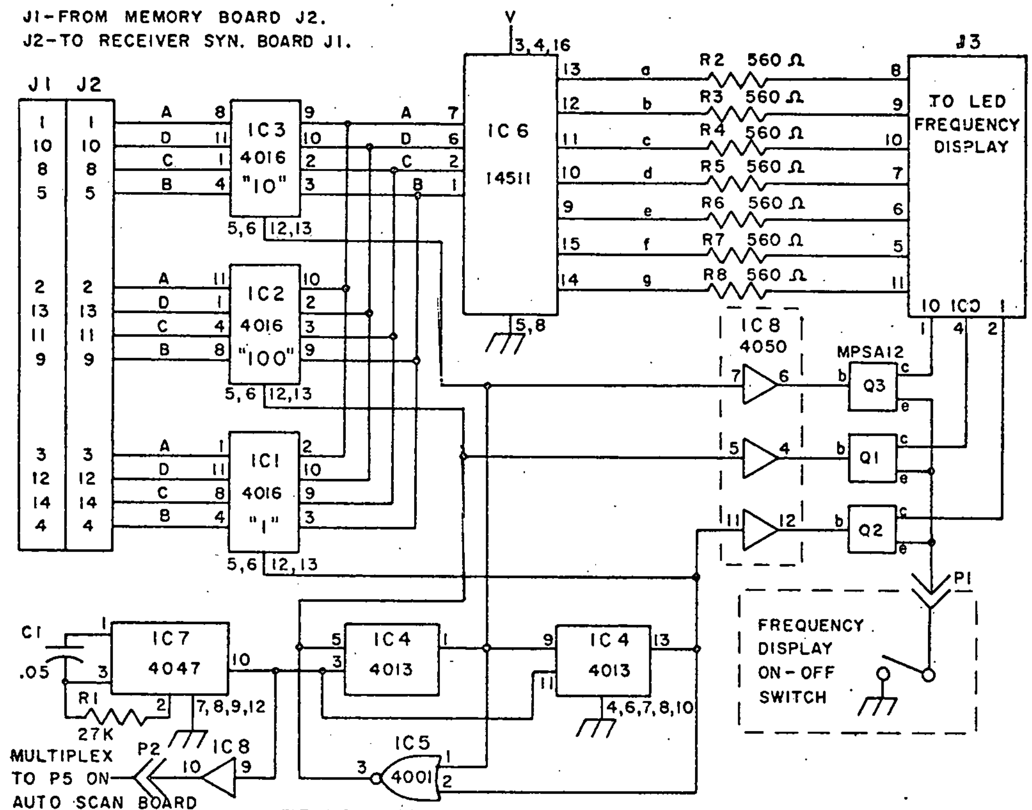


FIG 1-9 AUTO SCAN BOARD



FREQUENCY DISPLAY BOARD

FIG 1-10

C. Temperature Transmitter

Some design changes have been made in the temperature transmitter in the past year. Two problems were encountered in the earlier design. Under certain conditions the transmitter would self-bias and run continuously with only a change in the amplitude for each pulse. This was corrected by changing the transmitter switching circuitry to that shown in Figure 1-11.

Transistors Q_1, Q_2, Q_3 and Q_4 form an asymetrical multivibrator whose period is determined by the time constants T_1C_1 and R_1C_2. The time constant R_1C_2 is constant with temperature and determined the on time of the transmitter; in this case 25 milliseconds nominal. The resistance of thermistor T_1 varies with temperature and provides the period variation as a function of temperature. Transistors Q_3 and Q_4 provide the voltage sensing and switching, and Q_1 and Q_2 are used as active loads to achieve low power dissipation without the use of high collector loads. The use of high collector loads would cause a reduction in switching speed and make loading much more critical. Diode D_1 provides voltage and temperature compensation. Diode D_2 and transistor Q_5 provide level translation and transmitter switching. This same circuit is used as a voltage to frequency converter in the pressure tag.

We had hoped to be able to miniaturize the circuit by purchasing unbonded chips, having them wirebonded with the interconnections we require, and having the chip mounted in a small hermetic case. Although fundamentally there should be no difficulty with this technique we encountered two problems. First, since we have no in-house wire-bonding facility we had to contract with outside agencies. When we made our first inquiries to determine feasibility we were given estimates of approximately $10 per unit. When we requested bids the lowest was $76 per unit in 100 unit lots plus the cost of material. We decided to have several prototypes built; however, we have not been able to get delivery on the unbonded chips from RCA. Thus, while the miniaturization is quite straightforward we have not been able to field test any units at this time.

A complete evaluation of the accuracy, drift and other characteristics of the tag should be ready by October 1, 1976 and will be included in a later report. Our testing indicates the tag will be accurate to $\pm$ 0.5°C for a battery voltage of 1.2 to 1.4 and a variation of the transmitter temperature of $\pm$ 10°C either side of the calibration temperature. We have used 35 of these tags in evaluating the response of fish to a thermal plume environment at a power plant.

D. <u>Pressure Tag</u>

A pressure tag was developed to measure the response of fish to nitrogen supersaturated water (Figure 1-12). The design was chosen to minimize drift with battery voltage, temperature and change in operational amplifier characteristics. Amplifiers A and B of IC_1 provide input buffering and gain. The gain of

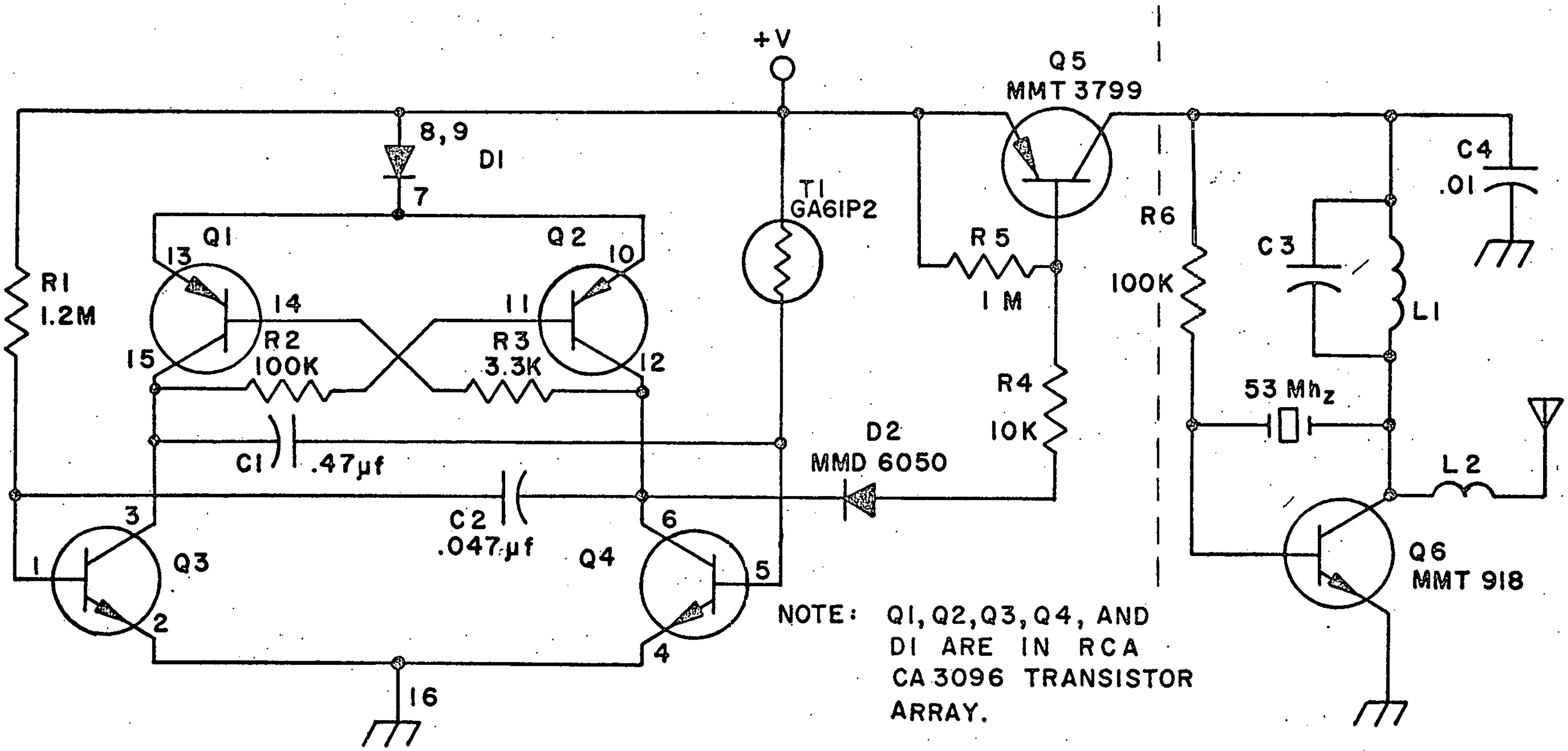
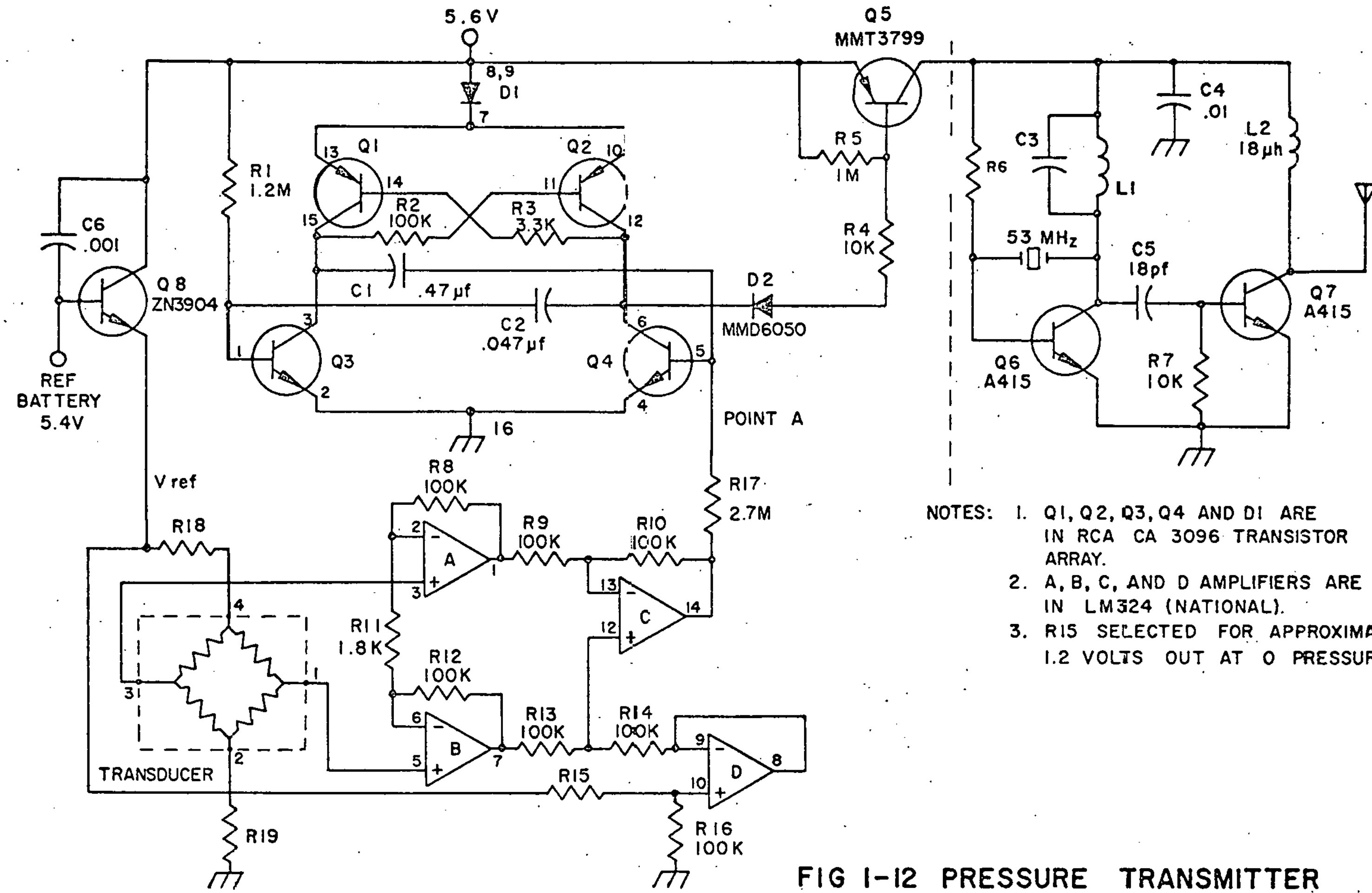


FIG 1-11 TEMPERATURE TRANSMITTER



NOTES:
1. Q1, Q2, Q3, Q4 AND D1 ARE IN RCA CA 3096 TRANSISTOR ARRAY.
2. A, B, C, AND D AMPLIFIERS ARE IN LM324 (NATIONAL).
3. R15 SELECTED FOR APPROXIMATELY 1.2 VOLTS OUT AT 0 PRESSURE.

FIG I-12 PRESSURE TRANSMITTER

the unit is determined by R_{11} which can be varied without affecting common mode rejection. Amplifier C of IC_1 gives the common mode rejection and changes the differential input to a ground referenced output. Common mode rejection is determined by the match in resistors R_9, R_{10}, R_{13} and R_{14} ; standard one-eight composition resistors were used. The values of these resistors were matched to within 0.5% at room temperature by measurement and selection. The use of three amplifiers in an instrument amplifier configuration also compensates for offset drift. Since all amplifiers are on the same chip, their offset drifts will also tend to track. If this is true, the offset drift of amplifier A and B of IC_1 will be equal in magnitude and opposite in sign. Amplifier C will then cancel the two drifts and will contribute very little additional error because its gain is unity (Tobey 1971). Amplifier D of IC_1 provides a convenient means to adjust the output voltage at point A without affecting common mode rejection or offset drift compensation. The ratio, $R_{15} : R_{16}$, is adjusted to give an output voltage of 1.2 volts at point A . If the voltage at this point were to drop below 1.0 volts, the voltage to pulse converter (IC_2) would stop pulsing.

We believe the stability (long term drift) is determined primarily by the voltage stability of the reference supply and drift in the transducer. Temperature drift of the reference supply has an insignificant effect on the output voltage. Evaluation of long term drift has not been completed at this time.

The evaluation of drift in the transducer is a more difficult problem. In order to obtain sufficient sensitivity at low pressure levels the transducer must be built using semiconductor elements and it must have a closed reference airspace with an inherent temperature drift. In lower sensitivity application (deep depths) the airspace can be partially or completely evacuated to reduce change in calibration with change in temperature. The semiconductor elements also may drift for several reasons, such as temperature, creep in the bonding or aging. These factors are currently being evaluated in the lab. A preliminary evaluation indicates long term drift (three weeks) can be held to within ± 0.5 meters for a maximum depth of 20 meters.

Two types of transducers have been used. The first was a Kulite TQH-360-25S with a parylene coating applied by Union Carbide. There were two problems with these transducers; delivery was unreliable and the parylene coating did not adhere properly to the metal case. The problems with the parylene coating caused some concern about the possibility of drift in calibration. Twenty-five of these units were delivered and put on fish. About 75% of the tags were retrieved and will be recalibrated to determine long term drifts.

Twenty transducers in a stainless steel housing were built for us by Bio-Tec, using a stainless steel housing and diaphragm. Environmentally this is much more reliable; however, the transducer is less sensitive and the resistances are lower. The lower resistance increases power consumption, a problem when the package size must be minimum. Consequences of these factors and alternatives must be evaluated before the design can be finalized.

There has been some indication that the calibration has drifted on some of the transmitters. This will be measured and evaluated on the transmitters that have been returned.

The remainder of the transmitter is similar to the temperature and is covered in that section.

E. Transmitters in Water

The increased demand to evaluate the response of fish to pollution components in water has increased the demand for transmitters and measurement systems that will give reliable data when the transmitter is submerged. We have attempted to evaluate several of the aspects of the problem we have been able to identify.

Most of the theoretical and measured data were produced by military contracts to evaluate communication between submarines or from air to submarines in salt water (Seigel 1973, Durrani 1962). These data and calculations make the assumption that water is a good conductor and deal only with the conductive components of the wave and assumes the displacement currents are negligible. In fresh water this is not the case; in reality, the conductive currents can be neglected and any radiated energy is due to displacement currents. Two recent papers have also considered this type of problem (Wu 1973, King 1974). However, because the highly theoretical nature of and the need to evaluate several complex integral equations these papers have only provided general ideas of what behavior we might expect. In general we would expect the antenna to look longer in water than in air. A first estimate would indicate the following relationship should apply:

$$\text{length in air/length in water} = \sqrt{\varepsilon_o \varepsilon_1}$$

where

ε_0 is the dielectric constant in air

ε_1 is the dielectric constant in water.

Using this relationship an antenna in water should appear nine times as long in water as in air. We attempted to evaluate this in a test tank and in a creek. Table 1-1 indicates the order of magnitude of the data obtained. The factor is more like two or three. We have not been able to determine why the difference has occurred. One source of error may be caused by making all the measurements near the surface and at the end of a coax cable. Ideally all the measurements should be made with the entire system submerged several wavelengths; however, our measurements were all made near the air-water interface. We also checked the measurements in a creek to determine whether the finite size of our measurement tank had a marked effect. There was some effect; however, it was only about 10%.

Table 1-1. Equivalent parallel resistance and reactance of antennas in air and in fresh water measured at 53.0 MHz. Antenna 22 A.W.G. tinned bus wire insulated with teflon tubing.

Antenna Length	AIR Resistance (ohms)	AIR Reactance (ohms)	WATER Resistance (ohms)	WATER Reactance (ohms)
8 inches	2500	-1360	800	-57
10 inches	2400	-1100	750	-77
12 inches	2300	-1000	650	-100
14 inches	2200	- 850	470	-136
16 inches	2100	- 790	325	-168
18 inches	2000	-750	185	-210

These data indicate that for efficient operation the drive level must be changed for operation in water because both the real and imaginary components of the impedance are lower. Therefore the tuning capacitance should be reduced and the drive level increased to maximize power output and range.

A second factor that has been known for some time is the reduction in range as the depth increases and as water conductivity increases. Figure 1-13 indicates data determined by experiment and data determined by using the standard attenuation equation. Similar results were determined by Saran (1960) using a radio station transmitter and a submerged receiver. Their data also indicate the best air to water transmission occurs when the antenna in the water is horizontally polarized and the antenna in air is vertically polarized. Our tests indicate that statement also applies in our case. The best range is achieved when the receiving antenna is vertically polarized and the antenna on the fish is horizontal.

F. Pulse Decoder

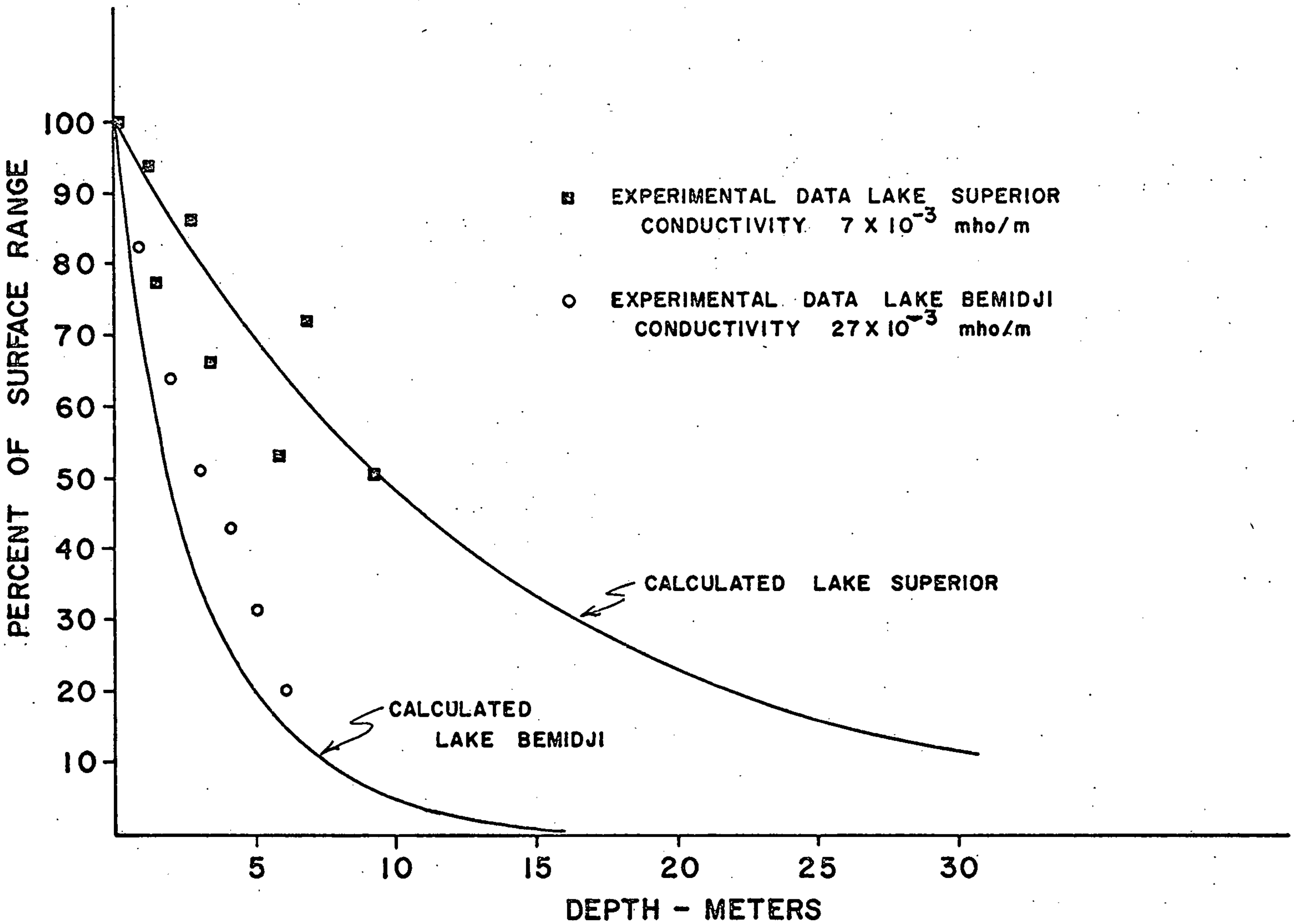
To save power most of our transmitters are built using pulse-code-modulation to transmit the information. More specifically, we use the interval between pulses (pulse period) to provide the information. For example, for both temperature and pressure, the time between pulses varies with the parameter.

This interval can be readily measured using standard commercially available pulse period counters; however, this technique has two disadvantages. First, most counters require AC power, a requirement not compatible with most field operations. Secondly, the output data are in two forms, the digital readout which can be recorded manually or the electronic output which can be used to control a digital recorder. The digital recorder method would be ideal for lab recording, but for field recording a digital clock is required to record time of day. Available digital recorders are costly and require more power than is ordinarily available in a field situation.

To meet the needs for a low-cost reliable field recorder to record data from temperature and pressure transmitters a recording system was developed. A functional block diagram is shown in Figure 1-14 and a complete circuit diagram is shown in Figures 1-15, 1-16.

The battery powered decoder receives its signal from either the standard or memory tracking receiver. In the first stage the pulses are shaped and a minimum and maximum pulse rate limit set. If the incoming pulse rate is outside the preset limits the counter is reset to zero and a new cycle started. Since the pulses from the receiver are not perfectly square some error will result depending on where the trigger level is set and how the pulse shape varies from pulse to pulse. This potential error can be reduced by averaging a number of pulses. We have done this in the decoder by counting the time for 10 pulses (or optionally 100 pulses). With this scheme we are dependent only on the triggering time of the start pulse (0th pulse) and of the stop pulse

FIG I-13 TRANSMITTER RANGE AS PERCENT OF SURFACE RANGE



(10th pulse). In addition, the error in these two pulses is divided by a factor of ten. Output of the decoder is available as digital readout from the front panel, a binary coded decimal signal or from the digital-to-analog (DA) converter. The DA converter is an eight-bit integrated circuit type with its output adjusted to 1 milliamphere full scale. The eight-bit converter is capable of dividing the 0 to 1 milliamphere scale in 2^8 or 256 parts. For our applications a Rustrak analog recorder is used. The entire system is powered by an automobile battery and has been used successfully in the field on several studies.

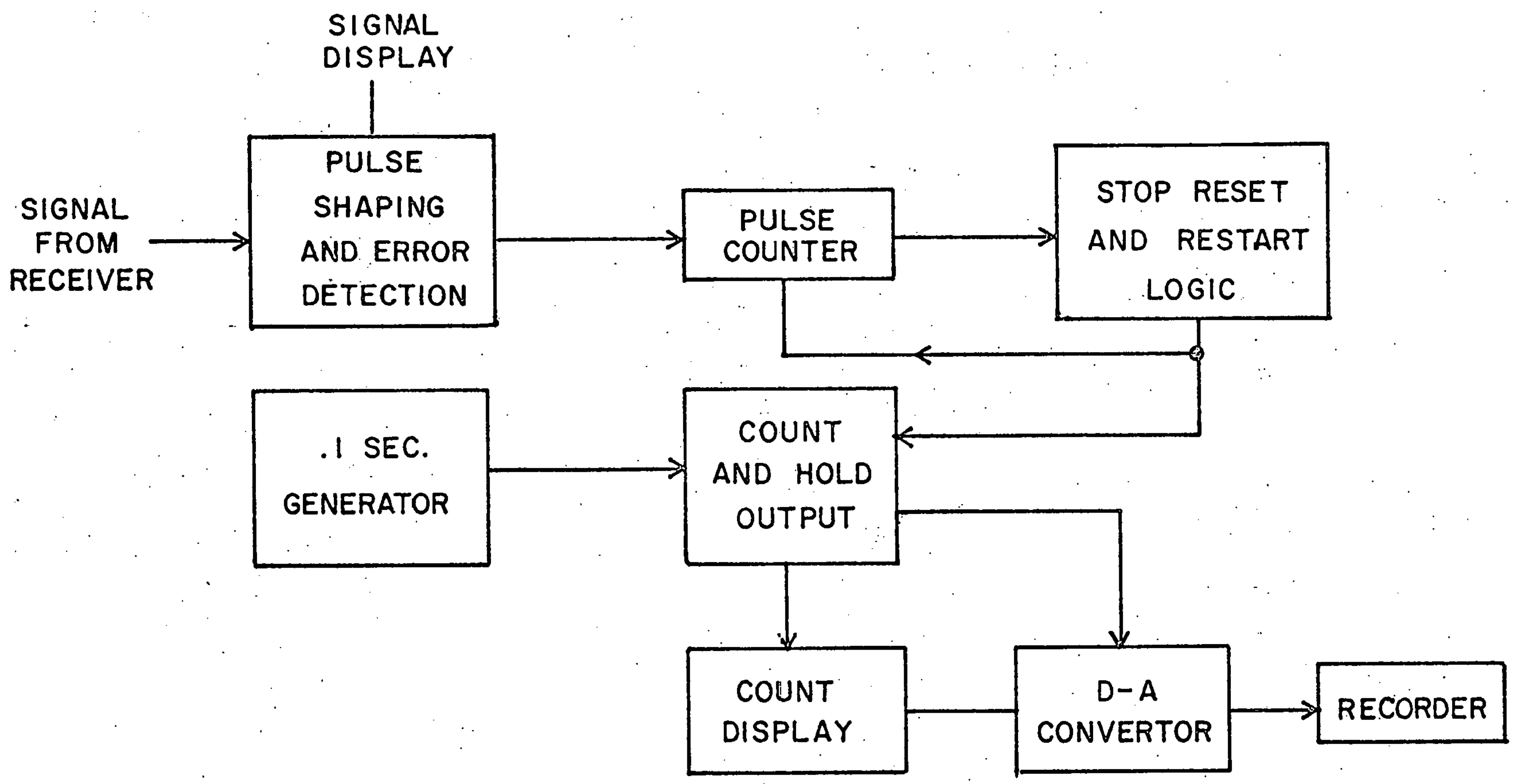


FIG 1-14 PULSE DETECTOR BLOCK DIAGRAM

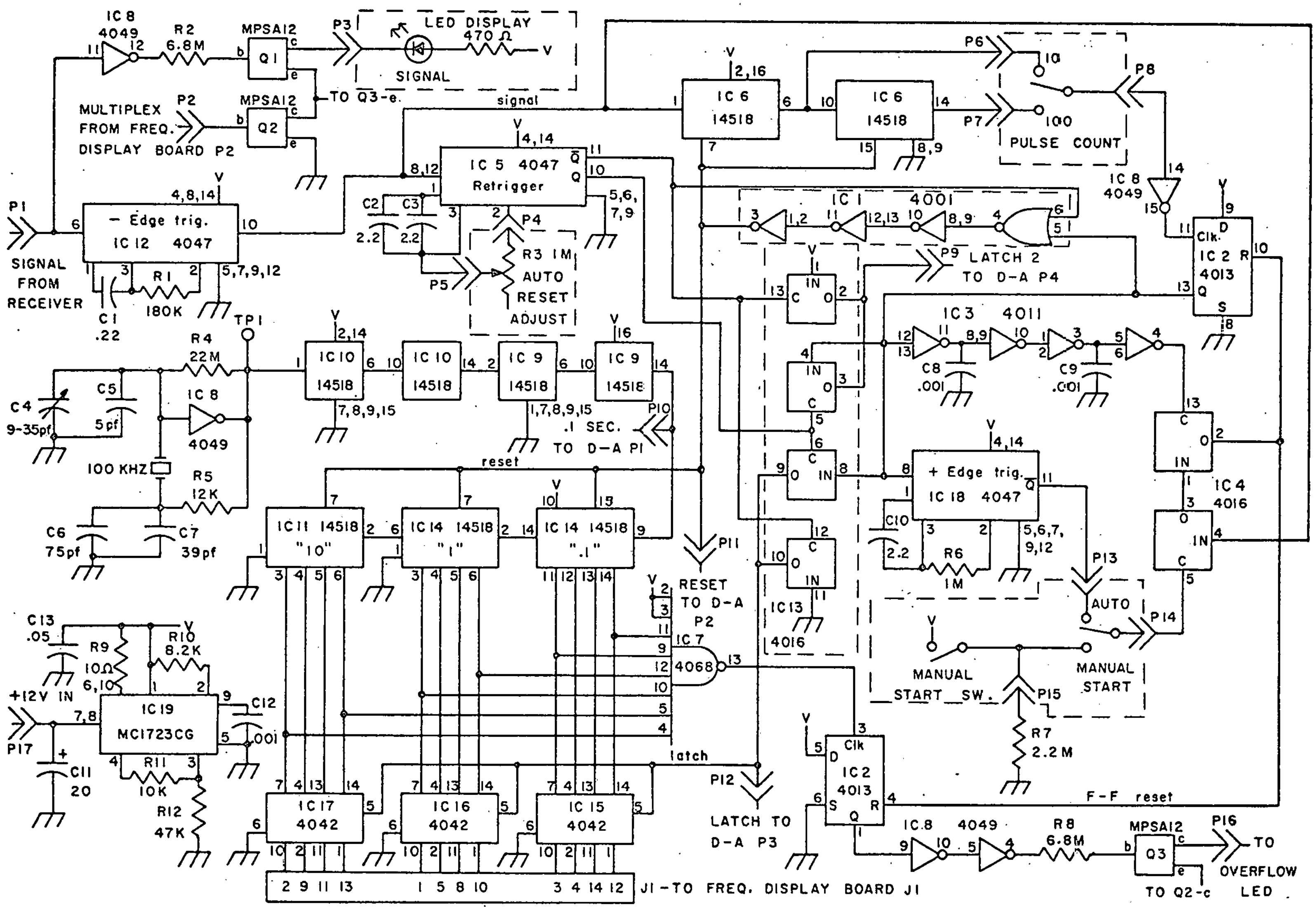


FIG 1-15 PULSE DECODER BOARD

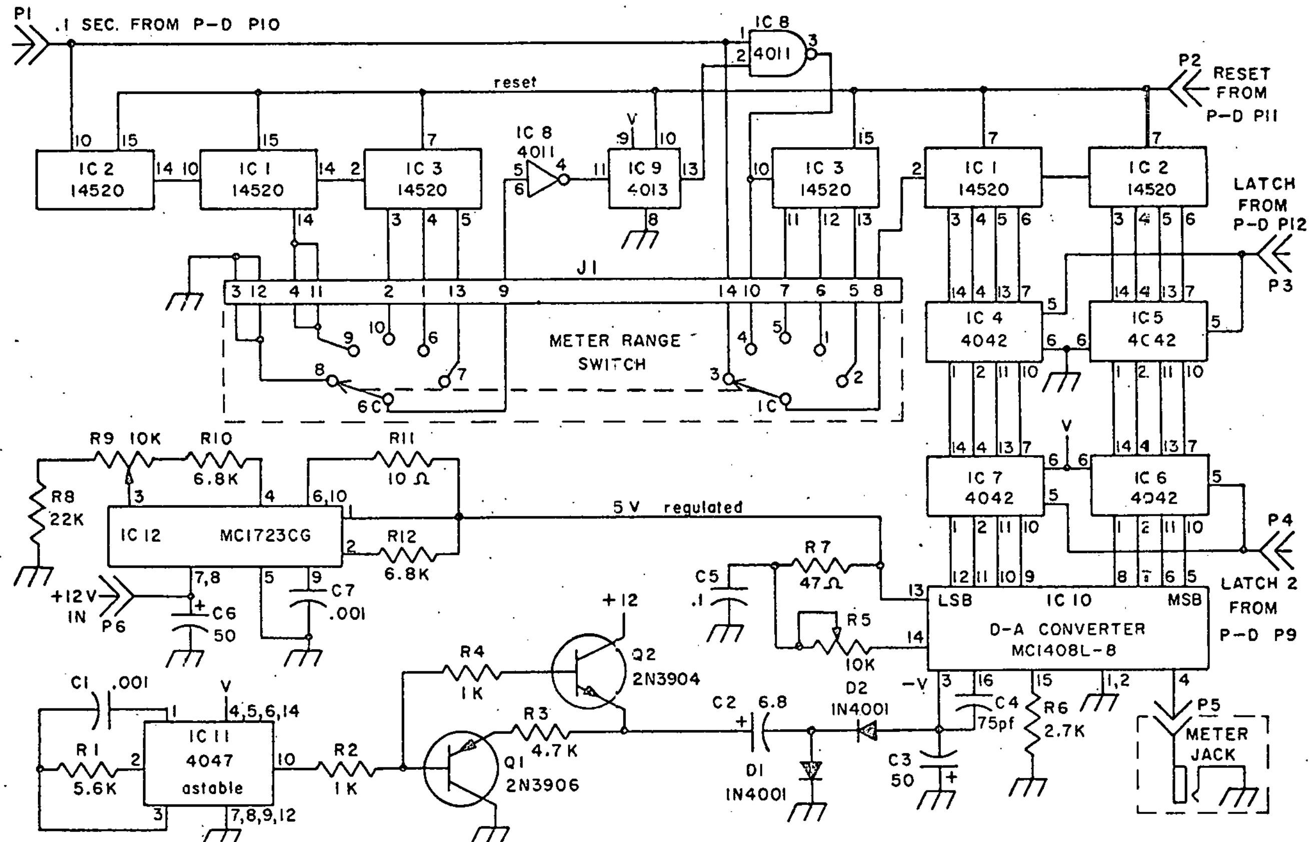


FIG I-16 DIGITAL ANALOG CONVERTER BOARD

SUBPROJECT TWO

STATISTICAL PROCEDURES AND QUANTITATIVE METHODS FOR ANALYSIS OF ECOLOGICAL AND BEHAVIORAL DATA

During the past year the Nova 2/10 computer was installed at Cedar Creek to process radio tracking and environmental data. The software system of 35 programs which was written in support of this installation are being tested and we are learning to integrate the data collection system of the Nova 2/10 with the Cyber 74. We are in the process of analyzing the programs and matching the data recorded on the Nova 2/10 magnetic tape system with those data which are recorded on the old film records. For example, the activity code now recorded must be completely checked to insure that the new codes reflect the old activity interpretations so that data are comparable.

Following installation of the Nova 2/10 at Cedar Creek a great deal of time has been spent in the past year updating and making more efficient the current software for the analysis of tracking data. We felt this area should be given high priority since the data generated by the Nova 2/10 will be much more voluminous than we were capable of obtaining from our film records and computer costs are climbing. Not all of the programs have been modified for efficiency and hence this area will continue in the next project year. Many of our research programs were at the stage of data analysis during the past year and hence computer time was a primary item. During the past year projects concerned with the Cedar Creek facility used $29,800 worth of Cyber 74 time of which $5,000 was provided by granting agencies. The rest of the time was subsidized by internal grants from the University of Minnesota's Computer Center. We estimate that approximately 50% of this time went to ERDA related projects.

The Hybrid Computer Laboratory, University of Minnesota, was contracted to provide the software system for the Nova 2/10. During the past year they provided us with three booklets fulfilling their part of this contract. These booklets were: 1) hardware documentation, 2) operator's manual, and 3) a very large volume which indicates the software systems specifications which they developed for our computer installation. Over the past year we have been working on these documents to bring them to a final format which will be required when the computer is fully operational, but still considerable editing and improvement is needed to insure that the documentation is sufficient to correct any difficulties which we may encounter in the future. This documentation is not included with our Proposal but is available for interested scientists.

As indicated in past progress reports, the analysis of vegetation has been complicated in that it has required a great deal of time to store vegetation data which can be integrated with the animal tracking information. During the past year we were successful in digitizing the Cedar Creek area vegetation map. This means that we placed a vegetation map of the Cedar Creek study area on a digitizer and recorded in XY coordinates the edges of all the vegetation polygons designated. These data are now a part of our Cedar Creek data storage unit and can be called when it is required that home range information be integrated with vegetation characteristics. Hoskinson and Siniff (COO-1332-127) have indicated the type of program required for integration of home range information and vegetation data. This program is currently part of the Cedar Creek software package.

SUBPROJECT THREE

COEXISTENCE AND POPULATION DYNAMICS OF SELECTED VERTEBRATES

The rationale for proposing a study of interspecific relations among tree squirrels on the Cedar Creek Natural History Area was based on the existence of the automatic radio tracking system, the specialized computer software system, and on the significant amount of baseline information from our previous studies on the gray squirrel.

For example, data have been evaluated to assess effects of environmental conditions of each season on activity rhythms of the squirrels. Pearson correlations and stepwise regressions of six weather factors, temperature, precipitation, wind, solar radiation, barometric high and low plus length of day were compared with the percent of day a squirrel was active. Correlations and regressions were done for 31 consecutive 15 day periods. Results of the analyses suggest that different weather variables influence squirrel activity at different times of the year, precipitation being most important during late summer and early fall and temperature being most important in mid-winter.

In addition, a more intensive investigation of habitat use, activity patterns, and home ranges of gray squirrels was initiated and completed to determine the feasibility of capturing and monitoring many squirrels in an area and to acquire more detailed knowledge of breeding behavior.

With this extensive field and lab experience and baseline information on the gray squirrel as a foundation, investigations were initiated in March, 1974, to study coexistence and population dynamics of three species of tree squirrels.

A study area was chosen in the high accuracy area north of the baseline and is being used for monitoring interactions among squirrels. Because these species have home ranges which may be only a few acres in extent, accuracy of the radio-determined locations must be very high to provide meaningful data. By positioning this study area in the optimum location with respect to the radio tracking towers, we were able to achieve an accuracy of ± 16 feet for each location. Although this did not enable us to determine the precise tree that an animal was using at any given time, it did locate the animal within the proper vegetative type. Field checks with portable receivers were used to determine exact den and resting locations when necessary.

The habitat within the boundaries of Cedar Creek has been mapped and classified in detail. A total of 148 habitat categories have been defined and their exact locations plotted on a base map. A digitizer was then used to convert the pattern of vegetation to numerical coordinates for use with our computer software system.

To serve as an intermediate step, detailed habitat maps were drawn and printed on a scale comparable to the activity ranges generated by the software program Homer. This will enable overlays of computer output to be placed on the maps and, thereby, allow measurement of habitat types and preferences within home ranges of each species.

Our first efforts were devoted to monitoring interactions among the squirrels on the study area during April and May, 1974. Twenty-seven gray squirrels and eight fox squirrels were marked with radio transmitters and monitored for the two-month period. The animals were recaptured in June, the transmitters removed, and individual biological data recorded. All data have been abstracted from microfilm records for these animals, and two software programs, Active and Homer, have been used to analyze the data. A third Program, A2DIST, will allow quantification of species interaction.

A second field phase began in September, 1974, and continued without interruption through March, 1975. The study area was retrapped, and all squirrels instrumented with a collar of 70-80 days duration. Three intensive trapping periods were required to insure continuity. The fall and winter seasons were critical to evaluate the interaction during these times of potential food shortage and competition for winter dens.

Trapping was conducted for eleven days in early September, 1974, and an attempt was made to capture all the tree squirrels in the primary study area. However, the presence of an abundant ripe mast crop interferred with the realization of this goal. A total of 21 gray squirrels were instrumented with radio collars during this period. Six of these were recaptures from the study which was conducted in the spring, 1974. In addition five fox squirrels were trapped and transmittered. Two of these were adult females originally marked during the spring of 1974. The remaining three were spring litter juveniles which dispersed during the next month to woodlots 1.5 to 4.5 kilometers away. No red squirrels were captured or observed during this period. Mortality was closely monitored, and two adult female gray were preyed upon by owls during the early fall months.

In a continued effort to transmitter all the tree squirrels, a second trapping period was initiated in late October even though the radio collars did not need batteries replaced. A total of 28 gray squirrels and eight fox squirrels were fitted with radio transmitters by the end of this season. Two summer litter juveniles suffered mortality during this time; both were believed to have been taken by Barred Owls (<u>Stryx</u> <u>varia</u>).

Since numerous sightings of Barred Owls were occurring in the study area, and since four radio tagged squirrels had been preyed upon during the early fall months, mist-netting was also begun in conjunction with the second trapping period. Two Barred Owls were captured and fitted with transmitters and, thereby, added an additional dimension to the study of interspecific activity.

The final trapping was conducted during early January, 1975. During this time period, within the same woodlot, 10 fox squirrels, 27 gray squirrels, one red squirrel and two Barred Owls were instrumented with radio transmitters.

It had been proposed to utilize the incoming data from this subproject to begin transformation to the new computer. However, since the installation of the computer had been delayed, such comparison did not occur. Significant comparisons of other hardware, specifically the Lithium battery transmitters and new receiver design, did undergo adequate and intensive field tests by research personnel, and critical revisions resulted from this daily use -- indicating the importance of testing in actual research paradigms. The receivers were utilized throughout the investigation, and, thus, a realistic evaluation of performance was possible. Not only were new design changes subjected to severe field conditions before final adoption, but several minor improvements also resulted from the field tests. Lithium batteries, although light in weight and twice the voltage of the mercury cell, were found to deteriorate and were thus very short-lived.

A total of 96 out of 151 months of data have been abstracted from the microfilm records and put on computer punch cards. This includes complete data on all 16 fox squirrels and on 15 of the 30 gray squirrels for approximately 50 percent of the time periods monitored.

Computer analyses of home range and activity rhythm have been completed on 72 of these data months. Species interaction has been analyzed for about 10 percent of these data. We are currently abstracting the remaining 55 data months on 12 gray squirrels.

A question of prime importance in this study concerns the possible effect of the radio transmitter on both the behavior and physiology of the marked squirrel. To evaluate behavioral effects an artificial feeding station was established and monitored by direct observation and time lapse photography. Twelve gray squirrels were fitted with radio collars. Observations and retrapping have not presented any evidence that jumping, running, climbing or feeding behaviors were different than those of animals marked only with ear-tags. Animals were not observed spending an inordinate amount of time manipulating the collar. Instrumented females with young at the feeder did not differ from the controls in feeding relations with the young. No differentiation in aggressive or threat postures was observed between instrumented and control squirrels, and the position of a squirrel in the social hierarchy was not affected by the radio transmitter.

Body weight was chosen as an indicator of physiological condition and was compared for transmittered and non-transmittered gray squirrels. A total of 587 weights, 94 of which came from transmittered squirrels, were analyzed.

A squirrel had to have carried a transmitter for at least three weeks before it was considered in the transmittered group. Many individuals in the transmittered group carried a transmitter for several months. Squirrel #1460 had a transmitter on for 7 months during which time she raised two litters. Squirrel #1467 carried a transmitter for a full year. At the end of this time she had just produced a litter and weighed within 7 grams of her weight at first capture.

Mean monthly weights of transmittered animals were plotted against the yearly weight curve for non-transmittered squirrels. Both male and female transmittered individuals had means close to or somewhat above those for non-transmittered squirrels. Figure 3-1 shows a comparison of known age spring litter juveniles, transmittered and non-transmittered. In June the groups were very close in weight. In September and October the transmittered animals were slightly heavier.

Squirrel weights within age groups were highly variable, with some ranges close to 200 grams. In the face of this kind of variation within the population, any real difference between transmittered and non-transmittered squirrels would have to be very pronounced to detect. In most cases variation within the population overshadowed any difference between the two groups. Where significant differences were found, transmittered animals were somewhat heavier.

Comparison of known age transmittered and non-transmittered juveniles did not indicate any detrimental effect on young squirrel development as a result of the radio transmitter. These data indicate there is no reason to believe that properly fitted radio transmitters of the type used in this study detrimentally affected the physiology of gray squirrels.

We are in the process of preparing papers with the following titles from data collected under this subproject:

1. Population dynamics and social coexistence of gray and fox squirrels as determined by radio telemetry.

2. Long range (exceeding one mile) excursion movements of gray squirrels on a regular, predictable basis.

3. The effect of radio transmitters on tree squirrels as measured by such physical parameters as weights, pelage conditions, reproductive success, nest building, rearing of young, and population dynamics.

4. A comparison of home ranges and population dynamics of tree squirrels by live trapping and radio telemetry: a technique comparison.

5. Trap success as a function of season based on four years of data.

6. Daily and seasonal activity patterns, home ranges and population dynamics of gray squirrels.

7. Tree squirrel predation and Barred Owl interaction as determined by radio telemetry.

8. Activity rhythms, patterns, and ranges of juvenile gray squirrels.

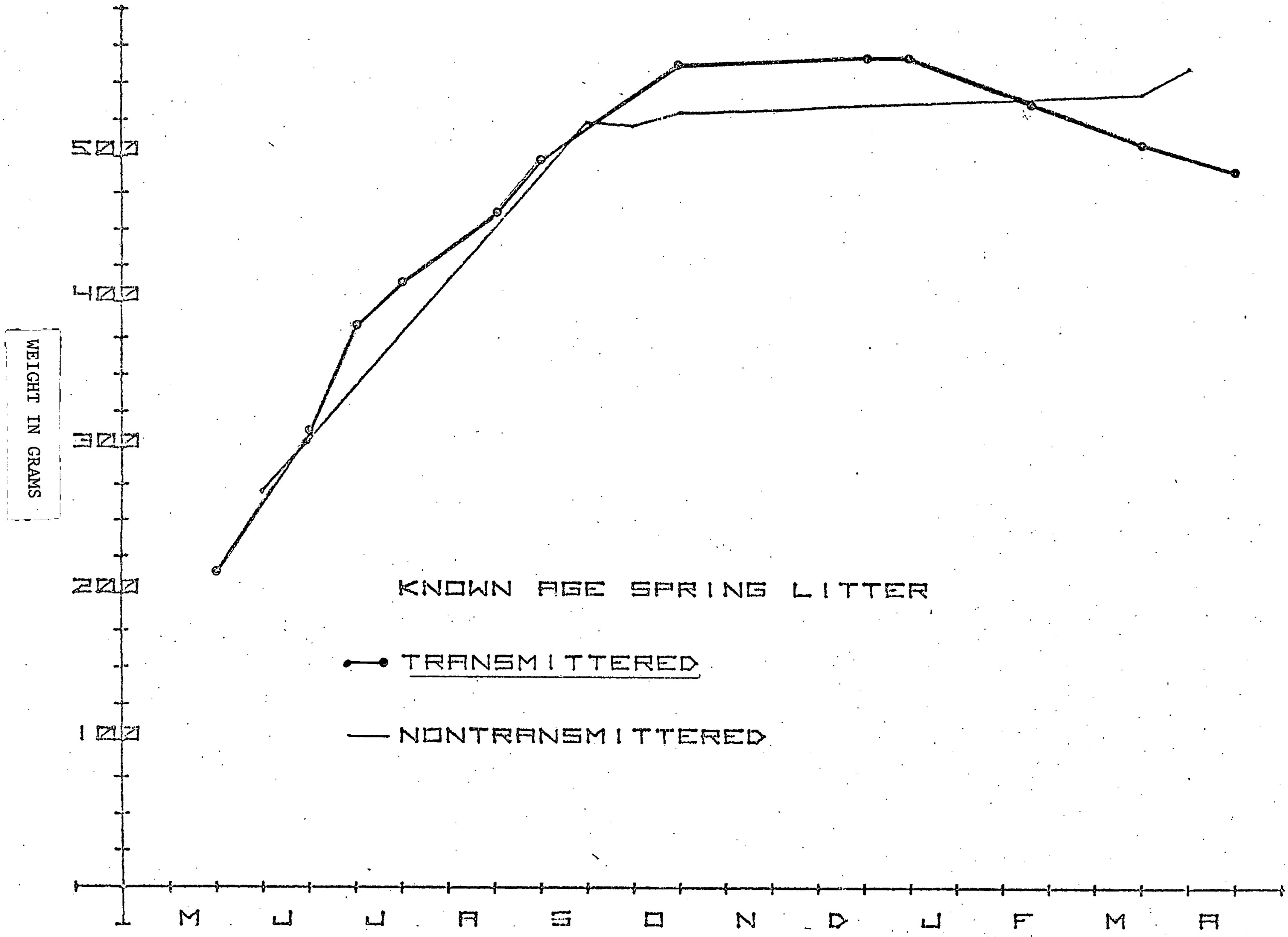

WEIGHT IN GRAMS
500
400
300
200
100
KNOWN AGE SPRING LITTER
TRANSMITTERED
NONTRANSMITTERED
M J J A S O N D J F M A

Figure 3-1

SUBPROJECT FOUR

APPLICATION OF RADIOTELEMETRY TO SELECTED PROBLEMS IN VERTEBRATE CENSUSING AND POPULATION STUDY

A supplementary proposal outlining Subproject Four was funded for the first time beginning March 15, 1975 and set forth general plans for research on sea otter populations at Amchitka Island, in other areas of Alaska and along the California coast. This research program called for the use of telemetry to obtain information on census methods and selected population problems. Emphasis was placed on the sensitivity of otter populations to environmental disturbances. The proposal suggested that it was important to initiate a long-term research program to: 1) develop population monitoring techniques, and 2) start data collection in order to evaluate the possible influences of environmental changes and disturbances. The following report summarizes our accomplishments on this Subproject for the period July 1, 1975 through June 30, 1976 in three areas: Amchitka Island and Prince William Sound, Alaska; and California.

PRINCE WILLIAM SOUND STUDIES

This work was initiated in July 1975 at Olson Bay, Alaska, in cooperation with Mr. Ancel Johnson, U.S. Fish and Wildlife Service, Anchorage, Alaska. The primary purpose of the research was to experiment with radio attachment procedures on sea otter. In Prince William Sound the Fish and Wildlife Service had constructed a floating net pen, approximately 24' x 12' with four foot of netting above and below the water surface. At the time we began field work two adult male otters were in captivity to be used as experimental specimens. The animals were removed from the pen with a modified salmon dip net and fitted with radio transmitters. Two types of attachment procedures were tested: a neck-collar mount and an ankle mount. Both attachments were fastened with brass nuts and steel bolts to facilitate corrosion and transmitter release after some period of time in salt water. Some stress due to handling occurred and it appeared that the more efficient methods for transmitter attachment would have to be developed.

The animals were held under observation for two days following attachment of the collar and one day following attachment of the ankle transmitter and then released. In neither case did the animals appear to be experiencing any difficulty as a result of the transmitter. Preliminary tests with radio receivers indicated a reception range of at least one mile with a good possibility for obtaining behavioral information from the quality of the signal transmission. These animals were monitored for several days and initial contacts from the boat indicated a transmitter range of 2 - 3 miles. The older male remained solitary but the second male joined a group of 5 - 15 otters. The older male was found dead on the beach about one month after release.

These initial tests indicated that the neck-collar mount is more difficult to attach but appears to give a steadier signal and is less susceptible to chewing and manipulation by the animal. The ankle mount is easier to attach but can readily be reached by the sea otter and gives a more intermittent signal. If properly fitted, neither form of attachment appeared to interfere with pelage insulation and buoyancy properties, at least in the short time frame of these observations.

In mid-May 1976 we again entered the field in Prince William Sound to cooperate with Mr. Ancel Johnson, U.S. Fish and Wildlife Service. Our intent was to carry out further tests on attachment problems, to collect data on movement patterns and to initiate a long-term tagging program. Also, we were awaiting information on our permit application of February 13, 1976 relative to the tests with oil contamination. The Fish and Wildlife Service was to provide holding tanks in Prince William Sound for these studies. However, when it became apparent in late June 1976 that the Federal permit was not going to include permission for this work, these plans were cancelled.

During the time from mid-May to the end of June 1976 we instrumented four otters with ankle radio transmitters. Two of these were released and two were held in captivity to study the effects of transmitters on behavior and general health. Of the two animals released into the wild, one died from what appeared to be a swelling of the ankle portion of the foot where the transmitter was attached. The other otter released apparently had no difficulty with the transmitter and was monitored for almost a month. The two otters that were held in captivity were kept for 15 days and again, one of these had difficulty with ankle swelling. The transmitter was repositioned but still the foot swelled. Finally this transmitter had to be removed and the otter released. The other otter held in captivity for 15 days suffered no apparent ill effects.

From these studies it is evident that proper fitting of the transmitter around the ankle is complicated. Thus, in the future we are anticipating using tranquilizing drugs to calm the animal to assure that a proper fit is secured. At the present time we are making plans to continue our work in July 1976 in California in cooperation with the California Fish and Game Department and the U.S. Fish and Wildlife Service.

AMCHITKA STUDIES

From August 20 to August 28, 1975 it was our intent to further test telemetry equipment on free ranging otters at Amchitka Island, Alaska. Numerous attempts were made to stalk animals which were hauled out on rock outcrops and to capture them with a salmon dip net. However, the capture technique did not prove to be successful and since proper logistic support and equipment for capturing animals at sea was not available, it was not possible to test telemetry equipment any further. Thus, the study was redesigned to collect census information and to take advantage of skulls found from natural mortalities along the beach.

Figure 4-1 is a summary of the census information accumulated from walking the beaches around Amchitka Island. Approximately four miles of beach were walked daily and counts were made at high landmarks along the beach front. These data are difficult to interpret because of the various biases associated with such counts; however, the range of numbers seen is much lower than indicated from previous studies (particularly Eshes and Smith 1973) and is indicative that the population at Amchitka has declined in recent years. We feel these data are of a sufficient interest that further consideration of the size of the otter population at Amchitka should be given some priority since past studies on this population have accumulated good long-term data.

Figure 4-1 also indicates the general vicinity where skulls were located from natural mortalities. Table 4-1 represents a list of the data on the 24 skulls that were found. Age was estimated in the laboratory using a system based on dentition (Lensink 1962). Because of the small sample size it is difficult to draw any conclusions from these data; however, in summarizing age categories it is evident that about 58% (14) of the skulls found had full adult dentition. This represents a higher percentage than that found by Kenyon (1969). Kenyon's two best samples of natural mortality were in 1959 and 1962 when 38% and 24% of animals picked up on the beach were adults (Kenyon p. 255). Of the 14 animals which were classified as adults in this study, only six possessed dental characteristics which indicated the animals were relatively healthy while eight animals possessed moderate to severe dental attrition or malformation. Again we feel even though these data are limited they do indicate an unusual number of adult animals dying of natural causes as compared to previous studies. Kenyon (p.258) points out there is a bias toward adults if the skulls are collected some time after the period of major mortality; this may contribute to the high percentage of adults in our collection.

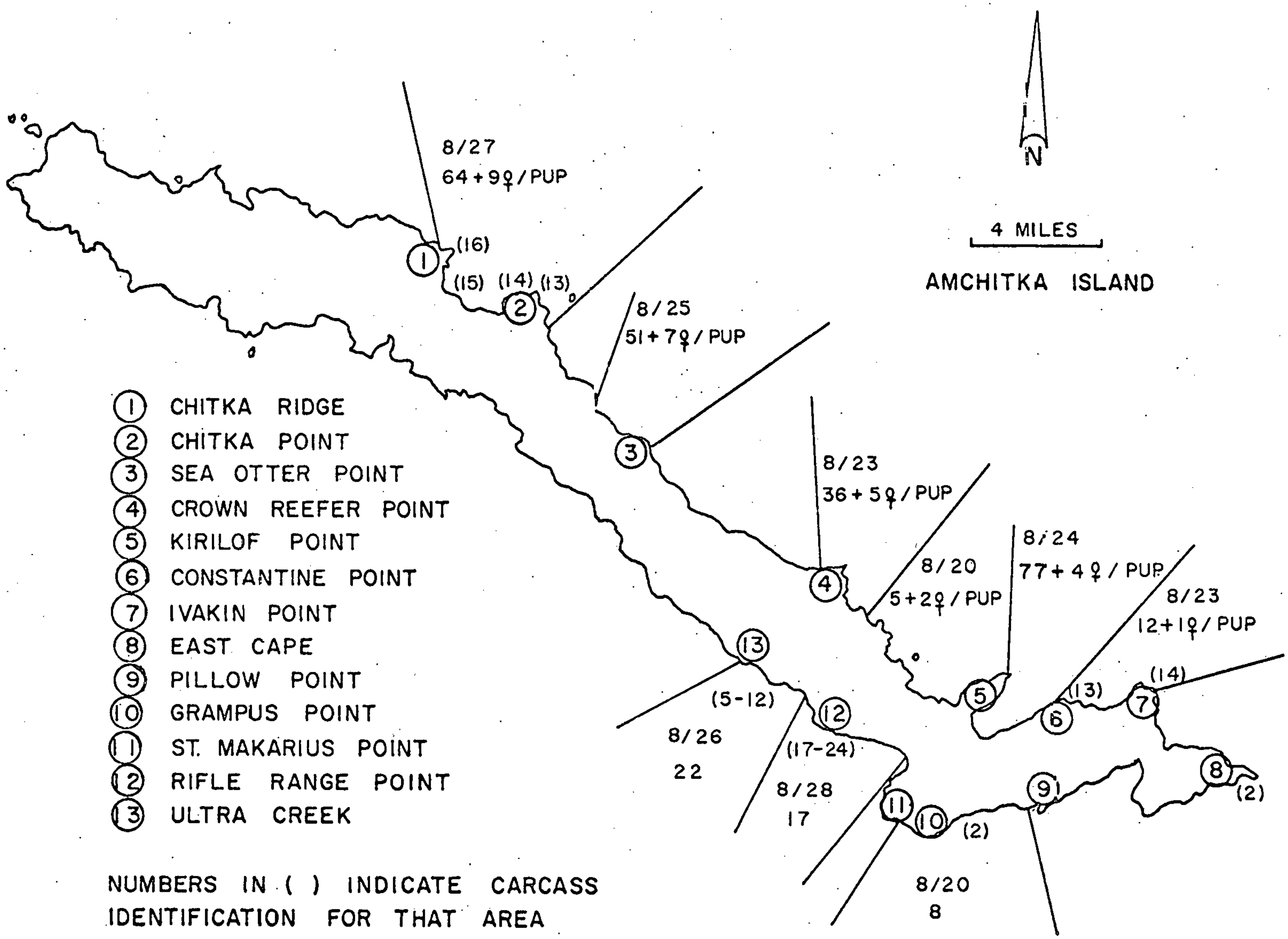
CALIFORNIA STUDIES

We are new in the area of sea otter research and hence have made every attempt to coordinate our efforts with other investigators. Our work in California was primarily aimed toward establishing relationships for future studies as well as obtaining an introduction to the facilities and problems that will be encountered when studying in this area. To this end one investigator spent most of August 1975 in the Monterrey vicinity assisting and consulting with researchers from the University of California, Los Angeles and the California Department of Fish and Game. This provided the opportunity to observe first hand the capture techniques developed for free-ranging otters in California and to further evaluate the telemetry equipment and its possible influences on otters. Specifically we assisted in the capture and instrumentation of one male adult otter in the vicinity of the Hopkins Marine Station, Pacific Grove, California. After release the otter was monitored for four days on a continuous basis and the transmitter collar appeared to not interfere with its normal and grooming activities. These contacts and experiences have been helpful in the design of further studies as outlined in our renewal proposal.

Table 4-1. Skulls collected Amchitka Island, August 1975

Skull Number	Sex	Age Class	Comments
1	M	Adult	Severe dental attrition
2	M	Subadult (16-24 months)*	
3	?	Subadult-Adult*	Partial skull, adult dentition, no attrition
4	?	Adult	Severe dental attrition
5	F	Adult	Severe dental attrition
6	?	Subadult (9-15 months)	
7	?	Adult	Moderate to severe dental attrition
8	M	Subadult (25-34 months)*	
9	M	Pup (5-8 months)	
10	?	Subadult (9-15 months)	
11	F?	Subadult (9-15 months)	
12	F?	Adult	Severe dental attrition
13	F?	Adult	
14	?	Adult	Moderate dental attrition
15	M	Subadult (9-15 months)	
16	M	Subadult (33-36 months)*	
17	F	Subadult (9-15 months)	
18	?	Subadult (16-24 months)*	
19	F?	Subadult (9-15 months)	
20	F?	Pup (5-8 months)	
21	?	Subadult (16-24 months)*	Malformation of upper left M and PM3, partial skull
22	?	Subadult (9-15 months)	Partial skull
23	F	Pup (4-5 months)	
24	?	Adult	Moderate to severe dental attrition, partial skull

*Adult dentition



N
4 MILES
AMCHITKA ISLAND
8/27
64+9♀/PUP
(16)
(15) (14) (13)
8/25
51+7♀/PUP
8/23
36+5♀/PUP
8/20
5+2♀/PUP
8/24
77+4♀/PUP
8/23
12+1♀/PUP
(13)
(14)
(2)
(5-12)
8/26
22
(17-24)
8/28
17
(2)
8/20
8
1 CHITKA RIDGE
2 CHITKA POINT
3 SEA OTTER POINT
4 CROWN REEFER POINT
5 KIRILOF POINT
6 CONSTANTINE POINT
7 IVAKIN POINT
8 EAST CAPE
9 PILLOW POINT
10 GRAMPUS POINT
11 ST. MAKARIUS POINT
12 RIFLE RANGE POINT
13 ULTRA CREEK
NUMBERS IN ( ) INDICATE CARCASS IDENTIFICATION FOR THAT AREA

Figure 4-1

SUBPROJECT FIVE

FISH RESPONSE TO ALTERATIONS IN WATER QUALITY RESULTING FROM POWER PRODUCTION

This subproject concerns a cooperative investigation between the Ecosystems Department of Battelle Northwest Laboratories and the Department of Ecology and Behavioral Biology at the University of Minnesota. The effect of gas supersaturated water on the behavior of migratory salmon in the Snake and Columbia River systems has been and is a major concern. This cooperative project is directed towards study of these effects. Field investigations are being carried out in the vicinity of Battelle Northwest Laboratories with the responsibility for the field work being delegated to Mr. Jim Haynes, a student working on a Ph.D. program at the University of Minnesota. Mr. Haynes is supported by a fellowship awarded by NORCUS, 100 Sprout Road, Richland, Washington 99352. A portion of the costs for telemetry equipment and engineering is paid by Battelle Northwest Laboratories and the electronic components required for the study are designed and built by the Bioelectronics Laboratory, University of Minnesota.

During the fall of 1975 it was the intent to monitor depth selection on fish using a depth transmitter to be developed by the Bioelectronics Laboratory. Difficulties were encountered in the development of this tag and it was not ready until late in the season when most of the fish had passed up river. Thus most of the work centered on testing the pressure tag which was eventually constructed and prepared for the spring pre-season period.

During the spring of 1976 30 chinook salmon were tagged with pressure tags and released below Little Goose dam on the Snake River. Of the 30 tags attached 15 were external tags and 15 were internal tags. For the external tags six fish with external tags intact crossed the dam, four fish with external tags which had been torn off crossed the dam, and the remaining five fish remained below the dam and were lost when the transmitter failed. Of the 15 internal tags put out none of the fish crossed the dam and all were eventually lost because the batteries reached their expected life. The general pattern was for the fish with external transmitters to move up to Little Goose dam within 24 hours after release four miles below, after which time one of four events usually occurred. These were: 1) remained in the spill until after the battery failed, 2) crossed the dam within a few days after being in the vicinity, 3) moved downstream then back to the dam on a daily basis, or 4) the tag failed in the first 96 hours.

The internally tagged fish showed three patterns. These were: 1) they reached the dam in 48 hours, remained in the spillway for a day or more and then moved downstream but did not return to the dam, or 2) moved downstream and never reached the dam, or 3) the tag failed in the first 96 hours. Three of the internally tagged fish dropped downstream between 30 and 60 miles before the battery failed. A comparison of the dam crossing results with National Marine Fisheries Service data indicated that perhaps the poor success experienced by the internal tag was due to a combination of size and weight of the tag. The pressure tags which were used were somewhat larger in size and considerably heavier in water than National Marine Fisheries internal tags. The pressure tags seemed to work fairly well, however, problems were encountered with stability. The tag calibration varied with time and hence new calibration curves were required in order to interpret results after a few days. Tests are being made to evaluate the results which were obtained. The automatic recording stations which recorded data on instrumented fish in the vicinity of the dams worked extremely well and recorded on a 24-hour basis depth information.

SUBPROJECT SIX

SEASONAL MIGRATIONS AND HABITAT SELECTION OF THE PRONGHORN ANTELOPE

A radio-telemetry study of pronghorn antelope seasonal movements began at the Idaho National Engineering Laboratory Site in October 1975. The purpose of the study is: to document the seasonal movements of antelope that summer in three mountain valleys north of the INEL Site; to determine their use of the INEL Site as winter range; to record their specific use of the areas near the INEL facilities; and to obtain information on migration routes, habitat selection, and summer ranges.

Antelope are commonly found on the INEL Site during spring and summer. In late fall large numbers of antelope migrate onto or through the INEL Site from mountain valleys in Idaho and Montana.

In addition to the telemetry study, a radioecology study is being conducted to determine the radioisotopes in pronghorn tissues on and near the INEL Site. Tissues are being utilized as a valuable bioindicator of radionuclides in the environment. In order to determine the significance of the radioisotope data, specific movements of individual antelope on the INEL Site are required. Because the INEL Site serves as winter range, knowledge of migration patterns is necessary to understand possible effects the INEL Site may have on pronghorns.

Migration data will be useful in the Idaho Department of Fish and Game and federal agencies which make decisions affecting the management of this species. Since these populations are subject to off-site hunting, data on the timing and routes of migration, habitat selection, and the location of summering areas are required. Detrimental land use decisions, such as sagebrush spraying or construction of fences, may be avoided if the movements and ecology of these antelope are known.

Data collection is necessary before proper decisions can be made. On and near the INEL Site in several places, the decisions affecting antelope are critical. In two of the three valleys, the land use pattern is shifting quickly to agricultural with its associated reduction in sagebrush and increase in fences, many of them antelope-proof. These practices threaten to completely sever migration routes. With an understanding of migrations and use of the areas on and near the INEL Site, this threat may be lessened.

This research is a cooperative effort of the Energy Research and Development Administration, Idaho Department of Fish and Game, and the University of Minnesota. The project will continue until September 1977.

METHODS

Antelope were captured in the Little Lost and Birch Creek Valleys in early December 1975 and in Crooked Creek Valley in early January 1976. All the populations had completed partial fall migrations and were near the north end of the Site. The antelope were herded into a corral trap with a helicopter. Captured antelope were sexed and aged, blood samples were taken, and ear tags attached. Selected animals were fitted with radio-collars operating in the 161-162 MHz range. Each radio transmits on a different frequency and each collar is color-coded, allowing for tracking and observation of individual antelope. In addition, each collar has a plastic laminated tag requesting the collar be returned. Embedded in this tag are TLD's which will be measured for radiation exposure when recovered. Additional antelope will be captured throughout the year with a tranquilizer dart-gun and cannon-net. Newborn fawns were captured by hand and radio-collared near their birth sites. Ground tracking of the radioed antelope utilizes a vehicle with a double Yagi antenna system mounted on a mast. Aerial tracking is done from a Piper Super Cub.

Temperature and wind are being monitored on the INEL Site using the existing weather stations. Snow depths were measured at 18 locations on and near the INEL Site using snow depth stakes set up last fall. These data will be analyzed to determine the effect of environmental conditions on pronghorn movements.

RESULTS

On December 4, 1975, 20 antelope were radioed in the Little Lost Valley near Howe, Idaho (5 km off-site). Twenty more were ear-tagged and 47 were released unmarked. Nineteen antelope were radioed in the Birch Creek Valley (8 km off-site) on December 7, 1975, and 40 others were ear-tagged. Fifteen antelope were radioed in Crooked Creek Valley (13 km off-site) on January 10, 1976; 46 others were ear-tagged, and 13 released unmarked. In late May and early June, 1976, 24 newborn pronghorn fawns were hand-captured and fitted with small, expandable radio-collars in the north end of Birch Creek valley about 55 km north of the INEL Site. Two were fawns of a radio-collared doe.

Two pronghorns from the Little Lost and one each from Birch Creek and Crooked Creek died shortly after being radioed, possibly from trap-related injuries. Two of the radioed fawns died shortly after being collared, one preyed on by coyotes and the other probably from starvation due to physiological problems. Two other fawns lost their collars but are not assumed dead. Two adults were probably poached in the Little Lost. One radio-collar disappeared for 45 days and was then found by a rancher. The second antelope was found up in a canyon where it had been hauled by trappers as bait. One other broke her neck on an antelope-proof fence. Two Birch Creek antelope died during winter but no indication of the cause of death was evident.

During winter 1975-1976 attempts were made to locate each antelope at least once a week. About 600 telemetry locations of the pronghorns were made on their winter ranges. Four pronghorns in the Little Lost wintered 17 km northwest and the rest wintered 5 km northwest of the trapsite in a herd of over 150 antelope (both areas off-site). All of the Birch Creek antelope were located on-site in areas heavily used in winter by antelope. Three radioed antelope wintered at Test Area North (TAN), about 25 km southwest of the trapsite. Most Crooked Creek antelope wintered within 10 km of the trapsite. However, two moved on-site (25 km) and associated with Birch Creek antelope.

Antelope were located approximately 140 times during spring migration, both from the ground and during 77.3 hours of aerial tracking. One doe from the Little Lost migrated 50 km south through the INEL Site. Two others left the Little Lost and migrated 40 km up Birch Creek valley. Four migrated 70 km up valley and are summering in the Pahsimeroi valley north of the Little Lost valley. Five migrated up the Little Lost about 45-50 km and three did not migrate.

One Birch Creek doe migrated 50 km to the Medicine Lodge valley, two radioed pronghorns are just north of the trapsite, and the rest have migrated up valley as much as 88 km. Two Crooked Creek pronghorns migrated northeast 30 km to an area just east of Medicine Lodge valley and another migrated 30 km southeast onto the desert. The others have migrated into and up Medicine Lodge valley as far as 80 km from their winter range. Three of them are in Montana and four others are just south of the border in Idaho.

Initial statistical analyses of the blood data collected from the trapped antelope show significant differences between populations with respect to hemoglobin, hematocrit, chloride, fibrinogen, BUN (blood urea nitrogen) and several other parameters. Perhaps the most interesting differences are those for BUN. The three populations are distinctly different from one another with virtually no overlap between populations. This parameter is a measure of the protein content of diet, and indicates significant differences between these populations with respect to their food intake over the several weeks prior to trapping.

PUBLICATIONS

Abraham, R.L. 1972. Mortality of mallards exposed to gamma radiation. Rad. Res. 49(2):332-327. (COO-1332-62).

Abraham, R.L. 1974. Vocalizations of the mallard (Anas platyrhynchos). The Condor 76(4):401-420. (COO-1332-74).

Andrews, R.D., G.L. Storm, R.L. Phillips and R.A. Bishop. 1973. Survival and movements of transplanted and adopted red fox pups. J. Wildl. Manage. 37(1):69-72. (COO-1332-82).

Archibald, H.L. 1974. Directional differences in the sound intensity of Ruffed Grouse drumming. The Auk 91(3):517-521. (COO-1332-96).

Archibald, H.L. 1975. Temporal patterns of spring space use by Ruffed Grouse. J. Wildl. Manage. 39(3):472-481. (COO-1332-106).

Ball, I.J., D.S. Gilmer, L.M. Cowardin and J.H. Riechmann. 1975. Survival of wood duck and mallard broods in north-central Minnesota. J. Wildl. Manage. 39(4):776-780. (COO-1332-105).

Christenson, G. and M.R. Fuller. 1975. Food habits of two long-eared owl families in east-central Minnesota. Loon 47(2):58-61.

Fuller, M.R. 1975. A technique for holding and handling raptors. J. Wildl. Manage. 39(4):824-825. (COO-1332-112).

Fuller, M.R., T.H. Nicholls and J.R. Tester. 1974. Raptor conservation and management applications of bio-telemetry studies from Cedar Creek Natural History Area. In Hamerstrom, F.N. et al. (eds.) Management of Raptors. Proceedings of the Conf. on Raptor Conservation Techniques, 1973 (Part 4). (COO-1332-87).

Fuller, M.R., P.T. Redig, and G.E. Duke. 1973. Raptor rehabilitation and conservation in Minnesota. The Loon 45(2):50-55. (COO-1332-88).

Fuller, M.R. and J.R. Tester. 1974. An automatic radio tracking system for biotelemetry. Raptor Res. 7(3/4):103-104. (COO-1332-89).

Gilmer, D.S., I.J. Ball, L.M. Cowardin and J.H. Riechmann. 1974. Effect of radio packages on ducks. J. Wildl. Manage. 38(2):243-252. (COO-1332-84).

Gilmer, D.S., I.J. Ball, L.M. Cowardin, J.R. Riechmann and J.R. Tester. 1975. Habitat use and home range of mallards breeding in Minnesota. J. Wildl. Manage. 39(4):781-789. (COO-1332-73).

Gilmer, D.S., V.B. Kuechle and I.J. Ball. 1971. A device for monitoring radio-marked animals. J. Wildl. Manage. 35(4):829-832. (COO-1332-63).

Gilmer, D.S., S.E. Miller and L.M. Cowardin. 1973. Analysis of radio-tracking data using digitized habitat maps. J. Wildl. Manage. 37(3):404-409. (COO-1332-80).

Heezen, K.L. and J.R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. J. Wildl. Manage. 31(1):124-141. (COO-1332-16).

Hessler, E., J.R. Tester, D.B. Siniff and M.M. Nelson. 1970. A bio-telemetry study of survival of pen-reared pheasants released in selected habitats. J. Wildl. Manage. 34(2):267-274. (COO-1332-41).

Hoskinson, R., J.R. Tester, R. Autenrieth, and O.D. Markham. 1975. Antelope migrations in and near the INEL site. In Markham, O.E. (editor), Summaries of the Idaho National Engineering Laboratory Site Ecological Information Meeting, July 10, 11, 1975. Idaho Natl. Eng. Lab., IDO-12079, pp. 3-4.

Houseknecht, C.R. 1969. Denning habits of the striped skunk and the exposure potential for disease. Bull. Wildl. Disease Assoc. 5:302-306. (COO-1332-52).

Houseknecht, C.R. 1970. Biotelemetry as a technique in disease ecology studies. J. Wildl. Diseases 6:414-417. (COO-1332-54).

Houseknecht, C.R. and R.A. Huempfner. 1970. A red fox-striped skunk encounter. Amer. Midl. Naturalist 83(1):304-306. (COO-1332-49).

Huempfner, R.A., S.J. Maxson, G.J. Erickson and R.J. Schuster. 1975. Recapturing radio-tagged ruffed grouse by nightlighting and snow-burrow netting. J. Wildl. Manage. 39(4):821-823. (COO-1332-102).

Kuechle, V.B. 1967. Batteries for biotelemetry and other applications. BioInstrumentation Advisory Council, Amer. Inst. Biol. Sci., Washington, D.C., Info. Module M10. 15 pp. (COO-1332-28).

McColl, J.G. and S.J. Maxson. 1974. Phenological and nutrient studies of trembling aspen: a prime food source of ruffed grouse. Submitted to Ecology. (COO-1332-101).

McKinney, F. 1965. The displays of the American Green-winged Teal. Wilson Bull. 77(2):112-121. (COO-1332-2).

McKinney, F. 1965. An analysis of pair-formation in Anas crecca carolinensis. (Abstract) Bull. Ecol. Soc. Amer. 46(3):110-111. (COO-1332-7).

McKinney, F. 1967. Breeding behavior of captive Shovelers. Wildfowl Trust, Ann. Rept. 18:108-121. (COO-1332-33).

McKinney, F. 1968. Nest building movements performed by male ducks. Wildfowl Trust, Ann. Rept. 19:64-66. (COO-1332-34).

McKinney, F. 1970. Displays of four species of blue-winged ducks. The Living Bird 9:29-64. (COO-1332-50).

McKinney, F. 1972. Ecoethological aspects of reproduction. In Breeding Biology of Birds. Natl. Academy of Sciences. Washington, D.C. (COO-1332-77).

McKinney, F. 1974. The evolution of duck displays. In Evolutionary Aspects of Behaviour. Niko Tinbergen Festschrift. Clarendon Press, Oxford.

Mech, L. D. 1965. Sodium pentabarbitol as an anesthetic for raccoons. J. Mammal. 46(2):343-344. (COO-1332-6).

Mech, L. D. 1965. A critical evaluation of the concept of home range. (Abstract) Bull. Ecol. Soc. Amer. 46(3):121. (COO-1332-9).

Mech, L. D. and N. V. Anderson. 1965. Renal hypoplasia and compensatory hypertrophy in a raccoon. J. Mammal. 47(-):128-129. (COO-1332-10).

Mech, L. D., D. M. Barnes, and J. R. Tester. 1968. Seasonal weight changes, mortality, and population structure of raccoons in Minnesota. J. Mammal. 49(1):63-73. (COO-1332-32).

Mech, L. D., K. L. Heezen and D. B. Siniff. 1966. Onset and cessation of activity in cottontail rabbits and snowshoe hares in relation to sunset and sunrise. Animal Behavior 14(4):410-413. (COO-1332-15).

Mech, L. D., V. B. Kuechle, D. W. Warner and J. R. Tester. 1965. A collar for attaching radio transmitters to rabbits, hares, and raccoons. J. Wildl. Manage. 29:898-902. (COO-1332-5).

Mech, L. D. and J. R. Tester. 1965. Biological, behavioral and physical factors affecting home ranges of snowshoe hares, raccoons, and white-tailed deer under natural conditions. Minn. Mus. Nat. Hist., Tech. Rept. 9, 11 pp. mimeo. (COO-1332-23).

Mech, L. D., J. R. Tester and D. W. Warner. 1966. Fall daytime resting habits of raccoons as determined by telemetry. J. Mammal. 47(3): 450-466. (COO-1332-13).

Mech, L. D. and F. Turkowski. 1966. Twenty-three raccoons in one winter den. J. Mammal. 47(3):529-530. (COO-1332-14).

Montgomery, G.G. 1974. Communication in red fox dyads: a computer simulation study. Smithsonian contributions to zoology, No. 187, Smithsonian Institution Press, Washington. (COO-1332-93).

Montgomery, G.G., J.W. Lang and M.E. Sunquist. 1970. A raccoon moves her young. J. Mammal. 51(1):202-203. (COO-1332-51).

Nicholls, T.H. and D.W. Warner. 1972. Barred owl habitat use as determined by radio telemetry. J. Wildl. Manage. 36(2):213-224.

Phillips, R.L., R.D. Andrews, G.L. Storm, and R.A. Bishop. 1972. Dispersal and mortality of red foxes. J. Wildl. Manage. 36(2):237-248. (COO-1332-56).

Preston, E.M. 1973. Computer simulated dynamics of a rabies-controlled fox population. J. Wildl. Manage. 37(4):501-512. (COO-1332-91).

Redig, P.T., M.R. Fuller, and D. Evans. 1974. Techniques for determining some biomedical parameters of migrating raptors. Pp. 151-154. In The Proceedings of the North American Hawk Migration Conference. Michael Harwood, ed. Hawk Migration Association of N. America, Washington, Connecticut. 165pp. (COO-1332-104).

Rongstad, O. 1969. A bull snake encounter with young ground squirrels. Minn. Acad. Sci. 35(2-3):95-96. (COO-1332-40).

Rongstad, O.J. and J.R. Tester. 1969. Movements and habitat use of white-tailed deer in Minnesota. J. Wildl. Manage. 33(2):366-379. (COO-1332-43).

Rongstad, O.J. and J.R. Tester. 1971. Behavior and maternal relations of young snowshoe hares. J. Wildl. Manage. 35(2):338-346. (COO-1332-58).

Sanderson, G.C., L.D. Mech and J.H. Schnell. 1971. A contribution to a bibliography of the raccoon (Procyon lotor). U.S. Atomic Energy Commission, Division of Tech. Info., 82 pp. (COO-1332-26).

Schladweiler, J.L. and I.J. Ball. 1968. Telemetry bibliography emphasizing studies of wild animals under natural conditions. Bell Mus. Nat. Hist., Tech. Rept. 15, 31 pp. mimeo. (COO-1332-42).

Schneider, D.G., L.D. Mech and J.R. Tester. 1971. Movements of female raccoons and their young as determined by radio tracking. Animal Behavior Monographs 4(1):1-43. (COO-1332-47).

Schneider, D.G., L.D. Mech and J.R. Tester. 1966. An eight-month radio-tracking study of raccoon families. Bull. Ecol. Soc. Amer. 47(3):149-150. (COO-1332-20).

Schnell, J.H. 1970. Rest site selection by radio-tagged raccoons. J. Minn. Academy of Science 36(2-3):83-88. (COO-1332-61).

Siniff, D.B., L.L. Eberhardt, D.D. DeMaster and R.J. Hofman. 1976. An analysis of the dynamics of a Weddell seal population. Ecological Monographs (submitted). (COO-1332-125).

Siniff, D.B. 1966. Computer programs for analyzing radio-tracking data. Minn. Mus. Nat. Hist., Tech. Rept. 12., 10 pp. mimeo. (COO-1332-18).

Siniff, D.B. and J.R. Tester. 1965. Computer analysis of animal-movement data obtained by telemetry. BioSci. 15(2):104-108. (COO-1332-3).

Siniff, D.B. and C.R. Jessen. 1969. A simulation model of animal movement patterns. Advances Ecological Res. 6:185-219. (COO-1332-36).

Storm, G.L., R.D. Andrews, R.L. Phillips, R.A. Bishop, D.B. Siniff and J.R. Tester. 1976. Morphology, reproduction, dispersal, and mortality of midwestern red fox populations. Wildlife Monographs No. 49, 82 pp. (COO-1332-79).

Storm, G.L. and G.G. Montgomery. 1975. Dispersal and social contact among red foxes: results from telemetry and computer simulation. In Fox, M.W. (editor), The Wild Canids, Van Nostrand Reinhold Co., New York. (COO-1332-83).

Sunquist, M.E. 1967. Effects of fire on raccoon behavior. J. Mammal. 49(4):673-674. (COO-1332-31).

Sunquist, M.E. 1975. Winter activity of striped skunks (Mephitis mephitis) in east-central Minnesota. Amer. Midl. Naturalist 92(2):434-446. (COO-1332-60).

Sunquist, M.E., G.G. Montgomery and G.L. Storm. 1969. Movements of a blind raccoon. J. Mammal. 50(1):145-147. (COO-1332-44).

Swanson, G.A., V.B. Kuechle and A.B. Sargeant. 1976. A telemetry technique for monitoring diel waterfowl activity. J. Wildl. Manage. 40(1):187-190. (COO-1332-120).

Tester, J.R. 1965. Status and value of biotelemetry in studies of vertebrate ecology. Congress des Biol. du Gibier. 7:195-199. (COO-1332-12).

Tester, J.R. 1966. Automatic radio-tracking system for studying animal movement and behavior. (motion picture) Bull. Ecol. Soc. Amer. 47(3):156. (COO-1332-19).

Tester, J.R. 1966. Potentials of radio-tracking in studies of vertebrate behavior. (Abstract) Proc. Engineering in Medicine and Biol. 19:155. (COO-1332-24).

Tester, J.R. 1971. Interpretation of ecological and behavioral data on wild animals obtained by telemetry with special reference to errors and uncertainties. In Symposium on Biotelemetry, Pretoria, South Africa, November 1971. pp. 385-408. (COO-1332-71).

Tester, J.R., F. McKinney and D.B. Siniff. 1968. Mortality of three species of ducks, Anas discors, A. crecca and A. clypeata, exposed to ionizing radiation. Rad. Res. 33:364-370. (COO-1332-30).

Tester, J.R. and J.C. Moulton. 1965. Movements and activity of pen-raised white-tailed deer (Odocoileus virginianus) after release in unfamiliar habitat. (Abstract) Bull. Ecol. Soc. Amer. 46(3):121. (COO-1332-8).

Tester, J.R. and D.B. Siniff. 1965. Aspects of animal movement and home range data obtained by telemetry. Trans. N. Amer. Wildl. Conf. 30:379-392. (COO-1332-4).

Tester, J.R. and D.B. Siniff. 1974. Relevance of home range concepts to game biology. International Congress of Game Biologists. 11:287-296. (COO-1332-97).

Tester, J.R., D.B. Siniff and C.R. Jessen. 1969. Use of telemetry as a means of studying spacing and behavior of animals. In Esser, A.H. (editor), Behavior and Environment, The Use of Space by Animals and Men. Plenum Press, New York, 411 pp. (COO-1332-48).

Tester, J.R., D.B. Siniff and O.J. Rongstad. 1967. Effects of radiation on behavior of unconfined raccoons and snowshoe hares determined by telemetry. Amer. Zoologist 7(4):404. (COO-1332-39).

Thorkelson, J. and R.K. Maxwell. 1973. Design and testing of a heat transfer model of a raccoon (*Procyon lotor*) in a closed tree den. Ecology 55(1):29-39. (COO-1332-81).

Turkowski, F. and L.D. Mech. 1968. An intensive analysis of the movements of a young male raccoon. J. Minn. Acad. Sci. 35(1):33-38. (COO-1332-22).

THESES

Abraham, R.L. 1971. An analysis of mallard vocalizations. Univ. Minn., M.S. Thesis. (COO-1332-64).

Archibald, H.L. 1973. Spring drumming activity and space use of ruffed grouse. Univ. Minn., Ph.D. Thesis. (COO-1332-70).

Ball, I.J. 1971. Movements, habitat use and behavior of wood duck (Aix sponsa) broods in north-central Minnesota as determined by radio tracking. Univ. Minn., M.S. Thesis. (COO-1332-65).

Ball, I.J. 1973. Ecology of waterfowl broods in a forested region of north-central Minnesota. Univ. Minn., Ph.D. Thesis. (COO-1332-86).

Barrett, Julie. 1973. Breeding behavior of captive mallards. Univ. Minn., M.S. Thesis. (COO-1332-92).

Gilmer, D.S. 1971. Home range and habitat use of breeding mallards (Anas platyrhynchos) and wood ducks (Aix sponsa) in north-central Minnesota as determined by radio tracking. Univ. Minn., Ph.D. Thesis. (COO-1332-73).

Heezen, K.L. 1965. Evaluation of animal-location data obtained by triangulation with observations on winter and spring movements of white-tailed deer in Minnesota. Univ. Minn., M.S. Thesis. (COO-1332-46).

Hessler, E.W. 1968. Survival of ring-necked pheasants released in selected habitats in Minnesota. Univ. Minn., M.S. Thesis. (COO-1332-41).

Houseknecht, C.R. 1971. Movements, activity patterns and denning habits of striped skunks (Mephitis mephitis) and the exposure potential for disease. Univ. Minn., Ph.D. Thesis. (COO-1332-59).

March, J.R. 1967. Dominance relations and territorial behavior in captive shovelers (Anas clypeata). Univ. Minn., M.S. Thesis. (COO-1332-38).

Maxson, S.J. 1974. Activity, home range, and habitat usage of female ruffed grouse during the egg-laying, incubation, and early brood periods as determined by radiotelemetry. Univ. Minn., M.S. Thesis. (COO-1332-108).

Montgomery, G.G. 1973. Communication in red fox dyads: a computer simulation study. Univ. Minn., Ph.D. Thesis. (COO-1332-93).

Moulton, J.C. 1966. Movement and activity of three white-tailed deer during the winter of 1964-1965 in east-central Minnesota determined by telemetry. Univ. Minn., M.S. Thesis. (COO-1332-27).

Nicholls, T.H. 1973. Ecology of barred owls as determined by an automatic radio-tracking system. Univ. Minn., Ph.D. Thesis. (COO-1332-90).

Riechmann, J.H. 1976. Factors affecting home range of mallard pairs. Univ. Minn., M.S. Thesis. (COO-1332-122).

Stolen, P.D. 1974. Fall and winter movements and activity of muskrats in east-central Minnesota. Univ. Minn., M.S. Thesis. (COO-1332-99).

Winter, J.D. 1976. Movements and behavior of largemouth bass (Micropterus salmoides) and steelhead (Salmo gairdneri) determined by radio telemetry. Univ. Minn., Ph.S. Thesis. (COO-1332-121).

PAPERS PRESENTED DURING REPORT PERIOD

August 1975. XIV International Etholgical Conference, Parma, Italy.
J.R. Tester. "Seasonal changes in circadian rhythms of free-ranging animals".

June 1976. American Society of Mammalogists, Lubbock, Texas.
J. Gull. "Behavior of immature gray squirrels (Sciurus carolinensis) as determined by biotelemetry".

LIST OF THESES AND PUBLICATIONS SUBMITTED WITH THIS PROPOSAL

Archibald, H.L. 1975. Temporal patterns of spring space use by Ruffed Grouse. J. Wildl. Manage. 39(3):472-481. (COO-1332-106).

Ball, I.J., D.S. Gilmer, L.M. Cowardin and J.H. Riechmann. 1975. Survival of wood duck and mallard broods in north-central Minnesota. J. Wildl. Manage. 39(4):776-780. (COO-1332-105).

Fuller, M.R. 1975. A technique for holding and handling raptors. J. Wildl. Manage. 39(4):824-825. (COO-1332-112).

Gilmer, D.S., I.J. Ball, L.M. Cowardin, J.R. Riechmann and J.R. Tester. 1975. Habitat use and home range of mallards breeding in Minnesota. J. Wildl. Manage. 39(4):781-789. (COO-1332-73).

Hoskinson, R. and D.B. Siniff. 1976. Computer analysis of radio-telemetry data to determine habitat selection. (manuscript to be submitted). (COO-1332-127).

Hoskinson, R., J.R. Tester, R. Autenrieth and O.D. Markham. 1975. Antelope migrations in and near the INEL site. In Markham, O.E. (editor), Summaries of the Idaho National Engineering Laboratory Site Ecological Information Meeting, July 10, 11, 1975. Idaho Natl. Eng. Lab., IDO-12079, pp. 3-4.

Huempfner, R.A., S.J. Maxson, G.J. Erickson and R.J. Schuster. 1975. Recapturing radio-tagged ruffed grouse by nightlighting and snow burrow netting. J. Wildl. Manage. 39(4):821-823. (COO-1332-102).

Montgomery, G.G. 1974. Communication in red fox dyads: a computer simulation study. Smithsonian contributions to zoology, No. 187, Smithsonian Institution Press, Washington. (COO-1332-93).

Riechmann, J.H. 1976. Factors affecting home range of mallard pairs. Univ. of Minn., M.S. Thesis. (COO-1332-122).

Siniff, D.B., L.L. Eberhardt, D.D. DeMaster and R.J. Hofman. 1976. An analysis of the dynamics of a Weddell seal population. Ecological Monographs (submitted). (COO-1332-125).

Storm, G.L., R.D. Andrews, R.L. Phillips, R.A. Bishop, D.B. Siniff and J.R. Tester. 1976. Morphology, reproduction, dispersal, and mortality of midwestern red fox populations. Wildlife Monographs No. 49, 82 pp. (COO-1332-79).

Swanson, G.A., V.B. Kuechle and A.B. Sargeant. 1976. A telemetry technique for monitoring diel waterfowl activity. J. Wildl. Manage. 40(1):187-190. (COO-1332-120).

Winter, J.D. 1976. Movements and behavior of largemouth bass (*Micropterus salmoides*) and steelhead (*Salmo gairdneri*) determined by radio telemetry. Univ. of Minn., Ph.D. Thesis. (COO-1332-121).

EFFORT REPORT

	Percent Effort Devoted to Project
Dr. J.R. Tester, Principal Investigator	
October 15, 1975 through July 15, 1976	25%
July 16, 1976 through October 14, 1976	25%
Dr. D.B. Siniff, Principal Investigator	
October 15, 1975 through July 15, 1976	17%
July 16, 1976 through October 14, 1976	17%
Mr. V.B. Kuechle	
October 15, 1975 through July 15, 1976	25%
July 16, 1976 through October 14, 1976	25%
Dr. S.C. Pierson	
October 15, 1975 through December 31, 1975	100%