MASTER

VERTEBRATE BEHAVIOR AND ECOLOGY

Progress Report

for Period July 1, 1977 - June 30, 1978

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VERTEBRATE BEHAVIOR AND ECOLOGY

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- (1) Engineering Design and Development
- (2) Application of Radiotelemetry to Selected Problems
in Vertebrate Censusing and Population Study

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SUMMARY

During the past several years our efforts have been concentrated on two subprojects, Engineering design and development and Application of radio telemetry to selected problems in vertebrate censusing and population study. The first of these subprojects has been active for many years and numerous significant advances in the technology of radio telemetry and in methods of analyzing telemetry data have been made. Engineering effort during the past 3 years has centered on designing and installing equipment for applied biological studies. Examples of significant design accomplishments are the programmable memory receivers, temperature and pressure measuring tags, and the application of microprocessors to field investigations. A very important contribution has been the on-site availability of assistance in engineering design. This availability allows the design of experiments incorporating both biological and engineering considerations rather than trying to design a field study around available equipment. It also allows immediate response when problems arise. The equipment and techniques developed by our engineering staff and the computer programs for analyzing data obtained by telemetry have received wide spread application. They have been used extensively by our own research group, other DOE researchers and non-DOE researchers. Details of our accomplishments during the past year are given in this report.

Our long-term goal in the subproject on the evaluation of census methods is to utilize the extensive experience, technology and equipment developed over the years in radio telemetry to resolve basic problems in animal census and population study methods. Our more immediate goals are to use radio telemetry to develop satisfactory methods for censusing and measuring important parameters of the sea otter and to apply these methods to otter populations in Alaska and along the California coast. We have developed and successfully attached a small transmitter, similar to a marking tag, through the webbing of the rear flipper of many sea otters. This tag has given us excellent results in California and Alaska and we are planning to continue its use during the summer and fall of 1978. Experiments have also been conducted on various types of immobilizing drugs suitable for sea otters and on the effects of contamination by crude oil on otter behavior and survival. Atorphine used in conjunction with Diazepam met most of the requirements for use under field conditions. Halothane, administered through an anesthetic machine, proved to be effective for use under clinical conditions. With respect to contamination by crude oil, partially soiled otters increased their overall level of activity, probably by grooming and eating to adjust for the loss of energy. Some soiling can apparently be tolerated and adjusted for by behavioral responses. Rehabilitation of soiled otters seems possible, but special facilities to keep the otters warm and dry after cleaning must be provided to restore the insulation qualities of their fur. Details of our field studies during the past year are given in this report.

Telemetry study of migratory behavior of pronghorn antelope was initiated at the Idaho National Engineering Laboratory Site in October 1975 and completed in summer 1977. Objectives were to document seasonal movements

of the antelope that summer in the areas north of the INEL site, to determine their use of the INEL site as winter range, to record specific areas of use near INEL facilities, and to obtain information on migration routes, habitat selection and summer ranges. A total of 77 antelope were marked with radios and followed during their migratory movements. Migration movements appeared to be related to changing temperatures and changes in the moisture content of vegetation on the range rather than to snowfall as indicated in the literature. A Ph.D. thesis has been completed (Hoskinson, R. L. 1977. Migration behavior of pronghorn antelope and summer movements and fall migration of pronghorn fawns in southeastern Idaho), one manuscript has been accepted for publication (Seal, U.S. and R. Hoskinson. In press. Metabolic indicators of habitat differences in three pronghorned antelope populations. J. Wild. Manage.) and one manuscript has been submitted for consideration (Hoskinson, R. L. and J. R. Tester. Migration behavior of pronghorn antelope in southeastern Idaho, J. Wildl. Manage.). Copies of the thesis and latter paper are included with this Progress Report. A pre-print of the first paper was submitted with the 1977 Progress Report.

Studies on the effect of gas super-saturated water on the behavior of migratory salmon (Onchorchynchus tshawytscha), which were carried out in cooperation with the Ecosystems Department of Battelle Northwest Laboratories, are now completed. Pressure sensitive depth transmitters were used to evaluate travel routes and depths of salmon in the Snake River during spring and fall migration in 1976 and spring migration of 1977. A Ph.D. theses has been completed and 2 manuscripts have been published based on findings from this project: Haynes, J. M. 1978. Movement and habitat studies of Chinook salmon and white sturgeon. Ph.D. Thesis, Univ. of Minn.; Haynes, et al. 1978. Seasonal movements of white sturgeon in the mid-Columbia River. Trans. Am. Fish. Soc. 107:275-280; Gray, R.H. and J. M. Haynes. 1977. Depth distribution of adult chinook salmon in relation to season and gas-supersaturated water. Trans. Am. Fish. Soc. 106:617-620. There is some indication from our data that chinook salmon avoid harmful gas super-saturation conditions near the water surface by swimming at different depths depending on water conditions. The data also indicate that the depth of travel of salmon was significantly different in the spill of the Little Goose Dam than in other areas of the Snake River. Such differences appear to be related to delays in migration upon encountering the Dam. Copies of the thesis and 2 papers are submitted with this Progress Report.

Field work terminated on a study of interspecific relations among tree squirrels at Cedar Creek in spring 1975. A total of 16 fox squirrels and 30 grey squirrels were monitored for a total of 151 data months. Analyses of these data are still in progress and two thesis and 1 manuscript based on our results have been completed: Bland, M.E. 1977. Daily and seasonal activity patterns in the eastern grey squirrel, Ph.D. thesis, Univ. Minn.; Gull, J. 1977. Movement and dispersal patterns of immature grey squirrels in east-central Minnesota. M.S. Thesis, Univ. of Minn.; Tester, J.R. In press. Analysis of circadian rhythms of free-ranging mammals. Biotelemetry IV, Proc. 4th Intl. Symp. Biotelemetry May 1978. Copies of the theses were submitted with the 1977 Progress Report and a pre-print of the paper is included with this Progress Report.

Over the past ten years a number of research projects have been carried out at Cedar Creek and at other localities utilizing radio telemetry technology developed partly through support from ERDA-DOE. Publications resulting from these research projects are still appearing and, of course, give credit to DOE support. Field work for these projects terminated well before the three year period covered by this Progress Report. However, because of delays in preparation of manuscripts and publication of accepted manuscripts, papers from these projects appear long after the field work has been completed. Results from these research projects will not be summarized here because the documents submitted with this Progress Report convey the current status. Of the reprints, pre-prints and theses submitted, five deal with ruffed grouse research at Cedar Creek, two with research on waterfowl populations in forested habitat in northern Minnesota and two with the development and application of radio telemetry techniques for monitoring movements and behavior of fresh-water fish.

SUBPROJECT ONE

ENGINEERING DESIGN AND DEVELOPMENT

Receiver Design

Effort has continued in design improvements on portable receivers and receiving systems. During the past year three items have received design attention. The first was changing the programmable memory system with respect to the maximum number of channels scanned. In the past the number of channels scanned was controlled by the binary counter with the maximum channel scan determined by the Q output of the counter. This meant the counter was incremented by 1, 2, 4, 8, 16, 32 and 64 counts. This is adequate up to about 16 channels; however, after that the spacing became inconvenient, requiring duplication of scan or other measures. In the present version the channel scan switch has been changed to also function as a maximum channel selector, thus allowing selection of any number as a maximum channel scan.

A second area of design effort has been in the application of phase lock loops (PLL). The use of PLL's has several advantages; however, we are primarily interested in application to detect signals in noisy environments. PLL's have the ability to detect signals from a wide band input with a high degree of noise immunity. These characteristics allow the accurate detection of signals without critically tuning the receivers to accomodate frequency drift in the transmitters. We have been able to improve the detection ability to -130 dbm by adjusting the filter response. However, we can readily detect signals by ear to -143 dbm, and would like to be able to detect signals electronically to -136 or -140 dbm. We will continue efforts toward reaching this goal.

A third area of development concerns improvement of linear range in the receiver. At present, our efforts are centered on the final detection circuit. If we can achieve a wider linear range the receiver will be more sensitive in detecting activity and should also make the detection of signals in noisy areas easier. We are also continuing efforts in increasing the field reliability of equipment by developing lab testing techniques and redesigning problem-prone components so as to prevent recurrent failures.

Transmitter Design

Since we are reaching the theoretical limits in receiver sensitivity, any increased range must come from increased power output from the transmitters. In the last year, design effort has centered on the frequency drift, power output and crystal specifications needed to correct common problems experienced in the field.

In applications where high speed automatic scanning is required, frequency drift becomes a problem because the transmitter frequency may have drifted off the frequency programmed into the receiver. The transmitter

will then either be received with decreased sensitivity or not at all depending on the amount of drift. Extensive testing was done to evaluate parameters affecting this drift. The only parameter having a significant effect is the temperature drift of the crystal. Temperature drift curves were run on crystals from several manufacturers; all followed the same general characteristics (Fig. 1-1) showing frequency decreasing as temperature increased. There was a greater range of drift rates among manufacturing lots than among crystals of the same lot or among manufacturers. We also tested units specified for reduced temperature drift. These exhibited a much lower drift rate and could be used to reduce drift, although at a higher cost per transmitter.

Considerable effort was expended to increase power output of the transmitters without decreasing efficiency. Several design changes were made to achieve this goal. The circuit has been changed to increase power output of the oscillator stage and also to make the circuit less dependent on crystal parameters. In the second stage, input was redesigned to achieve a better match from the oscillator, while the output circuit was redesigned to achieve a better match to the antenna. The primary difficulty with transmitter circuits is forcing the output of the oscillator stage high enough to properly drive the second stage into a class C model operation. This is especially difficult with single battery transmitters where the output of the oscillator is not sufficient to reach the 0.7 volt drive level necessary. An additional factor is the use of tripling versus doubling of the primary crystal oscillator output. We have found that the output of the tripled circuit is insufficient to properly drive the output stage. Tripler circuits have come into popular use because they will oscillate at lower levels and are less variable among crystal units. The circuit shown in Figure 1-2, representing our most recent efforts, is designed to work with 6 volts (2 lithium cells).

Transducer Transmitters

Two circuits were designed to transmit data from transducers on an animal to a remote site. The first of these was a gastric motility sensor to determine when an animal is feeding. This circuit (Fig. 1-3) is basically similar to that used with the pressure transducer designed to monitor swimming depth of fish. The sensor is a high resistance semi-conductor strain gage assembly constructed by interconnecting and glueing the gages into a linear arrangement. This assembly is then coated with silicon rubber and stitched to the gut wall. Construction of the linearly arranged bridge, combined with the 5000 ohm resistance of the gage, results in a system of sufficient sensitivity with less than 0.5 ma of current drain. While the system is operational, we have experienced some problem with fracture of the gage elements. More tests need to be done with backing material and lead attachment technique to eliminate these fracture problems. Metal foil gages have been used in some types of applications. However, these have a gage factor of 2, whereas semi-conductor gages have a gage factor of 150, making metal foil gages 75 times less sensitive. Metal foil gages also have a much lower resistance, usually 300 ohms versus 5000 for the semi-conductor element. The low resistance makes it difficult

Fig. 1-1 Transmitter frequency drift with temperature

Fig. 1-2 High power output transmitter

to design a low drain circuit. Metal foil gages do have the advantage of being less expensive and more resistant to fracture. However, their low gage factor and resistance will probably preclude their use in our circuit.

This gastric motility circuit was designed in cooperation with the Department of Veterinary Medicine and was field tested in several owls at the Cedar Creek Natural History Area. Using semi-conductor gage elements, the transmitters have 60-90 day life.

A second transmitter circuit was designed to measure light and temperature at the collar on a collar-type transmitter (Figure 1-4). Light information is transmitted as pulsed duration while temperature is transmitted as pulse interval. A decoder was also designed to decode and separate the two parameters. The transmitters measure light levels from less than 1 foot-candles to approximately 1000 foot-candles. For light levels above 1000 foot-candles, no further decrease in pulse width occurs. No cross coupling of light and temperature measurement could be detected.

Radio Tracking From Aircraft

Fixed wing aircraft have played an important role in censusing and observing vertebrates for many years. The ability of aircraft to quickly survey large and inaccessible areas gives numerous advantages over other kinds of mobile tracking units. In addition the reception of radio signals by airborne platforms is enhanced because of the near line of sight conditions from transmitter to receiver. Because of the wide-spread use of aircraft in radio tracking and lack of standardization, we have undertaken a cooperative study with the Northern Prairie Wildlife Research Center at Jamestown, North Dakota.

In determining optimum search procedures, our goal is to design a standardized antenna system that can be rapidly attached to any aircraft and will give uniform results throughout different applications. To achieve this objective a number of controlled tests were done to determine how various antenna arrangements, types of aircraft and altitude influence the sensitivity and directivity of airborne receiving systems.

In order to attach the receiving antenna to the aircraft, a bracket was designed which clamped to the wing strut and enabled adjustment of the antenna in several axes. In high frequency work, dual 5-element yagis were used as the primary antennas, with one mounted on the wing strut on each side of the aircraft. Tests were also conducted with the loop antennas at 30 Mhz. Static standing wave ratio tests were made with the yagi antennas to determine optimum placement on 3 different types of aircraft. Antenna gain and directivity measurements were made by placing the transmitter in the aircraft, and using a ground receiving station. The radio signal was radiated from the antenna normally used as the receiving antenna. The transmitter signal was received on the ground using a calibrated attenuator to maintain the received signal at a constant level. Although this is the reverse of the normal mode of operation; the reciprocity theorem indicates that a receiver and transmitter antenna can be interchanged without affecting transmission properties. Measurements were made on the ground because it was easier to keep the system calibrated and AC power was available. The signal was received by a quarter wave ground plane antenna and the output level was displayed on an oscilloscope and voltage

meter. Frequency was monitored with a frequency meter and held constant with the receiver fine tune control. A calibration signal was switched in to set the reference level of the system at the start of the test and to check the calibration after each run.

All measurements were relative; that is, all measurements were made as ratios to a fixed level. Absolute measurement would have been desirable because it would have allowed determination of antenna gain while on the aircraft. Unfortunately, making absolute power level measurements in an aircraft while it is airborne is difficult and requires specialized equipment. Moreover, from a practical standpoint, relative measurements are sufficient because they allow full pattern determination and allow comparisons between antennas and antenna configurations. Tests were conducted near Jamestown, North Dakota and Cambridge, Minnesota. Figure 1-5 gives a sample of the results of these tests. A complete summary and recommendations for aircraft used will be published in the fall of 1978.

Microprocessor Applications

As requirements for biological studies have become more stringent and as demand increases for large sample sizes to detect more subtle changes, older techniques have become inadequate. One approach toward solving such problems is to utilize the capabilities of microprocessors in telemetry systems. We are interested in developing our experience and capabilities in such use of microprocessors. To accomplish this we have been cooperating with the Environmental Protection Agency in the design of a monitoring system at their field station at a coal-fired electric generating plant at Monticello, Minnesota, about 30 miles from Cedar Creek. Here we are designing a system to automatically monitor the location of up to 64 fish in several man-made stream channels. The goal of the EPA project is to record movements and behavior of the fish in response to various pollutants and other stresses in experimental and control channels.

This project is being financed primarily by EPA; however, the experience being gained by our electronics staff while working on various aspects of equipment design and construction will be invaluable in development of instrumentation for DOE projects.

The RCA COSMAC 1802 microprocessor was chosen because it has the lowest power requirement and the highest immunity to noise. It is also suitable for operation over a wide range of temperatures and environmental conditions. We have assembled a microprocessor system including input/output hardware devices, along with 4K ram memory. This system is being used for prototype development with a view towards future expansion of capabilities.

A software support system was also purchased from RCA to allow for program writing and debugging on the CDC Cyber system at the University of Minnesota. This support package also cross assembles programs for use on a microprocessor. In addition some debugging of the assembled program via the simulator portion of this package can be done, greatly easing the programming task.

Fig. 1-5 Aircraft antenna pattern

CESSNA 172 AIRCRAFT, 0° TILT

Figure 1-6 is a block diagram of the system designed for the EPA fish locating experiment. The microprocessor selects the fish to be located by selecting its frequency on the receiver. It then makes a signal level measurements on the 16 antennas, situated at different points on the stream channels, compares the values and makes the decision as to where the fish is located. The position of the fish along with time of day and other pertinent information is then printed out. Ultimately, cassette tape will be used as the recording media, enabling direct interface with other computer systems. At the present time the hardware is being assembled and tested at the Monticello Field Station.

Fig. 1-6 Monticello microprocessor system

SUBPROJECT TWO
APPLICATION OF RADIO TELEMETRY
TO SELECTED PROBLEMS
IN VERTEBRATE CENSUSING AND POPULATION STUDY

General objectives of this subproject are to take advantage of new techniques in radio telemetry to obtain information on census methods and population problems. The work is being done in close cooperation with research supported at DOE's Pacific Northwest Laboratory under the project titled "Analysis of Natural Systems", directed by Dr. L. L. Eberhardt. An important part of the PNL program has been devoted to developing the improved quantitative methods in ecology required for DOE's environmental missions. In the process of this long term effort, it has become abundantly evident that improvements in census methods are of key importance, and require ecological advances of the kind developed under the present research program.

Our long-term goal is to utilize the extensive experience, technology and equipment developed over the years in radio telemetry to resolve basic problems in animal census and population study methods, as required to support environmentally oriented DOE missions. Our more immediate goals are to use radio telemetry to develop satisfactory methods for censusing and measuring other important parameters of the sea otter and to apply these methods to otter populations in Alaska and along the California coast.

Sea otters are particularly sensitive to environmental disturbances because of their high metabolic rate and sensitivity to contaminations such as hydrocarbons. We are particularly concerned about oil contamination which is likely to occur as shipping increases from the terminus of the Alaska pipeline at Valdez, Prince William Sound, Alaska. We feel that it is important that a long term research program be initiated to:

(1) develop population monitoring techniques and procedures and to shed light on population regulatory factors, (2) begin data collection to evaluate possible influences of environmental changes and disturbances and (3) to conduct experiments which will yield information relative to the influence of various contaminants on sea otter populations.

The following report summarizes our work on this subproject for the period July 1, 1977 to June 30, 1978. During this time a limited study was carried out in the area of Monterey, California, while our major field efforts were in Prince William Sound, Alaska.

Attachment of Transmitters

Previous progress reports have presented details regarding our work on attachment of telemetry transmitters to sea otters. In general, we tried neck collars and transmitters attached to the ankle with varying degrees of success. Mortality resulted from both attachment procedures. Neck attachment seems most feasible; however, fitting is critical and requires immobilization of animals for proper fit. Because of the complications in working out appropriate drugging techniques this attachment procedure has not been tried since our initial efforts. However,

cooperative work with Dr. Thomas D. Williams, Monterey, California has resulted in knowledge regarding safe drugging procedures (Williams, T. D. and F. H. Kocher. A comparison of anesthetic agents in the sea otter. Submitted to J. Am. Vet. Med. Assoc.). Hence, it is anticipated that neck collars will be used again in the near future.

We have successfully attached a small transmitter, similar to a marking tag, through the webbing of the rear flipper (Fig. 2-1). While this transmitter is relatively short-lived due to its light weight, the attachment technique has given good results in California and Alaska. We have continued to modify the procedure slightly and plan to use this method in our upcoming studies during the summer of 1978.

California Studies

Our work in California was of a limited nature during the current project period. In March 1978 a cooperative study with the California Department of Fish and Game was initiated to evaluate the effects of transmitter attachment. The California site was picked because continual behavioral observation of instrumented animals is possible in this location and future work is contingent upon acceptance of our tagging procedures by California officials. The planned research called for instrumentation of 4 animals which would be recaptured after 1 month for examination of physiological effects of attaching the transmitter. Four animals were instrumented in March 1978; 3 were released at Monterey and 1 at Santa Cruz. In mid-April extensive efforts were made to recapture these animals; however, these efforts failed and we were unable to determine the effects of transmitter attachment.

In California we have been limited to capture by a diver-held net which works satisfactorily under favorable weather and water conditions. The technique takes advantage of the natural reaction of otters when disturbed to dive beneath the surface. A diver-held net, open on one end and attached to an 8 foot pole, is pushed up over the otter, which dives into the bottom of the net. The draw string is quickly closed and capture is complete. The technique works well on otters for the first capture. However, it was found that recapture is difficult. In several attempts at recapture otters were in the net; however, they escaped upward before the draw string could be closed.

Observations indicated that, in general, little behavioral effect occurred as a result of the transmitter. Although the otters initially seemed concerned and groomed on and around the transmitters, this behavior varied among individuals. We have generally concluded that the transmitter offers little interference with normal activity and life style.

Another objective of our California studies was to determine the length of time that the transmitter would remain on the animal. It is essential because of the federal and state permit requirements that transmitters drop off after their electronic capabilities have expired.

In these studies small steel bolts about 2mm in diameter were used to attach the transmitters through the webbing. It was anticipated that they would rust through within about 1 month. One transmitter dropped off after 1 month; however 3 remained. At the present time as far as can be determined from direct observation, (the batteries have long since expired) 2 of the remaining transmitters have dropped off and 1 remains. Thus it seems that the length of attachment as controlled through natural corrosion varies considerably among individuals. This variation is probably caused by differences in general behavior such as the amount of time spent in feeding, resting and grooming and also by differences in general carriage of the feet by each individual.

Alaska Studies

We entered the field in Prince William Sound, Alaska in mid-May 1977 and terminated our work on 15 July. A summary of the animals handled was given in last year's Progress Report and is repeated in Table 2-1. In general, we monitored activity on 23 animals carrying radio transmitters using an automatic recording station placed in a mountain meadow about 360 feet above sea level. We are currently using the computer to analyze the 540 animal-days of activity data on the 23 instrumented animals listed in Table 2-1. In addition, the response of otters to contamination by crude oil was observed on captive animals and some information was obtained by spraying a small amount of crude oil on the dorsal surface of the cervical area of one animal and releasing it at the point of capture. Details of these experiments on the effects of crude oil are presented as a special section of this Progress Report.

An automatic recording station powered by solar panels was placed in a mountain meadow overlooking Sheep Bay where our instrumented animals stayed most of the time. A programmed receiver was set up so that each otter was monitored for 10 seconds each time the receiver scanned through the instrumented animals. These data were further broken into 10 minute intervals and are being analyzed by summarizing the most frequent activity during the 10 minute period. Interpretation of these data is complicated because we were unable to document precisely the activity actually taking place at the time a characteristic signal was being recorded. This occurred because at the Sheep Bay location it was extremely difficult to be close enough to instrumented animals to observe behavior without disturbing them. Future work (see Renewal Proposal) calls for documentation of activity through observation.

Some interpretation of activity has been possible and analysis is currently underway. This interpretation was possible because we know that in the 10 second segment we should receive approximately 7 to 8 pulsed signals if the animal was inactive and resting on the surface. As the animal became active and was either grooming or diving the loss of signal due to attenuation was apparent. Thus, during 10 second intervals, we could receive a maximum of 7 or 8 pulses depending on pulse rate down to zero depending on the extent of activity. The zero category is complicated because it could indicate that the animal had left Sheep Bay and was not being received. However, we assumed that if the animal was present in the next 10 second segment, it was in the Bay and its signal was recordable.

Table 2-1. OTTERS CAPTURED AND TAGGED IN SHEEP BAY, ALASKA: MAY-JULY 1977

Date	Tag	Color	Sex	Weight (lbs.)	Transmitter	Remarks
					Frequency	
19 May	45	Blue	Male	-	296	
19 May	46	Blue	Male	-	709	
26 May	47	Blue	Male	-	310	Tagged #4107 in 1976 - tag removed in 1977
26 May	48	Blue	Male	-	None	
26 May	49	Blue	Male	-	511	
26 May	44	Blue	Male	-	209	
26 May	43	Blue	Male	-	603	
26 May	42	Blue	Male	-	194	
8 June	41	Blue	Male	37	809	
8 June	40	Blue	Male	45	451	
8 June	39	Blue	Male	37	793	
11 June	38	Blue	Male	67	746	
11 June	37	Blue	Male	75	726	
14 June	36	Blue	Male	53	351	
14 June	35	Blue	Female	36	476	
15 June	34	Blue	Male	43	286	
15 June	33	Blue	Male	-	908	
15 June	32	Blue	Male	65	467	

Date	Tag	Color	Sex	Weight(lbs)	Transmitter Frequency	Remarks
15 June	31	Blue	Male	55	523	
15 June	375	Yellow	Male	70	495	
1 July	-	-	Male	65	None	Oiled - Not cleaned. Died 5 July.
1 July	-	-	Male	31	None	Died 5 July.
2 July	376	Yellow	Male	(taken) (released) 74 63	750	Drugged - Released.
2 July	385	Yellow	Male	(taken) (released) 62 60	475	Oiled - Cleaned - Released.
4 July	383	Yellow	Male	43	694	Oiled - Released.
8 July	387	Yellow	Male	46	727	Drugged - Released.

Figures 2-2 and 2-3 show activity patterns for two radio-tagged otters in Sheep Bay as recorded on strip charts by our automatic monitoring station. While there is variation between these otters, a general 24-hour pattern with peaks of diving, representing feeding, in mid-morning and evening is apparent. Some feeding, however, occurs throughout the 24 hours. We observed this pattern in the field in a general way, but documentation would not have been possible without radio telemetry.

Shimek and Monk (1977. Daily activity of sea otter off the Monterey Peninsula California. J. Wildl. Manage. 41(2):277-283) reported feeding at 0700 and 1700 and suspected that feeding also occurred at 2400 on the basis of limited visual records. In contrast, Laughlin (1977. Activity patterns, habitat partitioning, and grooming behavior of the sea otter in California. Ph.D. Thesis, Univ. Calif. Los Angeles. 110 pp.) indicated that sea otters in California showed no predictable activity pattern. However, we feel that a pattern probably exists but that Laughlin did not have an adequate sample nor the necessary recording technology to evaluate sources of variation.

Documentation of the activity rhythm of otters is particularly important when comparing populations. It has been hypothesized that the amount of time spent in each activity will vary greatly depending upon the availability of resources. Because otters have very high metabolic rates extensive feeding is required. The amount of time spent feeding, therefore, is a reflection of the amount of resources available to the population. Time spent feeding in areas where the resource base is low is likely to be quite high compared to the time spent feeding within a new area. Thus, activity patterns will reflect the relationship between the otter population and the ecosystem. In addition, in the analysis of the information on the effects of oil contamination (see below) we noted an increase in activity with the one animal which we contaminated and released. This increase in activity was thought to be due to an increase in feeding activity to accommodate the heat loss from the soiled area of fur. We feel that further documentation of the relationship between activity pattern and general condition of the ecosystem and/or the animal, is essential to understanding the full impact of environmental contamination and/or resource availability.

Response of Sea Otters to Oil Contamination

A manuscript based on data collected in summer 1977 is being prepared for publication. The rough draft is presented here in its entirety to provide DOE with all available information.

Introduction

It is generally accepted that sea otters possess certain characteristics that make them susceptible to oil contamination on the open ocean. These characteristics include a high metabolic rate, essentially no blubber layer, and reliance on the thick fur for insulation. Thus, any contamination that soils the fur causes loss of insulation qualities and the body temperature starts to fall. In response, the animal increases its metabolic rate to counter the loss of heat.

Figure 2-2. Daily activity pattern of otter 495 summarized for period June 7 through July 14, 1977 showing percent of days when animal was sleeping, active on surface, or diving for each 30 minute interval during the 24 hours.

Figure 2-3. Daily activity pattern of otter 523 summarized for period June 7 through July 14, 1977 showing percent of days when animal was sleeping, active on surface, or diving for each 30 minute interval during the 24 hours.

G. L. Kooyman *et al.* (1976. Physiological impact of oil on pinnipeds. Unpubl. U.S. Dept. Comm., NW Fisheries Cen., Processed Rept., 23 p.) carried out studies with sea otter pelts showing the increase in thermal conductivity due to soilage by oil. They pointed out that studies are needed on the effects of grooming, which may reduce the loss of heat due to soilage. However, it has generally been concluded that clean, well-groomed fur is essential for sea otter survival. K. W. Kenyon (1969. The sea otter in the eastern Pacific Ocean. U.S.B.S.F.W., N. Am. Fauna Series 68:1-352, see p. 281) discusses this point and indicates that "pollution of waters by oil and other by-products of industrial development preclude the possibility that sea otter can today reoccupy all of its former habitats." Thus, it is believed that once any soilage takes place the animal will soon become sick, usually of pneumonia, and die.

Although this conclusion seems clear there are several areas which remain unknown in the relationship between sea otters and oiling. As Kooyman *et al.* pointed out, behavioral responses to oil are poorly documented. It may be that sea otters can sense contaminated areas on the surface and avoid contact. Also, there is the problem of how much soilage a sea otter can tolerate and still survive. It would seem that there must be some relationship between the surface area of fur soiled and metabolic response. Thus perhaps a small area of contamination could be dealt with by the animal increasing food intake and perhaps cleaning the area by grooming. Questions such as this spurred our efforts to carry out studies on the reaction of otters to oil on the ocean surface and to monitor possible adjustments in normal life patterns to mediate effects of oil contamination of the fur.

Methods

During the summer of 1977 in Prince William Sound, Alaska, we conducted two studies to provide information on the above questions. In one, a captured otter was instrumented with a radio transmitter and released following contamination of the anterior dorsal region with 25cc of Prudoe Bay crude oil. In the second study, behavioral reactions of otters to crude oil on the water surface were observed in an above-ground swimming pool.

The otters were captured in Sheep Bay using 9 inch stretch mesh gill nets anchored at one end with the lead line eliminated. This technique has been used before by the State of Alaska as the primary technique to capture otters for transplant to other areas. The elimination of the lead line allowed otters once entangled in the net to surface and to remain there entangled until they are extracted by research personnel.

After capture, a radio transmitter weighing 30 grams was attached across a digit (Fig. 2-1) so that the whip antenna pointed upward when the animal was lying on its back in normal resting posture. Thus, when the animal was active the antenna moved or vibrated, modulating the radio signal emitted from the transmitter. This change in intensity was used as an index to activity and was recorded on a strip chart at an automatic monitoring station situated 360 feet above sea level on a mountain

adjacent to the release site. The data collected enabled us to determine the activity patterns of instrumented animals. We were able to record data on both control and experimental animals and thus evaluate changes in activity due to oil contamination.

Studies on behavioral reactions of otters to oil on the water surface were carried out in an above-ground swimming pool set up on the shore adjacent to the National Marine Fisheries Facility in Olsen Bay, Prince William Sound, Alaska. Otters were captured in Sheep Bay, transported to a holding facility, and then placed in the swimming pool as the experiments began. Figure 2-4 is a schematic of the design used in the pool. As shown, it was divided in half by a partition extending about 12 inches into the water. Two equal sized haul-out areas were constructed at each end of the partition. Behavioral observations were made from the National Marine Fisheries warehouse adjacent to the pool.

Two male otters weighing 62 and 65 pounds were placed in the swimming pool the morning of July 5. These animals had been in the floating holding facility for several days and had learned to eat squid. They were allowed to adjust to the swimming pool and timed behavioral observations were taken to determine which side of the swimming pool the otters preferred. At 1800 hours Prudoe Bay crude oil was dumped into the side of the pool most preferred by the otters. This oil was rapidly spread over the entire side of the pool. The barrier worked well in restricting the oil to one side of the pool. However, the "clean" side did not remain oil free long once the otters became contaminated and swam from side to side.

Results

Figure 2-5 shows the activity pattern of the otter oiled and released in Sheep Bay along with the activity patterns of two control animals. The control animals show a pattern with peak activity in early morning and early evening with a limited amount of activity scattered throughout the day. Also, there is a noticeable difference between individuals with more pronounced synchrony early in the morning. The animal that was oiled and released was monitored for about 4 days until it moved out of range of the automatic receiving station. It is noticeable, however, that this otter exhibited an increase in overall activity immediately after oiling and release. We feel that this increase was due to the increased metabolic activity and increased food requirements.

A summary of the general behavior observed for 2 hours following the dumping of oil on one side of the swimming pool is given in Table 2-2. It was difficult to keep precise second by second records of this behavior because movement around the pool was rapid. Even though stop watches were running on each individual, time was taken up on reading the watches and recording data.

The dumping of the oil was immediately responded to by a nervous curiosity. It was obvious that the otters knew something unusual had happened on the opposite side of the pool. Intensity of feeding and grooming increased shortly thereafter. The animals circled beneath the

Fig. 2-1. Method of attaching radio transmitter to phalanx on rear flipper of a sea otter.

Fig. 2-4. Design of above-ground swimming pool used to hold captive sea otters during experiments on effects of oil contamination on behavior.

Fig. 2-5. Activity patterns of control and oil-contaminated sea otters released in Sheep Bay, Prince William Sound, Alaska, July 1977. Each horizontal line represents data for a 24-hour period.

Table 2-2. Behavior of captive sea otters in response to oil contamination.

TIME	BEHAVIOR
1000	Two male otters put in swimming pool, explored
1030	Otter 1 hauled out Otter 2 swimming about
1130	Since 1030 Otter 1 hauled out Otter 2; 30.2 min. north side, 25.2 min. south side, 4.6 min. hauled out During afternoon, Otter 1 in water very little Otter 2 settled south side
1811	Dumped oil south side, Otter 1 hauled out Otter 2 north side resting
1822	Otter 2 dove under partition Hit oil for first time Immediately returned to north side
1839	Otter 2 entered water on oil side Otter 1 had been in oil 12 times
1847	Otter 2 hauled out
1900	Fed squid - Otter 1 feeding
1920	Otter 1 eaten at least 10 squid Otter 2 hauled out
2000	Otter 1 in oil 21 times for total of around 110 seconds Otter 2 in oil about 10 times for total of around 47 seconds

water around the perimeter of the pool and would occasionally come up in the oil, but would remain only for a few seconds. They became more intense at working at the fence surrounding the pool and made what seemed more determined efforts to escape than had been previously noted. They would look out over the haul out area next to the bay frequently. On occasion they would rear up on the partitions separating the oil and non-oil side and stare at the oil. One of the animals remained hauled out much more than the other, but this was also noted prior to the oil dumping. The one animal that spent the most time in the water (Otter 1 in Table 2-2) soon began to extend himself from the surface of the water some distance and shake head and shoulders rather violently. The sequence shows that time spent on the oiled side was much less than spent on the non-oiled side.

The otters were left in the swimming pool until 0600 the following morning. Behavioral observations taken throughout the night indicated the same general pattern that is presented in Table 2-2. As the night progressed more resting occurred with Otter 2 spending much of the time on the haul-out area and Otter 1 staying in the water. Feeding was fairly frequent although as time passed resting became more prevalent.

After the otters were taken from the pool, an attempt was made to remove the oil from Otter 1. Otter 2 was placed back into the floating holding facility without being cleaned.

To clean Otter 1 we used poly-complex 2, a detergent obtained from the California Department of Fish and Game, which had been used to clean waterfowl contaminated with oil. The oiled fur was wet with the detergent, rinsed in sea water and then rubbed thoroughly with towels. The animal was allowed to dry and groom itself until 1400 hours and then it was placed back in the floating holding facility.

The fur immediately became saturated with water and the otter was again removed from the floating pen, dried, and placed in a pen on a dry surface. This soaking of the fur seems to have been the result of removal of the natural as well as crude oil from the otter pelt. We suspect natural skin oils play an important role in the water-proof characteristic of otter pelts. Chemical test on cleaned and natural pelts are being currently conducted.

It has been reported that grooming behavior causes the fur to hold air and provide insulation (Kenyon 1969, cited above, p. 74). However, Otter 1 groomed vigorously after cleaning but this had no apparent effect on restoring the waterproof character of the pelt. This otter was again dried and left over night and released the next day at the point of capture with the transmitter attached. This transmitter failed after 24 hours and thus we do not know the final fate of the animal. However, after 24 hours it was alive and we feel that perhaps it did survive the traumatic ordeal.

Otter 2 who was not cleaned but placed back in the holding pen died at 1600 hour on July 6, 10 hours after he was removed from the swimming pool. Gross autopsy and histopathology suggested that he probably died from hypothermia.

Discussion

The increase in activity from an otter partly contaminated with oil corresponds to what one would predict based on a loss of energy and the need for the animal to maintain its body temperature and weight. It seems likely that animals partially soiled and in a good environment with abundant food could sustain this type of contamination easier than otters in a population near carrying capacity. Because of the size of Sheep Bay it was impossible for us to keep visual contact with the marked animals. The waters were rough and the animals were wary. Many times we tried to drift about with spotting scopes to pinpoint specific behavior. However, all of these attempts failed. We feel rather certain that the animal oiled and released in Sheep Bay did survive and after three days was able to groom in such a way so that the oil contamination was removed and its natural oils were restored. However, more work needs to be done to determine precise behavioral reactions to such insults.

Our swimming pool experiments showed that otters do recognize oil contamination and prefer not to enter such areas. However, there are many uncertainties in this work. Oil contamination was severe and they obviously recognized this as an undesirable area in which to spend time. The amount of oil required for this type of behavioral avoidance to occur is of course not known at this time and perhaps a small amount would remain totally unrecognizable to the animals.

The time spent on the oiled side by both otters was small, but was clearly enough for both to become badly soiled. In general, they always entered the oil slick head first. Then they would immediately surface dive so that most of the oil would be spread along their back, head and shoulders. The minutes spent in the oiled area decreased rapidly with time. Thus, rather quickly the otters became aware that of the oil and learned to avoid it. However, the pool complicated evaluation of their behavior. They continually pressed the netting and gave the appearance of attempting to escape.

What would happen if free ranging otters encountered oil is not clear. We feel they would probably enter the oil at least once and, depending on its distribution, probably more often. However, after that it seems they may tend to leave the area and seek an uncontaminated environment. Many variables make evaluation of this uncertain. These include the ability to perceive the location of oil and then to find areas where the oil will not reach them.

Oil contamination in nature will probably create abnormal movement patterns. However, depending on the environmental circumstances, this movement could complicate the situation more than help it.

Summary

Partially soiled otters increased their overall level of activity, probably by grooming and eating to adjust for the loss of energy. Some soiling can apparently be tolerated and adjusted for by behavioral responses.

How much adjustment is possible depends upon the basic physiological limitations and the ecological situation. In an area with low density and with rather large food resources adjustment may be easier than in an area of high density with low food resources. This hypothesis could be studied using contrast in activity pattern between high and low density areas. There was a behavioral adjustment to oil on the surface of the water but more work needs to be done on the ability of otters to detect small areas of oil rather than a massive surface contamination which our experiment tested. Rehabilitation of soiled otters seems very possible, but special facilities would help insure success of such a program. Otters must be kept warm and dry after cleaning to restore the insulation qualities of their fur.

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EFFORT REPORT

Percent Effort
Devoted to Project

Dr. J.R. Tester, Principal Investigator	
October 16, 1977 through July 15, 1978	31%
July 16, 1978 through October 15, 1978	75%
Dr. D.B. Siniff, Principal Investigator	
October 16, 1977 through July 15, 1978	11%
July 16, 1978 through October 15, 1978	36%
Mr. V.B. Kuechle	
October 16, 1977 through July 15, 1978	17%
July 16, 1978 through October 15, 1978	20%