SURVIVAL, HOME RANGE, MOVEMENTS, HABITAT USE, AND FEEDING HABITS OF REINTRODUCED RIVER OTTERS IN OHIO

A Thesis

Presented in Partial Fulfillment of the Requirements for the degree Master of Science in the Graduate School of the Ohio State University

by

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* * * * *

The Ohio State University

1989

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To My Parents

ACKNOWLEDGMENTS

I wish to thank my adviser, Dr. Theodore A. Bookhout, for his advice and encouragement throughout the study, as well as committee members Dr. Roy A. Stein and Dr. John D. Harder for their helpful input. I also thank Diane Rano for successfully guiding me through the university bureaucracy. Denis Case, Ohio Division of Wildlife, was instrumental in securing the funding for the project, obtaining the otters, and keeping the project intact. His support and advice are greatly appreciated.

I am grateful to Drs. Robert and Catherine Temple for performing the implant surgery and providing other veterinary services and advice, and for the many home-cooked meals and hot cups of coffee they graciously offered. I will always remember the wonderful Christmas dinner they shared with me in their log cabin during my first Christmas away from home. I am indebted to Jerry Vydra for allowing me to stay at his home during the field portion of the study. I thank Gary Hoskins, area manager, and Phil (Bud) Morgan and Larry Scholten, Grand River Wildlife Area, for their assistance, advice, and friendship. The crew at Mosquito Creek Wildlife Area also deserves thanks for their help, as do the Division of Wildlife District 3 personnel. Education Officer Sara Jean Peters deserves special thanks for handling the media and the school kids, and for providing the meals during the "otter project picnics." Jane Jennings provided the school kids and was easily the most enthusiastic supporter of this project. Her enthusiasm, friendship, and chocolate chip cookies were greatly appreciated.

I especially wish to thank my fellow graduate students (particularly the "wings crew") whose friendship, help, and occasional ribbing made home seem not so far away. Finally, I wish to thank Dr. Robert G. "Swampy" Schwab and my parents. Their encouragement and support were instrumental in my decision to continue on to graduate school and the success of this project.

This project was funded through the Ohio Division of Wildlife's Nongame and Endangered Species fund. The Ohio State University and the Ohio Cooperative Fish and Wildlife Research Unit provided support and facilities for the duration of the study.

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FIELD OF STUDY

Major Field: Zoology

Studies in Wildlife Biology

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INTRODUCTION

The northern river otter (Lutra canadensis), until the 19th century, was one of the most widespread mammals in North America, having a range extending throughout all major waterways in North America and Canada except the arid southwest and the frozen arctic (Toweill and Tabor 1982). Unregulated trapping, habitat destruction, and deteriorated water quality led to the decline of otters in much of their original range, including Ohio.

The recent establishment of nongame wildlife programs and the listing of the otter in Appendix II by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) as not presently threatened, but may become threatened unsless trade is subject to strict regulation (U. S. Fish and Wildlife Service 1977), have led to greater interest and study into the life history and potential for reintroduction of river otters. Many states have begun reintroducing, or already have successfully relocated or reintroduced, otters into areas they once occupied; these include Minnesota (Berg 1982), Arizona (Britt et al. 1982), Iowa, Illinois (Anderson and Woolf 1984), North Carolina (Bill

Cook, Smokey Mountain National Park, pers. comm.), Oklahoma, Pennsylvania (Serfass et al. 1986), Colorado (Mack 1985), Tennessee (Griess 1987), and West Virginia.

In Ohio, otters were considered common in the 1870's, but by the 1930's only an occasional otter could be found, and by the 1950's, according to a statewide survey of game protectors, only four recent sightings of river otters in Ohio had been made (Chapman 1955). The only recent record of a river otter in Ohio occurred in 1985, but that animal was an otter that had been reintroduced to West Virginia more than 100 km by air from where it was eventually trapped by an Ohio raccoon trapper (Denis Case, Ohio Division of Wildlife, pers. comm.). The Ohio Division of Wildlife, through the Ohio Cooperative Fish and Wildlife Research Unit, initiated a study in 1986 to determine the feasibility of reintroducing otters back into Ohio. From that study, the Ohio Division of Wildlife decided to reintroduce otters into Ohio later that same year. Otters were obtained and transported by the Division of Wildlife, were implanted with intraperitoneal radio transmitters by private veterinarians, and I monitored them via radio telemetry up to 18 months after they were released.

Introduction of animals into a new, unfamiliar area creates a situation similar to dispersal or emigration (Pullinean 1986), providing new insights into preferred habitat, how that habitat relates to daily and seasonal spacing and movement of individual animals, and how that spacing changes with time. Radio telemetry allowed for the monitoring of survival, movements, activity, mortality, associations among conspecifics, and home range size; The objectives of this study were to

1. monitor the survival, dispersal, and the reproductive success of reintroduced otters.

2. estimate the home range size of individual otters of known sex and age, and to document how home range size fluctuates seasonally.

3. measure the extent of home range overlap and interactions among conspecifics during each season.

4. record the daily and seasonal activities and movements of individual otters.

5. identify the number and types of den sites most frequently used by individual otters.

6. ascertain the seasonal feeding habits of reintroduced otters from scat analysis.

In so doing, I could determine the feasibility of establishing a viable population of river otters in Ohio, and gain insight into the variables necessary to successfully reestablish river otters in Ohio. Additionally, these types of data could lead to further understanding of the basic biology of river otters in small, dynamic populations, and may contribute to the further understanding of mustelids in general.

METHODS

Study Area

The highest quality habitat in Ohio for river otter reintroduction was determined from a survey of all major watersheds in the state during summer 1986. Based on descriptions in the literature (see Tumlinson and Shalaway 1985) and personal communications with wildlife agency personnel in Ohio and other states, a list of criteria defining exceptional otter habitat was developed. These criteria include

1. Waterways should be fairly long (>80 km of river), have a low stream gradient, and consist of an alternating riffle-pool structure.

2. Waterways should be wet year-round.

3. Waterways should be unpolluted and have high water quality.

4. Waterways should have a high stream meander index with abundant stream structure including fallen trees, log jams, exposed root cavities, beaver dams, and/or debris piles. Channelized waterways are unacceptable.

5. Waterways should have associated wetlands such as oxbow ponds, borrow ditches, marshes, beaver impoundments, associated backwaters, and tributaries.

6. Waterways should have abundant potential prey including fish, crayfish, and frogs.

7. Waterways should have abundant woody riparian cover along the banks. Cover should be at least 2 tree canopies wide.

A list of river systems best meeting the habitat criteria was compiled. Each potential site was ranked against the others for each of the listed criteria, and, from that, the Grand River ranked highest as potential river otter habitat.

The Grand River in northeastern Ohio was selected as the best possible reintroduction site in Ohio, and the 1,500-ha Grand River Wildlife Area in Trumbull County was selected as the release site. The Grand River is 158.5 km in length, beginning in Portage County and flowing through Trumbull, Ashtabula, and Lake counties before draining into Lake Erie (Fig. 1). With 53 tributaries that total 1,394 km, it drains an area of 1,844 km^2 and has an average fall of 1.71 m/km (Ohio Division of Water 1960). The upper part of the river from the headwaters north to where the river begins to flow west in Ashtabula County is generally characterized as being low gradient, slow flowing and meandering, and

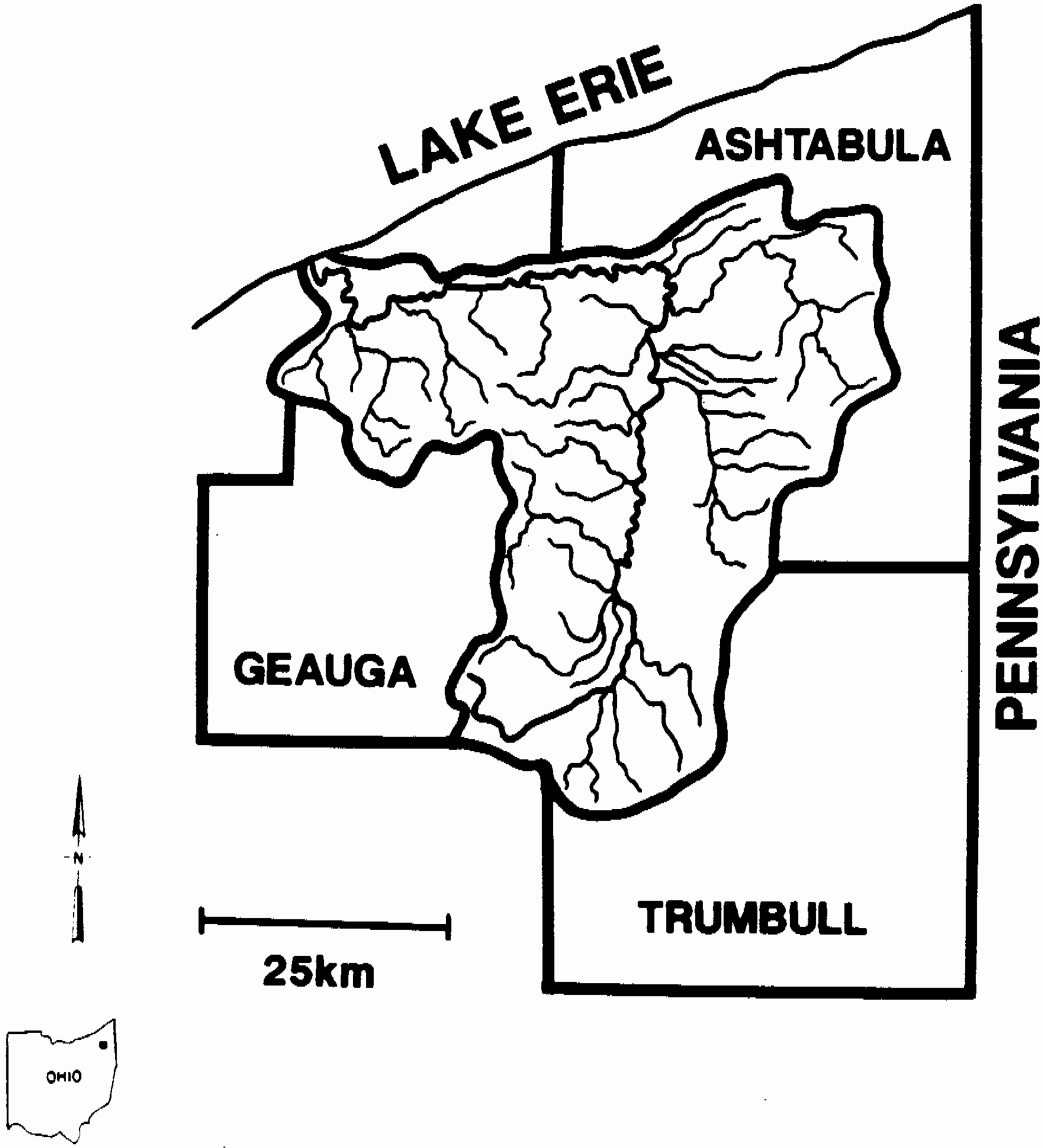


Fig. 1. Location of the Grand River watershed.

consisting of long pools with muddy bottoms and few riffles. An abundance of structure exists along the banks and within the channel, including fallen trees, log jams, and beaver dams. The lower part of the river from Harpersfield to Lake Erie is wider, meanders much less, and has a steeper gradient, a hard, rocky bottom, and steep, gorge-like banks.

The river basin consists primarily of Fitchville-Haskins-Sebering Association and Caneadea-Candice Association soils which are deep, nearly level to moderately steep, poorly-drained clayey soils on old glacial lake beds. Low gradient, sluggish streams often transect these soil associations (Ohio Division of Soil and Water 1986). Most of the Grand River and its tributaries flow through heavily wooded secondary growth forest. Dominant vegetation is that typical of a river floodplain-successional bottomland forest community (Barnes and Wagner 1981:48) and a wetland community (Reed 1988).

The fish community in the Grand River watershed is productive and diverse, as are populations of other aquatic prey species including crayfish, frogs (*Rana* sp.) and freshwater molluscs (Unionidae). The largest crayfish, *Procambarus* sp., escaped from a commercial fish farm, and is now found throughout the southern portion of the watershed. Major fish prey species are listed in Table 1.

Waterfowl are common during spring and autumn migrations, but Canada geese (Branta canadensis) are the only common year-round residents. Some nesting occurs along the river and in the associated wetlands, particularly by wood ducks (Aix sponsa) and Canada Geese, possibly providing additional food sources in the form of eggs and susceptible young.

The mammalian fauna is typical of that which occurs throughout Ohio (see Gottschang 1981). Beaver (Castor canadensis), muskrat (Ondatra zibethicus), and mink (Mustela vison) are common semi-aquatic mammals that otters will most often encounter.

The climate is characterized as being warm during summer (mean temperature 20.6 C), and cool to cold during winter (mean temperature -2.2 C). Precipitation occurs year-round, averaging 90.3 cm per year (U.S. Department of Commerce-NOAA 1988). The surfaces of the Grand River, its tributaries, and associated wetlands are usually frozen during winter, but access by otters under the ice is possible at beaver dams, log jams, and riffles where the ice is thinner or open, and along the banks where receding water levels cause the ice to drop and create air pockets along the bank. Otters also can

Table 1. Common fish species occurring in the Grand River, Ohio watershed (compiled from Trautman 1981).

Ictaluridae	
bullheads	*Ictalurus* sp.
madtoms	*Noturus* sp.
Catostomidae	
spotted sucker	*Minytrema melanops*
common white sucker	*Catostomus commerrsoni*
northern hog sucker	*Hypentelium nigricans*
redhorse	*Moxostoma* sp.
Cyprinidae	
carp	*Cyprinus carpio*
minnows	
river chub	*Nocomis micropogon*
creek chub	*Semotilus atromaculatus*
Esocidae	
chain pickerel	*Esox niger*
grass pickerel	*E. americanus*
Umbridae	
mudminnow	*Umbra limi*
Centrarchidae	
largemouth bass	*Micropterus salmoides*
rock bass	*Ambloplites rupestris*
white crappie	*Pomoxis annularis*
black crappie	*P. nigromaculatus*
sunfishes	*Lepomis* sp.
Percidae	
walleye	*Stizostedion vitreum*
darters	*Percina* sp., *Etheostoma* sp.

get under the ice by using underwater den entrances to beaver lodges.

Implantation Procedures

Twenty-three otters were obtained from Arkansas in December 1986-January 1987 through a cooperative trade agreement with the Arkansas Department of Game and Fish (ADGF). ADGF acquired the otters by purchasing them from independent trappers. Otters were housed in wooden pens until 4 to 6 otters were acquired. They were flown directly to the study area by Ohio Division of Wildlife personnel. The otters were usually shipped in groups of 2 to 4 in 136 X 91 X 49-cm wire mesh cages.

All otters were taken to Pukkerbrush Veterinary Hospital, operated by Drs. Robert and Catherine Temple. Each otter was restrained with a squeeze box (McCullough et al. 1986), anesthetized with a combination of Ketamine Hydrochloride and Acepromazine Maleate (20 mg/kg), sexed, aged (adult or juvenile), measured (total length, tail length, right foot length, right ear length, and chest girth), vaccinated against Diptheria, Hepatitis, Leptosporosis, Parainfluenza, and Parvo Virus, and examined for overall physical condition. Many otters had trap related injuries such as lacerated feet and broken toes that were treated. Each otter was also ear tagged with numbered #1 monel fingerling tags and rear-web tagged with numbered #3 monel fish tags.

Several otters were listless and lethargic, and consequently were considered to be in too poor condition for surgery. Those otters that appeared energetic and defensive, and that had no obvious major injuries (e.g., lacerations), were surgically implanted with a 164-MHz Telonics IMP/400L intraperitoneal radio transmitter equipped with a temperature sensor. The surgical procedure was done in a sterile environment, following procedures described by Melquist and Hornocker (1979) and Hoover (1984). A right lateral incision, rather than mid-ventral, was made to reduce the likelihood of dirt getting into, and contaminating the incision site. A lateral incision also prevents the weight of the transmitter from pushing against the incision site. Fur around the incision site was not shaved because bare skin increases heat loss. Fur also helps to cover the incision site, preventing the otter from licking it or pulling at the sutures. Body temperature of each otter was monitored during surgery; ice packs were used to cool the otter when the body temperature rose above 39 C. The procedure required less than 30 minutes per otter from the time of anesthetization until the end of the surgery. After implantation, otters were placed into the transport cages, allowed to recover, given food (fish and venison) and water, and were held from 12 hours to 2 days before being released.

Eight additional otters were obtained from Mr. LeRoy Sevin in Louisiana in May 1988. They were subjected to the same procedures as those described above, except they were held in an outdoor pen for 7 days before release, and were provided with food (primarily fish and ground nutria (Myocastor coypus)) and water ad libitum. Otters were energetic at the time of release, and did not show adverse effects to the implantation procedures. A tabular account of otters obtained for reintroduction is presented in Appendix A.

Telemetry Methods

Otters were located 4 to 7 days per week from 1 January to 1 March 1987, and from 1 June 1988 to 15 March 1989 with a Telonics TR-2/TS-1 receiver/scanner, a vehicle mounted 5-element Yagi antenna, and/or a 2-element hand held H-antenna. A Partinavia P68 airplane with a 2-element H-antenna mounted under each wing was used to locate otters when they could not be located from the ground.

Otter locations were determined by triangulation from 2 or 3 known points or by locating the individual on foot. I assumed that otters moved, foraged, and denned along the water course, and that they were either in the water or in a den along the bank. In areas where triangulation was not possible (i.e., due to poor access, interference from power lines), but where a single bearing could be obtained, the otter was assumed to be at the point where the triangulation bearing intersected the stream channel. If the intersection of two points used to triangulate an otter's position was near, but not along, a stream channel, the otter's position was plotted along the channel closest to the intersection of the points. When radio contact was made on foot, otters were located along the stream channel, and snow tracking during the winter showed that they were indeed moving along the water channel even when the surface was frozen; therefore I feel the assumption is valid. Woolington (1984) also reported always locating otters within 30 m from shore. When only a single bearing was possible, the bearing was taken from a position as close to perpendicular to the stream channel where the otter was located as was possible. If a location determination seemed improbable, attempts were made to locate the otter on foot to verify the location. Thirty-nine percent of the otter locations were determined on foot, 12% were determined with only 1 bearing, and 49% with 2 or more bearings. All location determinations were plotted on 1:24,000 USGS 7.5-minute topographic maps. Locations were then converted to UTM coordinates with a Jandel digitizer.

SURVIVAL

Introduction

Success of a reintroduction can best be measured by the survival of released animals and by their reproductive output. Otters have no natural enemies in Ohio; consequently, mortalities will be caused by humans (e.g., from trapping, road kills, fish nets) or other natural causes such as disease or parasitism. Long distance dispersal from the release area isolates individuals from the released otters, and could, in effect, be similar to a mortality because the individual would not contribute to population expansion. Determining survival and causes of mortality enables the success of this release to be judged, and provides information to increase survival in future releases.

Survival of otters reintroduced in other states is varied, but stress associated with capture and handling before release was a major cause of pre- and post-release mortality. Missouri reported yearly survival rates of 87.5% and 77.2% of 20 otters each at 2 release sites. Of those 40 otters, 3 died of stress soon after release, 4 died 2 months to 1 year post release, and 8 were unaccounted for at the end of 1 year (Erickson et al.

1984). Fourteen of 57 otters released in Colorado with radio transmitters died prior to or within 10 days post-release. Eleven of those 14 died from mishandling, surgical complications, stress, and self-induced injuries while in captivity. Survival of remaining otters was 72.4% (Mack 1985). Eight of 10 radioed otters died in Arizona within 2 weeks post-release. Mortality was attributed to stress associated transmitter implantation procedures, and to prey biomass being at a low point and high water levels impeding the otters' ability to effectively forage (Britt et al. 1982, 1984). Four of 10 radioed otters died within 5 weeks after release in Oklahoma (S. Lauzon, as reported in Erickson et al. 1984), and 1 of 11 died of emaciation soon after release in Tennessee. Two additional otters died from stress during transport when the transport vehicle became stalled in a snow storm (Griess 1987).

Methods

Implanted radio transmitters were equipped with temperature sensors, thus enabling mortality determination and carcass recovery soon after death. All carcasses were necropsied at Pukkerbrush Veterinary Hospital to determine cause of death. Survival was calculated by dividing the number of known and potential survivors by the total number of otters released.

Results

Combined Releases

Survival of Louisiana otters (longer than 10 days) was significantly greater than survival of Arkansas otters ($\underline{X}^2$=8.49, $\underline{P}$<0.01) (Table 2). All mortalities up to 10 days after release were attributed to stress and injuries incurred before arrival in Ohio. Therefore, subsequent survival estimates are based on those otters that survived longer than 10 days after release. Survival of the 13 otters that lived longer than 10 days was between 46% and 77%, depending on the fate of 4 otters that disappeared. Beaver trapping and road-kills accounted for 80% of the known mortalities (Table 3).

Arkansas Otters

Only 6 (26%) of the 23 otters obtained from Arkansas survived more than 10 days (Table 2). Nine otters died in captivity due to poor health - 5 before being implanted. Six otters died within 2 days post-release and 1 within 7 days post-release. One escaped before being implanted; she was being held in captivity and had not been implanted due to her poor condition. Her fate is unknown, but she probably did not survive. Of the remaining 6 survivors, M4875 was road-killed 44 days post-release, M6375 was killed in a beaver trap 45 days post-release, and M890 could not be located after 69 days. M4875 had gained 1.1 kg and M6375 had gained 3.1

Table 2. Numbers of otters from Arkansas and Louisiana released into the Grand River, Ohio, that survived more than 10 days. Arkansas otters were released in December-January 1986-87, and Louisiana otters were released in May 1988.

	Arkansas			Louisiana		
	Male	Female	Total	Male	Female	Total
Obtained	14	9	23	5	3	8
Implanted	12	5	17	5	3	8
Released	10	3	13	5	3	8
Survived > 10 days	6	0	6	5	3	8

Table 3. Causes of mortality of free ranging river otters released in the Grand River, Ohio, in December 1986-87 and May 1988.

Cause	Number
Roadkill	2
330 Conibear trap	2
Canine hepatitis	1

kg, indicating that prey was available even during the coldest part of winter. M662 was road-killed 13.5 months post-release and had gained 4.5 kg. M260 and M329 were both located near the release site more than 1 year after release. Therefore, only 3 or 4 of the 6 Arkansas otters survived longer than 12 months (50%-67%).

Louisiana Otters

Eight additional otters were acquired from Louisiana in May 1988. All were in good physical condition; all were implanted and released at the same site of the previous year. Otter F220 died 24 days post-release due to hepatitis viral infection possibly in combination with heartworm. Though vaccinated against hepatitis upon arrival in Ohio, she probably already harbored the virus. The other 7 Louisiana otters established themselves near the release site, remaining there through summer. They began moving extensively beginning in October 1988. M463 disappeared on 29 November 1988 and was never again relocated. M688 was last located near the release site on 18 January 1989, and M588 moved downstream and was last located on 19 January 1989 along the Lake Erie shoreline west of where the Grand River drains into the lake. M050 was killed on 18 January in a 330 Conibear body-gripping trap set for beaver, and was 1.4 kg heavier than when released 8 months earlier. Therefore known survival of Louisiana otters from 12 May 1988 to 15 March

1989 was between 38% and 75%, depending on the fate of those otters that could not be relocated.

Necropsy Results

Carcasses of the 16 Arkansas otters that died before or soon after release were necropsied to determine the cause of death. Fourteen of the 16 had swollen, purplish, hemorrhagic lungs, 3 with about 70% of the lung tissue pneumonic and nonfunctional. Eleven also had large, subcutaneous bruises that varied from 5 to 20 cm in diameter over the dorsal and ventral thoracic regions. The pericardial sacs of 2 of the otters were full of fluid, resulting in pericardial effusion and strangulation of the heart. One otter had a ruptured spleen and one had a punctured heart over which a small fibrinogen clot had developed. The clot collapsed just before the otter's release, resulting in massive internal hemorrhaging and death. Fourteen otters also had ulcers along part or all of the gastro-intestinal tract and were lacking body fat stores, symptoms often associated with prolonged stress. Only 1 of the 16 otters that died had no bruising or internal injuries, but she was emaciated. This otter moved about 3 km from the release site where she was found dead 10 days post-release. She was emaciated, her stomach was empty, and starvation appeared to be the cause of death. Erickson et al. (1984) and Woolf et al. (1984) described similar occurrences in otters implanted and released in Missouri and Illinois, respectively. Shock and trauma associated with various internal injuries appeared to be the cause of death in the other 15 (94%) otters (see Appendix B).

Discussion

Survival of Arkansas otters for reintroduction into Ohio was low. Louisiana otters were in better physical condition and survival was significantly higher, indicating that capture technique, handling methods, and housing of otters before reintroduction can dramatically affect survival. The 4 human-caused mortalities occurred during the late winter breeding season when male otters typically move long distances in search of mates. Because females were absent during the first year and scarce the second year, mortality might have been higher than would normally be expected due to potentially long range movements by males searching for females. Both road-killed males were more than 100 km by river from their last known locations; in fact, 1 was in a different watershed. Beaver trapping was not allowed on the wildlife area where the otters were released, but was heavy in places outside the wildlife area boundaries. Trapping and road kills will probably continue to be the primary cause of otter mortality in Ohio.

Although the fate of 4 of the reintroduced otters is unknown, I feel they survived and simply were not relocated because of battery failure in the transmitter or moving out of detection range. For example, despite intensive ground and aerial searches during winter 1987, I was unable to locate M260, M329, or M662 after less than 3 months of monitoring. M260 was relocated 4 months later near the release site, M662 was found road-killed 10 months later near a tributary of the Grand River close to Lake Erie, and M329 was relocated 14 months later near the release site. Therefore, because the otters are not located does not mean they are dead or even permanently removed from the population.

Internal injuries observed in Arkansas otters were probably caused by unintentional overexertion with a choker (restraining snare, rabies stick) when the otters were moved or handled. A choker consists of a wire cable attached at one end to a long, hollow handle. The other end of the cable loops back through the handle and out the opposite end. By pulling on the free end of the cable, an operator reduces the diameter of the cable loop, cinching the cable around the animal's neck or body. Most chokers have a ratchet-type mechanism that permits the cable to be tightened and held tight. An otter's head is smaller in circumference than its neck, which necessitates placing the cable behind the front legs, near the otter's center of gravity. This acts somewhat like a fulcrum, causing the weight of the front and rear portions of the body to be centered over the narrow cable. This also is the location of the thoracic injuries and subcutaneous bruises that were observed. If the otter is lifted off the ground, it is able to twist and flail, causing even more pressure to be exerted over that small, central portion of its body.

Melquist and Hornocker (1979) and Shirley et al. (1983) provide a description of techniques that are efficient at trapping otters and removing them from traps and holding cages, producing minimum stress or injury to otters, and are reasonably safe to the researcher. Individuals providing otters for reintroductions programs should be required to follow these recommendations. Transport cages should be constructed so that openings match the opening of the squeeze box recommended by McCullough et al. (1986). I found this design to be extremely efficient and less stressful than nets for temporarily restraining otters.

The Division of Wildlife has indicated that otters for future releases will be obtained from persons known to be familiar with, and knowledgeable of, proper capture, handling, and holding techniques. Future releases also will not involve radio-tagging otters, and a more even sex-ratio will be obtained, probably increasing survival.

HOME RANGE

Introduction

Home range is defined as the area that an individual occupies during its usual daily activities of food gathering, resting, mating, and caring for young, and usually does not include occasional exploratory movements outside the area (Burt 1943). Entire home ranges generally are not defended and may overlap those of other conspecifics (Pianka 1983). That some areas of an individual's home range are used with greater intensity than other areas was first recognized by Hayne (1949). Samuel et al. (1985a) called these areas core areas, defining them as the maximum area where the observed utilization distribution exceeds a uniform distribution. Core areas are probably areas within the home range that contain the individual's preferred den sites, dependable food sources, or, at least during part of the year, potential mates (Ewer 1968).

Several members of the mustelid family display a spacing pattern of inter- and intra-sexually overlapping home ranges, and even association among conspecifics of the same sex (Melquist and Hornocker 1983, Hornocker et al. 1983, Erickson et al. 1984). Other groups of the same species display intrasexually exclusive home ranges with little or no overlap (Erlinge 1967, Powell 1979, Foy 1984). This flexibility in spacing is thought to be an adaptation to, and result of, changing environmental conditions (Hornocker et al. 1983). Limited evidence suggests that a well established otter population will have intrasexually exclusive home ranges, whereas an unestablished, low density, or exploited population in a dynamic state, such as that in Ohio, tend to display much more overlap among home ranges. Otters confined to a narrow stream channel will more frequently have overlapping home ranges regardless of the status of the population, so must tolerate one another, or mutually avoid one another (Melquist and Hornocker 1983).

The well established otter population that Foy (1984) studied inhabited a protected marsh system with an evenly distributed food supply, and displayed nonoverlapping home ranges, whereas unestablished or exploited otter populations in Missouri and Idaho displayed extensive inter- and intra-sexually overlapping home ranges (Melquist and Hornocker 1983, Erickson et al. 1984). The otter population I studied was extremely small and resources were abundant, suggesting that home range overlap, group association among conspecifics, and lack of aggression among males would be predicted during summer and autumn. This type of spacing system was expected to change during winter as the breeding period approached.

A model presented by Schoener and Schoener (1980) suggests that in polygynous species such as otters, male reproductive output is limited by the availability of receptive females, so, at least during the breeding season in late winter and early spring, adult males are predicted to occupy larger, preferably intrasexually exclusive home ranges that overlap with the greatest number of females. Male home range size should increase with female density until intruder pressure becomes too great. Female reproductive output is limited by resources, not males, because the female must bear the energetically costly burden of bearing and raising young. Therefore, females are predicted to occupy high quality areas from which conspecifics are excluded year-round. Female home ranges are predicted to remain stable and not fluctuate seasonally like that of males.

Methods

Because otters always tended to be along a stream channel, they had 2-dimensional linear home ranges rather than 3-dimensional area home ranges. Total home range length per season was defined as total kilometers of stream that each otter was known to have used during each of 3 seasons: summer (June-August), autumn (September-November), and winter (December-February).

Total home range length often greatly exceeded the area that otters regularly used and travelled through, so home range core area also was estimated. Program HOME RANGE (Samuel et al. 1985b) was used to delineate the core area boundaries. Length of stream that otters were known to have used and that was contained within the core area boundary was measured, and defined as core length. One otter, F240, had a home range that was less linear, so the kilometers of shoreline contained within the core area and the total home range was used as an indicator of home range length and core length.

The Wilcoxon paired sign-rank test was used to test for significant differences between male summer and male autumn home range lengths. Statistical comparisons between male and female home range lengths, between male winter and summer or autumn home range lengths, and among female summer, autumn, and winter home range lengths were not made due to the small sample size.

Home range overlap was estimated by measuring the length of stream contained within an otter's core and total home range that was used by other otters. The length of stream shared by each otter pair with overlapping home ranges was converted to a percentage of each otter's individual total and core home range.

Differences in seasonal home range overlap among same sex and opposite sex pairs were investigated.

Results

Total home range lengths and core area lengths per season varied considerably among sexes and seasons (Table 4). Total and core home range lengths of males were smallest during summer, increased significantly during autumn (n=5, T=0, P=0.03), and remained near autumn size during winter. Median total and core home range lengths of females did not differ greatly from those of males during summer, remained at those levels during autumn when male home range lengths greatly increased, and decreased by almost 50% during winter (Table 5). Individual seasonal home ranges are illustrated in Appendix C.

Three pairs of otters had extensive home range overlap during summer. Males M513 and M588 were released at the same location and remained together throughout the summer. Their home ranges overlapped an average of 94% and they were usually in the same den. Male M329, an Arkansas otter released in 1987, and male M688 were located together 9 days after M688 was released on 12 May 1988. These 2 otters denned in adjacent sites and travelled together for at least 73 days during summer 1988, after which time M329 could no longer be located, probably due to battery failure. Male M688 later moved,

Table 4. Seasonal[a] home range lengths of Arkansas and Louisiana river otters released into the Grand River, Ohio, in December-January 1986-87 and May 1988, respectively.

			Summer			Autumn			Winter		
Otter	Source	Sex	*N*[b]	Core (km)	Total (km)	*N*[b]	Core (km)	Total (km)	*N*[b]	Core (km)	Total (km)
M260	Ark.	M							47	1.0	1.6
M329	Ark.	M							24	5.1	28.0
M4875	Ark.	M							20	2.2	26.1
M662	Ark.	M							51	5.1	7.7
M6375	Ark.	M							52	12.6	32.7
M890	Ark.	M							44	18.0	35.2
M050	La.	M	88	1.4	4.7	66	22.7	61.1	38	10.5	15.8[c]
F190	La.	F	91	8.5	13.6	78	18.4	28.9	100	5.9	11.3
F240	La.	F	97	10.1	10.9	65	4.6	11.4	82	3.9	8.0
M463	La.	M	88	6.6	17.5	68	20.4	65.1			
M513	La.	M	92	2.5	3.5	71	26.6	54.2	90	42.9	100.2
M588	La.	M	91	2.9	3.4	43	8.3	119.9			
M688	La.	M	62	6.6	11.4	69	55.6	92.4	39	52.1	89.2[c]

[a]Summer = Jun-Aug 1988, autumn = Sep-Nov 1988, winter = Dec-Feb 1986-87 and 1988-89.

[b]*N* = Number of telemetry locations.

[c]Includes data only through 18 Jan.

Table 5. Seasonal median total and core home range lengths (km) of male and female otters released in the Grand River, Ohio, in December-January 1986-87 and May 1988.

	Male		Female	
Season	$\tilde{X}$	n	$\tilde{X}$	n
Total				
Summer (1988)	4.7[a]	5	12.2	2
Autumn (1988)	65.1[a]	5	20.2	2
Winter[b] (1987, 1988-89)	26.1	9	9.6	2
Core				
Summer (1988)	2.9[a]	5	9.2	2
Autumn (1988)	22.7[a]	5	11.5	2
Winter[b] (1987, 1988-89)	10.5	9	4.9	2

[a]Columns with identical letters were significantly different at P=0.05.

[b]Includes data from Arkansas otters (1987) and Louisiana otters (1988-89). Data were not complete for all otters for complete season.

joining M513 and M588 at the den location they had been occupying since their release, and stayed with them for another month. Male M463 and female F190 also had considerable home range overlap during summer 1988 (Tables 6 and 7).

By autumn 1988, the 5 radio tagged male otters had extensively overlapping home ranges, and all 5 also overlapped that of female F190. Female F240 moved away from the main river channel soon after release and her home range never overlapped any of the other otters.

Home range overlap among male otters released during winter 1987 was extensive until mid-February when they could no longer be located. By the end of January 1989, only one male Louisiana otter could be located, so information on overlap for the entire season is unavailable, as is that for spring.

Discussion

Otter home range shape apparently is determined by drainage patterns, whereas home range length and use are influenced by prey availability, habitat, weather conditions, topography, reproductive cycle, and conspecifics; home ranges are usually marked by scent posts composed of feces, urine, and anal gland material (Melquist and Hornocker 1983, Foy 1984). In this study home ranges were generally linear, following river and tributary channels. Home ranges consisted primarily of

Table 6. Percent intra-[a] and inter-sexual home range overlap among river otters released into the Grand River, Ohio. Only those pairs of otters that had overlapping home ranges were included in percent overlap calculations.

	Male:Male			Male:Female		
Season	Percent overlap	Range	Number of overlapping pairs/number of possible pair combinations	Percent overlap	Range	Number of overlapping pairs/number of possible pair combinations
Winter (1987)	45.7	4.8-100	15/15			
Summer (1988)	95.4	81.5-100	2/15	43.6	16.0-78.4	2/10
Autumn (1988)	43.5	22.8-72.0	10/10	38.8	9.9-79.5	5/10
Winter (1988-89)	42.3	3.2-87.5	2/3	36.7	7.0-68.9	2/6

[a]Female home ranges did not overlap, so female:female overlap was not included.

Table 7. Percent intra-[a] and inter-sexual core home range overlap among river otters released into the Grand River, Ohio. Only those pairs of otters that had overlapping home ranges were included in percent overlap calculations.

	Male:Male			Male:Female		
Season	Percent overlap	Range	Number of overlapping pairs/number of possible pair combinations	Percent overlap	Range	Number of overlapping pairs/number of possible pair combinations
Winter (1987)	59.6	5.4-100	15/15			
Summer (1988)	96.9	87.8-100	2/15	74.4	6.5-83.8	2/10
Autumn (1988)	36.3	9.9-93.0	10/10	39.3	11.6-75.1	5/10
Winter (1988-89)	50.9	45.9-55.8	1/3	31.7	6.3-56.4	2/6

[a]Female home ranges did not overlap, so female:female overlap was not included.

frequently used den sites and the travel routes between those den sites. The harmonic mean method, as modified by Samuel and Garton (1985), identified core areas that fairly closely outlined the stream corridors used most heavily by each otter. To my knowledge, no previous studies involving linear home ranges have identified core areas.

After their release in May 1988, Louisiana otters dispersed short distances to apparently suitable locations, then remained sedentary. Because they rarely travelled great distances, home range size and overlap were small during this period. A severe drought during summer 1988 caused many pools to partially or completely dry. This concentrated prey sources in remaining pools, possibly minimizing otters' home ranges, home range overlap, and movement.

Increase in home range size coincided with the beginning of cold weather and sub-freezing temperatures in autumn. This is when frogs and crayfish, principal summer foods, become scarce or unavailable as they burrow into the sediments to overwinter. Four of the 5 males began moving downstream together during this period, and had considerable home range overlap. Female home ranges did not greatly increase at this time, but all 5 male home ranges did overlap female F190's home range. If females do indeed occupy higher quality home ranges with abundant prey resources, as suggested by Schoener and Schoener (1980), then resources within their home range should have been adequate, negating the need to increase home range size.

By late winter, only 1 male could be located, and his home range did overlap extensively (77%) with that of female F190. Three of the other males had disappeared by mid-January, and the fourth was killed in a beaver trap, so it is unknown whether they left in search of other females, or if they left for other reasons. Up to 3 males from the Arkansas release also could have been in the area defending against other males, but, again, this is unknown. The 6 male Arkansas otters released 2 winters previously showed strong home range overlap and association among conspecifics during early winter, but separated during February, which is the beginning of the breeding season, and all disappeared soon after. I feel they disappeared in search of females, which were absent in the watershed at that time.

Otter home ranges varied in size in other states as well, and male home ranges were considerably larger than respective female home ranges in those states except among reintroduced otters in Tennessee, where female home range size was slightly larger (Griess 1987).

Home range overlap among otters in this study was similar to that among otters reintroduced to Missouri.

Males were more sociable than females, and in riverine habitat, females were solitary except during late winter and early spring, the normal breeding period (Erickson et al. 1984). Interactions among otters in Texas and Tennessee were primarily between male and female otters, and no female:female home range overlap occurred (Foy 1984, Griess 1987). In a native population of Alaskan otters, family groups, consisting of an adult female and her young, used adjacent but non-overlapping home ranges (Woolington 1984).

The results of this and previous studies do tend to support the model of Schoener and Schoener (1980) that male otters in a dynamic population will tend to be more tolerant of one another and have overlapping home ranges, except during the breeding season when females become a defendable resource. If the population becomes saturated, males would be expected to exclude or mutually avoid one another. Although it is difficult to draw any conclusions about female spacing because of small sample size, the females in this and other studies did tend to be solitary and have smaller home ranges, thus supporting the models. If these models are indeed true, then the carrying capacity of a particular river system or watershed may be limited by the availability of quality habitat suitable to females, which in turn may limit the number of males that stay within the confines of the watershed.

MOVEMENT AND ACTIVITY

Introduction

Otters are capable of moving long distances in a relatively short period of time. Their travel routes generally follow stream corridors or shorelines, and the periods when they are active can vary considerably. Movement results from foraging, exploring, patrolling home ranges, marking boundaries, searching for mates, and/or dispersal (Erlinge 1967). Diel activity is influenced by many of these same physiological, behavioral, and environmental factors.

Den sites and prey resources should be abundant year-round to the small population I studied, so exploring/dispersal should be the major factor influencing movement during the nonbreeding season. Receptive females become a scarce, defendable resource to males during breeding season (Schoener and Schoener 1980), so searching for mating opportunities should be the major factor influencing movement of males during the breeding season. Females are predicted to select high quality areas capable of supporting themselves and their developing young, so they are not predicted to move great distances in search of resources or mating opportunities.

Long range dispersal is not unknown among otters. Movements of 160 km and 250 km were made by 2 otters the first year after their release in Missouri, and a third moved more than 320 km from its release site over a 3-year period (Erickson et al. 1984). An otter in Illinois moved 114 km from its capture/release site after being implanted with a transmitter (Anderson and Woolf 1984), and an otter released in West Virginia travelled more than 100 km before being captured in a drown-set raccoon trap in Ohio (Denis Case pers. comm.). Long distance movements by individual reintroduced otters effectively removes them from this breeding population and consequently, strongly influences reintroduction success.

Methods

Movement of radio-telemetered otters was measured as the distance between 2 consecutive locations based on the shortest travel distance along the stream corridor (Melquist and Hornocker 1983). I defined movement as the distance travelled by an otter when it moved from one den site to another between consecutive daily locations. If an otter was in, or active within 1 km of the den in which it had been located previously, no movement was recorded.

To determine at which times otters were most active, I divided the day into 4 time blocks: 0400-1000, 1000-

1600, 1600-2200, and 2200-0400 hours. Otters were located during a particular time block for 3 consecutive days, then during a different time block during the following 3 days until all time blocks were sampled. This procedure was then repeated. Adherence to this sampling plan was less strict during autumn 1988 because otters were moving long distances and daylight was needed to search for them. Additional opportunistic location determinations were made when possible regardless of the time block being sampled. Otters generally were located 4 to 7 times per week.

Once an otter was located, the transmitter signal was monitored a minimum of 5 minutes to detect fluctuations in signal intensity, which were assumed to be due to movement (Melquist and Hornocker 1983). If signal intensity fluctuations were detected, the otter was recorded as being active during that hour. The proportion of location determinations during which an otter was active per hour per season was calculated. The proportion of active fixes per hour per season were then combined into the proportion of active fixes during daylight hours (from mean sunrise to mean sunset) and dark hours (from mean sunset to mean sunrise).

A modified *t*-test for proportions (Snedecor and Cochran 1980:97) was used to test for significant differences in activity of otters between the daylight hours and the dark hours for all seasons.

Results

Thirteen otters were monitored for activity 1,633 times during the study. They were active from sunset to sunrise a greater proportion of times than from sunrise to sunset throughout the year (Figs. 2 and 3), and were significantly more nocturnal during summer (n=8, t=5.83, P<0.001) and winter (n=11, t=10.1, P<0.001) (Table 8).

Movements by male and female Louisiana otters through summer and into autumn were few, averaging 0.62 km per consecutive location (Table 9), and occurred as otters moved from one den site to another. Less than 18 days after her release on 10 May 1988, female F240 did move 13.6 km up a tributary to an large swamp, where she remained until at least September 1989. Some otters remained at the same den site through summer, never moving from the vicinity of the den site. However, by mid-October, the frequency and average distance of male movements increased dramatically to 3.14 km per consecutive location, whereas the frequency and distance of female movements did not greatly change. Four of the 5 males (M463, M513, M588, and M688) began moving downstream together into never-before-used territory. Males M513 and M688 moved 24.6 km and 53.89 km downstream before turning around and returning to the release area 1

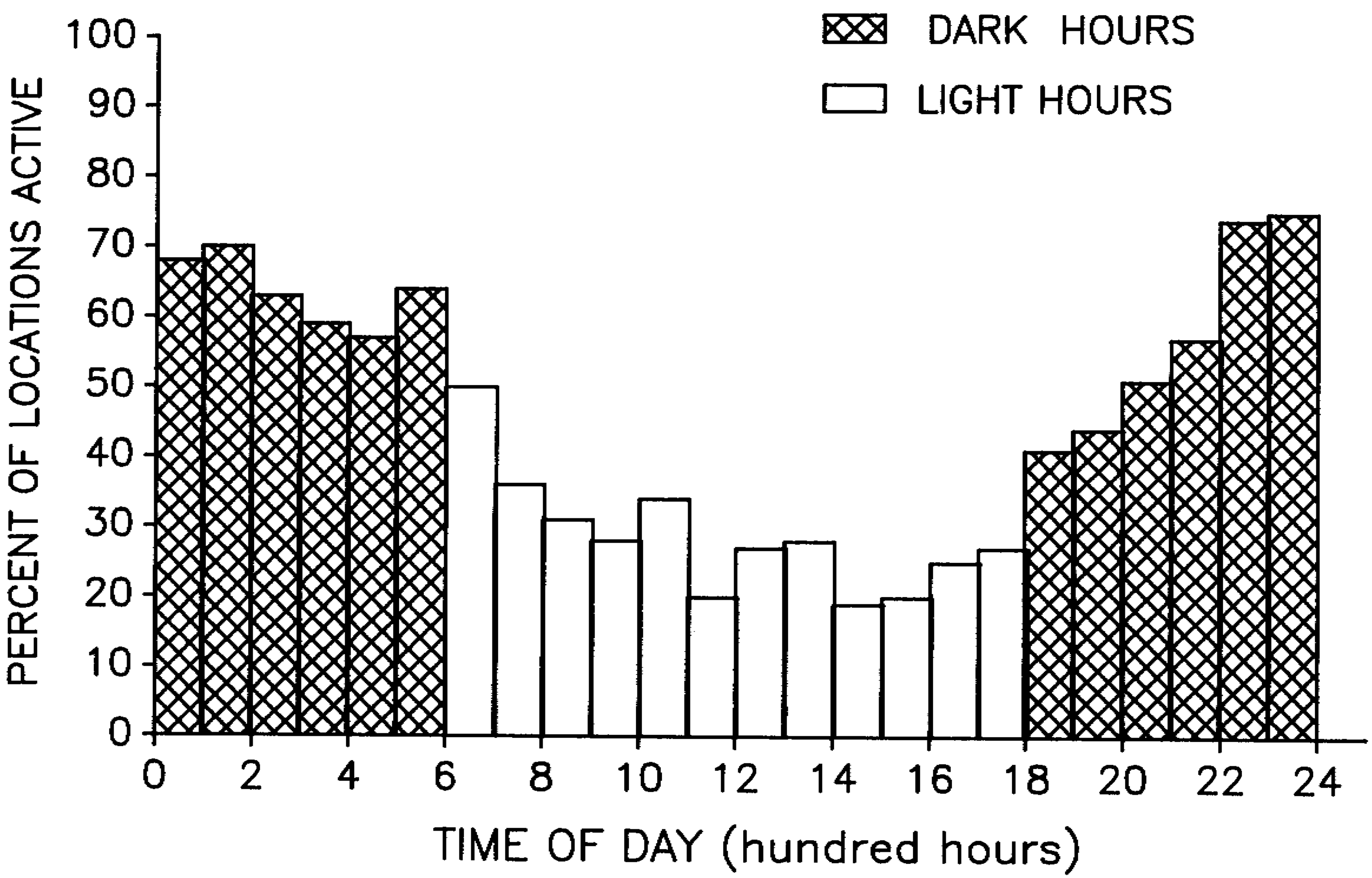
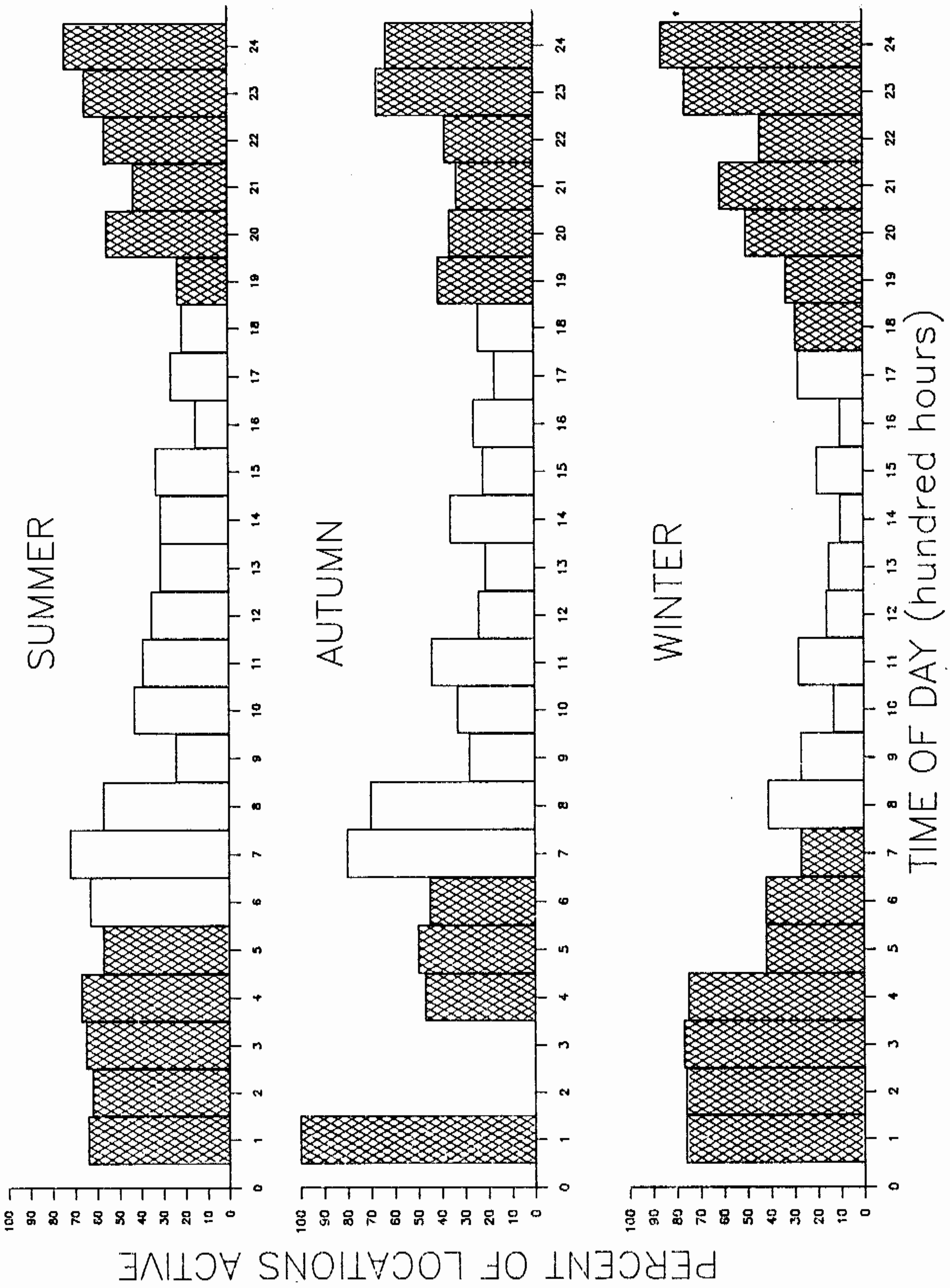


Fig. 2. Percent of locations (by hour) during which river otters released in the Grand River, Ohio, were known to be active during summer and autumn 1988, and winter 1987 and 1988-89.

Fig. 3. Percent of locations (by hour) during which river otters released in the Grand River were known to be active per season.



SUMMER
AUTUMN
WINTER
TIME OF DAY (hundred hours)
PERCENT OF LOCATIONS ACTIVE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
0 10 20 30 40 50 60 70 80 90 100

Table 8. Proportion of locations during which river otters released into the Grand River, Ohio, were active during dark hours (sunset to sunrise) and daylight hours (sunrise to sunset) in summer and autumn 1988, and winter 1987 and 1988-89.

		Sunset to sunrise		Sunrise to Sunset			
Season	*n*	Number of locations	Proportion of locations active	Number of locations	Proportion of locations active	*t*	*P*
Summer (1988)	8	392	0.62	470	0.34	5.59	<0.001
Autumn (1988)	7	113	0.45	319	0.35	1.72	<0.20
Winter (1987, 1988-89)	11	372	0.55	382	0.22	10.42	<0.001

Table 9. Average distance (km) moved between consecutive daily locations (by month) by male and female river otters released into the Grand River, Ohio, in December-January 1986-87 and May 1988.

	Male				Female			
Month-Year	n	Number of consecutive locations	$\bar{X}$	SD	n	Number of consecutive locations	$\bar{X}$	SD
Jun 1988	6	115	0.40	0.09	2	50	0.49	0.48
Jul 1988	6	121	0.33	0.16	2	50	1.17	0.15
Aug 1988	5	92	0.20	0.10	2	46	0.60	0.45
Sep 1988	5	73	0.38	0.17	2	30	1.37	0.35
Oct 1988	5	79	3.14	1.16	2	35	0.49	0.33
Nov 1988	4	76	3.70	1.45	2	34	0.78	0.77
Dec 1988	3	30	1.32	1.07	2	31	0.34	0.34
Jan 1987, 1989	9	171	1.64	0.72	2	54	0.18	0.17
Feb 1987, 1989	6	80	0.67	0.47	2	44	0.42	0.37

week and 2 weeks later, respectively. Male M588 moved 119 km in 15 days before contact with him was lost on 27 October. He was eventually relocated in January 1989 along the Lake Erie shoreline, 162 km (by river) from his original release site. Male M463 moved more than 108 km in 45 days before he disappeared. Both female otters remained in the same areas they had been using throughout the study.

Arkansas otters released during winter 1986-87 had an average daily movement of 0.38 km until mid-February when they suddenly dispersed and could not be relocated despite intensive aerial and ground searches. Prior to this, they were relatively sedentary and interacted extensively. Three otters were even located in the same den and were observed foraging and playing together on several occasions. Two (M260 and M329) eventually returned and were relocated near the release site, and the third (M662) was found road killed 13 months later on 2 February 1988, 142 km from the release site. Another of the Arkansas otters (M4875) was later found road-killed on 11 March 1987 in the Chagrin River watershed, 197 km by river from the release site (39 km straight line). One of the 3 Louisiana males, M688, disappeared during mid-January 1988 and also was never relocated. He had been moving/denning with M513 for 4 months before his disappearance. M513 stayed in the release area, and on the night of 23 February 1989 was in the same location as female F190, possibly breeding.

Discussion

Foraging, exploring, and searching for mates are probably the primary factors influencing the movements of reintroduced otters in Ohio, as well as occasional long range dispersal away from the release area for unknown reasons. The Arkansas and Louisiana otters moved little in the 6 weeks following their release. Arkansas otters were denning along beaver impoundments around which were observed the carcasses of several large carp, indicating that habitat was suitable and that their nutritional needs were probably being met. However, movement by Arkansas otters may have been restricted if they were affected by, and were recovering from, the types of injuries that afflicted their nonsurviving counterparts (Appendix B). Drought conditions during 1988 probably helped to restrict the movements of the Louisiana otters during the summer they were released. Many pools began drying up, concentrating aquatic prey resources in remaining pools. Kilham (1982) observed otters similarly exploiting a water hole in Florida where fish had concentrated during a drought year.

The longer, more frequent movements by male otters, beginning in October, were probably stimulated by a change in prey availability. Otters were feeding heavily on amphibians and crayfish during summer (see pages 61-70), but with the onset of sub-freezing temperatures these organisms burrow into the mud to overwinter, forcing otters to feed more heavily on fish. Prey availability in the higher quality areas female otters are thought to occupy probably was sufficient keep females from having to move as much.

A change in male social organization brought on by the onset of breeding season may stimulate long movements and subsequent disappearance of male otters during late winter. Females become the most important resource to males during the breeding season (Erlinge and Sandell 1986), and if females are unavailable, males increase their search radius. Consequently, disappearance of male otters during winter was probably directly related to lack of breeding females. No known females occupied the area when the Arkansas otters disappeared in late winter 1987, and only 1 female (F190) was in the area in 1988-89. The other female, F240, was essentially isolated from other otters.

Increased male movements and expanded home range size during the breeding season have been reported in many other species of mustelids as well (Gerell 1970, King 1975, Erlinge 1977, Powell 1979, Debrot and Mermod 1983, Hornocker et al. 1983, Sandell 1986). It was also during the breeding season when all human-caused mortalities occurred, possibly resulting from increased movement and activity associated with searching for females.

Movement and activity by otters during the nonbreeding season appears to be influenced by prey availability and distribution, and, for males, by the distribution and availability of receptive females during the breeding season. Long distance dispersal from the Grand River release area should be reduced in the future as more females become established in the Grand River drainage.

DEN SITE/HABITAT USE

Introduction

Otter habitat along inland waterways is characterized by a variety of physiographic features. Quality otter habitat tends to be bordered by extensive forests, and is in areas with good water quality and high productivity. Otters are most often found along waterways with deep pools containing slow moving water where stream flow prevents freezing to the bottom. Other important characteristics include long, meandering waterways, wooded riparian cover, abundant stream structure such as log jams, fallen trees, and debris piles, and many associated wetlands such as oxbows, wooded swamps, marshes, backwaters, and tributaries (Botoroff et al. 1976, Melquist and Hornocker 1983, Anderson and Woolf 1984, Mack 1985). Riverine habitat, including lowland streams, main river channels, and old, meandering river courses, seems to be of great importance to otters (Yeager 1938, Mowbray et al. 1979, Melquist and Hornocker 1983, Mack 1985, Polechla and Sealander 1985).

Several investigators argue that a facultative commensal relationship exists between otters and beavers

(Cardoza 1977, Tumlinson et al. 1982, Melquist and Hornocker 1983, Reid 1984, Polechla and Sealander 1985). Increases in otter populations in Arkansas and Missouri are felt to be directly related to increases in beaver populations (Joe Clark, Arkansas Department of Game and Fish, pers. comm., Dave Hamilton, Missouri Department of Conservation, pers. comm.). Beavers create water impoundments that effectively trap and store water, resulting in extensive wetlands consisting of slow, deep, productive waters in wooded areas (Hill 1982). These impoundments effectively increase the depth and area of the aquatic habitat, as well as the extent of the productive ecotone between the terrestrial and aquatic systems (Gard 1961, Allred 1980). Otters forage along shallow shorelines and backwaters, and among tree snags and stream structure, so beaver impoundments increase the available area along which otters forage. Beavers also create dens and lodges that otters use. Otters do not dig their own dens, but rather use those created by beavers, nutria (Myocastor coypus), muskrat, log jams, drift piles, root cavities, and jumbles of loose rock (Yeager 1938, Harper 1962, Cardoza 1977, Melquist and Hornocker 1983, Anderson and Woolf 1984, Reid 1984, Mack 1985). Melqust and Hornocker (1983), Reid (1984), and Polechla and Sealander (1985) obtained radio fixes from resting telemetered otters in beaver bank lodges and dens, and more than 38% of the resting sites used by otters in Idaho were beaver bank dens.

The Grand River watershed contains an abundant beaver population and is heavily wooded throughout its length, and the channel contains many fallen trees and other structure. Herein, I attempt to determine the types of dens used by reintroduced otters, and classify habitat surrounding those den sites.

Methods

Otters released in 1987 and 1988 were periodically located on foot to determine the types of dens they were most frequently using. Number of days otters were known to have occupied a den was recorded; one day spent at a den site by 1 otter was defined as 1 den day. Dens were classified by type, and the area immediately surrounding an identified den site was classified according Cowardin et al. (1979). If a den was located within 400 m of a beaver dam or log jam, the habitat was classified as impounded. The Wilcoxon matched-pairs signed rank test was used to test for significant differences among the types of dens used, among the number of den days spent per den type, and for differences in wetland habitat use.

Results

Otters released along the Grand River used a variety of den types (Table 10) in a variety of wetland habitats. Palustrine and impounded riverine habitats were the most

Table 10. Number and type of otter dens located in the Grand River, Ohio watershed from 1 January 1986 to 15 March 1989, and the total number of known days each type of den was occupied.

Den type	Number of dens	Den days
Beaver lodge	35	817
Bank den	27	131
Log jam	1	12
Root cavity	2	4
Hollow snag	1	1
Total	66	965

frequently used types of habitat. Otters were located at 66 different den/resting sites 95 times (e.g., more than 1 otter occupied the same den either simultaneously or independently) during the study, and were known to have occupied those sites for more than 965 den days. Of those 66 dens, 35 (53%) were beaver bank and dome lodges where the otters were known to have spent 817 (84%) den days. The remaining dens were beaver or muskrat bank dens, undermined root cavities along the bank, and, in one instance each, a fallen hollow tree and a log jam. The number of beaver lodges used and the number of bank dens used did not significantly differ (n = 6, T = 5, P=0.16), but otters spent significantly more days per den in beaver lodges (n = 13, T = -1, P<0.01).

All den sites were located in palustrine or riverine habitat (Table 11), and most of those known den sites (42 of 66) were located in beaver or man made impoundments. Otters spent more den days (89% of the known den days) in impounded habitat than in the non-impounded habitat (n = 13, T = -1, P<0.01).

Most (85%) den days spent in riverine habitat were in impounded sections of wooded tributary channels where the water was slow flowing. Dens used in nonimpounded riverine habitat consisted primarily of bank dens or lodges that were occupied for 1 or 2 days as otters moved along the river or tributary channels. All palustrine

Table 11. Numbers of river otter dens and den days located within wetland habitats classified according to Cowardin et al. (1979). Dens were located in the Grand River, Ohio, watershed during January 1987 through March 1989.

Wetland classification	Number of dens	Number of den days[a]
Riverine - lower perennial		
Emergent - impounded	1	10
Aquatic bed - impounded	17	459
Aquatic bed - no modifier	1	3
Unconsolidated bottom - impounded	6	60
Unconsolidated bottom - no modifier	23	93
Unconsolidated bottom - log jam	1	12
Total	49	637
Palustrine		
Forested (dead)/Aquatic bed-diked	3	108
Aquatic bed - impounded ditch	9	115
Scrub-shrub - impounded	3	61
Emergent - impounded	1	29
Forested (dead) - impounded	1	15
Total	17	328

[a]One den day is 1 otter spending 1 day at a den site.

locations were in beaver impounded or man-made marshes and ditches. Occasionally otters moved to a den site previously occupied by a different otter, so perhaps the odor of the former occupant was a stimulus for occupying a particular den site.

Discussion

Otters tended to occupy beaver or diked and ditched impoundments when exploiting an area for extended periods, using nonimpounded riverine habitat as travel corridors between these areas. During summer and early autumn, the 7 Louisiana otters denned away from the main river channel and were located exclusively in palustrine or impounded riverine habitat. Otters in Colorado also increased their use of beaver impoundments during the summer months, decreasing their use of river and stream habitat (Mack 1985). Beaver impoundments have been shown to have a greater density of fish, which may be why impounded habitat was used so frequently (Hanson and Campbell 1963).

Impoundment of riverine channels also reduces the current velocity, increasing retention of sediment and organic matter (Naiman et al. 1986) while reducing stream silt loads as much as 90% (Brayton 1984). Increased sedimentation makes water clearer, allowing otters to forage more effectively. Green (1977) reported that captive otters required 4 times longer to locate a prey object in murky water than in clear water. The Grand River is extremely turbid year round; often a definite gradient from clear to turbid could be seen where impounded tributaries flowed into the main river channel. Although no measurements were made, palustrine and impounded riverine habitats appeared clearer, with visibility often extending to the bottom as much as 2 m deep (personal observation). Mudminnow remains were identified in scats collected from impounded wetlands, supporting this conjecture, because mudminnows are usually located in undisturbed, clear water areas (Trautman 1981:242). Yeager (1938) and Foy (1984) similarly reported that deep, muddy rivers are used least by otters when alternative habitat exists. However, the riverine habitat is important as a corridor for movement within the watershed.

Beaver lodges also appeared to be of importance to otters reintroduced into Ohio. Beaver lodges are well insulated, and usually have underwater entrances that allow access under ice during the winter freeze. This was once observed, when, after a fresh snowfall, otter tracks were visible near a bank lodge and in the middle of an impoundment at a dead snag, but not between. The otter went underwater from the lodge and came up where the ice was thinner around the dead snag. Ice is thinner at riffles and beaver dams as well, allowing access into and out of the water. Otter tracks and fish remains, particularly large carp, were often found near open water around beaver dams.

Overall, the Grand River watershed appears to offer exceptional habitat for river otters, providing the diversity of features required for their survival. I feel the otters were keying on a variety of factors when selecting habitat, including prey concentration and availability, water clarity, available den sites, access under ice, previous occupation by other otters, and protection/security of the surrounding habitat. Associated wetlands away from the main river channel offer the greatest diversity of habitat features favorable to otters. That otters were often found in beaver impoundments supports the argument that a facultative commensal relationship exists between otters and beavers. However, otters can exist in a strictly riverine habitat as well, although at lower densities (Erickson et al. 1984), providing the channel contains sufficient structure, riparian cover, prey, and den sites. As long as the Grand River and its tributaries are allowed to remain in their present complex state, otters should become established and thrive in the watershed.

FEEDING HABITS

Introduction

River otters are opportunistic predators that feed primarily on fish, crayfish, and amphibians; however they also will eat birds, mammals, and even insects. Ryder (1955) hypothesized that otters feed on fish primarily in proportion to their abundance and in inverse proportion to swimming speed. I argue that rather than feeding on fish in inverse proportion to swimming speed, otters feed on fish based on availability to the otter, of which swimming speed is one component. Availability of prey also is influenced by such factors as habitat of prey, detectibility and agility of prey, the effect of ice during winter, water depth and temperature, and seasonal changes in prey abundance and distribution (Sheldon and Toll 1964, Route and Peterson 1988). Abundance and availability of prey can influence survival, movements, and spacing of otters.

Fish comprise the major component of an otter's diet, occurring with few exceptions in 70 to 100% of all scat and intestinal samples studied (Appendix D). Size and species of fish consumed however, varies considerably, ranging from minnows <6 cm (Hamilton 1961, Wise et al. 1981, Melquist et al. 1981) to spawning salmon >40 cm (Toweill 1974, Melquist et al. 1981). Erlinge (1968) reported that captive European otters (Lutra lutra) consumed highly motile prey less frequently than less motile prey, and that intermediate-sized fish (15 to 17 cm) were taken before small-sized fish, presumably because of their greater vulnerability, increased caloric value, and ease of handling. Otters had difficulty capturing fish less than 10 cm in length. Mack (1985) also noted that no fish less than 10 cm were consumed by otters reintroduced into Colorado. Liers (1951) reported that raising otters exclusively on fish could result in death to otters due to a Vitamin B deficiency, indicating the importance of other dietary components as well.

Crayfish and amphibians also comprise a substantial portion of otter diets when and where available (Appendix D). Otters released into the Grand River watershed should feed heavily on amphibians and crayfish during warm months when these organisms are most available. As temperatures decrease, frogs and crayfish burrow into the sediments to hibernate, becoming less available; at the same time, fish become more lethargic and probably more vulnerable. Otters should exploit easier-to-catch crayfish and amphibians during the warm months when they are abundant and more available, and prey more heavily on fish during colder periods when fish become more vulnerable.

Methods

Feeding habits were determined by identifying scales, bones, exoskeletons, and other undigested hard parts contained in otter scats. River otter scats were collected as they were encountered. Location and date of collection were recorded at the time of collection. Each scat was placed in a beaker containing a protein-cleansing detergent solution and was agitated for 15 minutes with a magnetic stirrer to remove mucous and dirt deposits. It was then rinsed through a 1-mm mesh ceramic sieve and placed in a drying oven.

Each scat was examined under a 10-25-power zoom dissecting microscope. The identity of fish scales, bones, hair, and other hard parts was determined with a key to fish scales (Lagler 1947) and with a reference collection developed during the study. Prey types were classified into the following categories: fish, crayfish, amphibians, birds, and mammals. Fish were further identified to Family to determine if the types of fish consumed differed seasonally. The frequency of occurrence of each prey type was determined for the period from October to March, hereafter referred to as cold months, and for the period from April to September, hereafter referred to as warm months. Insects, primarily beetles (Coleoptera) and flies (Diptera), occurred in a few scats from April to September, but I feel that insects were feeding on the scat after it was deposited, rather than having been fed upon by the otter. Therefore, insects were not included. The $\underline{X}^2$ test for homogeneity was used to investigate whether prey selection by otters differed between warm months (April to September) and cold months (October to March).

Results

I examined 462 scats containing the remains of prey consumed by 13 otters -- 343 collected from October to March and 119 collected from April to September. Fish (primarily sunfishes, catfishes, carp, and suckers) were the most frequently consumed prey during cold months. Amphibians and crayfish also contributed substantially to otter diets during these months (Fig. 4). Fish were frequently consumed during warm months as well (Fig. 4), but the percent frequency occurrence of sunfishes and suckers decreased, and the percent frequency occurrence of mudminnows increased significantly (Table 12). Consumption of crayfish and amphibians also increased significantly during warm months. Birds and mammals were unimportant to otter diets.

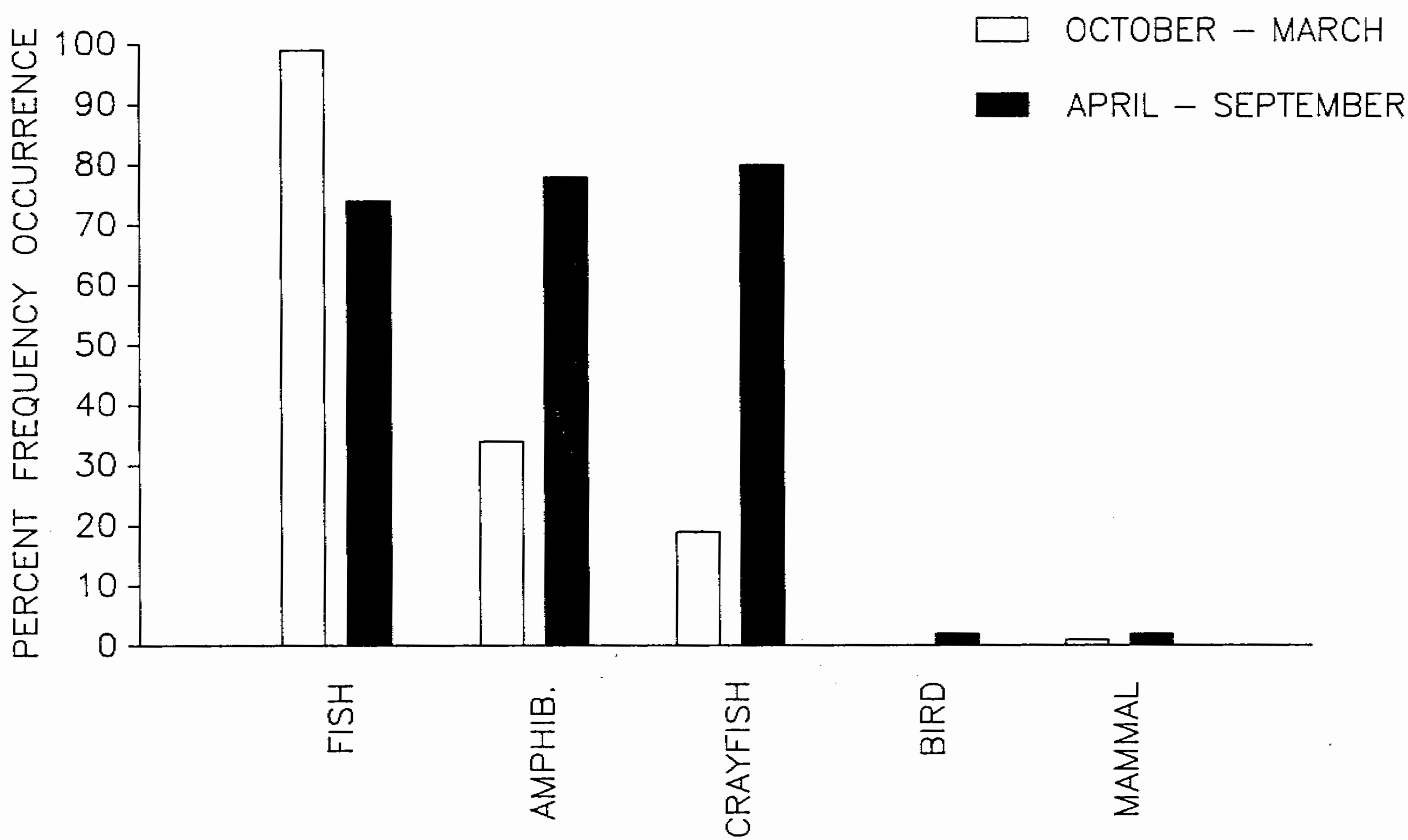


Fig. 4. Percent frequency occurrence of prey items identified in river otter scats collected in the Grand River, Ohio, watershed during cold months (N=343) and warm months (N=121). Scats were collected from January 1987 to March 1989.

Table 12. Percent frequency occurrence of prey items identified in river otter scats collected in the Grand River watershed during cold months (October to March) and warm months (April to September). Scats were collected from January 1987 to March 1989. Differences in percent frequency occurrence between cold months and warm months were tested for significance using the X^2 test for homogeneity.

Prey type	Percent frequency occurrence: Cold months (*n*=343)	Warm months (*n*=119)	X^2	*P*
Fish	99.1	73.9	9.03	.0001
Carp	28.6	0.0	6.56	.0001
Other cyprinids	8.4	1.7	2.55	.01
Catostomidae	15.7	1.7	4.04	.0001
Centrarchidae	85.1	27.1	11.78	.0001
Esocidae	2.3	0.0	1.70	.089
Ictaluridae	29.4	12.6	3.66	.001
Percidae	1.4	0.0	1.34	.194
Umbridae	1.2	52.9	13.80	.0001
Amphibian	34.1	78.2	8.31	.0001
Crayfish	19.0	79.8	12.02	.0001
Bird	0.0	1.7	2.45	.014[a]
Mammal	<1.0	1.7	1.14	.250

[a]The difference is not considered to be biologically significant due to the extremely small sample.

Discussion

Prey with a large proportion of hard material, such as crayfish and small cyprinids, may tend to be overestimated in feeding studies based on scat analysis. However, scat analysis, calculated by frequency of occurrence, still gives a reasonable assessment of the relative importance of different food categories (Erlinge 1968). Otters released in the Grand River consumed a variety of organisms. As expected, fish, crayfish, and amphibians contributed most to otter diets. High frequency of occurrence of crayfish and amphibians during warm months is probably due to the abundance and availability of these groups of organisms during these months. Amphibians and crayfish were frequently observed throughout the watershed into late September. However, they burrow into the sediments to overwinter during unfavorable low temperatures usually occurring from November to April, making them less available.

Other investigators also have noted the importance of crayfish to otters (Liers 1951, Wilson 1954, Ryder 1955, Hamilton 1961, Knudson and Hale 1969, Sheldon and Toll 1974, Toweill 1974, Serfass et al. 1986, Route and Peterson 1988). Delibes and Adrian (1987) reported that crayfish replaced fish as the most important prey item for European otters in Guadalquivir marisimas, Spain, only 7 years after the exotic crayfish were introduced.

This illustrates the adaptability of otters to readily switch prey types as the abundance and availability of those prey types changes.

Significant increases in the occurrence of carp, sunfishes, and suckers in otter diets during cold months probably occurred for 2 reasons: 1) amphibians and crayfish became less available as they burrowed into the sediments to overwinter, causing the otters to prey more on fish, and 2) fish become much more lethargic and probably easier to catch as the surrounding water temperature decreases. Evidence to support this comes from this and other studies. Tumlinson and Karnes (1987) noted that fish were preyed upon more than crayfish during low water levels as the usually easier-to-catch crayfish burrowed into the mud and fish became concentrated. Crayfish were preyed upon more frequently during other times of the year. Wise et al. (1981) also noted that European otters in Devon, England, diversified more into non-fish prey during the summer when fish became less available. Other examples of otters adapting to changes in availability are provided by Toweill (1974) and by Melquist et al. (1983). They both noted increases in consumption of salmon during the periods when salmon were spawning.

During winter 1987, partially eaten carcasses of more than 25 large carp, varying in size from 51 to

86 cm, were observed on the ice and shore near beaver dams and open water riffles where otters were observed entering and exiting the water. No carp carcasses were observed along the shore during summer months and no remains were found in summer collected scats. Consequently, large carp were probably available to otters only during the winter months when the water temperature was such that even the largest fish were lethargic and easy to catch, and the cost of handling was less than the benefit gained by capturing such large prey. No other studies have reported prey as large as this being captured and consumed by otters.

The high frequency of mudminnows in otter diets from April to September was unexpected because of their (mudminnows) small size. Adult mudminnows usually range from 5 to 10 cm in length. Mudminnows are normally present in abundance in undisturbed, clear-water areas of low gradient where bottoms are of organic debris, muck, peat, and aquatic vegetation (Trautman 1981:242); conditions found in many of the Grand River's associated wetlands and beaver impoundments. Mudminnows burrow into the soft bottom sediment to hide, rest, or aestivate, and probably were encountered as otters foraged for frogs, crayfish, and other benthic prey. Ninety-seven percent of the scats containing mudminnow remains also contained frog and/or crayfish remains, supporting this conjecture.

The results of this and other studies (see above citations) illustrate the opportunistic foraging behavior of otters. Prey availability is determined by a complex interaction of environmental, physiological, and ecological factors that continuously change. Otters respond these changes by shifting their diet to the most abundant and/or available prey resources at the time. The diversity of prey types and the range of prey sizes ($<$ 6 cm (mudminnows) to $\geq$ 86cm (carp)) consumed by otters in the Grand River watershed illustrate this well. The Grand River and its associated tributaries and wetlands are very productive and complex, and offer the diversity of prey resources to easily sustain a population of river otters.

RECOMMENDATIONS

Habitat components necessary to support river otters are available in the Grand River watershed. The major limiting factor in this study appeared to be female otters. Males would be less likely to disperse great distances, as they did in the Grand River, if the sex ratio was 1:1. The Ohio Division of Wildlife plans to release 20 additional otters (10M:10F) into the Grand River when they become available. The greatest immediate threat to these and future otters could come from clearing or channelizing the river channel and its tributaries, and/or from reduced water quality. The U. S. Army Corps of Engineers currently is conducting a study to determine the feasibility of constructing a reservoir/canal system connecting Lake Erie to the Ohio River. Although unlikely, if built, this would destroy much of the existing wetlands within the watershed. A more immediate threat comes from landowners whose property along the river has been flooded. They have requested their legislators take steps to clear debris (fallen trees) from the river to help prevent future flooding.

If the habitat remains undisturbed, but no additional otters (other than the additional 20 currently planned) are reintroduced, then the long-term limiting factor will be genetic diversity. The Grand River population, even with 20 additional otters, will still represent a small, founder population, especially if not all 20 additional otters breed. Over time, a small, finite population such as this experiences a loss of important alleles and a reduction in genetic variability. The speed with which variability decays is directly related to the effective population size, which in polygynous river otters is the number of breeding females and probably a small proportion of the males (Soulé 1987). Loss of genetic variability can lead to inbreeding and reduced fitness, and as a result, variable alleles may become homozygous, including deleterious recessive alleles. Inbreeding has also been linked to increased juvenile mortality, decreased birth weight, and reduction of viability and fertility (Ralls and Ballou 1983).

If loss of alleles and the rate at which genetic variability decays in the small population is to be slowed or prevented, new otters must be added to the population. Establishing other populations of otters that could allow immigration is one way to add new alleles and reduce the decline in genetic variation over time. A panmixa can also be artificially achieved by moving as few as 1 or 2 individuals at random into the population per generation, providing that the individuals actually reproduce (Chesser 1983). In polygynous species such as otters, additional females will almost certainly reproduce and add new genetic variation to the population. A successfully breeding male can rapidly add even more genetic variability to the population, but his success of breeding is not as certain as that of the females because other, established males will be vying for the same females. Foose (1983) recommended releasing pairs into a small population, rather than just one sex, to mitigate a depression of the effective population size that can occur when there is a disproportionate number of males or females reproducing. Therefore, both males and females should periodically be added to the population(s) to ensure genetic variability.

Management Recommendations

1. Obtain at least 20 additional otters for immediate release into the Grand River. Persons providing otters should be required to follow the recommendations by Shirley et al. (1983) for trapping and moving otters, and a squeeze box should be used to restrain otters (McCullough et al. 1986).
2. Monitor the population via aerial snow track

surveys, ground track surveys, and by reports of otter sightings by the public.

3. Determine the feasibility of establishing additional populations of otters in northeastern Ohio so immigration can occur.
4. Release additional breeding otters into the population(s) at regular intervals to maintain genetic variability and to reduce the chances of inbreeding and of deleterious lethal alleles being expressed. This should continue until other otter populations in Ohio, Pennsylvania, and/or West Virginia expand to allow natural immigration to occur.
5. Take precautions to ensure that the Grand River corridor and its associated wetland habitats, as well as other potential reintroduction sites, maintain high water quality and remain unchannelized, uncleared, and free of major human impacts.

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APPENDICES

APPENDIX A

Statistics of otters reintroduced into the Grand River, Ohio, in December-January 1986-87 and May 1988, and the fate of those otters.

Table 13. Statistics of otters releases in the Grand River, Ohio, in December-January 1986-87 and May 1988, and the fate of those otters.

Animal number	Sex	Weight (kg)	Total length (cm)	Tail length (cm)	Chest girth (cm)	Arrived	Released	Fate
M000	M	4.9	102.2	35.6	30.5	12/24/86	No	Died 12/24/86 following anesthesia
F001	F	5.1	108.0	39.4	33.0	12/24/86	No	Escaped on 1/10/87-Was not implanted
F002	F	3.9	101.0	38.1	30.5	12/28/86	No	Died in captivity on 12/28/86-Was not implanted
M003	M	5.3	-----	----	----	12/28/86	No	Died in captivity on 12/28/86-Was not implanted
F004	F	---	-----	----	----	1/8/87	No	Died in captivity on 1/9/87-Was not implanted
M030	M	7.9	119.4	43.2	38.4	12/24/86	12/26/86	Died 12/26-12/27/88
M050	M	9.6	116.0	42.0	42.2	5/7/88	5/12/88	Killed in 330 Connibear on 1/18/87

Table 13. Continued.

Animal number	Sex	Weight (kg)	Total length (cm)	Tail length (cm)	Chest girth (cm)	Arrived	Released	Fate
F110	F	5.1	105.3	38.7	34.9	12/20/86	12/21/86	Died on 12/21/86
M171	M	7.8	115.6	39.5	37.5	12/20/86	12/21/86	Died on 12/22/86
F190	F	8.7	112.8	40.5	43.8	5/7/88	5/12/88	Last monitored on 9/9/89
F220	F	6.4	105.0	33.0	37.5	5/7/88	5/10/88	Died on 6/3/88
F240	F	7.1	111.5	38.5	38.2	5/7/88	5/12/88	Last monitored on 9/9/89
M260	M	11.1	128.0	44.5	45.1	12/28/86	12/29/86	Last monitored on 2/13/88
M329	M	8.1	117.5	41.0	40.0	12/20/86	12/21/86	Last monitored on 7/24/88
M350	M	5.5	106.0	38.1	36.2	12/24/86	12/26/86	Died on 12/26/86
F452	F	4.1	101.6	37.5	29.5	1/8/87	No	Died in captivity on 1/8/87-Was not implanted
F4625	F	7.6	120.7	40.0	40.0	1/8/87	No	Died in captivity on 1/10/87

Table 13. Continued.

Animal number	Sex	Weight (kg)	Total length (cm)	Tail length (cm)	Chest girth (cm)	Arrived	Released	Fate
M463	M	8.5	113.3	39.5	42.7	5/7/87	5/12/88	Last monitored on 11/29/88
M4875	M	8.4	117.5	41.9	41.6	1/8/87	1/26/87	Killed by automobile on 3/11/87
M5125	M	9.5	118.7	41.9	43.2	1/8/87	No	Died in captivity on 1/9/87
M513	M	8.9	120.2	42.7	41.4	5/7/88	5/12/88	Last monitored on 3/15/89
F5875	F	5.5	103.2	33.7	40.3	12/20/86	12/21/86	Died between 12/24 and 12/31/87
M588	M	9.1	128.0	45.5	42.6	5/7/88	5/12/88	Last monitored on 1/19/89
M662	M	4.7	108.7	33.7	40.3	12/20/86	12/21/86	Killed by automobile on 2/2/88
M6375	M	7.9	117.5	43.8	43.2	12/28/86	12/29/86	Killed in Connibear trap on 2/15/87

Table 13. Continued.

Animal number	Sex	Weight (kg)	Total length (cm)	Tail length (cm)	Chest girth (cm)	Arrived	Released	Fate
F6875	F	5.3	104.6	35.3	34.6	12/20/86	12/21/86	Died on 2/22/87
F6875(2)	F	8.0	114.5	38.7	38.4	12/24/86	No	Died in captivity on 12/26/86
M688	M	10.2	127.0	42.5	45.0	5/7/88	5/12/88	Last monitored on 1/19/89
M870	M	7.2	115.2	41.9	37.5	12/20/86	12/21/86	Died on 12/21/86
M870(2)	M	7.0	119.4	43.2	37.5	12/24/86	12/26/86	Died on 12/26/86 following surgery
M890	M	8.0	119.4	41.9	43.2	12/24/86	12/26/86	Last monitored on 3/3/87

APPENDIX B

Necropsy results from otters obtained for reintroduction into Ohio.

Male #M000

History: Presented on 12/24/86. He died within 2 minutes of anesthetization.

Necropsy: The lungs showed massive areas of swelling and hemorrhage. Free blood and clots were present in the thoracic and abdominal cavities. The spleen was ruptured with a moderate amount of local clotting. Bruises were present along the inside right surface of the abdomen, and there were large hemorrhagic areas of subcutaneous bruising on the dorsal and lateral aspects of the thorax and abdomen. There was no body or tail fat and the stomach and gastro-intestinal (GI) tract were empty.

Cause of death: Shock, trauma, and splenic rupture.

Female #F002

History: Presented on 12/28/86. She was anesthetized, and upon physical examination was found to be thin and hypothermic (35 ^{C}). She was vaccinated, given antibiotic and steroid injections, and was kept in a warm room. She died 2 hours later.

Necropsy: Small hemorrhages were present on the apical lobe of the left lung. The lungs were swollen and purplish in color. Blood was present in the intestinal tract and petechial hemorrhages were present throughout the stomach and entire GI tract. Large hemorrhagic areas of subcutaneous bruising were present over the dorsal and lateral thoracic regions. Her stomach was empty and she was lacking body and tail fat.

Cause of death: Shock and trauma.

Male #003

History: Presented on 12/28/86. He was very lethargic and unresponsive in his transport cage. He was restrained for vaccination and antibiotic injections, but was not anesthetized. He was kept in a warm room and provided with food and water, but died within 30 hours.

Necropsy: There was a large laceration extending laterally from the dorsal to the abdominal region. All lung lobes were severely swollen and hemorrhagic. Approximately 80% of the lung tissue was nonfunctional. There were large hemorrhagic areas of subcutaneous bruising over the dorsal and lateral thoracic region. Gastric ulcers and black, tarry stool were present throughout the GI tract. The stomach was empty and body and tail fat were lacking.

Cause of death: Shock and trauma.

Female #004

History: Presented on 1/8/87. She was lethargic and unresponsive in the transport cage, and appeared emaciated. Her right front foot was lacerated dorsally and ventrally. Her left front foot was severely lacerated dorsally and ventrally, and all of the metacarpals were broken and exposed. She was restrained for vaccination and antibiotic injection, but was not anesthetized. She was kept under a heat lamp throughout the night and was placed in an outdoor holding pen the following day. She died that night.

Necropsy: There was bruising on the left lung lobes with pneumonic lesions present on all lobes. The adrenal glands were enlarged and hemorrhagic. Ulcers and frank hemorrhages were present throughout the GI tract. This animal was extremely emaciated with no body or tail fat. She was in fact in a catabolic state with deteriorating muscle mass.

Cause of death: Starvation with subsequent trauma, shock, and stress.

Male #030

History: Presented on 12/24/86 with excoriated, thickened, and inflamed scrotal epithelium. He was anesthetized, the scrotum was treated. A radio transmitter was surgically implanted. He was held for 2 days before being released on 12/26/86. He died less than 6 hours after release.

Necropsy: The pericardial sac was full and hyperextended with serosanguinous fluid. There was food in the stomach and the stool in the GI tract appeared normal. Large, hemorrhagic areas of subcutaneous bruising were present between shoulders and ventrolaterally along the left thoracic area. There was a minimal amount of body fat and tail fat, and the lungs appeared normal.

Cause of death: Trauma resulting in pericardial effusion and subsequent strangulation of the heart.

Male #050

History: Presented on 1/19/89 after being caught in a 330 Conibear trap set for beaver. A radio transmitter was surgically implanted and was released on 5/12/88.

Necropsy: The animal appeared to be in excellent condition There were no visible internal or external injuries, and no visible negative reactions to the transmitter were apparent. He had gained 1.4 kg since his release 8 months earlier.

Cause of death: Drowning associated with accidental capture in an underwater set 330 Conibear trap.

Female #110

History: Presented on 12/20/86 with the left front foot severely lacerated dorsally and ventrally and the middle carpals broken and exposed. The leg was swollen to the middle of the radius/ulna region. She was anesthetized, the foot was surgically repaired, she was vaccinated and injected with antibiotics, and a radio transmitter was surgically implanted. Her body temperature was depressed during the surgery (34.4 C) and she was slow to recover from the anesthesia. She appeared normal the following morning and had a normal temperature. She was held overnight and released the next morning. She died soon after release.

Necropsy: The apical lobe of the right lung was severely swollen, hemorrhagic, and pneumonic with all of the lobes having a purplish discoloration. Gastric ulcers with free blood and clots were present in the stomach, and black tarry stool was present throughout the GI tract. The mesenteric nodes were enlarged and hemorrhagic as were the adrenal glands. There were large hemorrhagic areas of subcutaneous bruising over the dorsal thoracic area. There was no food in the stomach, and body and tail fat was lacking.

Cause of death: Shock and trauma.

Male #171

History: Presented on 12/20/86 with dorsal and ventral lacerations on the left front foot and with exposed metacarpal joints. The leg was swollen to the elbow. He was anesthetized, the foot was surgically repaired, and one 00 buckshot was removed from the dorsal neck region. He was vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. He was held overnight and released the following morning. He died 30 hours later.

Necropsy: All lung lobes were swollen, pneumonic, and hemorrhagic with purplish discoloration. There were gastric ulcers present and the entire GI tract was empty. The mesenteric nodes were enlarged and hemorrhagic as were the adrenal glands. There were large hemorrhagic areas of subcutaneous bruising over the dorsal and right lateral thoracic area. The stomach was empty and body and tail fat was lacking.

Cause of death: Shock and trauma.

Female #F220

History: Presented on 6/3/88. She was vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. She appeared to be in excellent condition when released on 5/10/88.

Necropsy: The weight of this animal at necropsy represented about a 50% loss from the time of her release on 5/10/88. She was very thin, about 10 to 15% dehydrated, and uniformly jaundiced. Gross necropsy revealed a discolored and slightly swollen liver. Her lungs were uniformly discolored with focal pneumonic areas and focal areas of consolidation throughout. There was frank hemorrhage throughout the length of the large intestine. Some large intranuclear inclusion bodies were present within liver and lung lesions. There was focal hepatitis with associated hepatocytic necrosis in the liver. Numerous microfilaria were present within the vessels and parenchyma of the lungs and the liver.

Cause of death: Adenovirus infection (infectious canine hepatitis), and microfilariasis (canine heartworm larvae). Either of these 2 diseases if present alone could have been responsible for death, but, the hepatitis was the more fulminating of the 2 at the time of death. It is probable that the animal was incubating these diseases at the time of her arrival into Ohio.

Male #350

History: Presented on 12/24/86 with the right front foot swollen and superficial lacerations on the third and fourth digits. He was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. He appeared to have a good appetite and was released on 12/26/86. He died 6 hours later.

Necropsy: All lung lobes were pneumonic, swollen, and hemorrhagic. The dorsal lung lobes had areas of pneumonia. There were large hemorrhagic areas of subcutaneous bruising in the dorsal and lateral thoracic regions. His stomach was full and the stool in the GI tract was normal looking, but body and tail fat was lacking.

Cause of death: Pneumonia, shock, and trauma.

Female #F452

History: Presented on 1/8/87 emaciated with her left front foot severely lacerated dorsally and ventrally, and all of her metatacarpals were exposed and the pad edematous. She was anesthetized, vaccinated, and injected with antibiotics. All but the second left front metacarpals were amputated and the wounds were sutured closed. She was not implanted with a radio transmitter, and began recovering from the anesthetic within 45 minutes. She died soon after recovering from the anesthesia.

Necropsy: All lung lobes were swollen, atelectic and hemorrhagic; approximately 90% of the lung tissue was non-functional and purple-brownish in color. There was a massive amount of free blood in the thoracic cavity. There were large areas of hemorrhagic subcutaneous bruising along the dorsal and lateral body surfaces. Body fat was lacking and no food or fecal material was present in the GI tract.

Cause of death: Shock and trauma.

Female #F4625

History: Presented on 1/8/87 with left rear foot severely lacerated dorsally and ventrally with all metacarpals broken and exposed. She was anesthetized, vaccinated, and injected with antibiotics. A radio transmitter was surgically implanted, and all but the second left rear metacarpals were amputated and the wounds sutured closed. During the surgical procedure her heart rate weakened and respirations ceased. She was given pericardial injections of epinephrine and dopram, after which both functions returned to near normal. She was very slow recovering from the anesthetic and was held indoors under a heat lamp overnight. She was placed in an outdoor pen the following morning and provided with food and water. She registered an extremely high temperature that afternoon, so was given another antibiotic injection.

Necropsy: All lung lobes were septic, swollen, and hemorrhagic with a purplish discoloration. The adrenal glands were enlarged and hemorrhagic. The stomach and intestinal tract were devoid of food or fecal material, but showed no signs of ulcers or hemorrhage. There was a minimal amount of body fat. This animal was pregnant with 4 implanted, developing embryos.

Cause of death: Trauma and shock.

Male #4875

History: Presented on 3/11/87 after being killed by an automobile. A radio transmitter had been surgically implanted, and he was released on 1/26/87.

Necropsy: Multiple internal and head injuries were present. No visible negative reaction to the transmitter was apparent. The animal was 1.1 kg heavier than when released.

Cause of death: Massive internal injuries, broken bones, and severe trauma associated with being run over by an automobile.

Male #5125

History: Presented on 1/8/87 with a 7-cm laceration on the left shoulder. He was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. He was placed in an outdoor pen following surgery and provided with food and water. He went into a seizure-like episode at 8:30

a.m. the following morning. He was immediately captured, treated for trauma, and placed indoors under a heat lamp. He died that afternoon.

Necropsy: Approximately 90% of the right lung and 10% of the left lung lobes were hemorrhagic and pneumonic. There were petechial hemorrhages and small ulcers throughout the GI tract. The adrenal glands were enlarged and hemorrhagic. There were hemorrhagic areas of subcutaneous bruising in the thoracic and right hip regions.

Cause of death: Cardiovascular accident (stroke), trauma, and shock.

Female #5875

History: Presented on 12/20/86. She was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. She was held overnight and released the following morning. She died sometime between 12/24 and 12/31/86.

Necropsy: The lung tissue appeared normal. There was no body or tail fat and she appeared emaciated. There were gastric ulcers with free blood and clots in the stomach and black tarry stool throughout the GI tract. The mesenteric nodes were enlarged and hemorrhagic as were the adrenal glands.

Cause of death: Shock and trauma.

Male #662

History: Presented on 2/2/88 after being killed by an automobile. He had been surgically implanted with a radio transmitter and was released on 12/21/86.

Necropsy: Multiple internal injuries were present. No visible negative reaction to the radio transmitter was apparent. The animal was 4.5 kg heavier than when released.

Cause of death: Massive trauma associated with being hit by an automobile.

Male #6375

History: Presented on 2/25/87 after being killed in a 330 Conibear trap. He had been surgically implanted with a radio transmitter and was released on 12/29/86.

Necropsy: The animal appeared to be in excellent condition. There were no visible internal or external injuries, and no visible negative reactions to the transmitter were apparent. He had gained more than 3.1 kg since from the time of his release 14 months previously.

Cause of death: Drowning associated with accidental capture in an underwater set 330 Conibear trap.

Female #6875

History: Presented on 12/20/86 with lacerations on the dorsal and ventral side of her left front foot. She was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. She was held overnight and released the following morning, but she died in less than 6 hours.

Necropsy: Approximately 70% of the lungs were swollen, pneumonic, severely hemorrhagic, and apparently non-functional. There were gastric ulcers with free blood and clots in the stomach and black tarry stools throughout the GI tract. The mesenteric nodes were enlarged and hemorrhagic as were the adrenal glands. There were large hemorrhagic areas of subcutaneous bruising over the dorsal and left lateral thoracic area. There was no food in the stomach and body fat was lacking.

Cause of death: Shock and trauma.

Female #6875(2)

History: Presented on 12/24/86. She was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. She was held for 2 days, during which time she appeared to have a good appetite. However, she became sluggish the morning of 12/26 and died before being released.

Necropsy: There were some areas of pulmonary swelling and hemorrhage. The cardiac muscle was hemorrhagic on its surface, and there was blood in the pericardial sac and free blood in the thoracic cavity. The pericardial sac was ruptured and the right ventricle of the heart had a small hole in it with evidence of a fibrinous clot at the rupture site. There were many areas of embolism over most of the surface of the liver. The stomach had food in it and the GI tract had normal appearing stool. There was a minimal amount of body and tail fat.

Cause of death: Cardiac puncture (most probably caused by trapping trauma, with evidence of an attempt to repair itself) causing exsanguination, shock, and death.

Male #870

History: Presented 12/20/86 with a swollen right front foot. He was anesthetized, vaccinated, injected with antibiotic, and a radio transmitter was surgically implanted. He was held overnight and released the next morning. He died 30 hours after release.

Necropsy: All lung lobes were swollen, pneumonic, and hemorrhagic with purplish discoloration. There were gastric ulcers present and the entire GI tract was empty. The mesenteric nodes were enlarged and hemorrhagic as were the adrenal glands. There were large areas of subcutaneous bruising between the shoulders and extending ventro-laterally along the left side.

Cause of death: Shock and trauma.

Male #870(2)

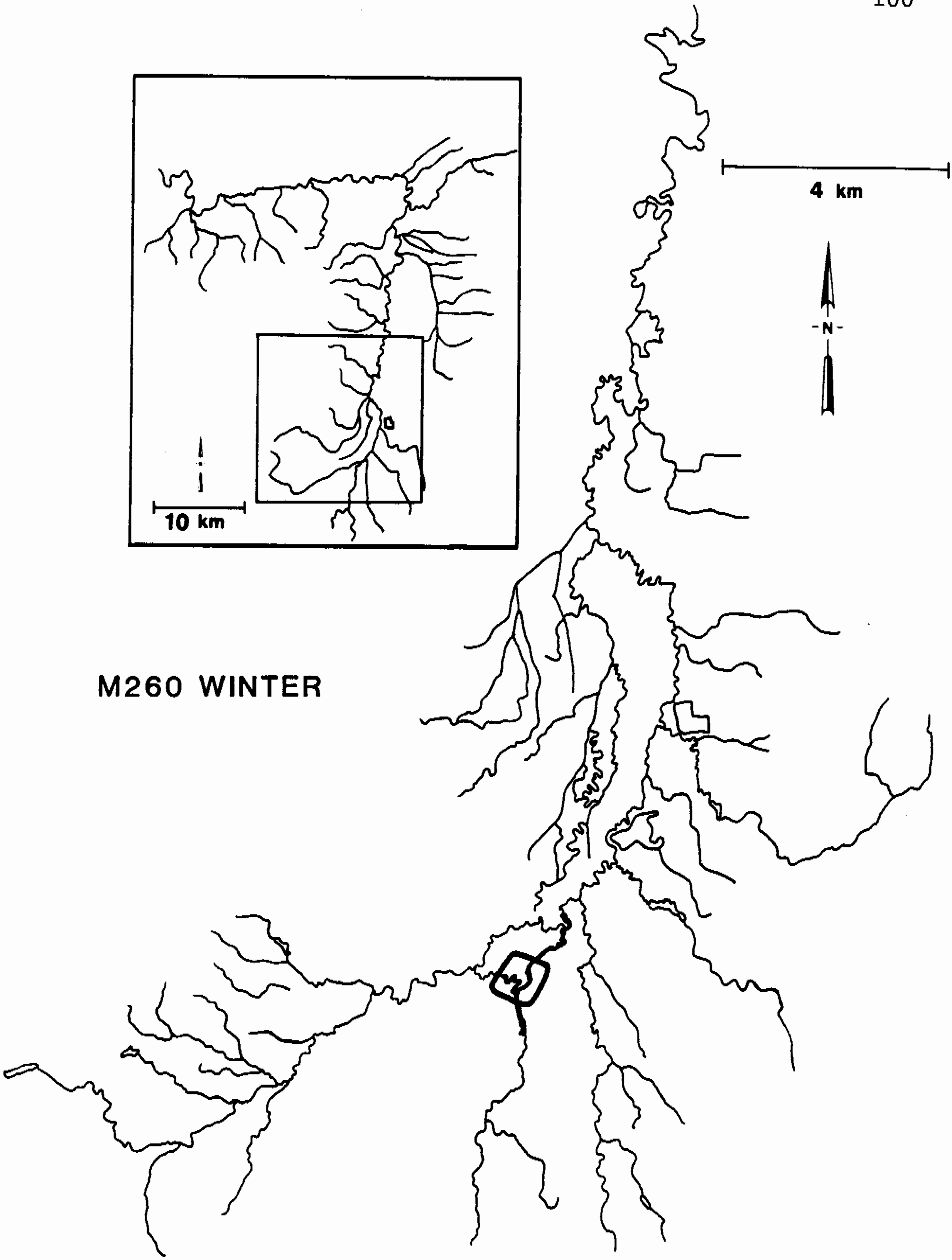
History: Presented 12/24/86 with right front digits disarticulated and exposed. The leg was swollen to the carpus. He was anesthetized, vaccinated, injected with antibiotics, and a radio transmitter was surgically implanted. He died a few minutes after surgery.

Necropsy: There were free blood and clots in the thoracic cavity. There were blood and clots in the stomach with areas of gastric ulceration, and black tarry stool throughout the GI tract. Large hemorrhagic areas of subcutaneous bruising were present over the dorsal and lateral thoracic regions.

Cause of death: Shock and trauma.

APPENDIX C

Sasonal core home ranges and length of stream used by otters released in the Grand River, Ohio. Darkened sections of streams denote use by otters (total home range). Darkened sections of stream within the illustrated core area (as determined by program HOME RANGE) represent the core length.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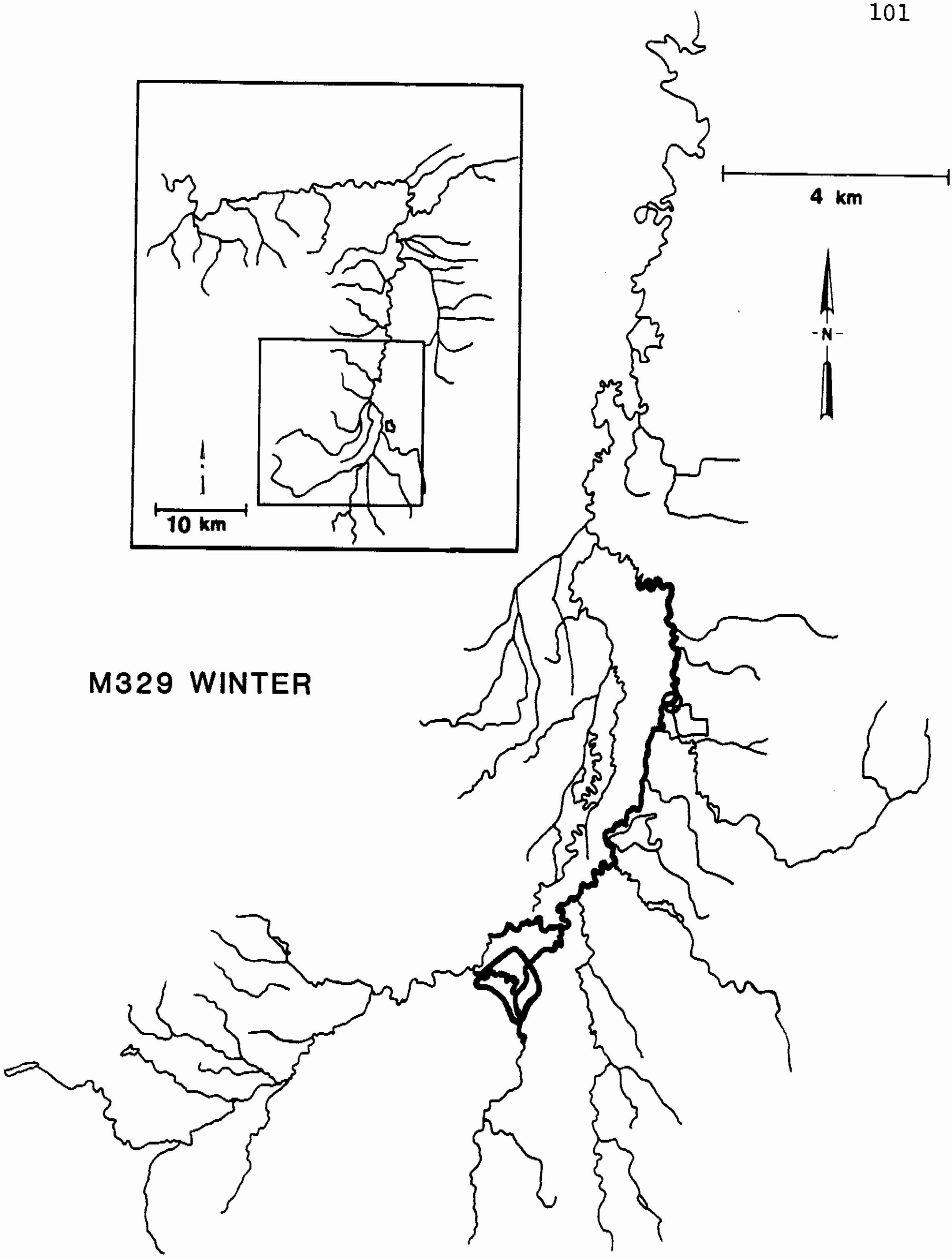
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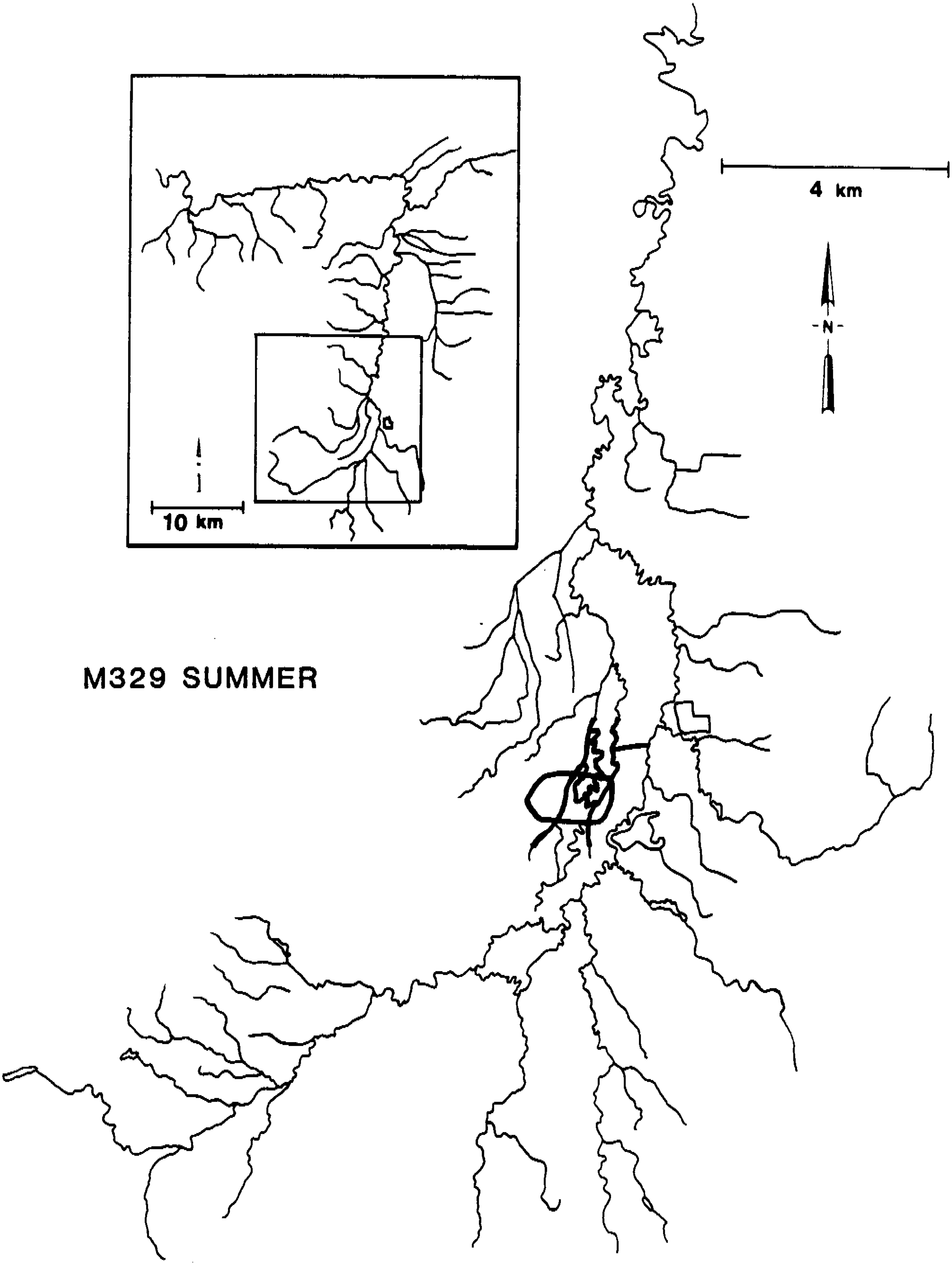
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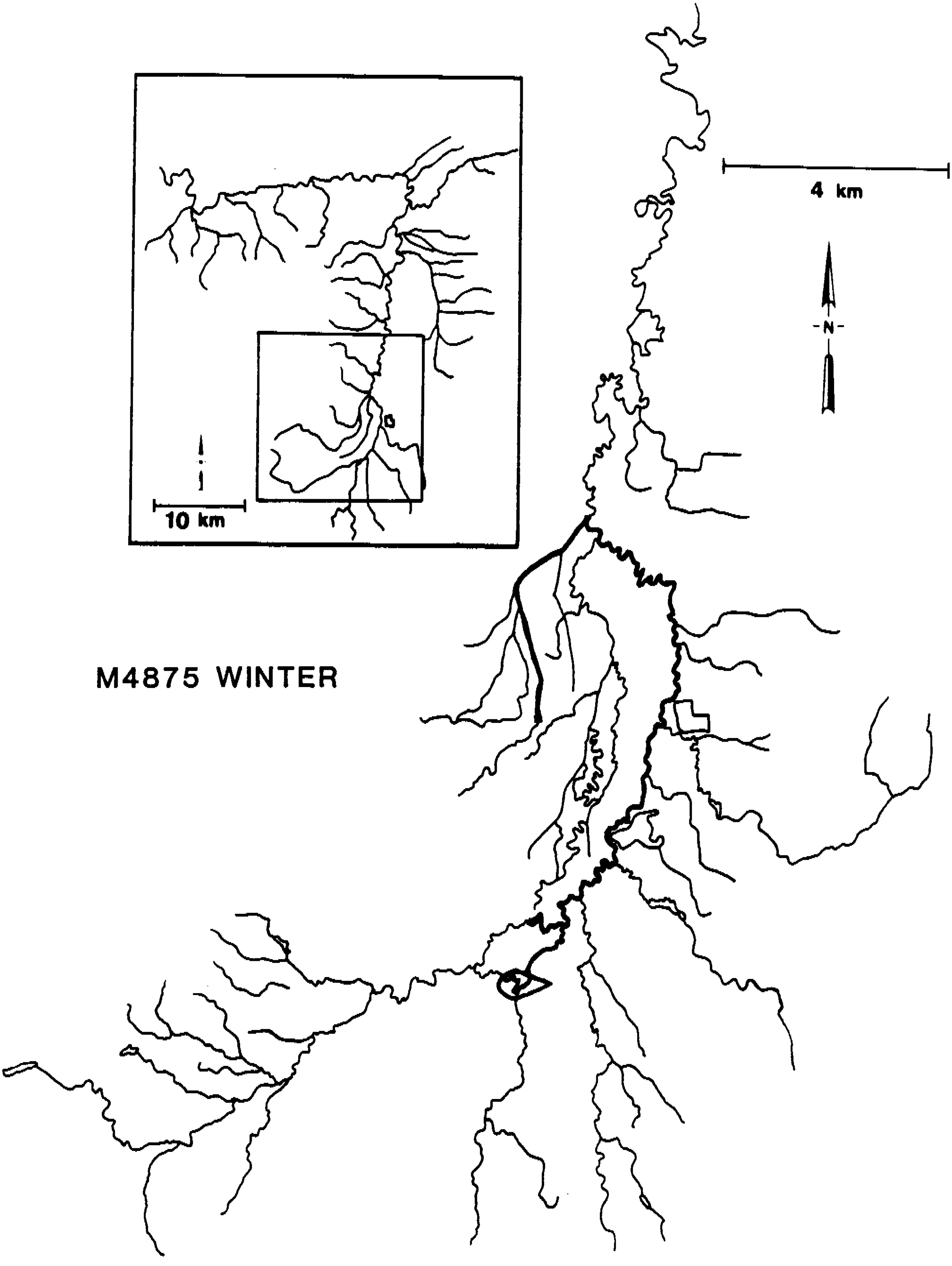
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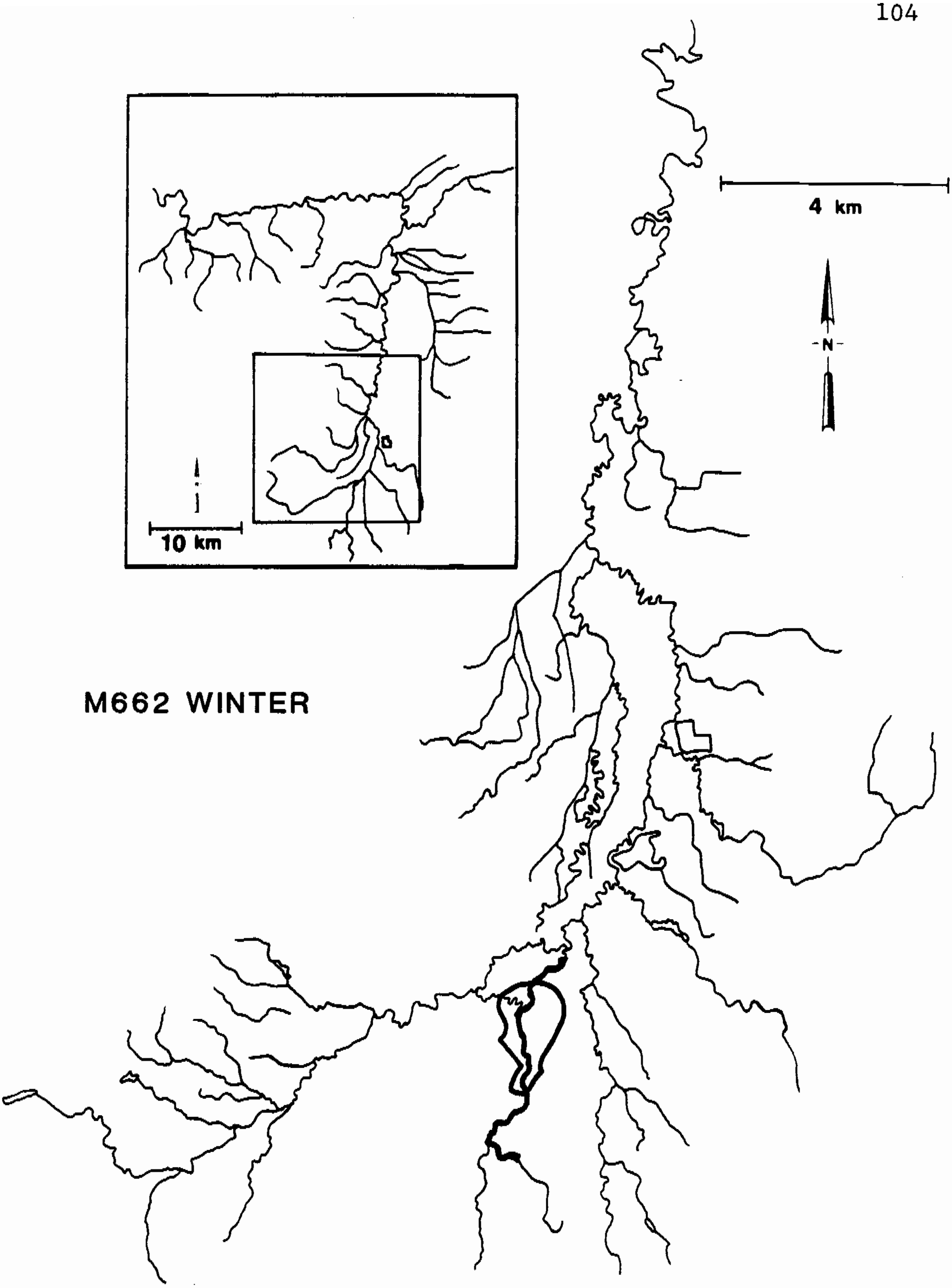
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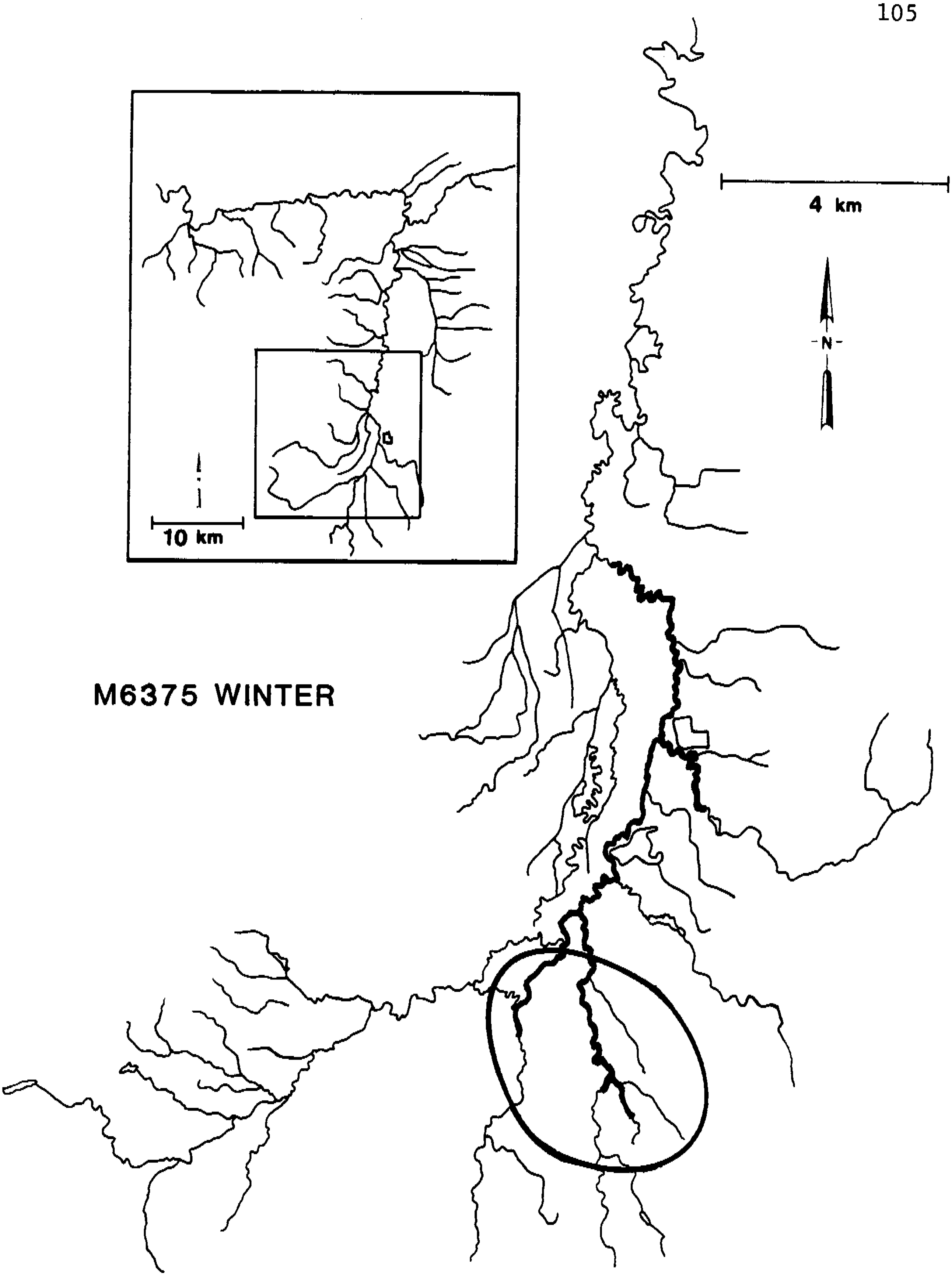
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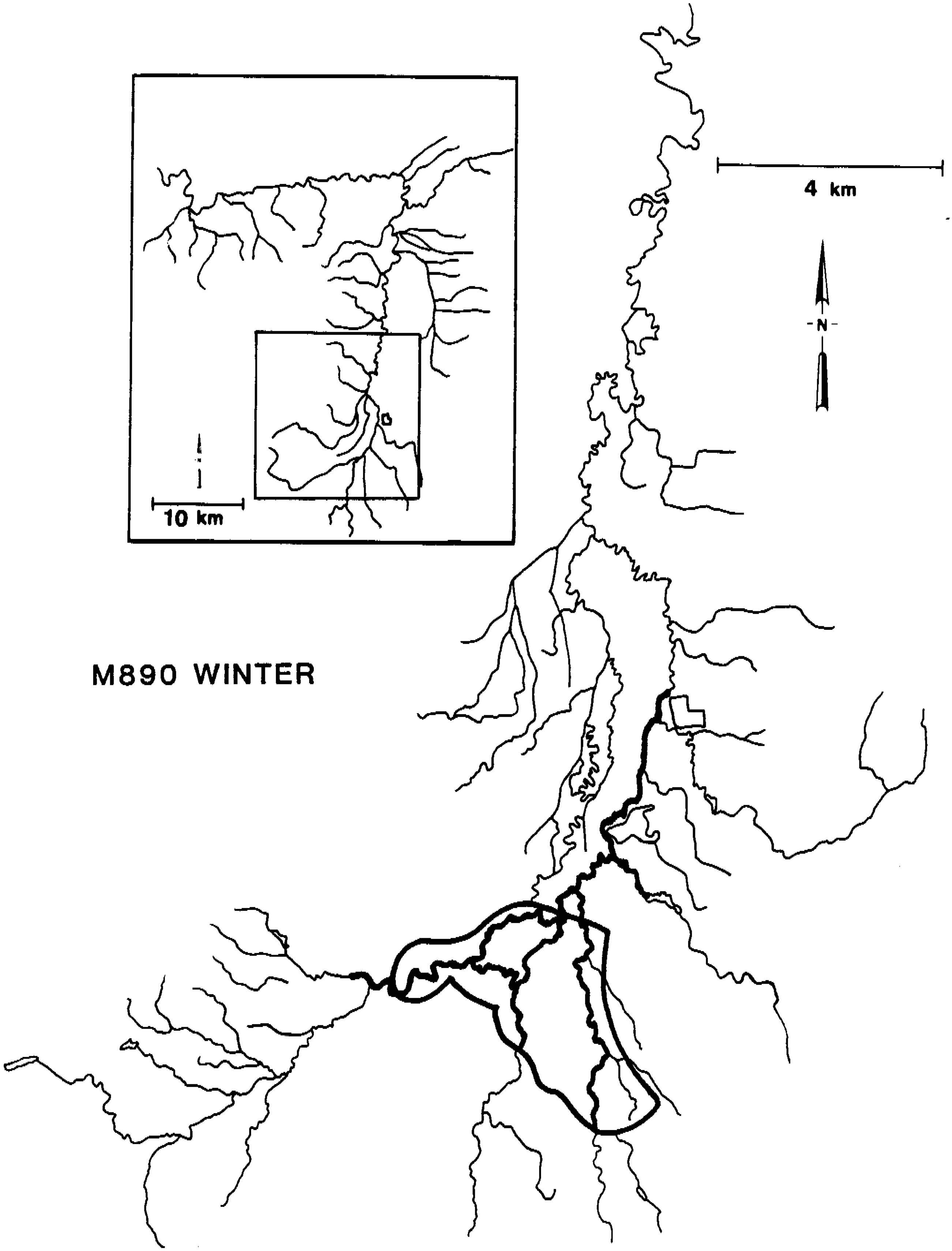
M6375 WINTER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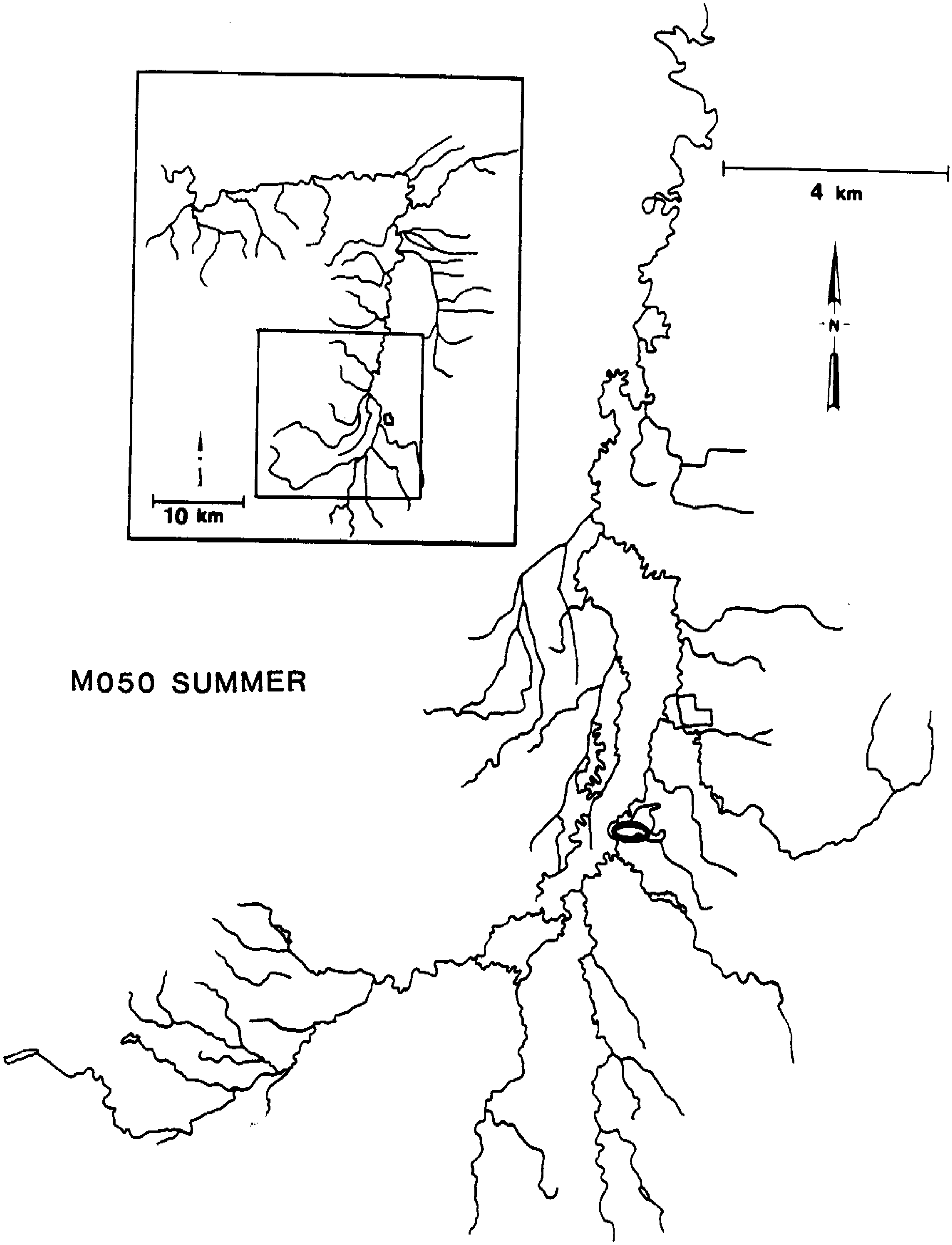
M890 WINTER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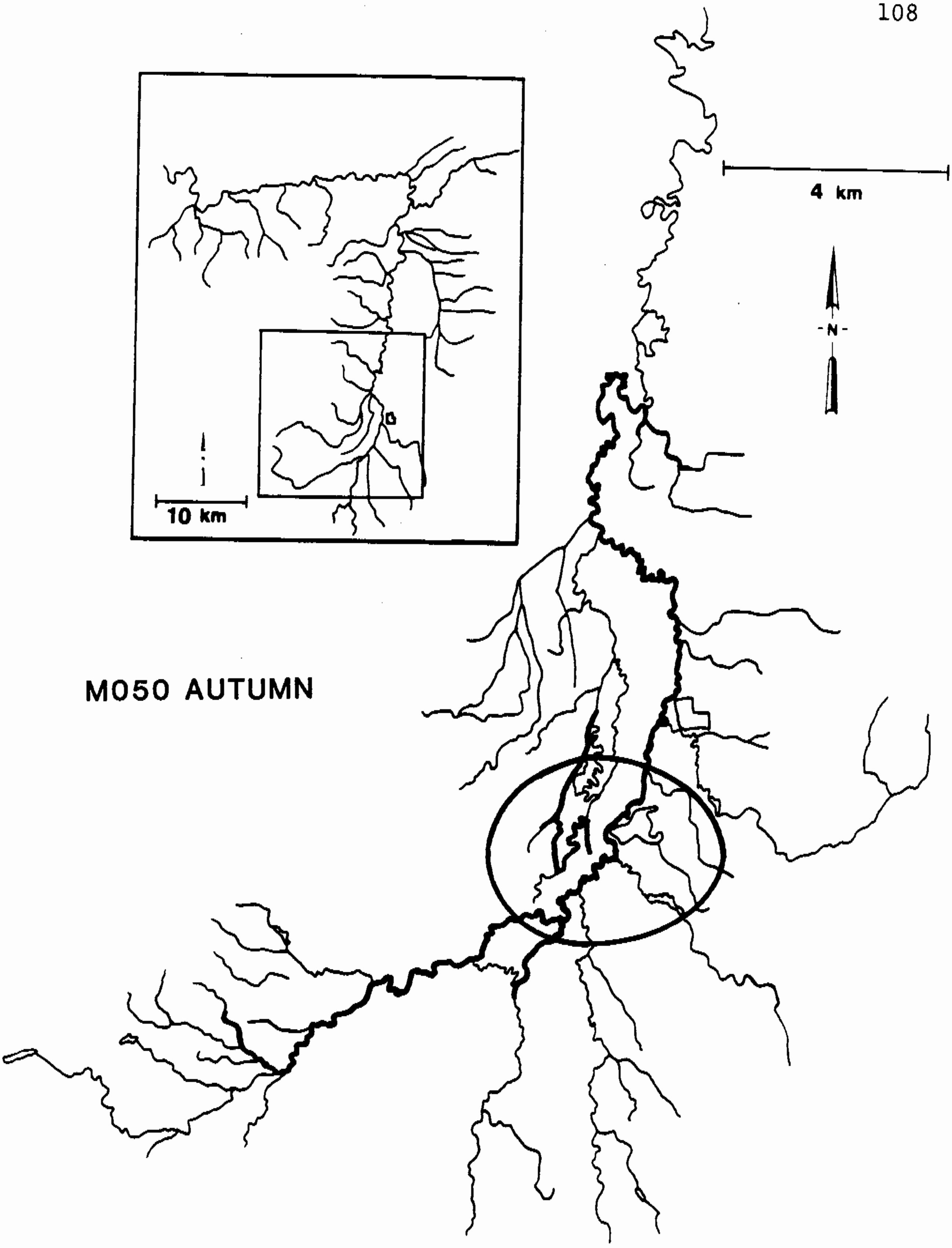
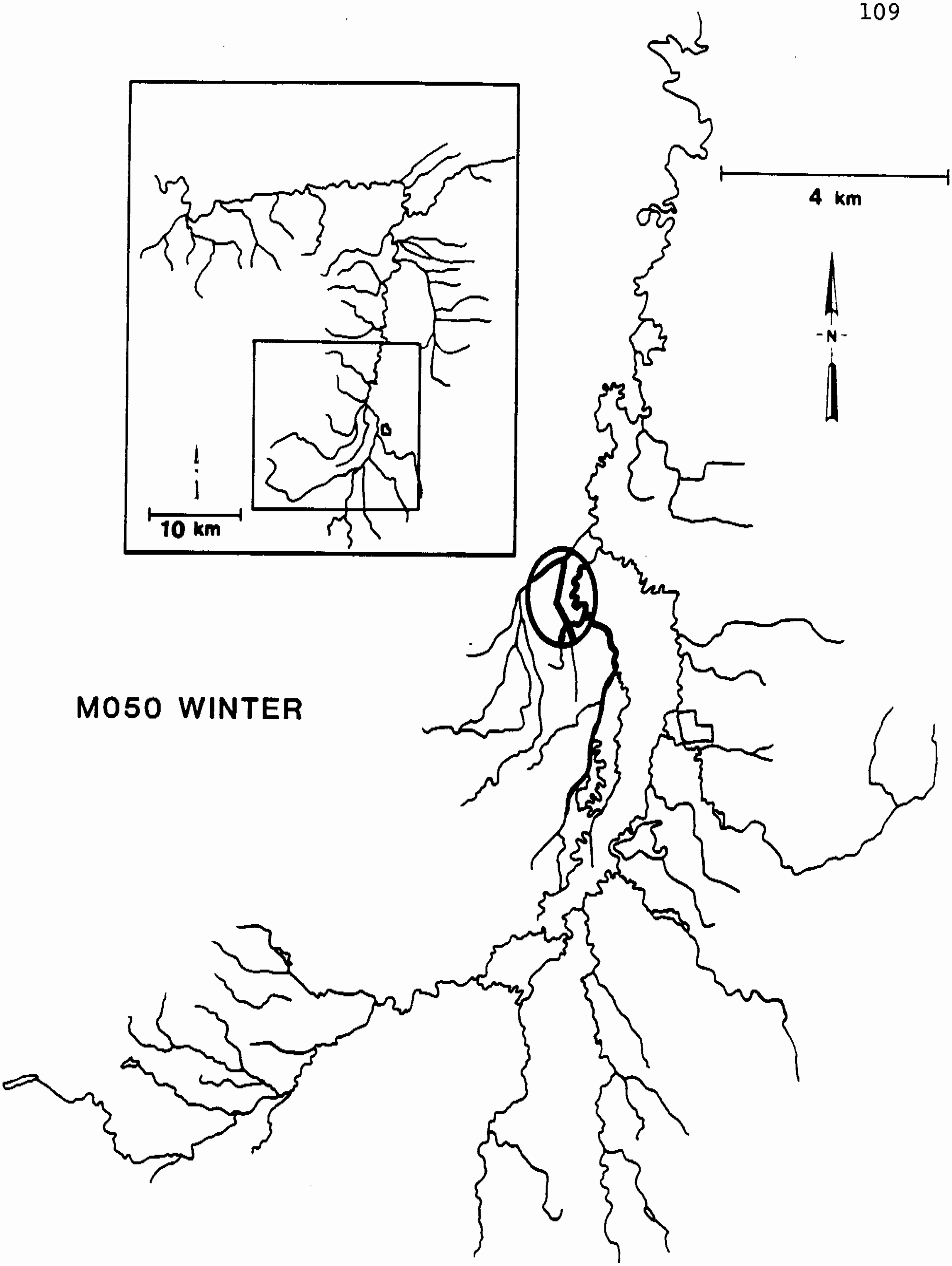
M050 SUMMER



M050 AUTUMN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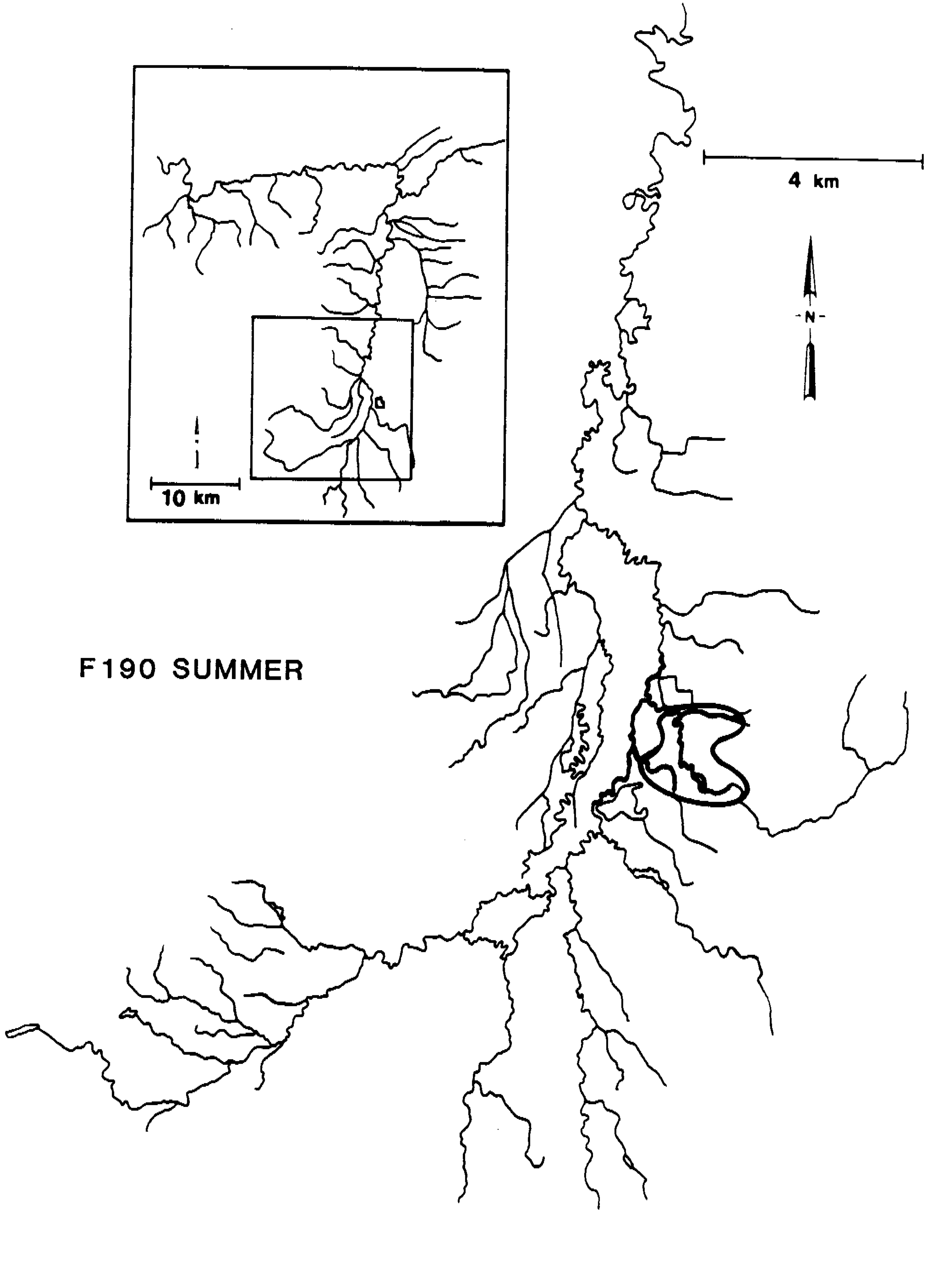
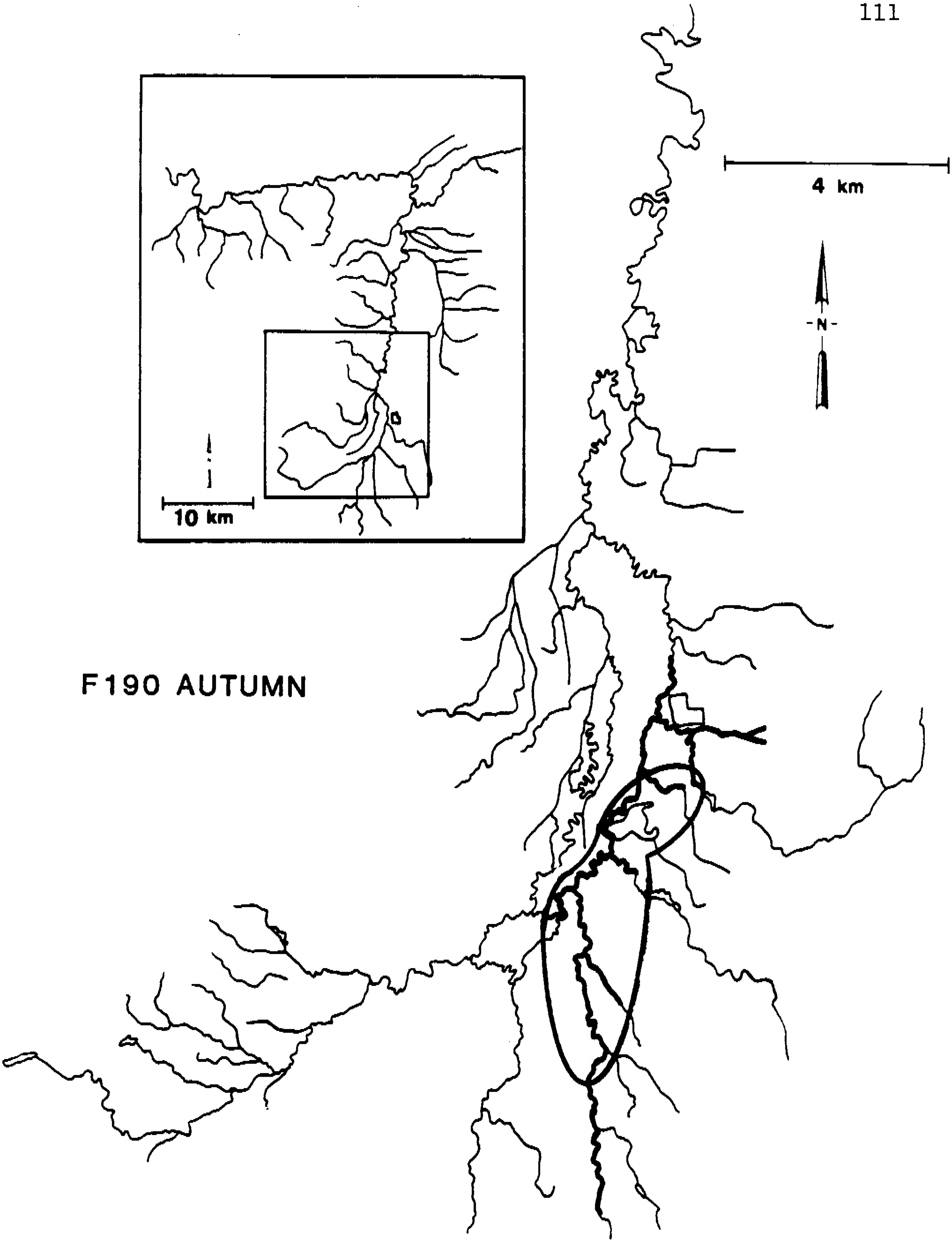


F190 SUMMER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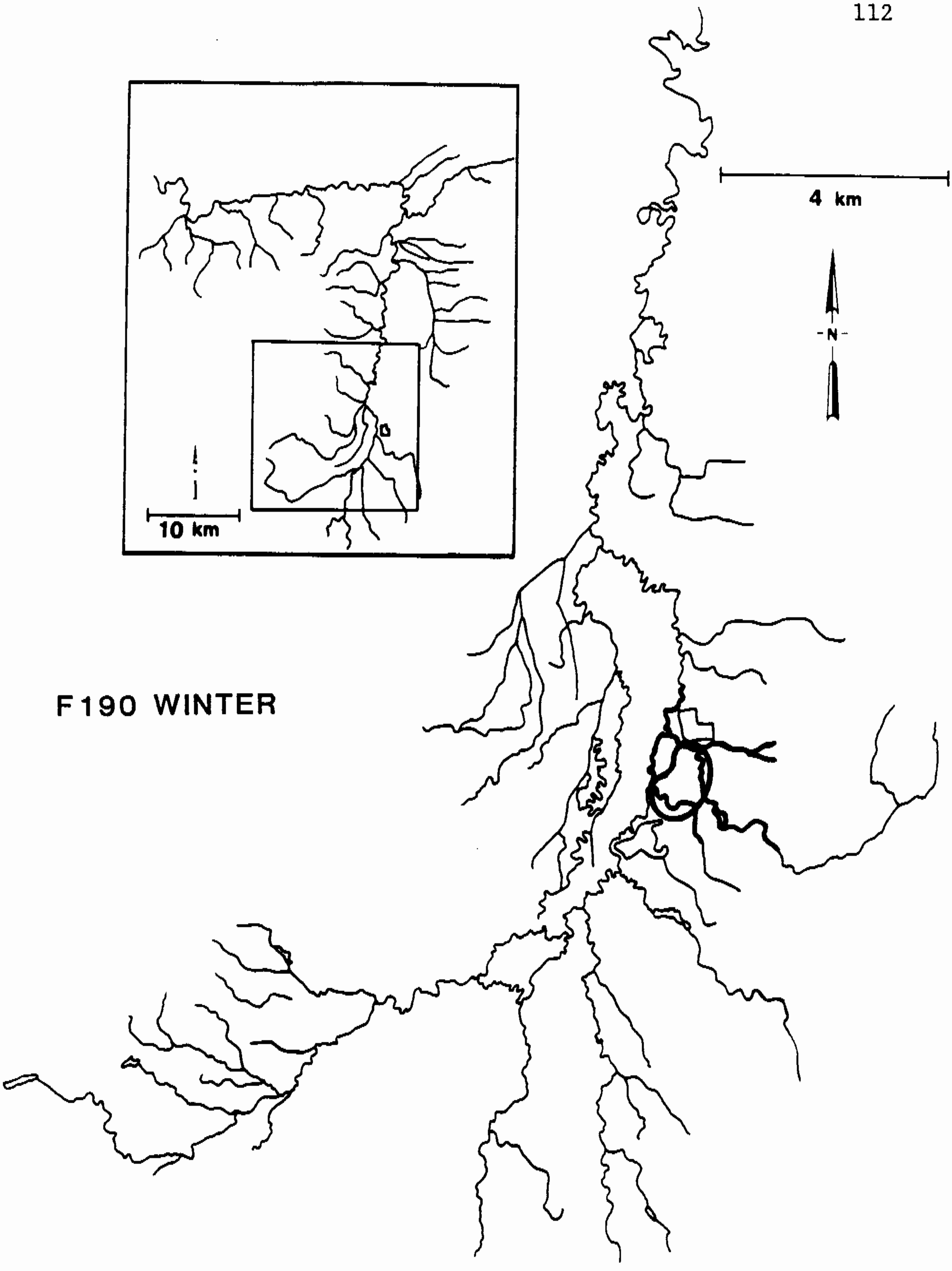
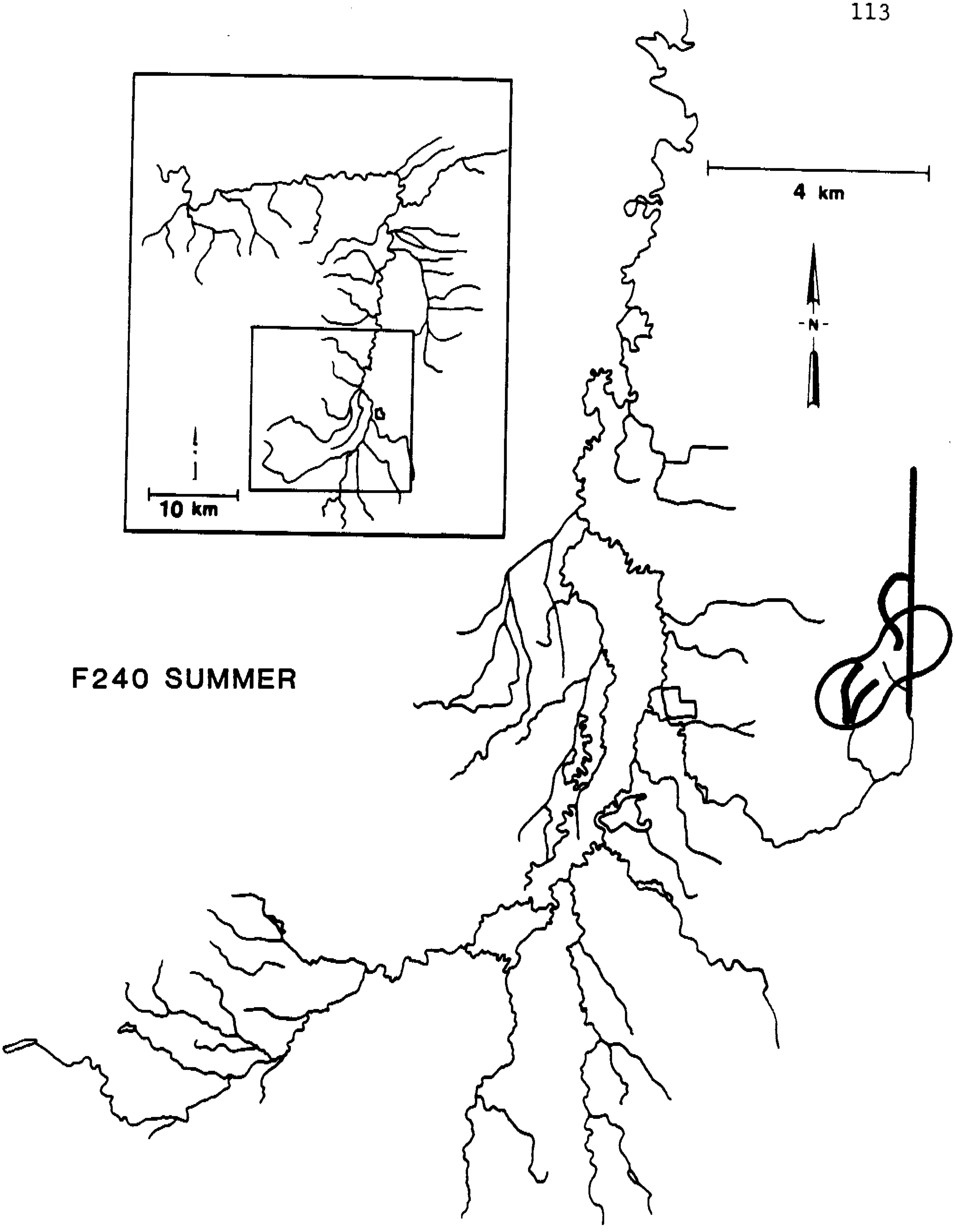
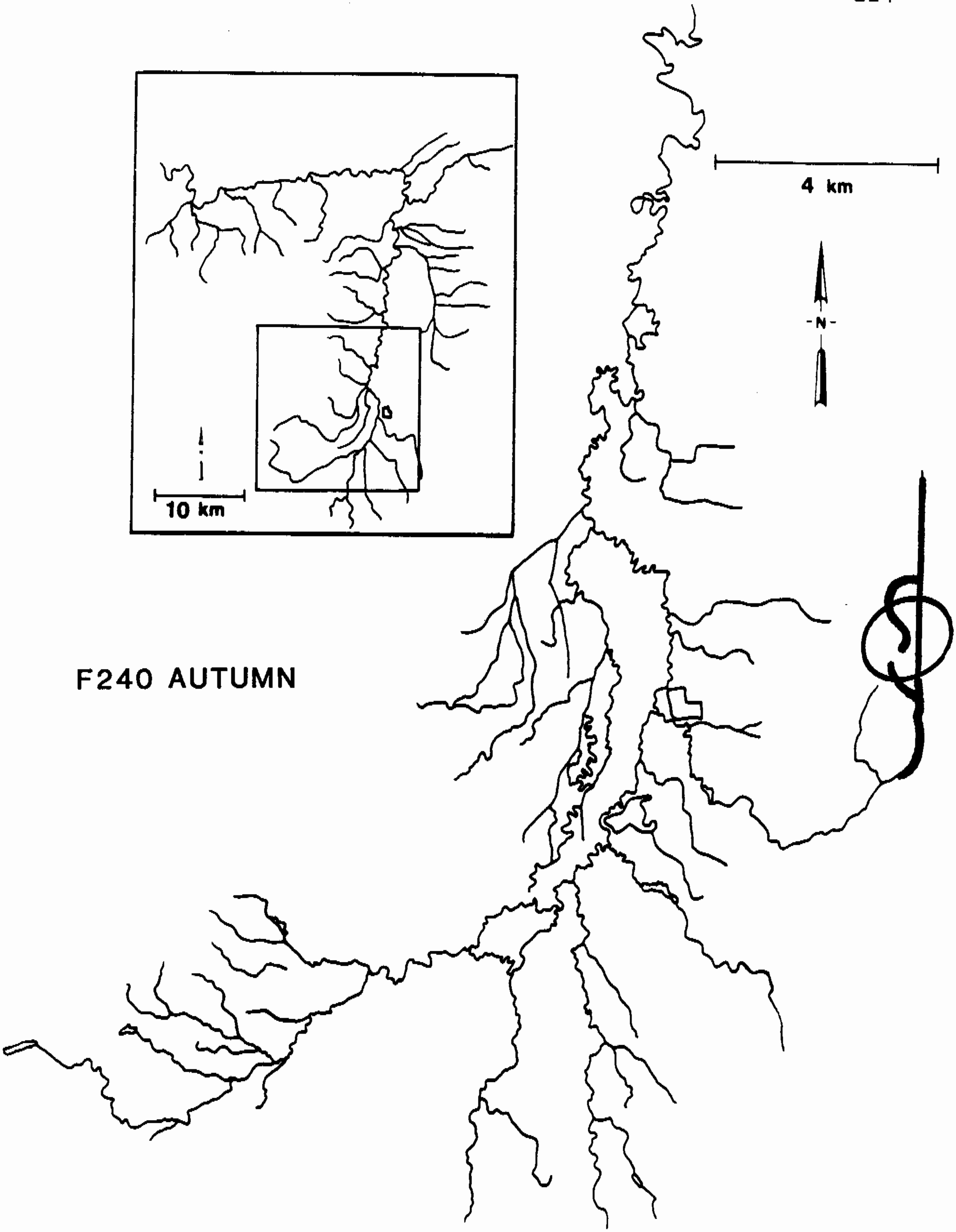


F190 WINTER



F240 SUMMER



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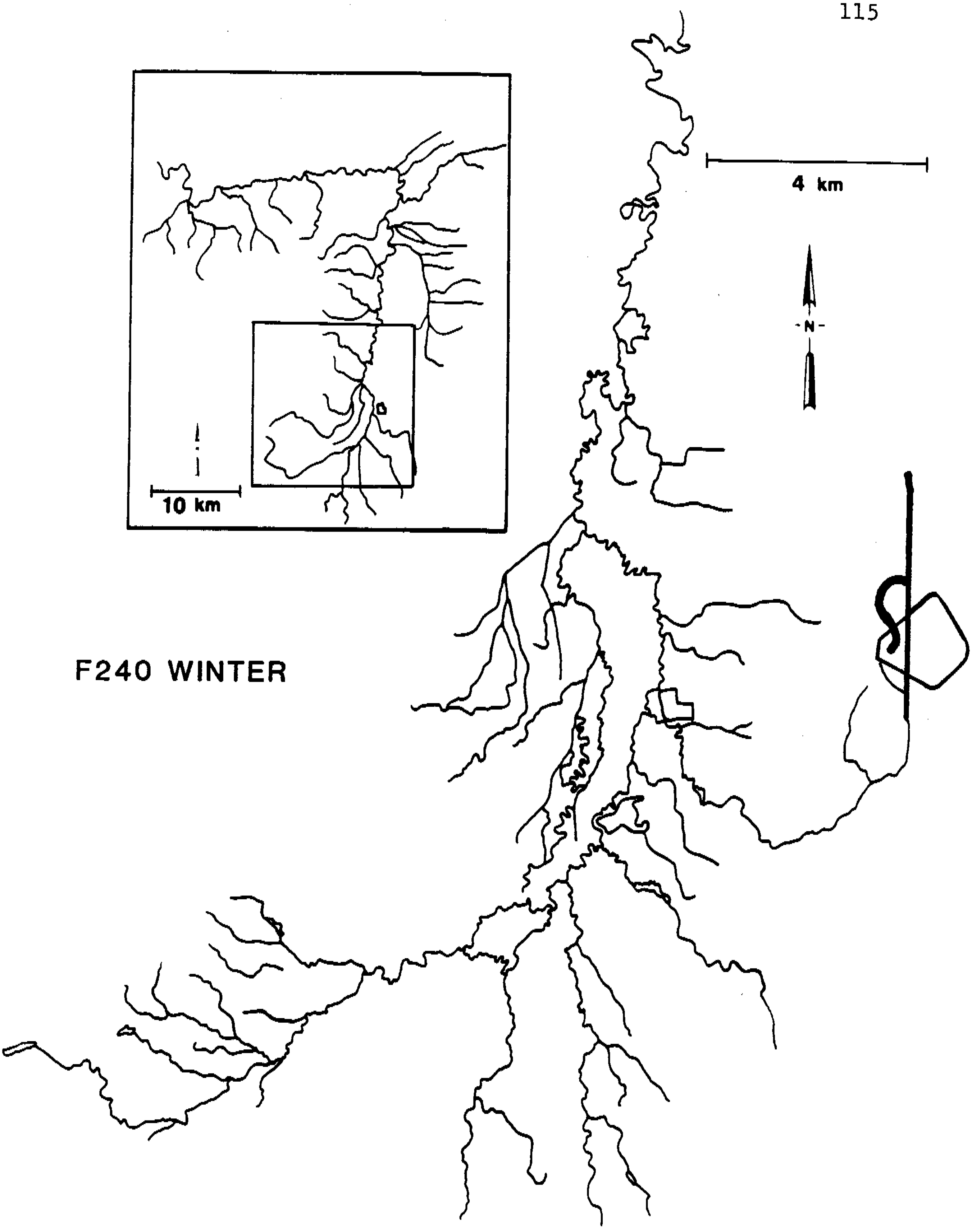
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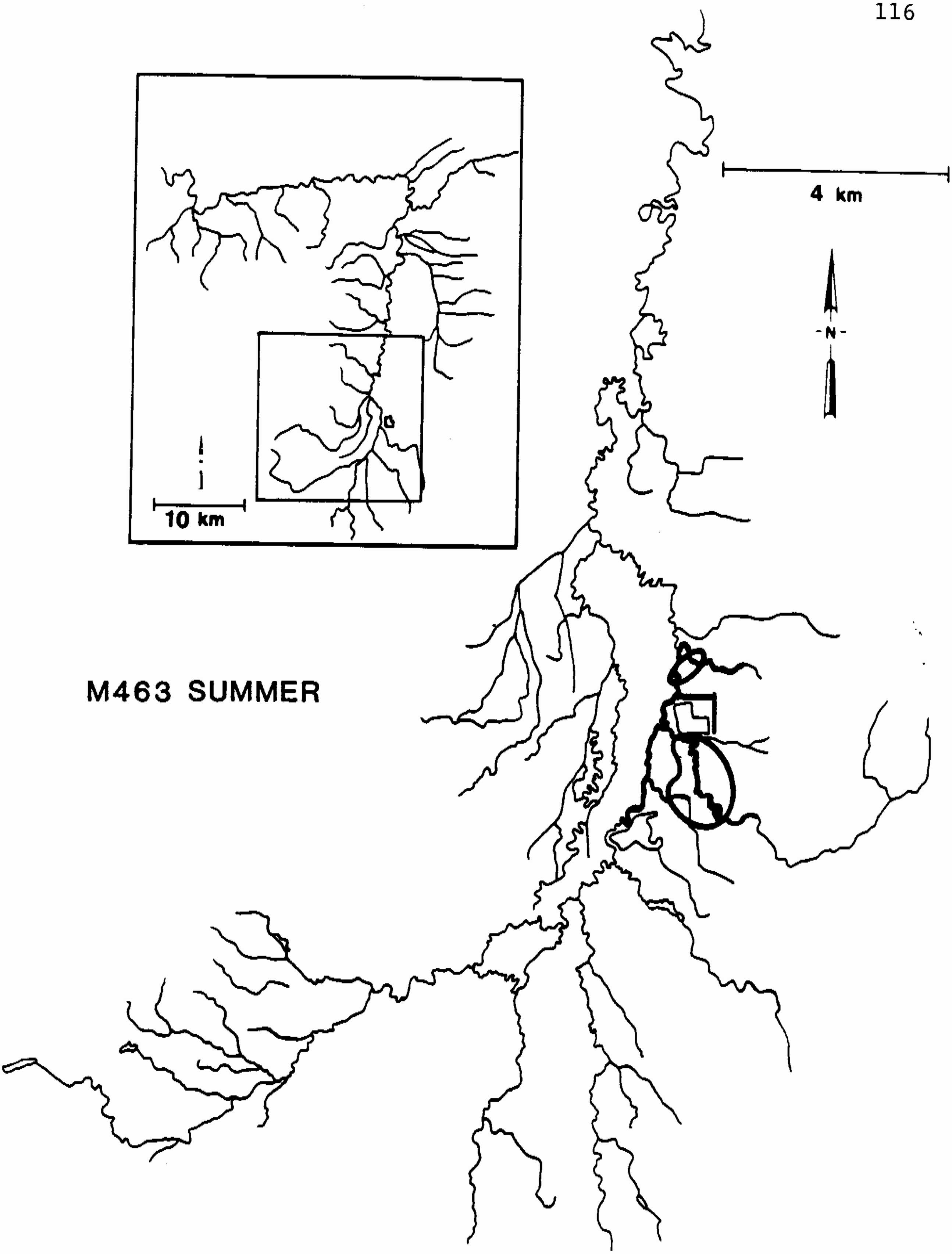
F240 WINTER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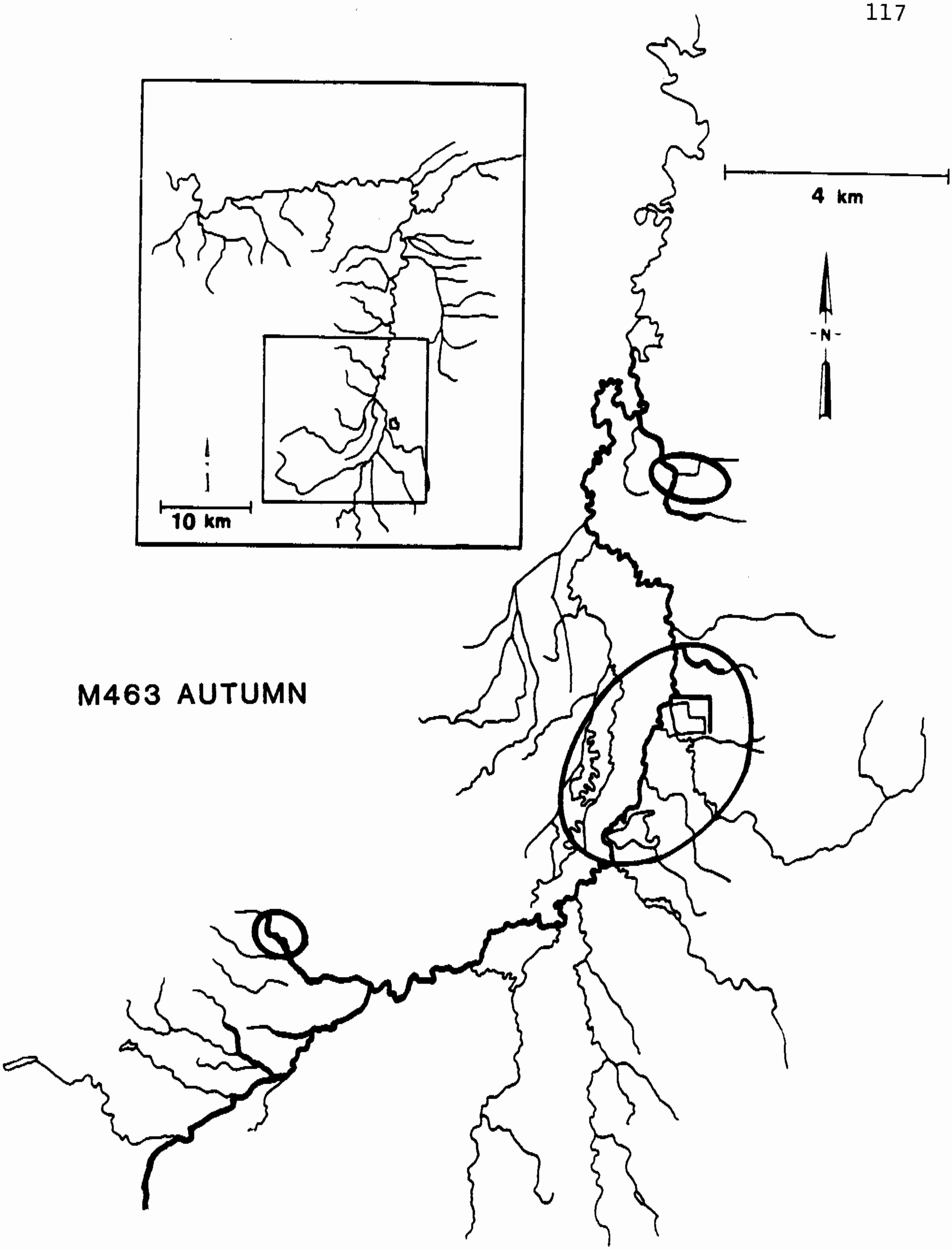
M463 SUMMER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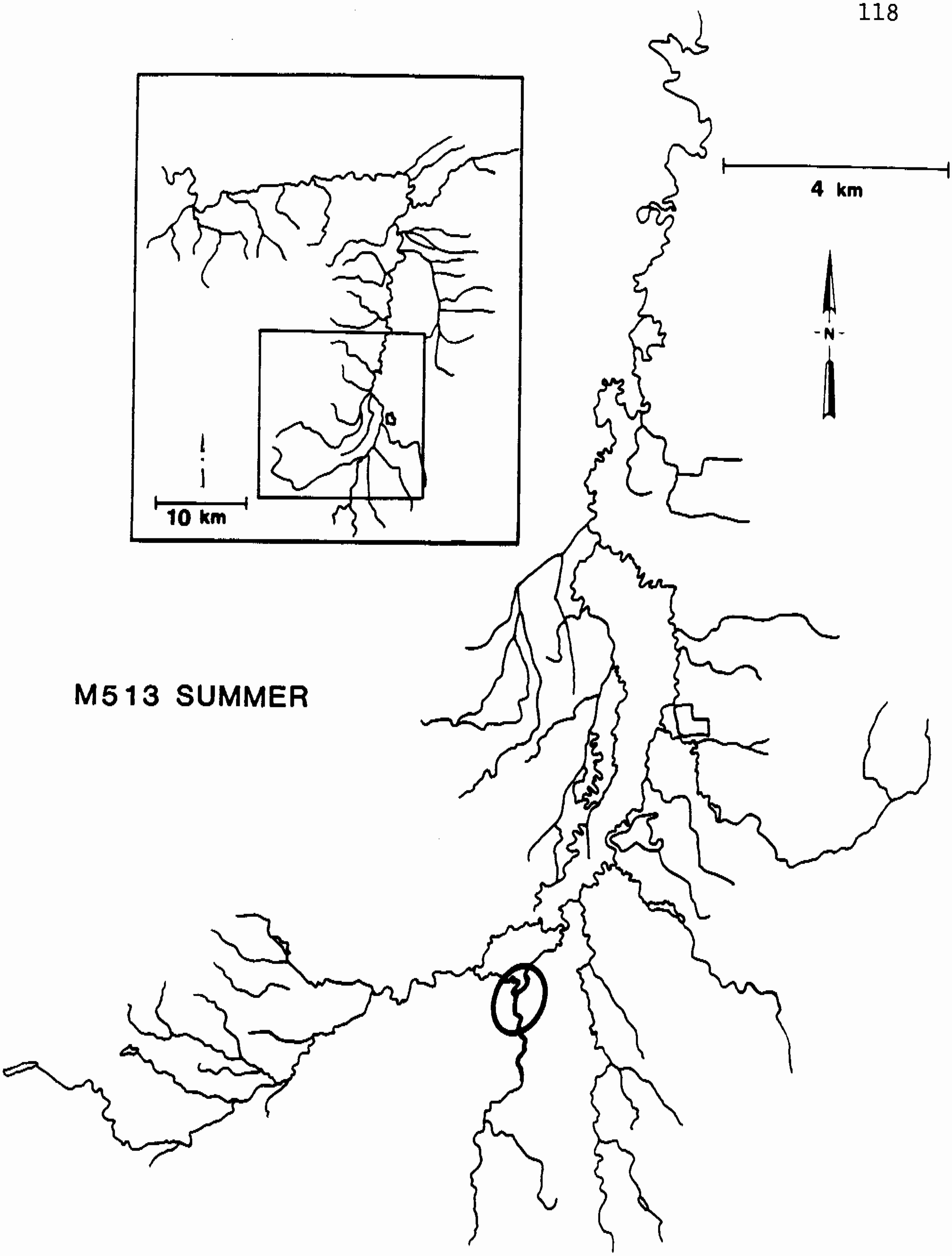
M463 AUTUMN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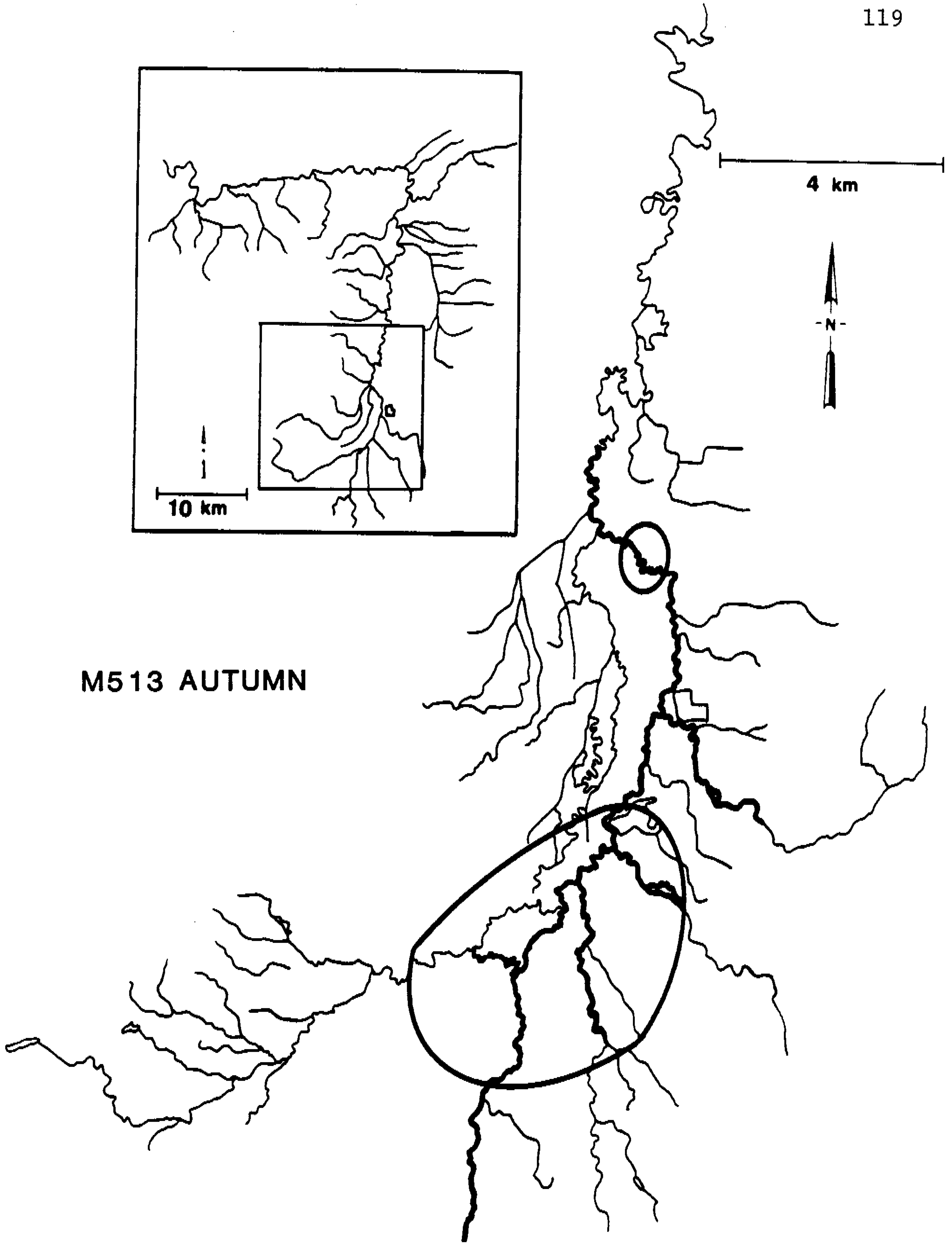
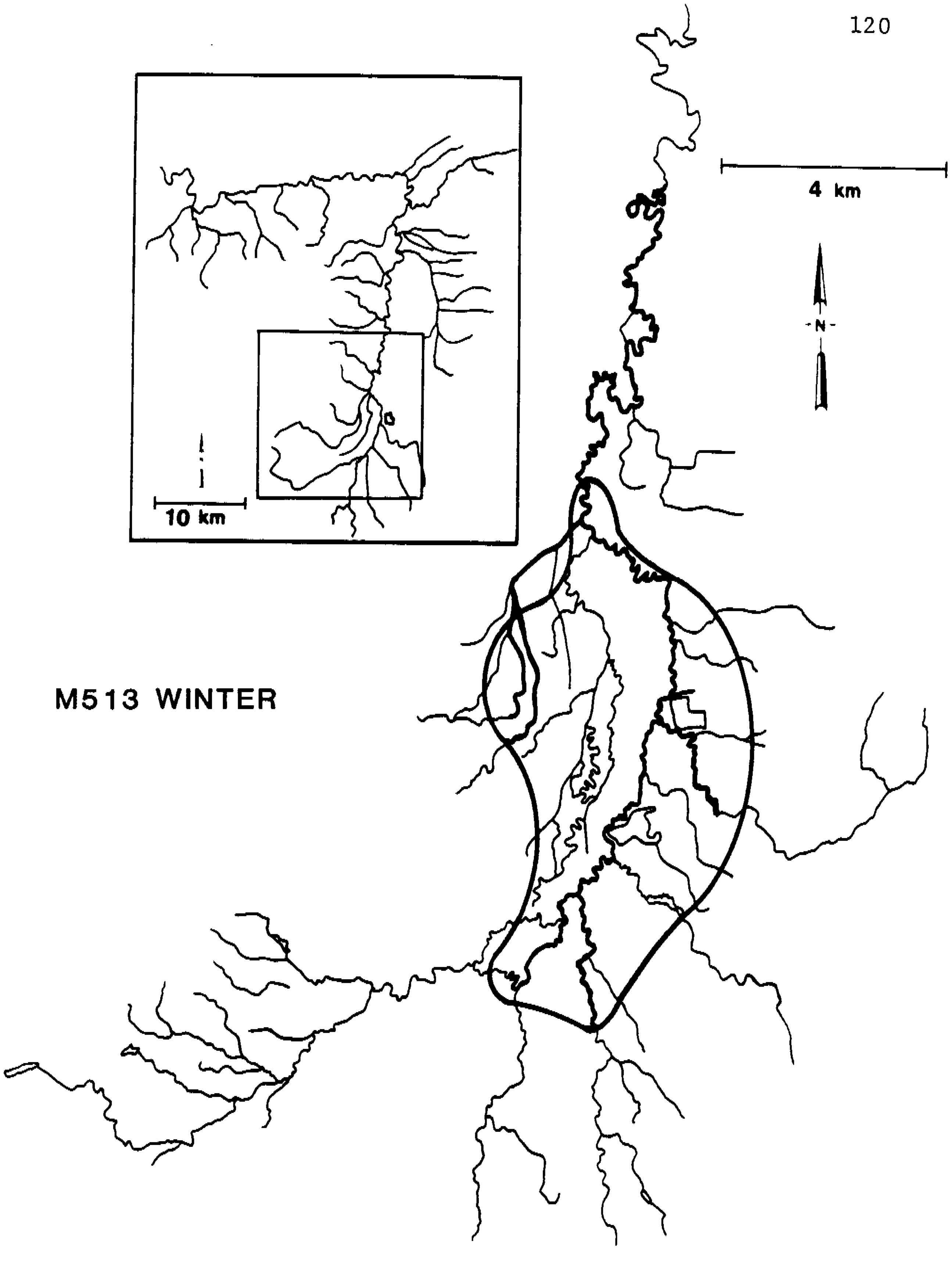
M513 SUMMER



10 km
4 km
N
M513 AUTUMN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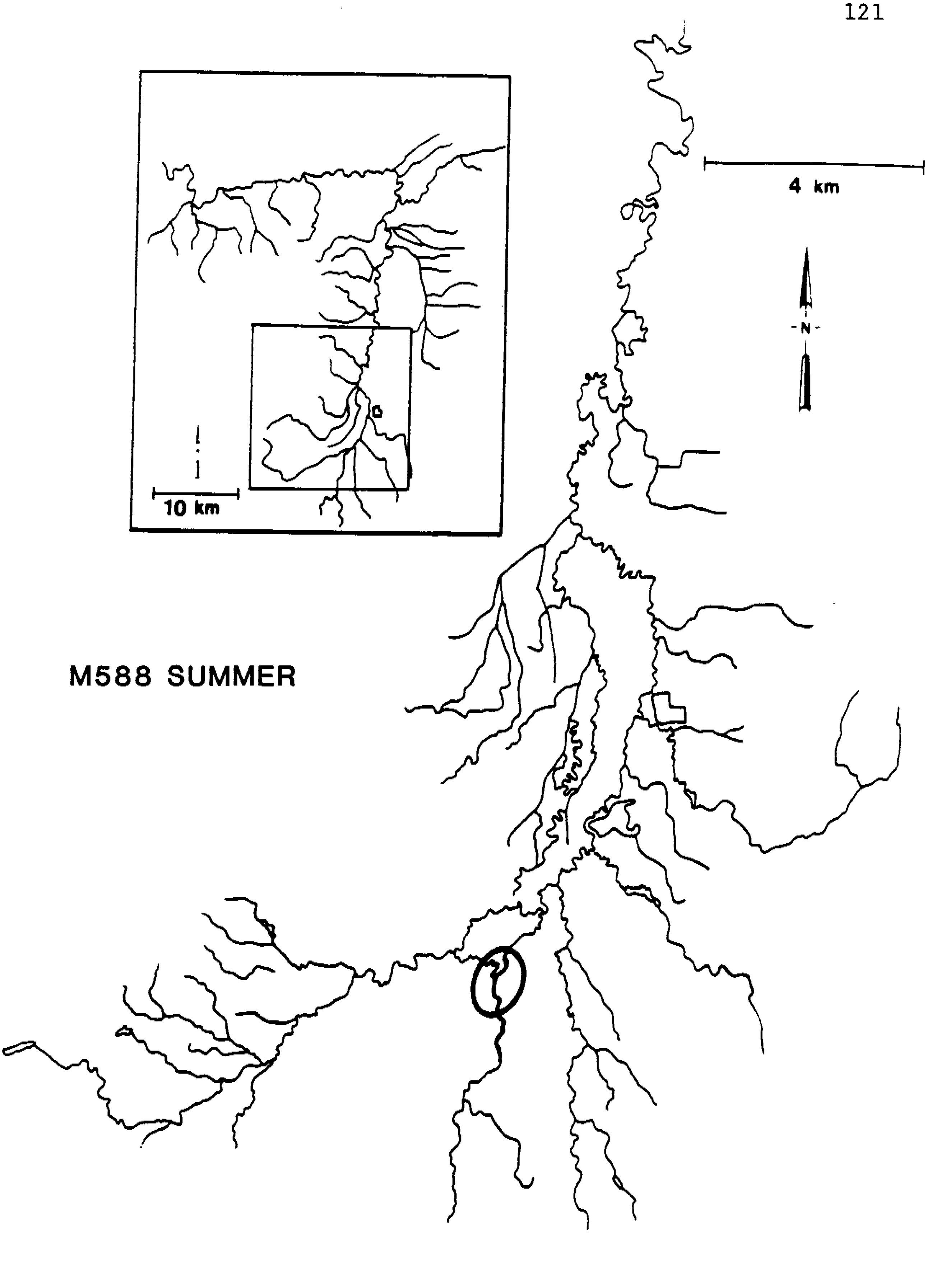
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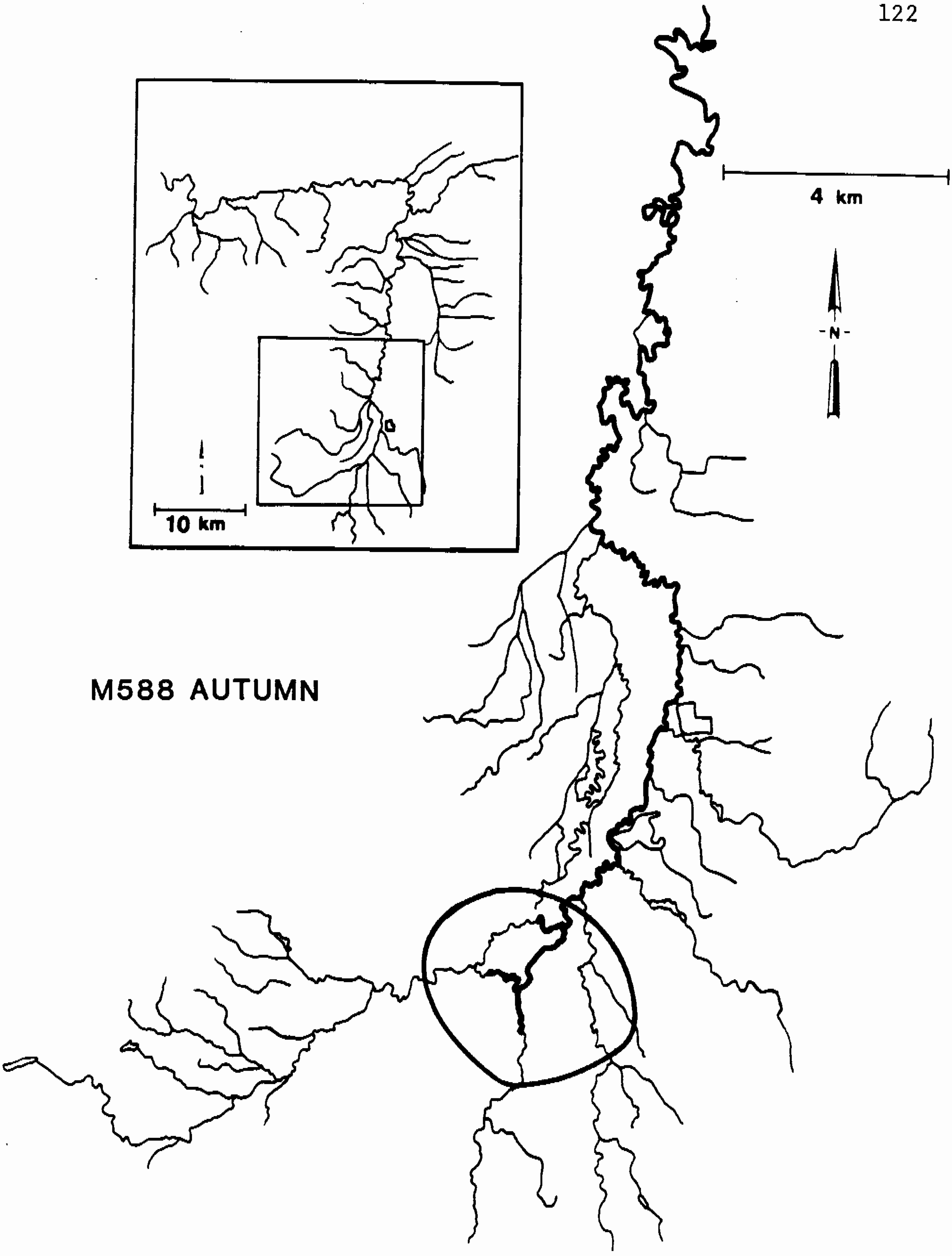
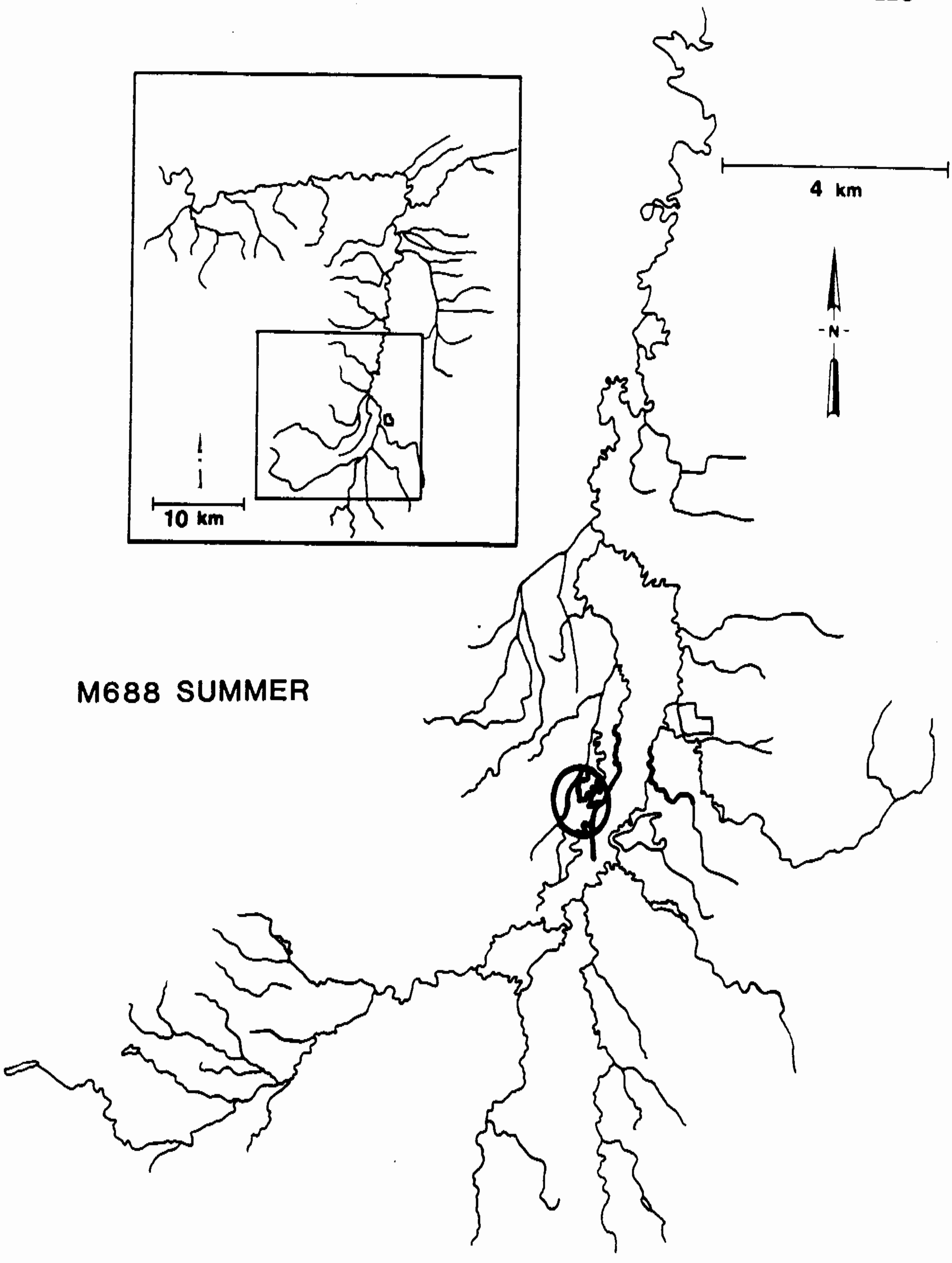
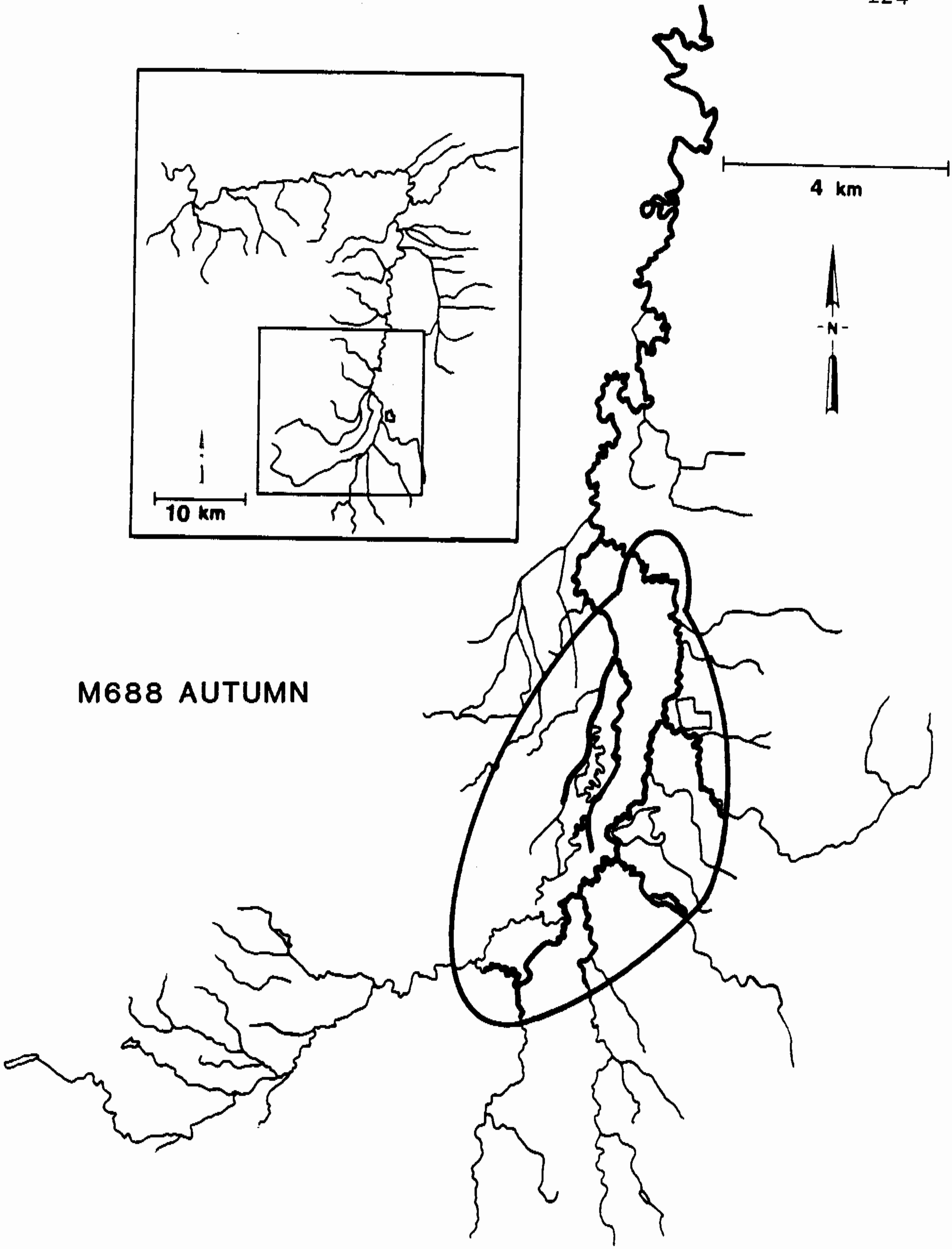
M588 SUMMER



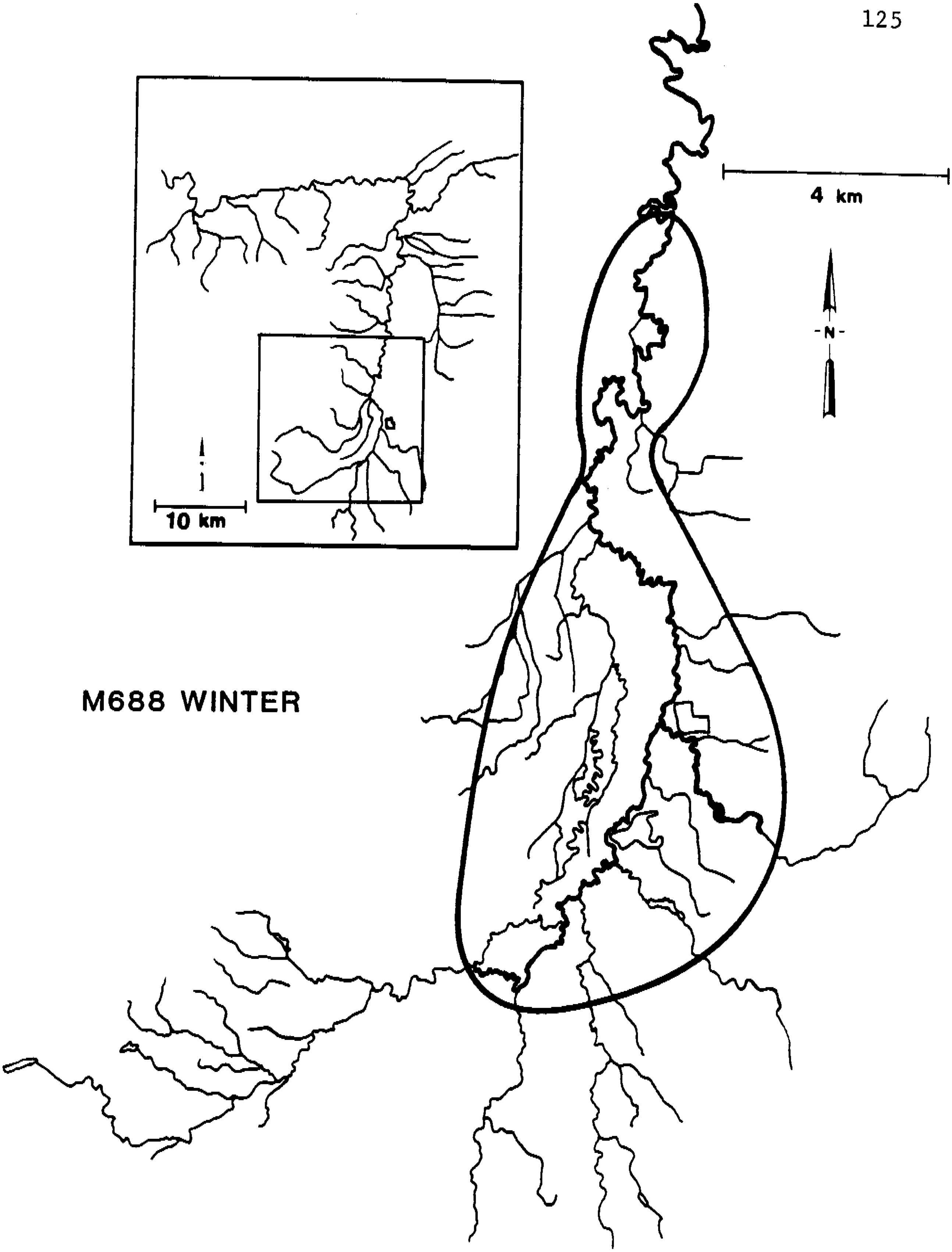
M588 AUTUMN



M688 SUMMER



M688 AUTUMN


4 km
N
10 km
M688 WINTER

APPENDIX D

Summary of river otter food habit studies (as adapted from Toweill and Tabor 1982).

Table 14. Summary of river otter food habit studies (adapted from Toweill and Tabor 1982).

State	Sample size	Sample type	Months of collection	Percent frequency occurrence: Fish	Crustacean	Insect	Amphibian	Bird	Mammal	Other	Source
Mich.	173	S	Mar-Apr	56	35	13	16	P	P	4	Lagler and Ostenson 1942
Mich.	220	I	Mar-Apr	76	59	32	25	P	P	1	Lagler and Ostenson 1942
N.C.	85[b]	S,F	Dec-Feb	91	39	6	6	3	1	2	Wilson 1954
Mich.	47	S	Mar-Apr	55	22	13	17	-	-	-	Ryder 1955
Mont.	99	F	Dec-Feb	100	-	26	9	5	2	-	Greer 1955
Mont.	596	F	Mar-May	91	-	42	20	7	8	P	Greer 1955
Mont.	604	F	Jun-Aug	93	-	44	19	4	5	P	Greer 1955
Mont.	75	F	Sep-Nov	100	-	33	12	1	3	-	Greer 1955
N.Y.	141	G	Oct-Apr	70	35	13	25	P	4	-	Hamilton 1961
Fla.	18	S	Dec-Mar	61	32	-	17	-	-	-	McDaniel 1963
Md.	102	F	Dec-Feb	99	32	4	-	1	3	2	Sheldon and Toll 1964
Md.	73	F	Mar-May	90	53	4	-	1	4	0	Sheldon and Toll 1964
Md.	226	F	Jun-Aug	87	48	10	-	1	4	3	Sheldon and Toll 1964
Md.	116	F	Sep-Nov	97	48	5	-	-	-	1	Sheldon and Toll 1964
Wis.	131	S	Jan-Dec	81	31	8	13	-	5	2	Knudson and Hale 1968
Wis.	260	I	Jan-Dec	85	40	19	2	-	3	-	Knudson and Hale 1968
Mich.	28	S	Feb-Apr	79	29	7	11	-	-	7	Knudson and Hale 1968
Mich.	4	I	Feb-Apr	81	59	22	10	-	-	7	Knudson and Hale 1968
Minn.	12	S	Feb-Apr	100	17	33	17	-	-	-	Knudson and Hale 1968
Minn.	29	I	Feb-Apr	90	34	38	-	-	-	-	Knudson and Hale 1968
Ore.	44	S	Nov-Feb	86	20	P	9	9	P	P	Toweill 1974
Ore.	75	I	Nov-Feb	80	27	P	12	7	P	P	Toweill 1974

Table 14. Continued.

State	Sample size	Sample type	Months of collection	Fish	Crustacean	Insect	Amphibian	Bird	Mammal	Other	Source
				Percent frequency occurrence							
Calif.	120	F	Jan-Dec	29	98	8	-	38	7	15	Grenfell 1974
Ala.	315	G	Nov-Feb	92	58	-	5	P	1	4	Lauhachinda 1978
La. (Salt marsh)	126	G	Dec-Feb	83	25	-	-	2	8	2	Chabreck et al. 1982
La. (swamp)	53	G	Dec-Feb	83	41	-	-	-	8	9	Chabreck et al. 1982
Alberta	498	F	Apr-Nov	85	1	20	-	15	10	4	Gilbert & Nancekivel 1982
Id.	260	F	Dec-Feb	99	-	12	-	1	1	-	Melquist & Hornocker 1983
Id.	264	F	Mar-May	100	-	2	-	1	1	-	Melquist & Hornocker 1983
Id.	326	F	Jun-Aug	93	-	7	-	12	4	5	Melquist & Hornocker 1983
Id.	1052	F	Sep-Nov	97	-	10	-	1	3	1	Melquist & Hornocker 1983
Alaska	193	F	Apr-Oct	-	-	-	-	85[c]	-	-	Quinlan 1983
Colo.	81	F	Dec-Feb	100	-	2	-	1	-	-	Mack 1985
Colo.	55	F	Mar-May	100	-	5	-	2	2	-	Mack 1985
Colo.	65	F	Jun-Aug	100	-	31	-	5	5	-	Mack 1985
Colo.	21	F	Sep-Nov	100	-	38	-	5	5	-	Mack 1985
Penn.	124	F	Mar-May	98	42	6	5	-	2	-	Serfass et al. 1986
Penn.	115	F	Jun-Aug	85	63	10	17	2	6	1	Serfass et al. 1986
Penn.	105	F	Sep-Nov	92	38	3	4	-	4	1	Serfass et al. 1986
Penn.	108	F	Dec-Feb	99	28	1	1	-	2	-	Serfass et al. 1986

Table 14. Continued.

State	Sample size	Sample type	Months of collection	Percent frequency occurrence: Fish	Crustacean	Insect	Amphibian	Bird	Mammal	Other	Source
Tenn.	75	F	Apr-Sep	90	95	5	21	-	-	19	Griess 1987
Mich.	796	F	Apr-Mar	72	71	14	11	P	P	2	Route and Peterson 1988

[a]S=Stomach; I=Intestine; G=GI tract; F=Feces; P=Present; - = not present in sample or not presented in the data.

[b]Based on combination of 61 scats and 24 digestive tracts.

[c]Author was looking only for bird remains.