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POPULATION DYNAMICS, FOOD HABITS, MOVEMENT AND HABITAT USE OF NORTHERN PIKE IN THE COEUR d'ALENE LAKE SYSTEM, IDAHO

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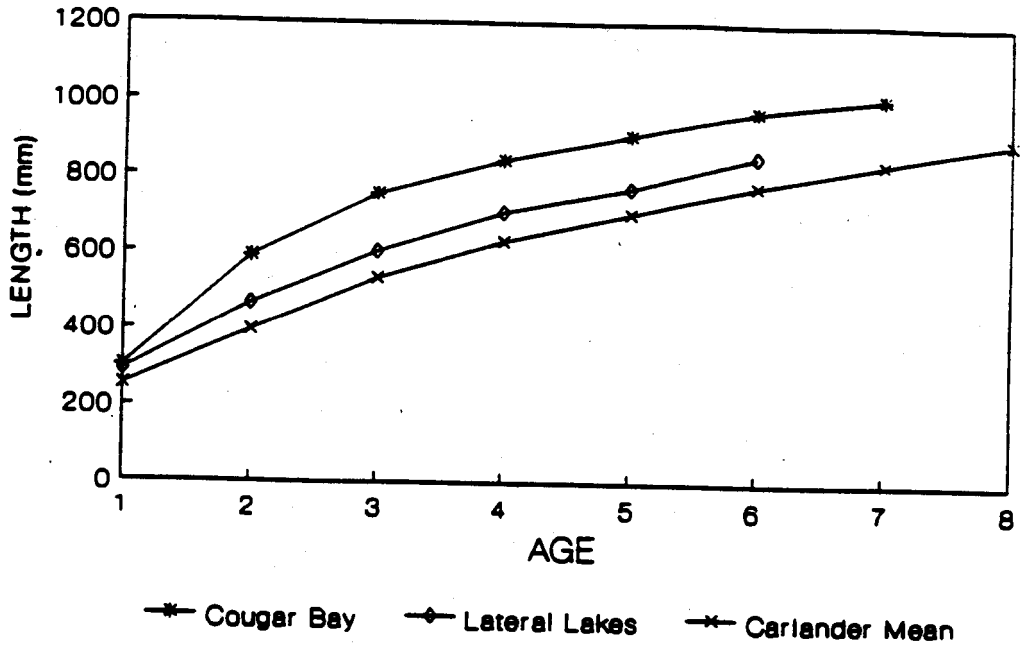

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ABSTRACT

Northern pike Esox lucius, illegally introduced into the Coeur d'Alene River System (14,400 hectares) in about 1973, now support the only significant esocid fishery in Idaho. An understanding of this population was necessary as a result of the increasing popularity of the northern pike fishery, the apparent expansion of northern pike distribution within the system, and possible predatory impacts on kokanee Oncorhynchus nerka and native Westslope cutthroat trout O. clarki lewisi. Young and adult northern pike were sampled primarily by electrofishing and gill and trap netting in suitable habitat in four of the Lateral Lakes of the Coeur d'Alene River and in Coeur d'Alene Lake from March 1989 to November 1990. Electrofishing catch rates of young-of-year northern pike were similar in both years. Adult northern pike densities were in the lowest quartile of the range reported in the literature whereas somatic growth rates and condition factors were in the highest. Angler exploitation was directly proportional to accessibility and popularity of lakes and bays. Prey type varied seasonally and with local prey availability. Yellow perch Perca flavescens, salmonids, and catostomids were more common prey items while brown bullhead Ictalurus nebulosus and tench Tinca tinca were least common. Twenty-one northern pike (1.7-9.0 kg) implanted with radio transmitters from March through August 1990 used all areas of continuous shallow (<7 m), vegetated habitats, although little use of pelagic or non-vegetated sites was observed. Large males (x = 7.5 kg) used locations in deeper water, but closer to shore, than did small males (x = 4.4 kg). Age 2 female northern pike manifested smaller home ranges than same age males. Information gathered in this study should be useful for managing northern pike fisheries in the Coeur d'Alene River System and similar systems and for evaluating species interactions and habitat associations of potential northern pike introductions into other systems.

INTRODUCTION

Northern pike Esox lucius are important sport and commercial fish throughout their natural range (Simpson and Wallace 1982). In the northern hemisphere, northern pike have circumpolar distribution, but in North America their natural range extended east of the Great Plains region (Carlander 1969). Northern pike have been legally and illegally introduced outside their natural range in North America as a sport fish and for prey fish control (Carlander 1969).

The Coeur d'Alene River System currently supports the only significant northern pike fishery in Idaho. Northern pike were illegally introduced into the system in the early 1970's. Catches of northern pike were low until about 1980, when pike fishing became popular in the Lateral Lakes and within a few years in several areas of Coeur d'Alene Lake, especially Cougar Bay. The connected lakes at the mouth of the lower St. Joe River (Benewah, Chatcolet, and Round) contain northern pike but do not have popular northern pike fisheries.

Adfluvial Westslope cutthroat trout Oncorhynchus clarki lewisi, a state species of special concern, spawn and rear in many of the tributary streams in the Coeur d'Alene River System (Lukens 1978; Apperson et al. 1988). The depressed nature of the cutthroat trout population led to concern about possible predatory effects of northern pike on cutthroat trout.

While cold water fisheries have traditionally been most important to anglers in Idaho (Rieman et al. 1980), angler interest and management emphasis on warm water species has recently increased (Rieman 1987). Increasing local popularity of warm water fisheries and possible predatory effects of northern pike on cutthroat trout necessitated collection of basic ecological information about northern pike in the Coeur d'Alene River System.

OBJECTIVES

1. To describe population dynamics of recruitment, age and growth, mortality, and abundance of northern pike in the Coeur d'Alene River System.

2. To evaluate the food habits of northern pike in the Coeur d'Alene River System.

3. To describe movement and habitat use by various size classes of northern pike in the Coeur d'Alene River System.

STUDY AREA

Coeur d'Alene Lake, a natural glacial lake with a surface area of 12,700 hectare (31,370 acres) located in the Idaho Panhandle, has a mean depth of 24 m and maximum depth of 61 m (Figure 1). The lake level was raised approximately 2.5 m in 1906 when Post Falls Dam was constructed on the outlet by Washington Water Power Company. The normal maximum pool elevation is 849 m (2,128 ft) through the summer but is typically drawn down 1 to 2.5 m (3.3 to 8.2 ft) during the fall and winter months (Rieman et al. 1980). Conductivity ranges between 30 and 60 umhos. The lake could be classified as mesotrophic because of nutrient input levels, except that algal inhibition from heavy metal loading keeps the lake at a lower productivity level better described as oligtrophic (C.M. Falter, University of Idaho, personal communication).

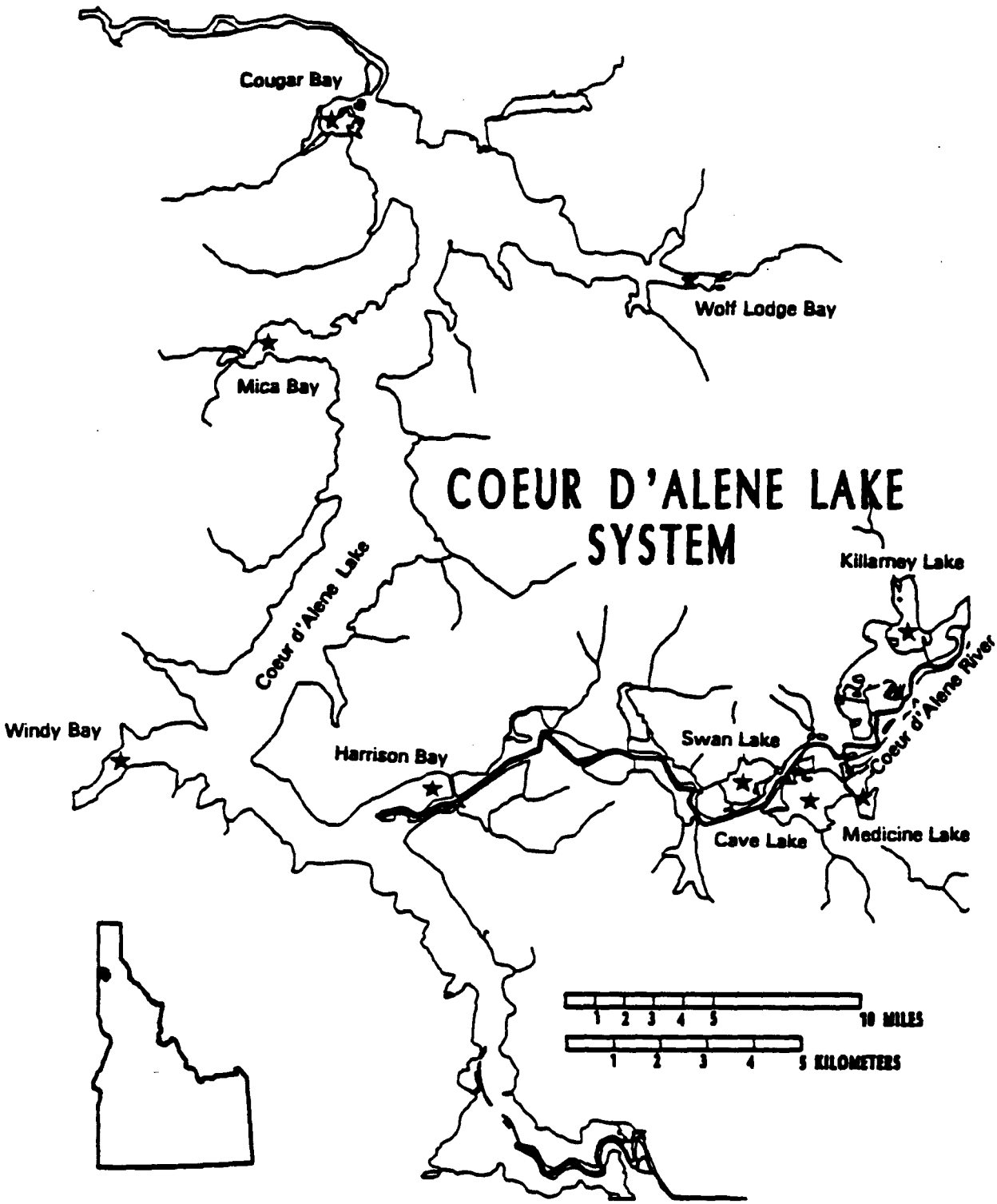

Figure 1. Map of the Coeur d'Alene Lake system, Idaho. Stars denote principal northern pike sampling areas 1989-90.

The elevated level of Coeur d'Alene Lake inundated several Lateral Lakes along the lower Coeur d'Alene River. Water levels in these lakes fluctuate annually in response to runoff patterns and operations at Post Falls Dam. In addition to annual lake level fluctuations, the lakes continue to be affected by heavy metals from the Silver Valley mining and smelting area (Rabe and Bauer 1977). Flesh of northern pike taken from an upstream lateral lake contained detectable levels of cadmium, copper, lead, mercury, and zinc (Bennett et al. 1990).

The Coeur d'Alene River System has important fisheries for kokanee O. nerka, chinook salmon O. tshawytscha, Westslope cutthroat trout, northern pike, largemouth bass Micropterus salmoides, black crappie Pomoxis nigromaculatus, and brown bullhead Ictalurus nebulosus. Chinook salmon were first introduced in 1982 (LaBolle 1986) and reproduce naturally in the system. Other species present in the Coeur d'Alene River System include bull trout Salvelinus confluentus, northern squawfish Ptychocheilus oregonensis, longnose sucker Catostomus catostomus, largescale sucker C. macrocheilus, tench Tinca tinca, yellow perch Perca flavescens, pumpkinseed sunfish Lepomis gibbosus, and sculpin Cottus spp.

Four Lateral Lakes and five major bays of Coeur d'Alene Lake were selected as sampling areas (Figure 1). Cave and Medicine lakes receive high fisherman use due to accessibility, Killarney Lake has a reputation as a good northern pike fishery, and Swan Lake is relatively inaccessible but in close proximity to Cave Lake. These four lakes range in surface area from 100 to 350 hectare, have an average maximum depth of 5.8 m, and an average mean depth of 3.1 m. Cougar Bay, on the northwest side of Coeur d'Alene Lake, was chosen because of its proximity to the city of Coeur d'Alene and an emerging and popular northern pike fishery. Harrison, Mica, Windy, and Wolf Lodge are major bays distributed around the shore of Coeur d'Alene Lake and were potential northern pike rearing and adult habitation areas.

Northern pike have produced inconsistent fisheries in the Lateral Lakes, based on reports from law enforcement personnel. The fishery was unregulated until 1988 when a state-wide daily bag limit of five northern pike was initiated because of public concern that overfishing might be occurring (Cindy Robertson, Regional Fishery Biologist, Idaho Fish and Game Department, personal communication).

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Chapter 1. Population Dynamics of Northern Pike in the Coeur d'Alene River System.

INTRODUCTION

The northern pike is a piscivorous top predator usually found in low densities (4-12 kg/hectare) within shallow, vegetated areas of boreal aquatic systems (Scott and Crossman 1973; Raat 1988). Recruitment is typically variable, difficult to quantify, and related more to annual environmental conditions than to abundance of parental stocks (Kipling and Frost 1970; Mann 1985; Raat 1988). Growth rates vary greatly but tend to decrease at progressively higher latitudes while longevity increases along the same gradient (Scott and Crossman 1973). Mortality rates of northern pike vary widely but are generally high and often largely attributable to fishing (Raat 1988).

Knowledge of population dynamics of piscivorous fish is essential to managers concerned with fish communities that include popular or sensitive prey species. The Coeur d'Alene River System has significant sport fisheries for chinook salmon, kokanee (also important prey for chinook salmon), indigenous adfluvial Westslope cutthroat trout (a state species of special concern), northern pike, and largemouth bass. The objective of this study was to describe population dynamics of northern pike for future management.

METHODS

Fish Collection

Yearling and larger northern pike and other fish species were sampled by gill and trap netting in the Lateral Lakes (spring and fall 1989) and Coeur d'Alene Lake (1990). Horizontal monofilament and multi-filament sinking experimental gill nets (30 x 1.6 m with 40, 50, 80, and 125 mm stretch mesh) were set perpendicular to shore, generally in water 1-4 m deep. Eight or fewer gill nets were generally set between one hour before sunrise and one hour after sunset, and checked at <2 hr intervals. Trap nets were 1.8 m deep, with 23 m leads that were attached to shore, and had black nylon knotless 19 mm (bar) mesh. Trap nets were checked daily in the morning.

Total length (mm), weight (g) determined by spring scale (Jennings 1989) and 6-10 scales from between the lateral line and the posterior half of the dorsal fin (Toner and Lawler 1969) were collected from each northern pike. All yearling and older northern pike were jaw tagged with serially numbered metal bands and sexed using external characteristics (Casselman 1974).

Recruitment

I sampled young-of-year northern pike by boat electrofishing along entire shorelines of Killarney Lake and Cougar Bay in fall 1990 and 1991, using a Smith-Root (Vancouver, WA) SR16 electrofishing boat with 500 V and 3-4 A of pulsed DC current. Shoreline seining and rotenone treatments were used in these areas during summer 1989.

Temperature and depth information was collected during northern pike spawning and rearing periods in the shallows at Killarney Lake in spring 1989 and at Cougar Bay (Coeur d'Alene Lake) in spring 1990. Temperature was recorded on a minimum/maximum mercury thermometer suspended at mid-depth and depth was

recorded from a vertical staff gauge placed at the same location. Reported temperatures are median values of the minimum and maximum recorded in the interval between readings.

Age and Growth

Acetate impressions of scales were read on a microfiche reader, annular lengths marked on paper strips, and measurements digitized using the DISBCal program (Frie 1982). Lengths were back-calculated using the Fraser-Lee method (Everhart and Youngs 1981):

$$L_t = C + St / S (L - C),$$

where L_t = the calculated length of a fish at age t,
L = length of fish at time of capture,
S_t = scale radius at age t,
C = a correction factor representing fish length at scale formation; 35 mm is commonly used for northern pike (Carlander 1969), and
S = scale radius at time of capture

Average back-calculated total length was compared by ANOVA (polynomial contrast) for ages 1-3 in years 1985-86 (eliminating annual environmental effect). Age determinations from scales and cleithra (Casselman 1979) were compared to determine the efficacy of the scale method.

Mortality and Exploitation

Total instantaneous mortality (Z) was determined by catch curve (Ricker 1975). Exploitation was estimated with angler returns of $5.00 reward tags (Lackey and Hubert 1977):

$$E = r/m$$

where E = annual exploitation rate,
r = number of recaptures, and
m = number of marked fish.

Fishing mortality (F) was calculated as:

$$F = \frac{E \times Z}{A}$$ (Lackey and Hubert 1977),

where E = Exploitation rate,
Z = Total instantaneous mortality, and
$A = 1 - e^{-Z}$.

Natural mortality (M) was found by subtraction:
$$(M = Z - F)$$

Abundance

Population abundance of northern pike was estimated from mark recapture data using fish jaw tagged during spring gill and trap *netting* operations. Population

estimates and 95% confidence intervals were made by the Schumacher and Eschmeyer method (Ricker 1975):

$$\frac{1}{\hat{N}} = \frac{\Sigma\ (m_t * r_t)}{\Sigma\ (C_t * m_t^2)}$$

where $\hat{N}$ = estimated population size,
m_t = total marked fish at large at the start of the tth day,
C_t = total sample taken on day t,
r_t = number of recaptures in the sample Ct,

and

t = number of catches examined,

where $$s^2 = \frac{\Sigma(r_t^2/C_t) - (\Sigma r_t m_t)^2 / \Sigma(C_t m_t^2)}{t - 1}$$

variance of $\frac{1}{\hat{N}} = \frac{s^2}{\Sigma C_t m_t^2}$

95% confidence interval =

$\frac{1}{\hat{N}} \pm s * t$ value (alpha=0.05, n-1 df).

Northern pike biomass was estimated as the product of the population estimate and the average weight. Biomass was then divided by surface area to provide standing crop estimates (kg/hectare).

Condition and Proportional Stock Density

Length-weight relationships were determined by regression:

LogW = Constant + (slope * LogL)

where:

LogW = common Log of weight (g)

and

LogL = common Log of total length (mm).

Weights of northern pike in spring were used to calculate relative weights (Wr), an index of well being or condition (Willis 1989). Wr is calculated by:

$$Wr = \frac{W}{Ws} \times 100$$

where W = the weight of an individual northern pike
and Ws = a length specific standard weight.

A random sample of fifteen angler caught northern pike (from throughout the Coeur d'Alene River System) 560-815 mm in TL was inspected for intestinal tract parasites.

Proportional Stock Density (PSD) was estimated for northern pike in the Lateral Lakes (spring 1989) and Cougar Bay (Coeur d'Alene Lake spring 1990). The PSD represents the percentage of stock-length fish (>350 mm TL) that are also of quality length (>530 mm TL) (Gablehouse 1984):

$$PSD = \frac{\text{number > minimum quality length (350 mm)}}{\text{number > minimum stock length (530 mm)}} \times 100$$

RESULTS

Recruitment

At least one young-of-year or yearling northern pike was sampled at every sampling location in the Coeur d'Alene River System (n = 10). Fall electrofishing was the most successful technique for sampling young-of-year northern pike (n = 85), and catch-per-unit effort averaged 0.21 YOY northern pike/min and was greatest at lower water temperatures (Table 1). Summer shore seine hauls (n = 115) yielded eight young-of-year northern pike. Young-of-year northern pike captured by seining on 14 June, 1989 were significantly larger at Killarney Lake (mean = 89 mm TL, SD = 11.0, n = 3) than those at Medicine Lake (mean = 45 mm TL, SD = 6.4, n = 3)($t = 5.99$, $p < .025$). Rotenone application inside block nets yielded no northern pike.

Age and Growth

Largest annual growth increments for northern pike from the Lateral Lakes (289 mm; n = 116) and Coeur d'Alene Lake (301 mm; n = 202) were from Age 0 fish. Average length-at-age was significantly larger at Coeur d'Alene Lake than at the Lateral Lakes (location effect, $F = 36.11$, $p = 0.0001$), but year differences were not significant ($F = 0.24$, $p = 0.622$). Actual average back-calculated total lengths at ages 1,2, and 3 in the Lateral Lakes were 296, 478, 591 and 312, 604, and 749 mm TL in Coeur d'Alene Lake (Figure 2).

Mortality and Exploitation

Fishing accounted for the highest proportion of northern pike mortality in the Coeur d'Alene River System. Natural mortality rates were low (M = 0 to 0.14), and exploitation (E) averaged 30% throughout the Coeur d'Alene River System (Table 2). Exploitation was highest at Killarney Lake (E = 0.59) and lowest in Cave Lake (E = 0.11). Mortality rates in the Lateral Lakes were pooled (mean Z = 0.29), because slopes from catch curves (gill netting) were similar ($F = 0.62$, df 3,8; $p > 0.25$), as were those from gill netting and trap netting at Cougar Bay (mean Z = 0.30) ($F = 0.47$, df 1,4; $p > 0.25$).

Abundance

The estimated population sizes of Age 1 and older northern pike were 30 (95% CI = 22 - 47) in Medicine Lake; 132 (95% CI = 87 - 271) in Cave Lake; and 550 (95% CI = 380 - 994) in Cougar Bay. Insufficient recaptures were made at other sampling locations to estimate local population sizes. Estimated densities of adult northern pike were 0.31, 0.44, and 1.15 fish/hectare for Medicine Lake, Cave Lake, and Cougar Bay, respectively. Standing crops of adult northern pike

Table 1. Fall electrofishing results (young-of-year northern pike only) for the Coeur d' Alene River System, 1989 and 1990. Catch-per-unit-effort based on the amount of time electrical circuit was closed, about 33% of total time. Catch=number of YOY pike; CPUE=Catch per minute of electrofishing.

Water Area	Date	Water Temp (°C)	Catch	CPUE
Killarney Lake	10/07/89	12.5	7	0.13
	11/03/89	7	25	0.37
	11/04/89	7	26	0.39
	11/03/90	6	15	0.19
Cougar Bay	10/06/89	13	4	0.08
	11/02/90	10	8	0.09
			Mean =	0.21

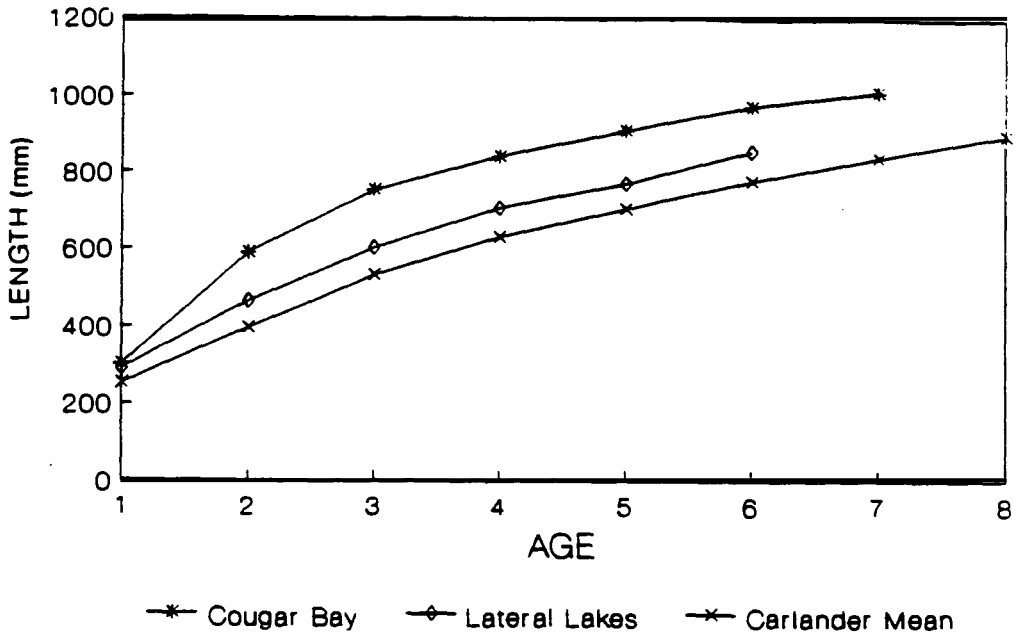


Figure 2. Back calculated total-lengths-at-age of northern pike at Cougar Bay (1990), Lateral Lakes (1989), and the North American average (Carlander 1969).

Table 2. Estimated mortality for northern pike in the Coeur d' Alene River System, Idaho.

Water Area	E	Z	A	F	M
Cave Lake	.11	.25	.22	.13	.12
Medicine Lake	.22	.41	.34	.27	.14
Swan Lake	.30	.35	.30	.35[a]	0
Killarney Lake	.59	.69	.50	.69[a]	0
Lat. Lakes (Combined)	.29	.43	.35	.36	.07
Cougar Bay (CDA Lake)	.30	.32	.27	.32[a]	0

a) when F>Z, F was set equal to Z.

were calculated at 0.8 kg/hectare (95% CI = 0.6 - 1.2), 1.2 kg/hectare (95% CI = 0.8- 2.5), and 4.6 kg/hectare (95% CI = 3.2 - 8.4) for Medicine Lake, Cave Lake, and Cougar Bay, respectively (Figure 2).

Condition and Proportional Stock Density

Length-weight relationships were LogW = -6.018 + 3.308 LogL for northern pike from the Lateral Lakes (Spring 1989) and LogW = -6.282 + 3.423 LogL for Cougar Bay, Coeur d'Alene Lake (Spring 1990). Relative weight of northern pike was 109 (n = 100) for the Lateral Lakes and 127 (N = 194) for Cougar Bay. Proportional Stock Density (PSD) for northern pike was 83 for the Lateral Lakes (1989) and 94 for Cougar Bay (1990) (Figure 3). Infestation rate of northern pike sampled for intestinal tract parasites was 93% for the Cestode parasite Proteocephalus ambloplites. Each host contained multiple individuals.

DISCUSSION

Recruitment

Presence of young-of-year (YOY) or Age 1 northern pike in any sampling area implied successful spawning and rearing in the given water area. Based on this assumption, spawning and rearing of northern pike occurs successfully in suitable habitat throughout Coeur d'Alene Lake and the lateral lakes of the Coeur d'Alene River. Catch curves indicate that recruitment varies annually among lakes and within individual lakes in the system among years (assuming that annual mortality is constant among age classes and years) (Figure 4). This variation is probably a result of fluctuating spring water temperatures and levels or siltation from spring runoff (Figure 5). Hassler (1970) reported embryonic mortality of northern pike approaching 100% associated with sudden drops in water temperature below 10°C or prolonged water temperatures near 5°C, and 97% embryonic mortality or higher due to silt deposition of 1.0 mm per day.

Other sources of variation in annual recruitment could include predation on young-of-year northern pike by yearling and older largemouth bass or yellow perch. Bowles (1985) reported a five- to six-fold fluctuation in largemouth bass recruitment in the Lateral Lakes between 1981 and 1982. Lethal levels of dissolved oxygen or hydrogen sulfide (H S) may also affect juvenile survival. While seining for YOY northern pike in Cave Lake (June 1989) several dead YOY yellow perch were sampled with mouths agape which indicated asphyxiation as the cause of death. The site was a typical juvenile fish rearing area in the Coeur d'Alene River System, water <1 m deep with a large mass of rotting Equisetum sp. producing many rising bubbles, which smelled of H_2S. Seifert et al. (1973) reported reduced survival of larval northern pike at oxygen tensions of ≤33% saturation. Smith and Oseid (1974) reported survival rates for northern pike fry of 98, 34 and 0% at H_2S concentrations of 0.035, 0.046, and 0.086 mg/l, respectively.

Age and Growth

Growth rates of northern pike in the Coeur d'Alene River System are the highest reported in the English language literature. Lengths at age for the Lateral Lakes and Cougar Bay average 13% and 31% higher than the North American average reported by Carlander (1969). Annual growth increment was highest in young-of-year northern pike similar to that for other populations (Diana and Mackay 1979). In growth year 2, northern pike in the Coeur d'Alene River System

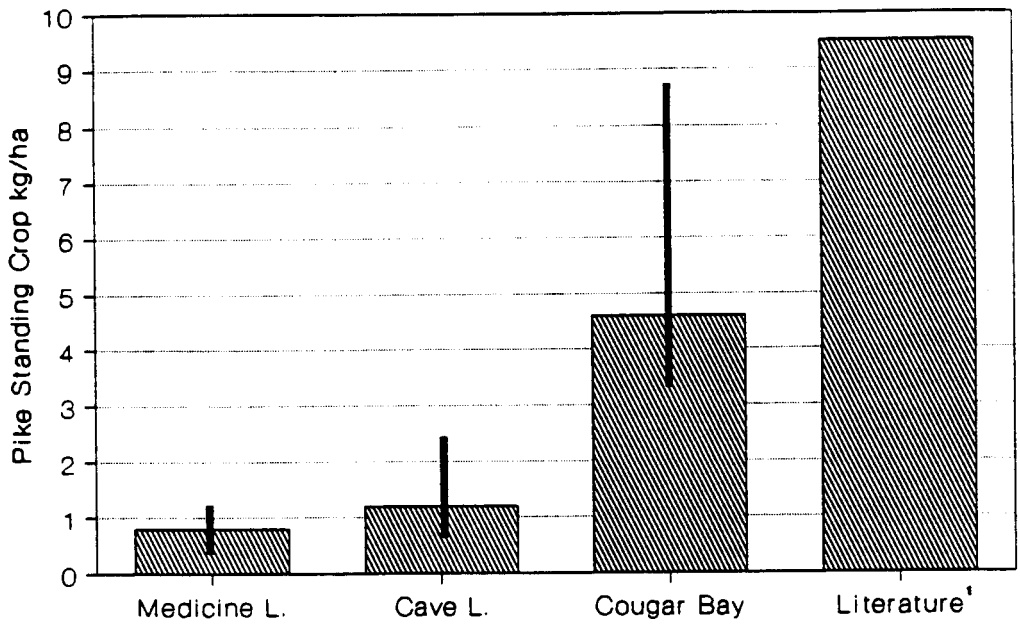


Figure 3. Standing crop (kg/ha) estimates for northern pike in the Coeur d'Alene River System: Medicine and Cave Lakes (1989), Cougar Bay (1990), and literature average (Carlander 1955). Vertical bars represent 95% confidence intervals on estimates.

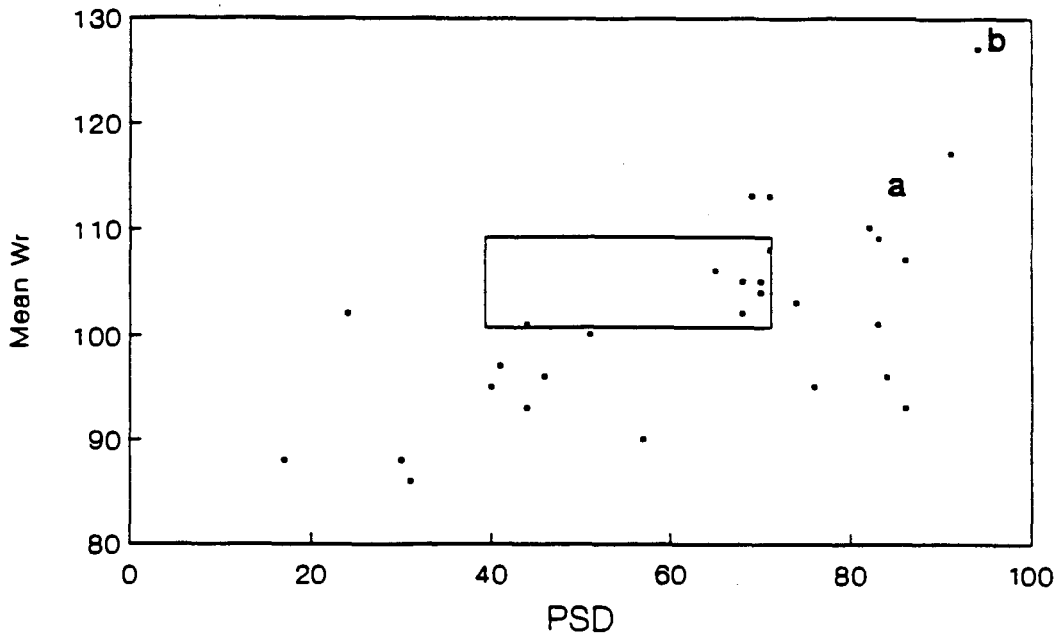
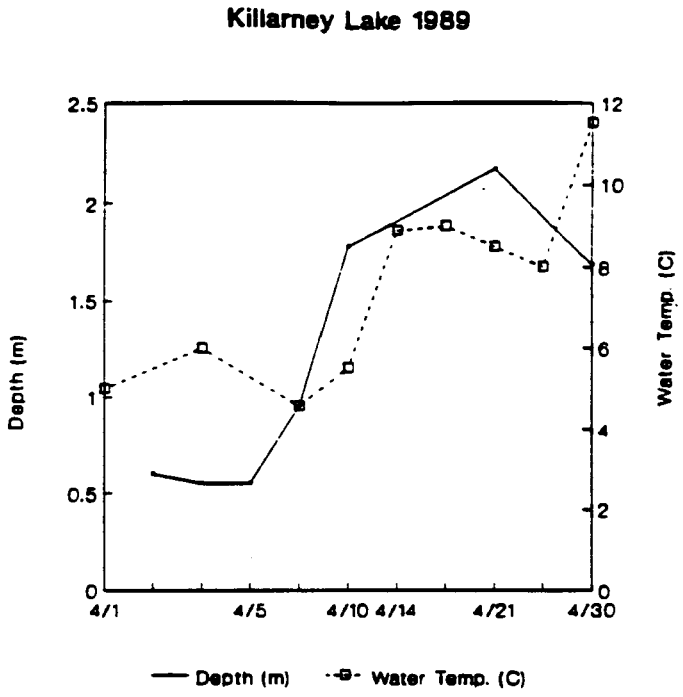


Figure 4. Relationship of Proportional Stock Density (PSD) and mean relative weight (Wr) for 27 data sets from 19 northern pike populations; modified from Willis and Scalet (1989) to include a) Lateral Lakes in Spring 1989, and b) Cougar Bay in Spring 1990. Box indicates management objective window.



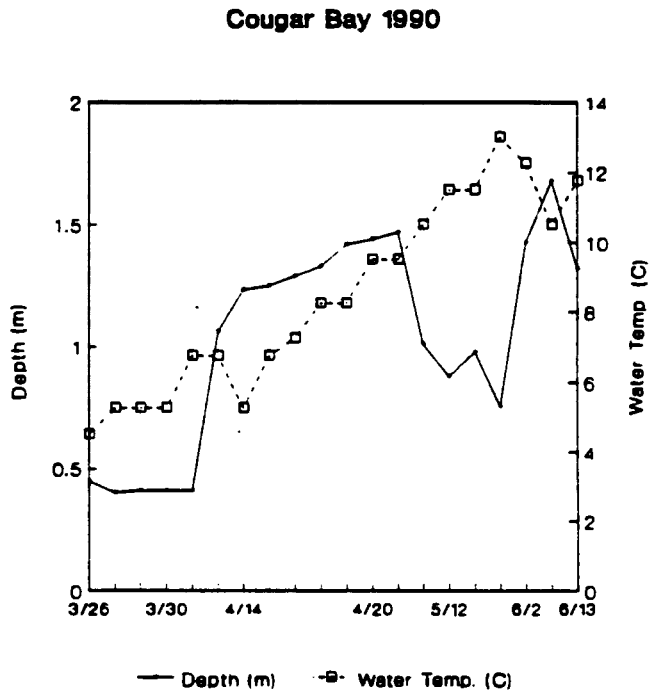


Figure 5. Temperature and depth fluctuations in spawning shallows during Spring 1989 at Killarney Lake (top) and Spring 1990 at Cougar Bay (bottom). Spawning occurred about April 12, 1989 at Killarney Lake and March 31, 1990 at Cougar Bay.

surpass typical northern pike populations in somatic growth (18% and 49% greater length at age than average for the Lateral Lakes and Cougar Bay), although most northern pike, including those in the Coeur d'Alene River System, become sexually mature during their second year of growth (Raat 1988).

The oldest northern pike sampled was Age 8, although individuals as large as 15 kg collected. Scott and Crossman (1973) described an inverse relationship between growth rate and longevity related to increasing latitude. The rapid growth rate of northern pike in this system probably limits longevity.

Growth of northern pike in Cougar Bay of Coeur d'Alene Lake is unequalled by those from other stocks reported in the international literature (Carlander 1969; Scott and Crossman 1973; Raat 1988). Phenomenal growth in the Coeur d'Alene River System is probably the result of a combination of optimal summer water temperatures of 17 to 22°C (Casselman 1978; Appendix **A)**, low northern pike densities, and availability of large soft-rayed prey fishes at optimum sizes and densities (Beyerle 1978).

Age determinations on a representative sample of 10 paired scale impressions and cleithra corroborated the efficacy of the scale method and the exceptionally high growth rates (John Casselman, Ontario Ministry of Natural Resources, personal communication). The use of scales for aging esocids Age 10 or younger is acceptable in some populations having rapid growth rates (Casselman 1979; Laine et al. 1991) and was validated for northern pike in Squeers Lake, Ontario (Laine et al. 1991).

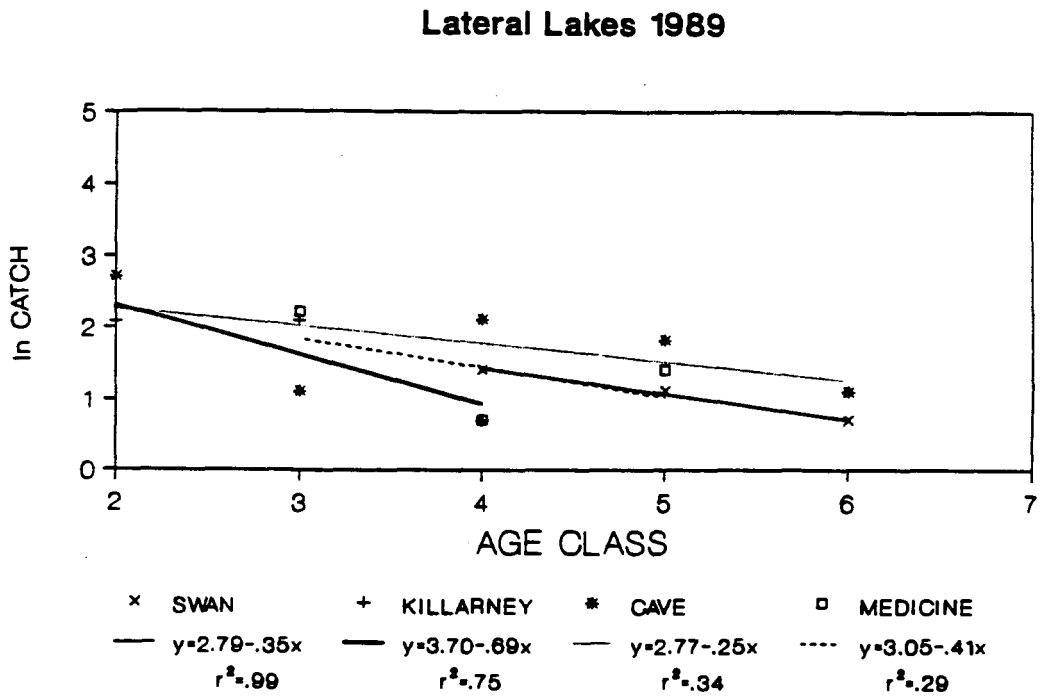
Mortality and Exploitation

Natural mortality of northern pike was low in the Coeur d'Alene River System and nearly all mortality was attributable to fishing. Raat (1988) reported total annual mortality rates world-wide of 45-70%; mortality in the Coeur d'Alene River System is below this range (Table 1). Natural mortality of northern pike is density dependent (Raat 1988) which may explain why the low density populations of the Coeur d'Alene River System have low natural mortality. Northern pike are typically quite vulnerable to anglers, especially in small bodies of water such as Killarney Lake (Appendix B). Kempinger and Carline (1978) attributed the vulnerability of northern pike to angling to their preference for littoral habitats and voracious feeding habits.

My estimates of total annual mortality for northern pike in the Coeur d'Alene River System may be inaccurate since the assumption of constant recruitment was not met (Ricker 1975). Catch curves (Figure 6) indicate that recruitment in this system is variable among lakes within years and among years within lakes. Least squares regression of points in the descending right limb of the catch curve gives a best estimate of total annual mortality which is probably inherent in other stocks since variable recruitment is common in northern pike populations (Raat 1988). Fishing mortality for northern pike in the Lateral Lakes may have been lower than average in 1989, because weak ice precluded a popular and ordinarily successful winter northern pike fishery (Idaho Dept. of Fish and Game, unpublished data).

Abundance

Scott and Crossman (1973) reported the range of standing crops for northern pike as 3.6 to 11.5 kg/hectare. Northern pike subpopulations in the Coeur d'Alene River System have low densities (=1-5 kg/hectare), not different than values reported by Kipling (1983) for Lake Windermere in the 1970's (3.3-10.2 kg/hectare). Standing crop of northern pike in both Coeur d'Alene Lake



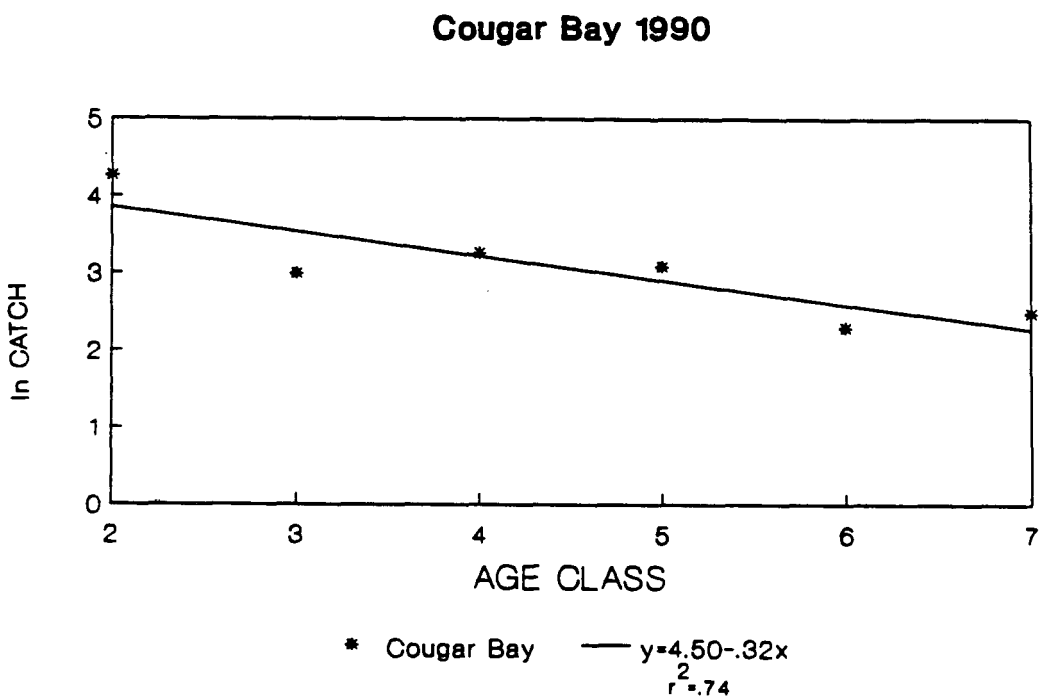


Figure 6. Catch curves (descending right limbs only) for northern pike sampled in the Lateral Lakes (1989) by gill netting (top) and Cougar Bay (1990) by gill and trap netting (bottom).

(12,700 hectares) and Lake Windermere (14,800 hectares) reflect densities only in shallow vegetated habitats, approximately 4% of the respective lake areas.

Condition and Proportional Stock Density

Management objectives set for North American northern pike populations (Wr between 95 and 105; Proportional Stock Density (PSD) between 40 and 70) by Willis and Scalet (1989) were both exceeded by northern pike in the Coeur d'Alene River System (Figure 3). While no apparent drawback exists from exceedingly high condition factor (Wr), Anderson and Weithman (1978) stated that high PSD values can be indicative of low recruitment rates. Future PSD values for northern pike in the Coeur d'Alene River System will probably decrease to more typical levels due to increasing popularity of the fishery and subsequent increased exploitation of older age classes. Relative condition factor (Wr) will probably remain high despite the apparently high infestation rate of northern pike in the Coeur d'Alene River System by Proteocephalus ambloplites, a common parasite of northern pike in North America (Toner and Lawler 1969).

LITERATURE CITED

Anderson, R.O. and A.S. Weithman. 1978. The concept of balance for coolwater fish populations. American Fisheries Society Special Publication 11:371-381.

Apperson, K.A., M. Mahan, and W.D. Horton. 1988. North Idaho Streams fishery research. Idaho Dept. of Fish and Game Report. Rivers and Streams Investigations. Study completion report, Project F-73-R-10, Subproject IV, Study IV.

Bennett, D.H., C.M. Falter, and W.D. Sawle. 1990. Pilot sampling for heavy metals in fish flesh from Killarney Lake, Coeur d'Alene River system, Idaho. Department of Fish and Wildlife Resources, University of Idaho. Moscow, Idaho. 45 pp.

Beyerle, G.B. 1978. Survival, growth and vulnerability to angling of northern pike and walleyes stocked as fingerlings in small lakes with bluegills or minnows. American Fisheries Society Special Publication 11:382-389.

Bowles, E.C. 1985. Recruitment and Survival of Young-of-the-year largemouth bass (Micropterus salmoides) in the Coeur d'Alene River System, Idaho. Master's Thesis, University of Idaho, Moscow, Idaho.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology. Vol. 1. Iowa State University Press, Ames, Iowa.

Cassellman, J.M. 1974. External sex determination of northern pike, Esox lucius Linnaeus. Transactions of the American Fisheries Society 103(2):343-347.

Cassellman, J.M. 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike. American Fisheries Society Special Publication 11:114-128.

Cassellman, J.M. 1979. The esocid cleithrum as an indicator calcified structure, p. 249-272. In: J. Dale and Y. Gravel, eds. Proc. 10th Warmwater Workshop, Special Publication, Northeast Division, American Fisheries Society. Published by Quebec Ministry Loisir, de la Chasse and de la Peche, Div. de la Recherche Farbique, Montreal, Quebec. 285 pp.

Diana, J.S. and W.C. Mackay. 1979. Timing and magnitude of energy deposition and loss in the body, liver, and gonads of northern pike Esox lucius. Journal of the Fisheries Research Board of Canada 36:481-487.

Everhart, W.H., and W.D. Youngs. 1981. Principles of fishery science. Second edition. Cornell University Press, Ithaca, New York.

Frie, R.V. 1982. Measurement of fish scales and back-calculation of body lengths using a digitizing pad and a microcomputer. Fisheries. 7(6):5-9.

Gablehouse, D.W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Hassler T.J. 1970. Environmental influences on early development and year-class strength of northern pike in Lake Oahe and Sharpe, South Dakota. Transactions of the American Fisheries Society. 99:369-375.

Jennings, M.R. 1989. Use of spring scales for weighing live fish in the field. North American Journal of Fisheries Management 9:509-511.

Kempinger, J.J. and R.F. Carline. 197B. Dynamics of the northern pike population and changes that occurred with a minimum size limit in Escanaba Lake, Wisconsin. American Fisheries Society Special Publication 11:382-389.

Kipling, C. and W.E. Frost. 1970. A study of mortality, population numbers, year class strengths, production and food consumption of northern pike Esox lucius L., in Windermere from 1944 to 1962. Journal of Animal Ecology 39:115-157.

LaBolle, L. 1986. Enhancement of Kokanee on Priest and Pend Oreille Lakes. Idaho Dept. of Fish and Game. Lake and Reservoir Investigations. Job Performance Report, Project F-73-R-7, Subproject III, Study III.

Lackey, R.T. and W.A. Hubert. 1977. Analysis of exploited fish populations. Virginia Polytechnic Institute and State University. VPI-SG-76-04. Blacksburg, Virginia, U.S.A.

Laine, A.O., W.T. Momot and P.A. Ryan, 1991. Accuracy of using scales and cleithra for aging northern pike from an oligitrophic Ontario lake. North American Journal of Fisheries Management 11:220-225.

Lukens, J.R. 1978. Abundance, movements and age structure of adfluvial Westslope cutthroat trout in the Wolf Lodge Creek drainage, Idaho. M.S. Thesis. University of Idaho, Moscow, Idaho.

Mann, R.H.K. 1985. A northern pike management strategy for a trout fishery. Journal of Fish Biology 27(Suppl. A):227-234.

Raat, A.J. 1988. Synopsis of biological data on the northern pike Esox lucius Linnaeus, 1758. Food and Agriculture Organization of the United Nations. Rome.

Rabe, F.W. and S.B. Bauer. 1977. Heavy metals in lakes of the Coeur d'Alene River Valley, Idaho. Northwest Science, Vol. 51, No. 3. pp. 183-197.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Rieman, B.E. 1987. Fishing and population dynamics of largemouth bass (Micropterus salmoides) in select Northern Idaho Lakes. PhD Dissertation, Univ. of Idaho, Moscow, Idaho. 133 pp.

Rieman, B.E., B. Bowler, L. Labolle, and P. Hassemer. 1980. Coeur d'Alene Lake Fisheries Investigations. Idaho Department of Fish and Game Dept. Lake and Reservoir Investigations. Job Performance Report, Project F-73-R-2, Subproject III, Study V.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Bulletin 184.

Seifert, R.E., W.A. Spoor, and R.F. Syrett. 1973. Effects of reduced oxygen concentrations on northern pike (Esox lucius) embryos and larvae. Journal of the Fisheries Research Board of Canada 30:849-852.

Simpson, J.C. and R.L. Wallace. 1982. Fishes of Idaho. University of Idaho Press, Moscow, Idaho.

Smith, L.L. and D.M. Oseid. 1974. Effect of hydrogen sulfide on development and survival of eight freshwater fish species. In Blaxter, J.H.S. ed., The early life history of fish. Berlin, Springer-Verlag. 417-430.

Toner, E.D. and G.H. Lawler. 1969. Synopsis of biological data on the northern pike, Esox lucius (Linneaus, 1758). FAO Fisheries Synopsis No. 30 Rev. 1.

Willis, D.W. 1989. Proposed standard length-weight equation for northern pike. North American Journal of Fisheries Management 9:203-208.

Willis, D.W, and C.G. Scalet. 1989. Relations between proportional stock density and growth and condition of northern pike populations. North American Journal of Fisheries Management 9:488-492.

Chapter 2. Food Habits of Northern Pike in the Coeur d'Alene River System.

INTRODUCTION

Northern pike are ubiquitous piscivores (Raat 1988), supporting circumpolar fisheries (Scott and Crossman 1973) with established populations in over half of the freshwater in North America (Carlander et al. 1978). Northern pike predation is often species-specific (Hunt 1965; Mauck and Coble 1971; Hottell 1976; Wolfert and Miller 1978; Stein and Enzler 1983), related to seasonal prey availability (Frost 1954; Toner and Lawler 1969; Finnell 1988), and can control prey species populations (Frost 1954; Grimm 1981b; Mann 1985).

Since northern pike can control prey fish populations but are not native to northern Idaho waters which support various important fisheries, knowledge of their food habits was considered necessary for future management. The objective of this study was to describe prey use by northern pike in the Coeur d'Alene River System.

METHODS

Stomach contents of northern pike were sampled primarily in spring and fall 1989 and fall 1990 in the Lateral Lakes and in spring and fall 1990 in Coeur d'Alene Lake. The stomach contents of live northern pike captured with gill nets, trap nets, by anglers, and by pulsed DC electrofishing were removed by gastric lavage (Foster 1977; Light et al. 1983; Finnell 1988). A stream of water from a bilge pump was directed through a 5 mm copper tube into the northern pike's stomach to quickly disgorge most food items. Some prey items, particularly spiny rayed fishes, were pulled from the esophagus by the tail with a long nose pliers or fish hook remover (Finnell 1988). After removal of prey items from the stomach, the copper tubing was reinserted into the esophagus and moved laterally (in combination with gentle thumb pressure on the northern pike's abdomen) to release air and water remaining in the stomach from the lavage process. This alleviated unnatural buoyancy of released northern pike. Angler mortalities were eviscerated and prey items removed through an incision in the stomach wall. A subsample of northern pike sampled for stomach contents by lavage was eviscerated as a check.

Prey items were visually identified to species and measured for total length (mm). Total lengths (TL) of partially digested prey items were estimated. Prey items not readily identified due to partial digestion were frozen or preserved in an ethyl alcohol and glycerine solution and identified in the laboratory with bones from known prey specimens. Well-digested prey fish were assigned the mean length of that species found in northern pike stomachs during that particular sampling period. Prey fish not identifiable were classified as unidentified fish. Weights of prey items were estimated using length-weight regression equations of species from Coeur d'Alene Lake or the literature. Total lengths of prey fish sampled concurrently with young-of-year and yearling northern pike by fall electrofishing were used to test for size selection by northern pike.

RESULTS

Frequency of Empty Stomachs

A total of 511 stomachs from northern pike were sampled throughout this study, of which 74% (n = 66) and 63% (n = 206) were empty during spring at the Lateral Lakes (1989) and Cougar Bay (1990), respectively. Frequencies of empty stomachs in principal capture gears were 61% (n = 87) and 64% (n = 107) in gill and trap nets, respectively. Frequency of empty stomachs in the fall was 69% (n = 74) at Killarney Lake (1989) and 45% (n = 53) for adults at Coeur d'Alene Lake (1990).

Prey Use

Yellow perch was the dominant food item of northern pike in the Lateral Lakes. In spring 1989, 17 of the 66 northern pike sampled on four Lateral Lakes (Cave, Killarney, Medicine, and Swan) contained food items. Yellow perch accounted for 95% (numerically) of the prey (average TL = 114 mm, SD = 42.6). The remaining items were unidentifiable fish and similar in size to the perch consumed.

Twenty three of the 74 northern pike sampled in Killarney Lake during fall 1990 contained food items. A few large cutthroat trout (average TL = 215 mm; 17% numerically and 45% by weight) and numerous small perch (average TL = 92 mm; 41% numerically and 14% by weight) dominated the stomach contents (Figure 7).

Eighty of 206 northern pike sampled at Cougar Bay during spring 1990 contained food items (Figure 8). Large longnose suckers (average TL = 366 mm) dominated the diet by weight (62%) but accounted for only 13% of prey numerically. Yellow perch (average TL = 128 mm) were numerically dominant (44% of diet) but comprised only 11% of the diet by weight. Salmonids comprised 22% of the diet by weight and 23% numerically. These were large cutthroat trout (average TL = 309 mm, 13% of the northern pike diet by weight and 5% numerically), small kokanee (average TL = 99 mm, 3% of diet by weight and 16% numerically), and hatchery rainbow trout O. mykiss (average TL = 250 mm, 6% of northern pike diet by weight and 2% numerically).

Twenty nine of 53 northern pike sampled by angling in fall 1990 at Cougar Bay contained prey items. Kokanee (average TL = 224 mm) made up 58% of the diet by weight and 42% numerically. Cutthroat trout were second in dietary importance (average TL = 250 mm; 21% by weight and 10% numerically) followed by yellow perch (average TL = 136 mm; 15% by weight and 39% numerically; Figure 9).

Analysis of all food habits data collected throughout the Coeur d'Alene River System (1989-90) revealed that all of the 16 fish species present were consumed by northern pike except bull trout and largescale sucker. Tench and brown bullhead were least commonly found in northern pike stomachs (only one individual of each these species was found) although those species were common in the system (Table 3). Odonata larva (<0.02% by weight) and one vole Microtus spp. were the only non-fish items found in northern pike stomachs.

Size Selection

Young-of-year and yearling northern pike (n = 24) sampled by fall electrofishing (Killarney Lake, 1990) contained 94% (by weight) yellow perch (n = 21, average TL = 66.9 mm, SD 19.5)(73% of diet numerically). Northern pike

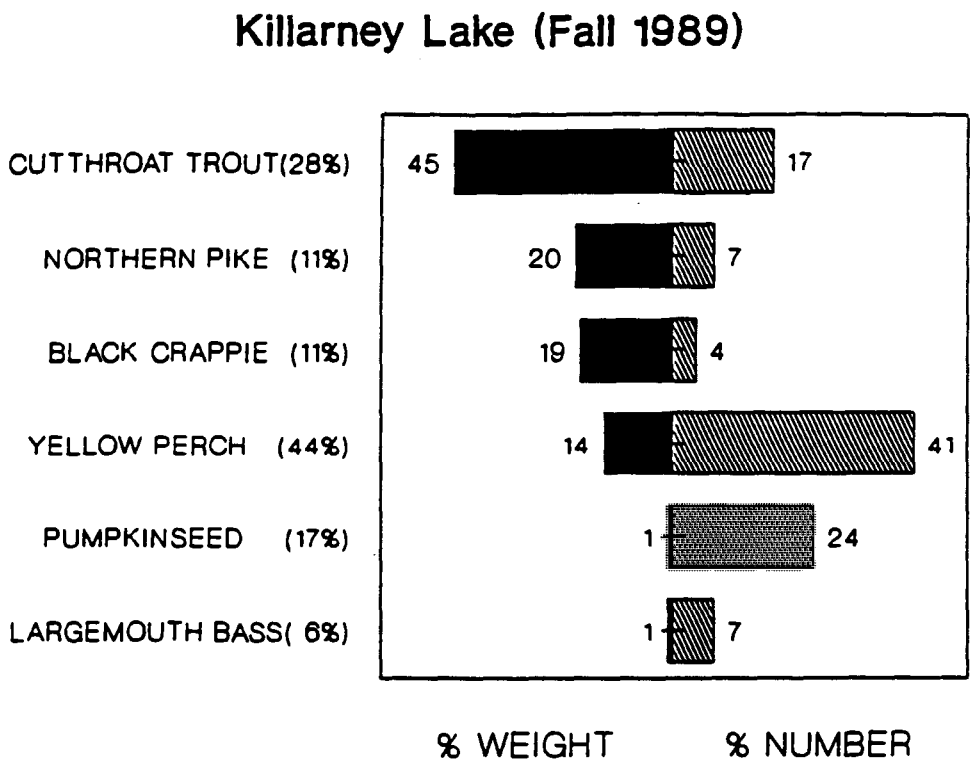


Figure 7. Stomach contents of northern pike at Killarney Lake, fall 1989 (23 of 74 pike sampled contained prey). Frequency of occurrence in parentheses.

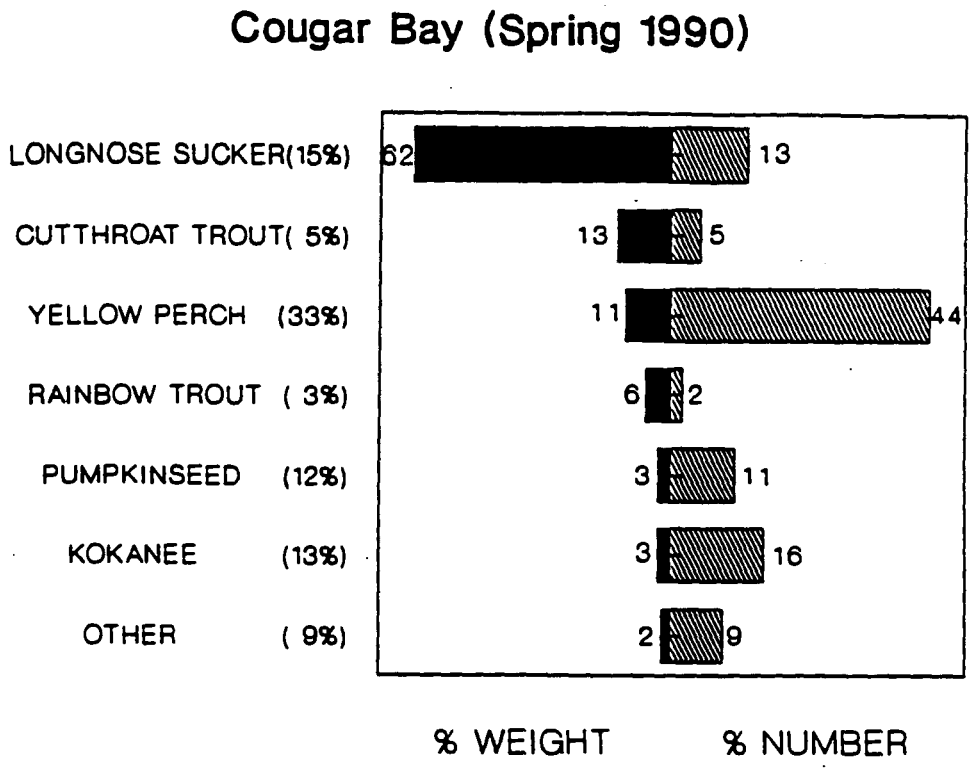


Figure 8. Stomach contents of northern pike at Cougar Bay (Coeur d'Alene Lake), spring 1990 (80 of 206 pike sampled contained prey). Frequency of occurrence in parentheses.

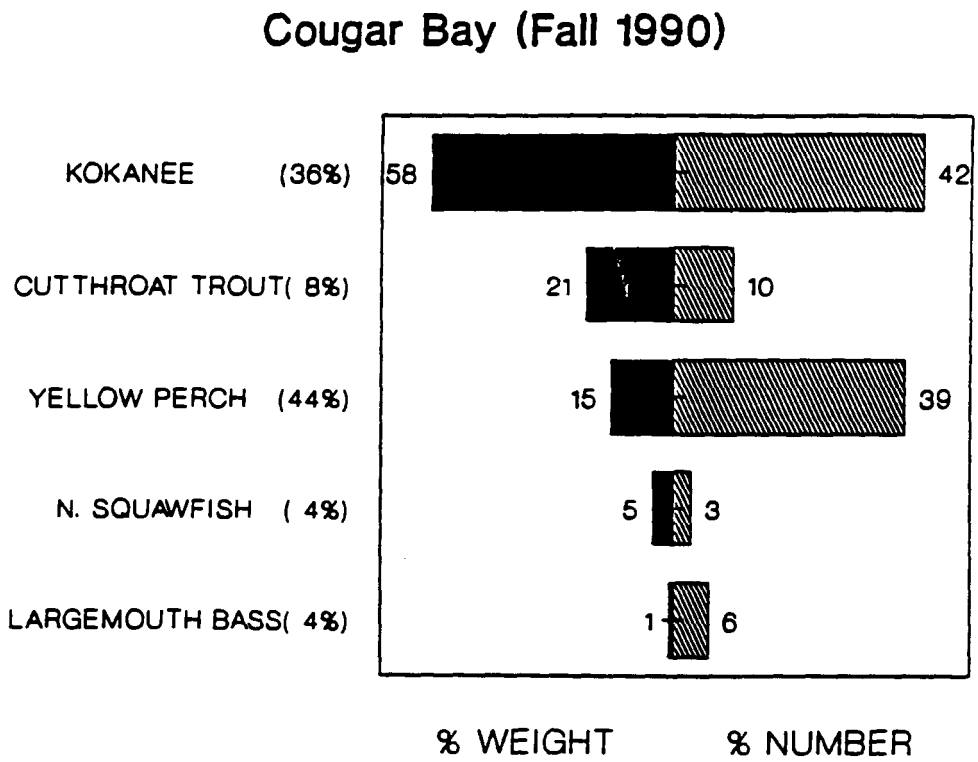


Figure 9. Stomach contents of northern pike at Cougar Bay (Coeur d'Alene Lake), fall 1990 (29 of 53 pike sampled contained prey). Frequency of occurrence in parentheses.

Table 3. Numbers and relative frequency of various fish species captured by trap and gill netting in the Lateral Lakes (spring and fall 1989) and Cougar Bay, Coeur d' Alene Lake (spring 1990).

	Lateral Lakes (1989)		Cougar Bay (1990)	
	Number Sampled	Relative Frequency	Number Sampled	Relative Frequency
Brown bullhead	2120	64%	2652	56%
Yellow perch	522	16%	592	13%
Northern pike	235	7%	237	5%
Black crappie	175	5%	166	4%
Tench	164	5%	654	14%
Largemouth bass	45	1%	58	1%
Pumpkinseed	39	1%	288	6%
Brook trout	1	<1%		
Cutthroat trout	7	<1%	8	<1%
Kokanee			1	<1%
Rainbow trout			3	<1%
Largescale sucker	1	<1%		
Longnose sucker			41	1%
Northern squawfish	2	<1%	1	<1%
Total	3311	100%	4702	100%

consumed yellow perch similar in size to those subsampled concurrently by electrofishing (n = 78, average TL = 65.9 mm, SD = 24.7; t = 0.1749 N.S.; Figure 10). The mean prey - predator length ratio at Killarney Lake (fall 1990 electrofishing sample) for yellow perch and northern pike that preyed on them was 0.19 (n = 21, SD = 0.05, range = 0.09 - 0.30), similar to the prey - predator length ratio for yellow perch available and northern pike in sample which preyed on yellow perch. Average prey length - northern pike length ratios were 0.24 for all sizes of northern pike at Cougar Bay in spring 1990 (n = 80, SD = 0.11, range = 0.05 - 0.55) and 0.31 for all sizes of northern pike Cougar Bay in fall 1990 (n = 25, SD = 0.09, range = 0.13 - 0.57). Prey lengths (n = 139) increased as a function of northern pike length (Figure 11).

DISCUSSION

I have confidence in the data collected in this study based on the demonstrated effectiveness of the gastric lavage. I evacuated a random sample of 10 northern pike harvested by anglers first by gastric lavage and then by actual excision of the stomach. The lavage technique was 100% effective in removing food items. Foster (1977) similarly reported 100% effectiveness on grass pickerel Esox americanus vermiculatus. Additionally, similar frequency of empty stomachs between trapnets and short-set (<2 h) gill nets (the primary modes of capture) indicated no apparent regurgitation problem, a source of potential bias described by Treasurer (1988).

Frequency of Empty Stomachs

The frequency of empty stomachs found in the Coeur d'Alene River System seemed high (x = 64%) but was similar to those reported in the literature. Finnel (1988) found frequencies of empty stomachs throughout the year to average about 40% at Elevenmile Canyon Reservoir (Colorado) and Diana (1979) found 29-62% empty stomachs at Lac Ste. Anne (Alberta) on a monthly basis. Northern pike feed infrequently, but consume large meals and feeding time is short relative to time between meals (Diana 1979). Seaburg and Moyle (1964) reported that northern pike require about 50 h to completely digest a full meal of yellow perch during summer, but about 12 d are required in winter (Diana 1979).

Prey Use

Many authors have reported that the food of northern pike consisted almost exclusively of fish (Lawler 1965; Seaburg and Moyle 1964; *Mann* 1982; Wolfert and Miller 1978). My data indicate that non-fish organisms are insignificant in the diet of yearling and older northern pike in the Coeur d'Alene River System.

Yellow perch was the most important prey item numerically of northern pike in the Coeur d'Alene River System although soft-rayed salmonids and catostomids were most important by weight (Figures 7-9). An exception was in spring 1989 in the Lateral Lakes, when all food items identified were yellow perch. Small perch typically have less mass than larger soft-rayed fishes. Yellow perch are taken by a larger proportion of northern pike than any other prey item, however, they represent a small proportion of the northern pike population's annual caloric ration. Diana (1979) determined that large and rare prey items (≤7% by number) constitute up to 35% of the annual ration of northern pike. In Coeur d'Alene Lake, longnose suckers, kokanee, and cutthroat trout provided the majority of the northern pike ration by weight (Figures 7-9) although these species were uncommon in gill net and trap net catches (Table 3).

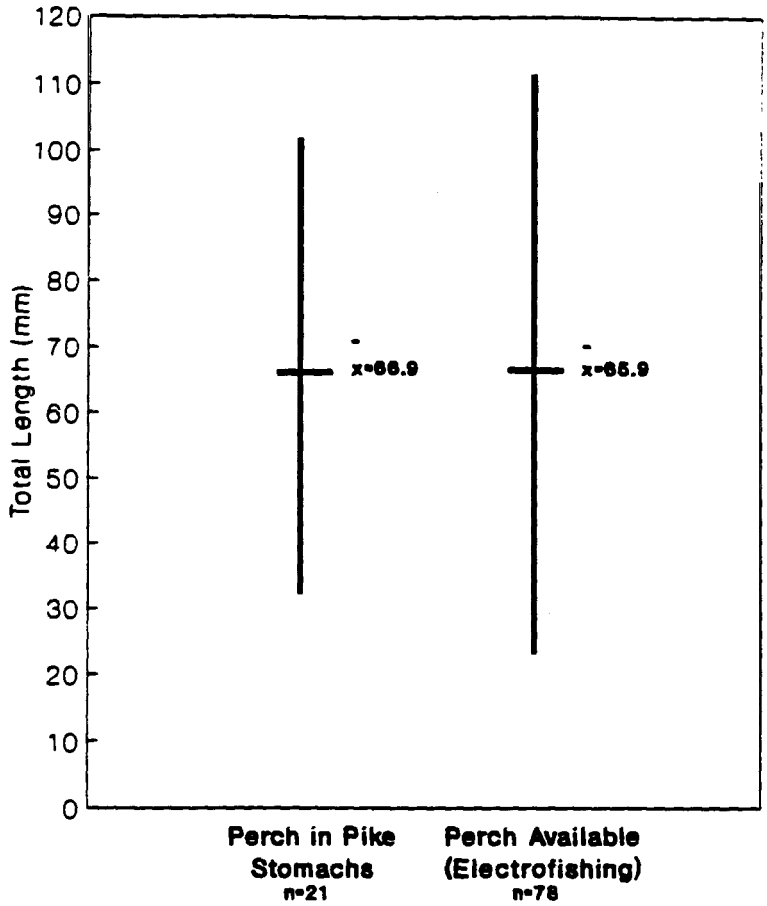


Figure 10. Comparison of mean length of yellow perch found in stomachs of young-of-year and yearling northern pike and available perch (sampled simultaneously by electrofishing) at Killarney Lake, fall 1990. Vertical bars represent 95% confidence intervals.

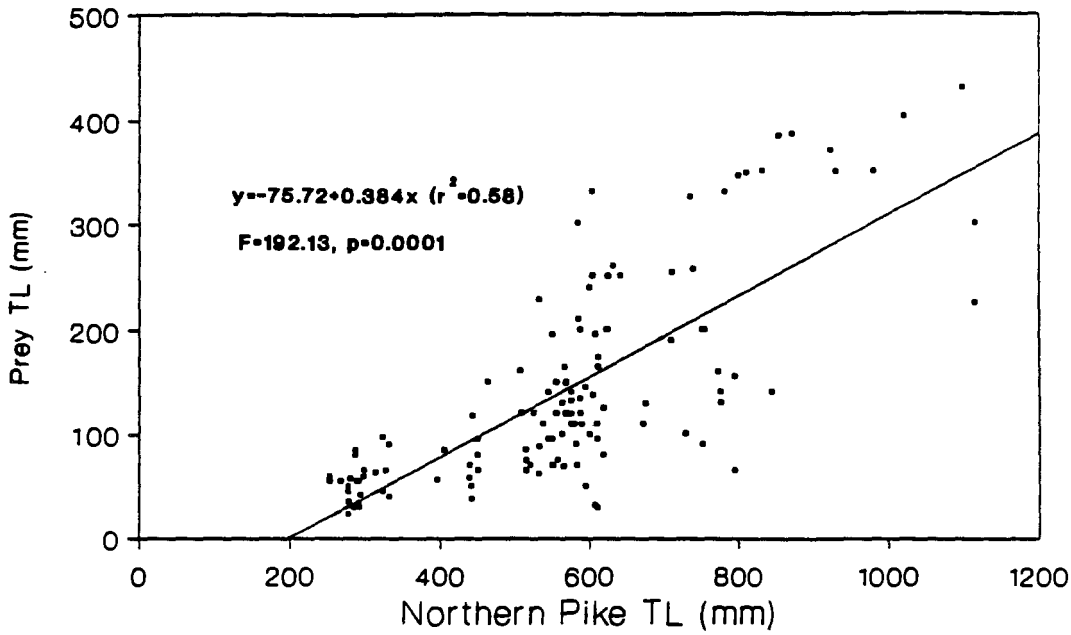


Figure 11. Regression of prey fish lengths of pike which consumed them in the Coeur d'Alene River System 1990 (n=139).

Catostomid and salmonid species were seasonally available to northern pike. Lawler (1965) and Frost (1954) determined that relative abundance and seasonal availability probably determined the incidence of prey consumed. Others have also reported high seasonal consumption of salmonid prey including migrating Atlantic salmon Salmo salar smolts and sea-run adult brown trout Salmo trutta (Mann 1982), brown trout, and char Salvelinus alpinus willughbii (Frost 1954), brown trout (Toner and Lawler 1969), and rainbow trout and kokanee (Finnell 1988).

Northern pike select for certain prey fishes, especially salmonids when available. Wolfert and Miller (1978) found that northern pike in eastern Lake Ontario selected alewife Alosa pseudoharengus over white perch Morone americanus or yellow perch. Rainbow trout were selected by northern pike over brown trout (Hunt 1965) in a Wisconsin stream, and recently stocked hatchery rainbow trout were selected for over yellow perch (the otherwise primary diet item) in two Georgia reservoirs (Hottell 1976). Roach Rutilus rutilus were selected over perch Perca fluviatilis in Slapton Ley, England (Bergazzi and Kennedy 1980) and yellow perch were selected for over various centarchids in two Minnesota lakes (Seaburg and Moyle 1964). In raceways, Stein and Enzler (1983) concluded that northern pike selected trout over rudd Scardinius erythrophtalmus and hatchery trout over wild trout.

I believe cutthroat trout were selected for by northern pike in the Coeur d'Alene River System, because they are optimal prey items (fusiform shape, lacking spines) and, as characteristic surface feeders, they present a behaviorally stimulating target for ambush feeding northern pike. Coble (1973) reported that behavior of prey was more significant in food selection of northern pike than prey brightness, color, or form of tail in laboratory experiments. Ivlev (1961) found that food selection by northern pike was determined by both vulnerability of available prey and predator preference. Innate inclination, satiation and conditioning of predator, prey appearance, behavior, abundance, relative abundance, size distribution, and armament may affect preference (Coble 1973; Ivlev 1961; Raat 1988).

Northern pike exhibit food preferences for soft-rayed and fusiform fish over spiny-rayed prey fish (Mauck and Coble 1971; Wahl and Stein 1988; Beyerle and Williams 1968). Mauck and Coble (1971) found that soft-rayed and fusiform fish were most vulnerable to northern pike predation, more laterally compressed fish without and with spines were intermediate and fish with highly laterally compressed body forms and those with both dorsal and lateral spines (Ictalurids) were least vulnerable. In the Coeur d'Alene River System, two of the more abundant littoral species were the less common food items. Brown bullheads in the Coeur d'Alene River System average about 240 mm (TL), have very large spines, and have reportedly low vulnerability to northern pike predation (Mauck and Coble 1971). Soft-rayed tench are important as food for northern pike in some European lakes or broads (J.M. Cassellman, personal communication) although Simpson and Wallace (1982) indicated few tench are consumed by predators.

Size Selection

Young-of-year perch in Killarney Lake were preyed on without regard to individual size by small northern pike in fall (ie. apparently were optimal prey with minimal cost:benefit ratio; Gillen et al. 1981). Prey:predator length ratios observed for northern pike in the Coeur d'Alene River System were similar to those of Nursall (1973), who found optimal prey size equal to 25% the length of northern pike. Prey length increased with and was about one third the length of northern pike (Figure 11), concurrent with the findings of Frost (1954), Lawler (1965), Willemson (1965), and Mann (1982).

Cannibalism

Frequency of occurrence of northern pike in northern pike stomachs (cannibalism) was insignificant (1.5%) in the Coeur d'Alene River System, similar to systems containing other available prey (0-2%, Frost 1954; Lawler 1965; and Wolfert and Miller 1978). Cannibalism is reduced when other food items are abundant and available (Raat 1988), however, intraspecific predation by northern pike can be significant enough to control biomass of small northern pike (Grimm 1981a, 1981b).

Northern pike in the Coeur d'Alene River System utilize salmonids for a significant portion of their annual caloric ration. Introduced kokanee provide a sport fishery and also are forage for chinook salmon. The cutthroat trout, however, is an indigenous species that is suffering from habitat degradation and competition with introduced salmonids. High predation by northern pike on cutthroat trout is due to spatial and temporal overlap of the two species and certain physical and behavioral characteristics of the cutthroat trout. When exotic predators are introduced into coolwater systems, predation on stocked salmonids, establishment of successful sport fisheries, and elimination of native fishes all can occur (Wydoski and Bennett 1981). Subsequent to the illegal introduction of northern pike into the Coeur d'Alene River System, predation on both stocked and naturally reproducing salmonids occurred, and a successful northern pike fishery developed. Because of the vulnerability of northern pike to angling (Weithman and Anderson 1976; Kempinger and Carline 1978), an increasingly popular and basically unregulated northern pike fishery should limit numbers of large northern pike and thereby minimize predation by northern pike on Westslope cutthroat trout in the Coeur d'Alene River System.

LITERATURE CITED

Bergazzi, P.R. and C.R. Kennedy. 1980. The biology of pike Esox lucius L., in a southern eutrophic lake. Journal of Fish Biology 17:91-112.

Beyerle, G.B. and J.E. Williams. 1968. Some observations of food selectivity by northern pike in aquaria. Transactions of the American Fisheries Society 97:28-31.

Carlander, K.D., J.S. Campbell and R.J. Muncy. 1978.Inventory of percid and esocid habitat in North America. American Fisheries Society Special Publication 11:27-38.

Coble, D.W. 1973. Influence of appearance of prey and satiation of predator on food selection by northern pike (Esox lucius). Journal of the Fisheries Research Board of Canada 30(2):317-320.

Diana, J.S. 1979. The feeding pattern and daily ration of a top carnivore, the northern pike (Esox lucius). Canadian Journal of Zoology 57:2121-2127.

Finnell, L.M. 1988. The fisheries of Elevenmile Canyon Reservoir, Colorado, 1982-1987. Colorado Division of Wildlife, Aquatic Research, Special Report 63, Denver.

Foster, J.R. 1977. Pulsed gastric lavage: an efficient method for removing the stomach contents of live fish. Progressive Fish Culturist 39:166-169.

Frost, W.E. 1954. The food of pike Esox lucius L., in Windermere. Journal of Animal Ecology 23(2):339-360.

Gillen, A.L., R.A. Stein, and R.F. Carline. 1981. Predation by pellet-reared tiger muskellunge on minnows and bluegills in experimental systems. Transactions of the American Fisheries Society 110:197-209.

Grimm, M.P. 1981a. The composition of northern pike (Esox lucius L.) populations in four shallow waters in the Netherlands, with special reference to factors influencing the 0+ biomass. Fisheries Management 12:61-76.

Grimm, M.P. 1981b. Intraspecific predation as a principal factor controlling biomass of northern pike (Esox lucius L.). Fisheries Management 12:77-79.

Hottell, H.E. 1976. The growth rate and food habits of the northern pike (Esox lucius) and the chain pickerel x northern pike hybrid (E. niger x E. lucius) in two northern Georgia reservoirs. M.S. Thesis. University of Georgia. 64 pp.

Hunt, R.L. 1965. Food of northern pike in a Wisconsin trout stream. Transactions of the American Fisheries Society 94:95-97.

Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, Newhaven. 302 pp.

Lawler, G.H. 1965. The food of the pike, Esox lucius, in Heming Lake, Manitoba. Journal of the Fisheries Research Board of Canada 22:1357-1377.

Light, R.W., P.H. Adler, and D.E. Arnold. 1983. Evaluation of gastric lavage for stomach analyses. North American Journal of Fisheries Management 3:81-85.

Mann, R.H. 1982. The annual food consumption and prey preferences of pike (Esox lucius) in the River Frome, Dorset. Journal of Animal Ecology 51:81-95.

Mann, R.H. 1985. A pike management strategy for a trout fishery. Journal of Fish Biology 27(Suppl. A):227-234.

Mauck, W.L. and D.W. Coble. 1971. Vulnerability of some fishes to northern pike Esox lucius predation. Journal of the Fisheries Research Board of Canada 28:957-969.

Nursall, J.R. 1973. Some behavioral interactions of spottail shiners (Notropis hudsonius), yellow perch (Perca flavescens), and northern pike (Esox lucius). Journal of the Fisheries Research Board of Canada 30(8):1161-1178.

Raat, A.J. 1988. Synopsis of biological data on the northern pike, Esox lucius Linnaeus, 1758. Food and Agriculture Organization of the United Nations. Rome.

Scott W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Bulletin 184. 966pp.

Seaburg, K.G. and J.B. Moyle. 1964. Feeding habits, digestive rates, and growth of some Minnesota warmwater fishes. Transactions of the American Fisheries Society 97:269-285.

Simpson, J.C. and R.L. Wallace. 1982. Fishes of Idaho. University of Idaho Press, Moscow, Idaho.

Stein H. And H. Enzler. 1983. Beutelselektion and Futterverwertung beim Hecht. Fischwirt 33(9):61-62.

Toner, E.D. and G.H. Lawler. 1969. Synopsis of biological data on the pike Esox lucius (Linnaeus 1758). FAO Fisheries Synopsis 30(Rev.1). 38 pp.

Treasurer, J.W. 1988. Measurement of regurgitation in feeding studies of predatory fishes. Journal of Fish Biology 33:267-271.

Wahl, D.H. and R.A. Stein 1988. Selective predation by three esocids: the role of prey behavior and morphology. Transactions of the American Fisheries Society 117:142-151.

Weithman, A.S. and R.O. Anderson. 1976. Angling vulnerability of Esocidae. Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commisioners 30: 99-102.

Willemson, J. 1965. Het voedsel van de snoek Visser-Nieuws 18:298-305.

Wolfert, D.F. and T.J. Miller. 1978. Age, growth and food of northern pike in eastern Lake Ontario. Transactions of the American Fisheries Society 107:696-702.

Wydoski, R.S. and D.H. Bennett. 1981. Forage species in lakes and reservoirs of the Western United States. Transactions of the American Fisheries Society 110:764-771.

Chapter 3. Movement and Habitat Use of Northern Pike in the Coeur d'Alene River System

INTRODUCTION

Habitat selection is an integral part of the ecology of any organism. Description of habitat use can require fairly intensive study, especially in aquatic systems where activities of organisms are not obvious. To fully understand the habitat preferences of northern pike in the Coeur d'Alene River ecosystem, Idaho, I studied their movement and habitat use during summer 1990. Movement was monitored by radio-telemetry, supplemented by mark and recapture (Moen and Henegar 1971; Kipling and LeCren 1984; Clark 1990).

The presence of important salmonids in the Coeur d'Alene River System such as the Westslope cutthroat trout and kokanee made it imperative to determine whether northern pike move little (Diana 1980) during their peak feeding season within shallow, vegetated habitats (Diana et al. 1977; Inskip 1982), or utilize a diversity of habitats, including deep, unvegetated sites, as a predatory advantage (Chapman and Mackay 1984a). The purpose of this study was to describe movement, habitat use, and home range use of northern pike in Coeur d'Alene Lake.

METHODS

Twenty one northern pike were radio-tagged in Coeur d'Alene Lake (Cougar and Wolf Lodge Bays, Figure 1). All northern pike were released immediately after field implantation of radio tags, at the site of capture (Appendix C). Radio transmitters were 30 Mhz Model P-40 (17 x 100 mm, cylindrical) (Smith-Root Inc., Vancouver WA.), powered by 180 day lithium batteries and had external whip antennae. Transmitters were surgically implanted into the coelomic cavity using a method modified from Ross and Kleiner (1982). Instead of shielding the needle, I used a nasal speculum inserted through the abdominal incision to lift the abdominal wall away from the visceral mass, thereby creating a safe space in the coelom through which to pass the needle from its insertion posterior of the pelvic girdle to the more anterior incision.

Northern pike were tracked with a Model RF-40 30 Mhz receiver and Model SR-40 multi-channel scanner (Smith-Root Inc., Vancouver WA.), using directional handheld, omni-directional whip, and directional Yagi antennae. Transmitters placed at 10 m deep produced a maximum effective range of 2 km. A coaxial antenna was used to determine actual fish location within 1.6 in.

Long-term Movement

An additional 366 northern pike were tagged with numbered jaw tags. Recapture of tagged fish from the sport fishery and other ongoing studies provided additional information on long-term movement.

Habitat Use

Northern pike equipped with transmitters were relocated in the early morning or late afternoon every 1-8 days (x = 5 d). Most northern pike were tracked from late March until October. Additionally, location and habitat use of randomly selected northern pike were monitored once every 3 h during 24 h periods with random starting times. At each fish location, Julian date, time of day, location

(UTM grid coordinates), error polygon size (Heezen and Tester 1967), water depth, distance from shore, water temperature profile (1 m intervals), substrate type, vegetation presence-absence, vegetation type, and structure type (shelf, point, creek channel, floating structure etc.) were recorded.

All locations were mapped by sighting compass azimuths (accurate to 0.5°) on three known-location landmarks. These locations were marked on a USGS quadrangle map (1-24,000 scale) and transformed to UTM (Universal Transverse Mercator) coordinates for determination of home range size (Ackerman et al. 1990). If a fish's actual location could not be reached due to physical barriers, triangulation was used. Water depth was measured either with a 3 m measuring stick or the marked probe cable on the temperature/dissolved oxygen meter and distance from shore was measured with an optical rangefinder (Model 1000, Ranging Inc., Rochester, NY) or directly from quadrangle maps. Water temperature and dissolved oxygen profiles were taken with a Model 58 YSI meter (Yellow Springs Instrument Company, Yellow Springs, OH), substrate and vegetation types were determined visually or sampled by dragging a fluked anchor along the bottom, and structure type was determined visually or with a Lowrance Model X-16 graph depth recorder (Lowrance Co., Tulsa OK). Statistical tests (Ott 1988) were used for comparisons, and stepwise logistic regression (Dixon 1985) was used to determine habitat variables most important in determining location of different sex and age classes of northern pike.

Home Range

Relocation data were plotted with a GIS (Geographic Information System) and analyzed for size of harmonic mean home range (Burt 1943; Dixon and Chapman 1980) and core activity area using Program Home Range (Ackerman et al. 1990). Standard statistical tests (Ott 1988) were used for comparisons.

RESULTS

Nineteen northern pike were located a total of 475 times in Coeur d'Alene lake and individual tracking duration averaged 123 d (range 49-203 d) (Appendices D and E). Ten northern pike (x = 6.16 kg, range 4.05-9.05 kg) were tracked at Cougar Bay, and nine at Wolf Lodge Bay (x = 3.14 kg, range 1.70-6.45 kg). Anglers harvested five northern pike implanted with tags in summer 1990, from 51 to 215 d post-implantation.

Long-term Movement

Few long distance movements (>10 km) were observed during the study. Only two (of 116) northern pike jaw tagged in the Lateral Lakes were recaptured in locations other than where they were originally captured and released. One northern pike moved from Killarney Lake up the Coeur d'Alene River to Mission Slough (20.8 km, 175 d and overwinter), and the other moved from Killarney Lake down the Coeur d'Alene River to Black Lake (13.8 km, 88 d). In Coeur d'Alene Lake, no jaw tagged fish were harvested >12.6 km from their release site. Movement of northern pike with radio-tags in Coeur d'Alene Lake indicated high fidelity to individual main lake arms (Cougar-Kidd Island-Mica Bay complex and Wolf Lodge Bay). Movements to adjacent bay areas within an arm were always followed by return to the release area.

Habitat Use

At Cougar Bay, summer habitat use of four large males ($\bar{x}$ = 7.54 kg, range 6.8-8.15 kg) and four significantly ($t = 9.30$, $p < 0.01$) smaller males ($\bar{x}$ = 4.40 kg, range 4.05-4.75 kg) were compared. Large males used significantly ($t = -2.3$, $p = 0.023$) deeper water ($\bar{x}$ = 3.98 m, SD = 2.11) than did smaller males ($\bar{x}$ = 3.03 m, SD = 1.41) (Figure 12). Conversely, small males used locations significantly ($t = 2.086$, $p = 0.040$) farther from shore ($\bar{x}$ = 173.92 m, SD = 185.3) than did larger males ($\bar{x}$ = 109.34 m, SD = 67.97) (Figure 13). Average bottom water temperatures were similar for small (18.5°C) and large (17.8°C) males ($t = 0.72$, $p = 0.47$) (Figure 14).

Radio-tagged northern pike at Cougar Bay were located primarily at vegetated sites (86%) in water <5 m deep (84%) and <400 m from shore (94%). Preferred habitats were mud substrate (92%), with Potamogeton spp. (87%) and mixed macrophyte stands containing Potamogeton spp. (8%) (Table 4, Figure 15). Shelves (large, relatively shallow areas of low gradient substrate) (54%) and dropoffs (23%) were the predominant structures at locations. At least 18% of all locations were associated with floating structure.

The stepwise logisitic regression process chose from among habitat describers (depth, distance from shore, vegetation presence/absence, vegetation types present, principal vegetation type, substrate type, structure types present, principal structure type, and water temperature at surface, mid-depth, and bottom) to determine which variables were most important in determining differential habitat use by large ($\bar{x}$ = 7.5 kg) and small ($\bar{x}$ = 4.4 kg) male northern pike. The following significant model was chosen:

$$y(size) = 1.077 + 0.6742(depth) - 0.59174 \times 10 - 2(dfs) - 0.13609(btem)$$

where size = large (7.5 kg) or small (4.4 kg),
depth = depth of water (m),
dfs = distance from shore (m), and
btem = water temperature (°C) at bottom (goodness-of-fit $X^2 = 95.405$, DF = 76, $p = 0.066$).

At Wolf Lodge Bay, habitat use by three Age 2 sexually mature males ($\bar{x}$ = 1.92 kg, range 1.7-2.1 kg) and three Age 2 sexually mature females ($\bar{x}$ = 2.31 kg, range 2.17-2.56 kg)($t = 2.27$ weight difference N.S.) was similar. Both males and females used an average water depth of 2.90 m (male range 1.5-4.6 m, SD = 0.88; female range 0.9-7.7 m, SD = 1.39); distance from shore averaged 70.2 m (range 9-183, SD = 52.3) for males and 69.2 m (range 6-183, SD = 51.9) for females; and average water temperature at bottom was 21.2°C for both males and females.

Radio-tagged northern pike at Wolf Lodge Bay were located primarily at vegetated sites (87%), in water <5 m deep (97%), and <120 m (88%) from shore (Table 4). Substrate at these locations was predominantly silt (91%), with Potamogeton spp. (60%), Elodea nuttallii (17%), and mixed macrophyte stands containing Potamogeton spp. (16%) the main vegetative types (Figure 15). Shelves (62%) and dropoffs (34%) were the predominant bottom configurations with 5% of all locations associated with floating structure. No model was found that could successfully predict sex of Age 2 northern pike based on habitat use.

Home Range

Size of summer home range for the four large males at Cougar Bay ($\bar{x}$ = 478.5 hectare, range 226-759 hectare) was similar to that of the smaller males ($\bar{x}$ = 254.8 hectare, range 166-360 hectare). All four large males had core activity areas (average = 36.7% of home range area contained 65.3% of utilization) while

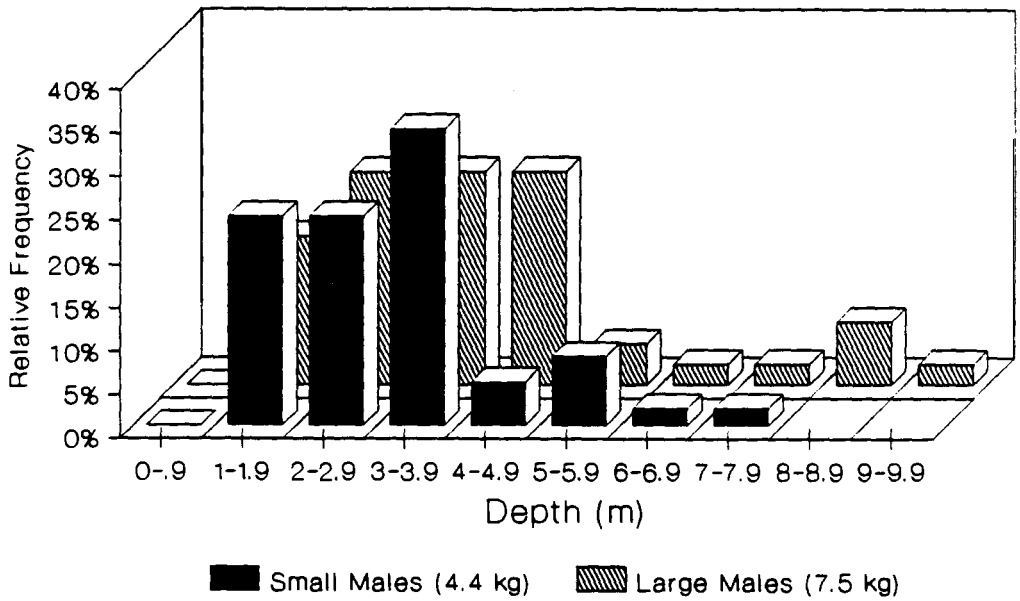


Figure 12. Depth (m) at relocations of two size classes of male northern pike in Cougar Bay, Coeur d'Alene Lake, Idaho, summer 1990.

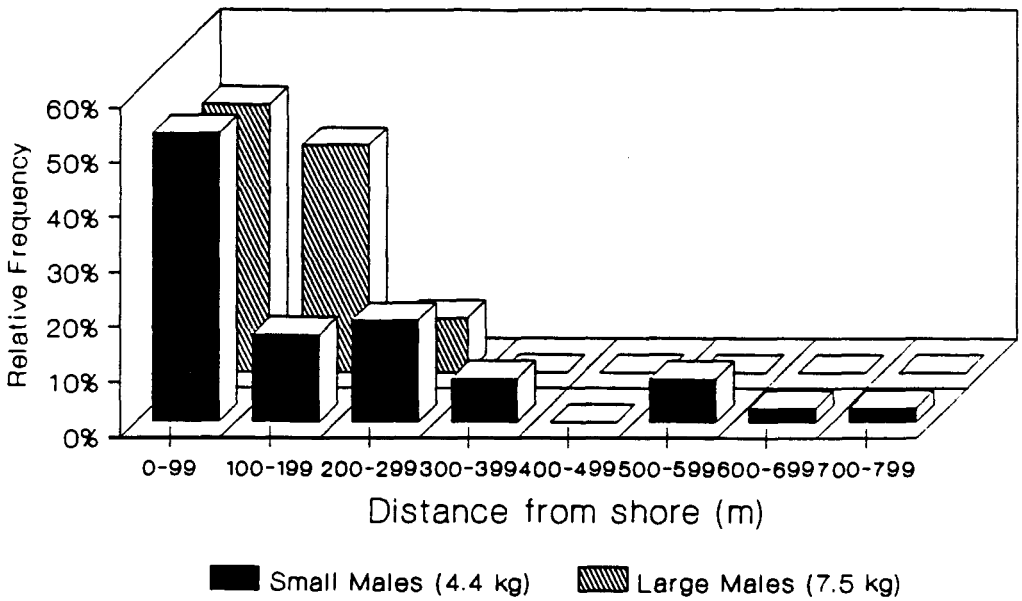


Figure 13. Distance from shore (m) at relocations of two size classes of male northern pike at Cougar Bay, Coeur d'Alene Lake, summer 1990.

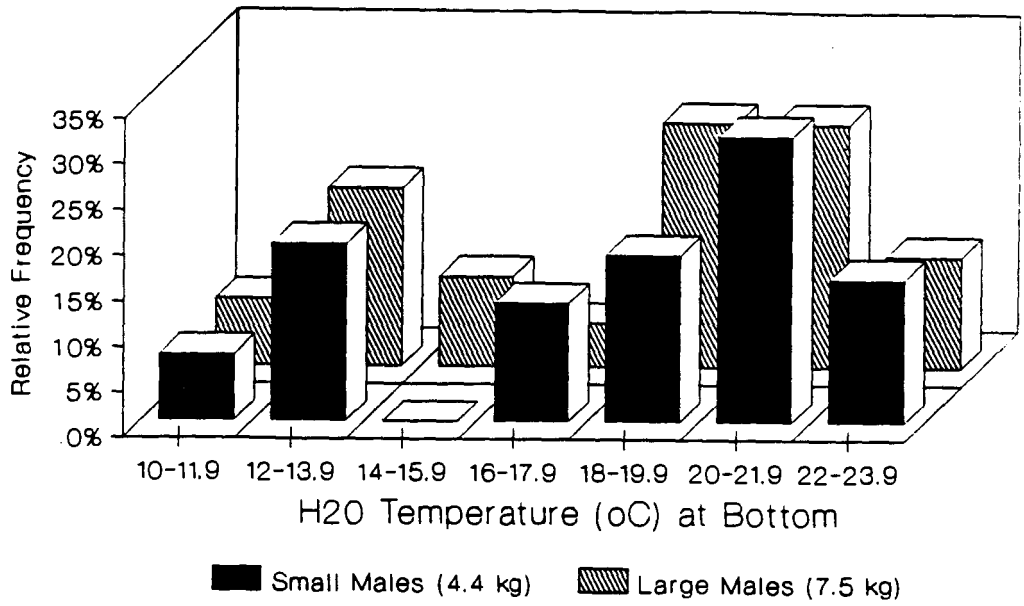


Figure 14. Bottom water temperatures at relocations of two size classes of male northern pike at Cougar Bay, Coeur d'Alene Lake, Idaho, summer 1990.

Table 4. Comparison of summer habitat use by northern pike at Elevenmile Reservoir, Colorado, Seibert Lake, Alberta, and Lac Ste Anne, Alberta, modified from Cook and Bergerson (1988) to include Coeur d'Alene Lake (Cougar and Wolf Lodge Bays).

Habitat	Cougar Bay	Wolf Lodge Bay	Elevenmile Reservoir,CO[1]	Seibert Lake, AB[2]	Lac Ste. Anne, AB[3]
			VEGETATION		
Unvegetated	14%	13%	24%	27%	5%
Vegetated	86%	87%	76%	73%	95%
			DEPTH		
0-1.9m	20%	17%	35%	67%	52%
2-3.9m	48%	61%	40%	29%	43%
4+m	32%	22%	25%	4%	5%
			DISTANCE FROM SHORE		
0-99m	51%	74%	51%		40%
100-299m	40%	26%	27%		38%
300-599m	6%		17%		19%
600+m	3%		5%		3%

[1] Cook and Bergerson 1988
[2] Chapman and Mackay 1984a
[3] Diana 1977

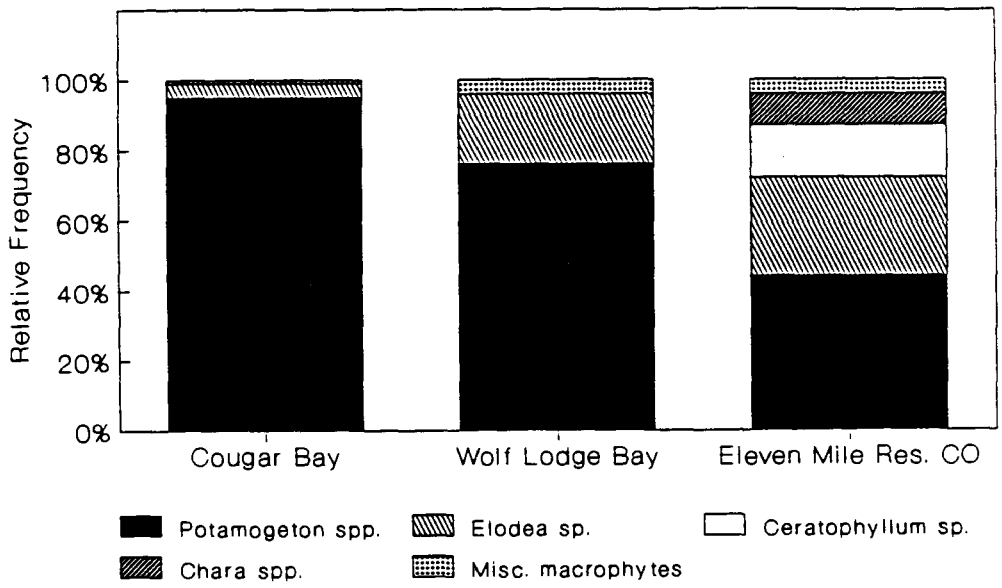


Figure 15. Macrophytes at relocations of norther pike at Cougar and Wolf Lodge Bays, Coeur d'Alene Lake, Idaho and Elevenmile Reservoir, Colorado (Cook and Bergerson 1988).

only one of four small males had a core activity area (40% of home range area contained 61% of utilization).

Size of summer home range of Age 2 males (R = 350.7 hectare, range = 216.6-450.6 hectare) was significantly larger ($t = 3.01$, $p < .05$) than that of Age 2 females ($\bar{x}$ = 124.3 hectare, range = 83.0-178.8 hectare). Two of three males had core activity areas ($\bar{x}$ = 22.5% of home range area contained 64.3% of utilization) as did two of three females ($\bar{x}$ = 32.0% of home range area contained 61.5% of utilization).

DISCUSSION

Inspection of several gill net and angler caught fish (6-215 d post implantation) showed that the fish had grown at normal rates, were feeding actively, and had no obvious inflammation or other problems as a result of the implanted transmitter. This agrees with the findings of Cook and Bergerson (1988). Several implanted fish were also visually observed during the study and appeared unimpaired.

Movement of northern pike in the Coeur d'Alene River System was largely limited to contiguous vegetated littoral areas where individual northern pike were captured, tagged, and released. Movements through deep, unvegetated lacustrine habitats were noted, but were the exception and those individuals (n = 6) returned to original habitation areas, similar to findings in other systems. In Lake Oahe, a Missouri River reservoir, approximately 80% of tagged northern pike were recaptured within 32 km of the release site (Moen and Henegar 1971). As high as 60% of individual release groups were recaptured less than eight km from point of release. Makowecki (1973) predicted from mark-recapture data in Seibert Lake, Alberta that northern pike have restricted home ranges and show little displacement. In Lake Windermere, northern pike were recaptured at the same spring spawning location for several years (Kipling and Lecren 1984) possibly indicating homing to preferred spawning areas. Clark (1990) found that 79% of northern pike recaptured (n = 698) over eight years at East Harbor, Lake Erie, were limited in movement to the shoreline area where they were released, suggesting a homing trend.

Habitat Use

I determined that radio-tagged northern pike in the Coeur d'Alene River System generally used shallow (<5 m) vegetated (86%) sites during summer 1990. Others have found similar summer use of depth (<4 m) and vegetated habitat (range 73-95%; Diana et al. 1977; Chapman and Mackay 1984a; Cook and Bergerson 1988). Although oxygenated depths ($\bar{x}$ = 24 m, max. 61 m) in Coeur d'Alene Lake are deeper than in other study areas (Lac Ste. Anne, mean depth 4.8; Seibert Lake, 11 m max. depth; Eleven Mile Reservoir mean depth 11 m), summer use of depth by northern pike was similar. Distance of locations from shore was similar among systems (Diana et al. 1977; Chapman and Mackay 1984a; Cook and Bergerson 1988) except that at Wolf Lodge Bay, distance from shore was much less, probably a result of steep bottom gradients (Table 4).

The literature is replete with evidence of preference for vegetated habitats by northern pike (Makowecki 1973; Diana et al. 1977; Diana 1979; Grimm 1981, 1983). However, my findings do not support those of Chapman and Mackay (1984a) who suggested that northern pike are not obligately oriented to vegetated areas. In Coeur d'Alene Lake, large males (R = 7.5 kg) used vegetated habitat 93% of the time although <10% of the area is vegetated. Northern pike used locations with primarily *Potamogeton spp.* or mixed macrophyte stands (Figure 15). Cook and Bergerson (1988) found similar results at Eleven Mile Reservoir, Colorado.

Substrate type was of lesser importance although 91% of summer locations in Coeur d'Alene Lake were over silt, which is probably related to the distribution of aquatic macrophytes.

I know of no other study that has described the use of bottom temperature or structure by northern pike. Both of these habitat variables should be inherently important in selection of habitat by northern pike because of their tendency to be substrate oriented relative to location in the water column (Diana et al. 1977; Chapman and Mackay 1984b). In Cougar and Wolf Lodge Bays, water temperatures from 10-25°C were available in close proximity, yet large and small males at Cougar Bay utilized temperatures averaging 17.8°C and 18.5°C, respectively (Figure 4). Age 2 northern pike of both sexes at Wolf Lodge Bay used water averaging 21.2°C at the bottom. Larval northern pike have a physiological optimum at 26°C (Hokanson et al. 1973), and Cassellman (1978) reported that in the laboratory maximum growth in body weight for young-of-year and yearling northern pike occurred at 19°C. I propose that optimum temperatures for somatic growth of northern pike are inversely related to northern pike size (weight) and does not differ between sexes in young age classes. Adaptation to local conditions could be a confounding factor when comparing thermal optima among aquatic systems. For example, Bevelhimer et al. (1985) reported optimum growth of young northern pike of hatchery origin in Ohio at 25°C, warmer than preferenda normally reported for populations at higher latitudes.

Use of structure was similar at Cougar and Wolf Lodge bays where northern pike were located most frequently (54-63%) on shelves and less frequently (23-34%) on dropoffs. Both of these areas likely have certain foraging, thermal, and predator avoidance advantages. High use of locations shaded by floating structures could indicate a preference for reduced light intensity, lower water temperature, or some other predatory advantage. Helfman (1979) described an increased ability of fish under floating objects to detect approaching fish.

In summary, stepwise logistic regression determined that summer habitat use by two distinct size classes of male northern pike at Coeur d'Alene Lake is dictated by depth, distance from shore, and bottom temperature (or related but unmeasured habitat variables) at sites which are invariably vegetated. The importance of depth and distance from shore to location of male northern pike are reported (Cook and Bergerson 1988), as are the tendencies of northern pike to be located on or near bottom (Diana et al. 1977; Chapman and Mackay 1984b) and for large northern pike to use deeper water than smaller ones (Chapman and Mackay 1984b). My data agreed with previous findings except that large male northern pike used locations closer to shore (although deeper) than did small males, contrary to the findings of Cook and Bergerson (1988). This difference was due to the unique basin morphometry of Coeur d'Alene Lake, where near-shore dropoffs into deep water can be adjacent to large shallow shelves extending far from shore.

I believe that my habitat use information, particularly the scarcity of locations in unvegetated areas, is particularly useful because of the lack of "non-locations" in this study (i.e. all fish were located every day they were sought, therefore no speculation is necessary as to where they were on days they could not be found). The ability to locate fish easily under any conditions was facilitated by use of low frequency (30 mhz) radio transmitters. Muskellunge <u>Esox masquinongy</u> have also been tracked with radio transmitters (Minor and Crossman 1978), with reception unhindered by 100% vegetative cover in summer. Ultrasonic transmitters, as were used by Diana et al. (1977), Henley and Applegate (1982), and Cook and Bergerson (1988), have severe signal attenuation due to warm surface water, turbidity and vegetation (Winter 1983).

Home Range

Size of home range for northern pike in Coeur d'Alene Lake was positively related to the area of continuous suitable habitat at a given habitation area. Previous description of northern pike home range use and size have been affected by short tracking duration and/or an artificial thermal source (Malinin 1969, 1971; Ross and Winter 1981; Henley and Applegate 1982; Diana et al. 1977), use of orally implanted transmitters (Diana et al. 1977), or small size of systems. Diana et al. (1977), Diana (1980), Chapman and Mackay (1984b), and Cook and Bergerson (1988) reported no definable home range (ie. northern pike utilized various areas throughout the particular lake or reservoir). These systems were relatively shallow and small: Lake St. Anne, Alberta, mean depth 4.8 m, area = 5700 hectares (Diana et al. 1977, 1980); Eleven Mile Reservoir, Colorado, mean depth of 8.85 m, area = 1362 hectare (Cook and Bergerson 1988); Seibert Lake, Alberta, maximum depth 11 m, area = 3482 hectare (Makowecki 1973). Northern pike in Coeur d'Alene Lake utilized all areas of continuous suitable habitat. Females used smaller home ranges than same aged males, possibly minimizing roaming to conserve energy. Home ranges of northern pike commonly overlapped in Coeur d'Alene Lake and no evidence of territoriality was observed.

LITERATURE CITED

Ackerman, B. B., F. A. Leban, M. D. Samuel, and E.O. Garton. 1990. User's manual for Program HOME RANGE. Second Edition. Technical Report 15, Forestry, wildlife, and Range Experiment Station, University of Idaho, Moscow, Idaho, U.S.A. 80 pp.

Bevelhimer, M.S., R.A. Stein and R.F. Carline. 1985. Assessing significance of physiological differences among three esocids with a bioenergetics model. Canadian Journal of Fisheries and Aquatic Sciences 42:57-69.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy. 24(3):346-352.

Cassellman, J.M. 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike. American Fisheries Society Special Publication 11:114-128.

Chapman, C.A., and W.C. Mackay. 1984a. Versatility in habitat use by a top aquatic predator, Esox lucius L. Journal of Fish Biology 25:109-115.

Chapman, C.A., and W.C. Mackay. 1984b. Direct observation of habitat utilization by northern pike. Copeia 1:255-288.

Clark, C.F. 1990. Movements of northern pike tagged in waters tributary to Lake Erie. Ohio Journal of Science 90(1):41-45.

Cook, M.F. and E.P. Bergerson. 1988. Movement, Habitat Selection, and Activity Periods of northern pike in Eleven Mile Reservoir, Colorado. Transactions of the American Fisheries Society. 117: 495-502.

Diana, J.S., W.C. Mackay, and M. Ehrman. 1977. Movements and habitat preference of northern pike (Esox lucius) in Lac Ste. Anne, Alberta. Transactions of the American Fisheries Society 106(6):560-565.

Diana, J.S. 1980. Diel activity pattern and speeds of swimming northern pike (Esox lucius) in Lake St. Anne, Alberta. Canadian Journal of Fisheries and Aquatic Sciences. 37:1454-1458.

Dixon, K.R., and J.A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61(5): 1040-1044.

Dixon, W.S. Ed. 1985. BMDP Statistical Software. University of California Press. Los Angeles.

Grimm, M.P. 1981. The composition of northern pike (Esox lucius L.) populations in the Netherlands, with special reference to factors influencing 0+ pike biomass. Fisheries Management 12(2):61-76.

Grimm, M.P. 1983. Regulation de la biomasse de brochet (Esox lucius L.) de petite taille (<41 cm) et efficate de l'introduction d'individus de 4-6 cm. In Le brochet, edited by R. Billard. Paris, INRA, pp. 253-270.

Heezen, K.L., and J.R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. Journal of Wildlife Management 31:124-141.

Helfman, G. S. 1979. Fish attraction to floating objects in lakes. Pages 49-57 in D.L. Johnson and R.A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division American Fisheries Society Special Publication 6.

Henley, D.T. and R.L. Applegate. 1982. Seasonal distribution of esocids in a powerplant cooling reservoir. Progressive Fish Culturist 44(1):40-41.

Hokanson, K.E.F., J.M. McCormick and B.R. Jones. 1973. Temperature requirements for embryos and larvae of northern pike Esox lucius. Transactions of the American Fisheries Society 102(1):89-100.

Inskip, P.D. 1982. Habitat suitability index models: northern pike. U.S. Department of Interior, Fish and Wildlife Service. FWS/obs-82/10.17. 40 PP•

Kipling, C., and E.D. Le Cren. 1984. Mark-recapture experiments on fish in Windermere, 1943-1982. Journal of Fish Biology 24:395-414.

Makowecki, R. 1973. The trophy pike, Esox lucius, of Seibert Lake. M.S. Thesis. University of Alberta. 239 pp.

Malinin, L.K. 1969. Uchastki obitaniya instinkt vozvroskcheniya ryb. [Home range and homing instinct of fish.] Zoologicheskii Zhurnal 48:381-391. (Fisheries Research Board of Canada Translation Series 2050).

Malinin, L.K. 1971. Home range and actual paths of fish in the river pool of Rybinsk reservoir. Biologiya Vnutrennykh vod Informatsionii Byulleten 22:158-166. (Fisheries Research Board of Canada Translation Series 2282).

Minor, J.D., and E.J. Crossman. 1978. Home range and seasonal movements of muskellunge as determined by radio telemetry. American Fisheries Society Spec. Publ. 11: 146-153.

Moen, T. and D. Henegar, 1971. Movement and Recovery of tagged northern pike in Lake Oahe, South and North Dakota, 1964 - 1968. American Fisheries Society Special Publication, 8: 85-93.

Ott, L. 1988. An introduction to statistical methods and data analysis. 3rd edition. PWS-KENT Publishing Co., Boston.

Raat, A.J. 1988. Synopsis of biological data on the northern pike Esox lucius Linnaeus, 1758. Food and Agriculture Organization of the United Nations. Rome.

Ross, M.J. and J.D. Winter. 1981. Winter Movements of four fish species near a thermal plume in Northern Minnesota. Transactions of the American Fisheries Society. 110: 14-18.

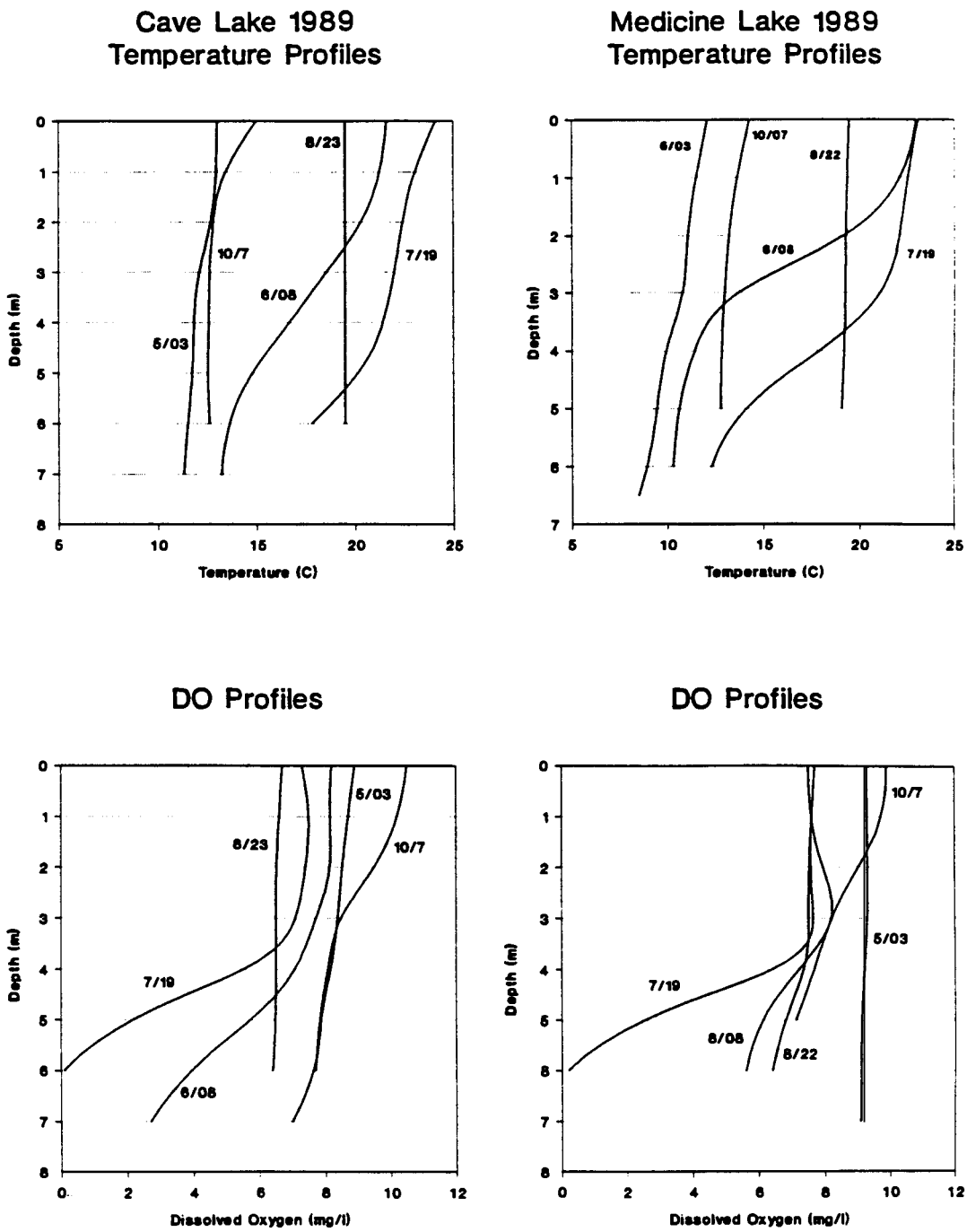
Ross, M.J. and C.F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish Culturist 44:41-43.

Winter, J.D. 1983. Underwater biotelemetry. In: Nielsen, L.A. and D.L. Johnson, eds. Fisheries techniques. American Fisheries Society. Bethesda, Maryland.

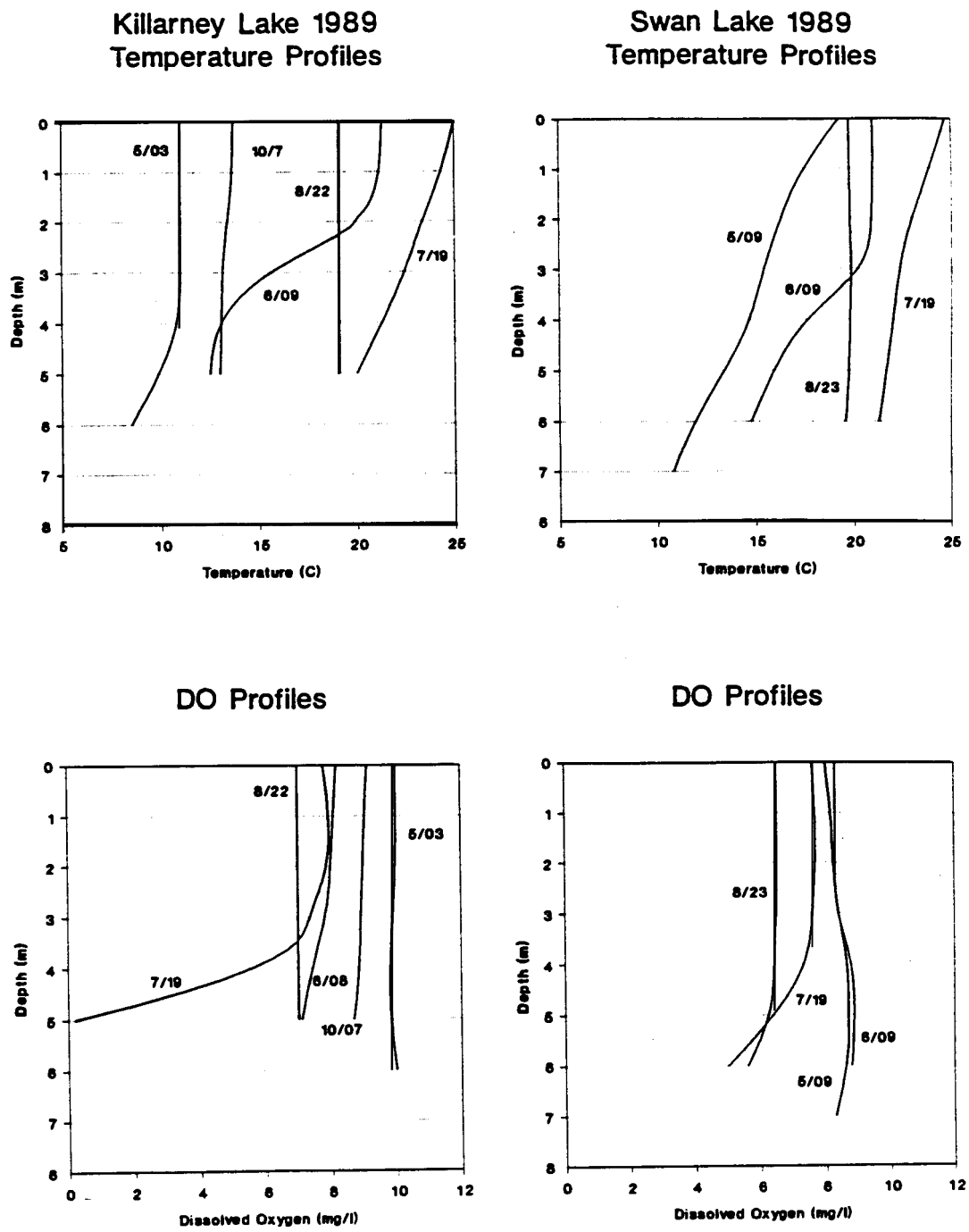
A P P E N D I C E S

APPENDIX A

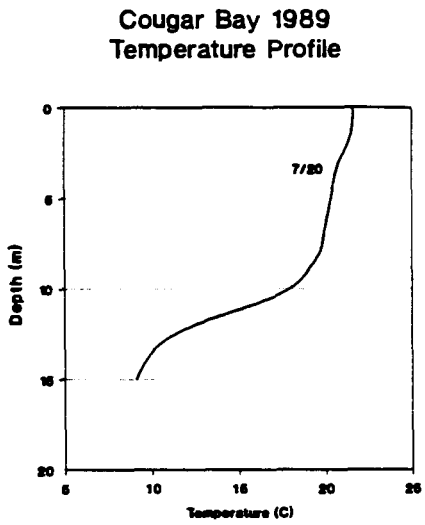
Limnological Profiles for the Coeur d'Alene River System, Idaho

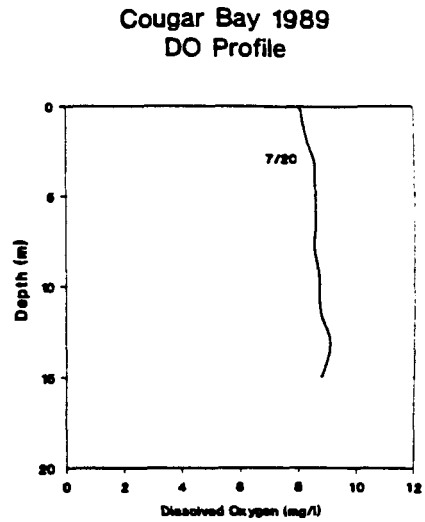


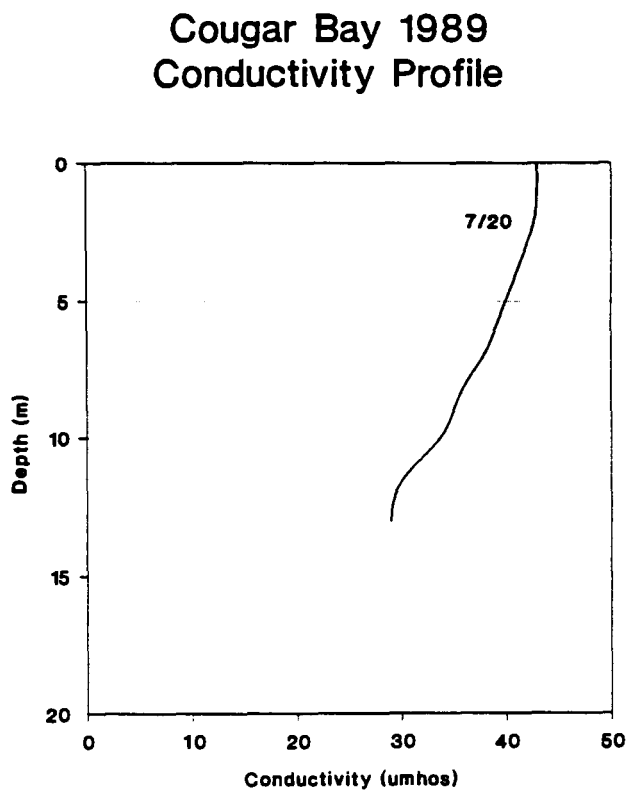
A-1. Temperature and dissolved oxygen (DO) profiles for Cave Lake (left) and Medicine Lake (right) 1989.



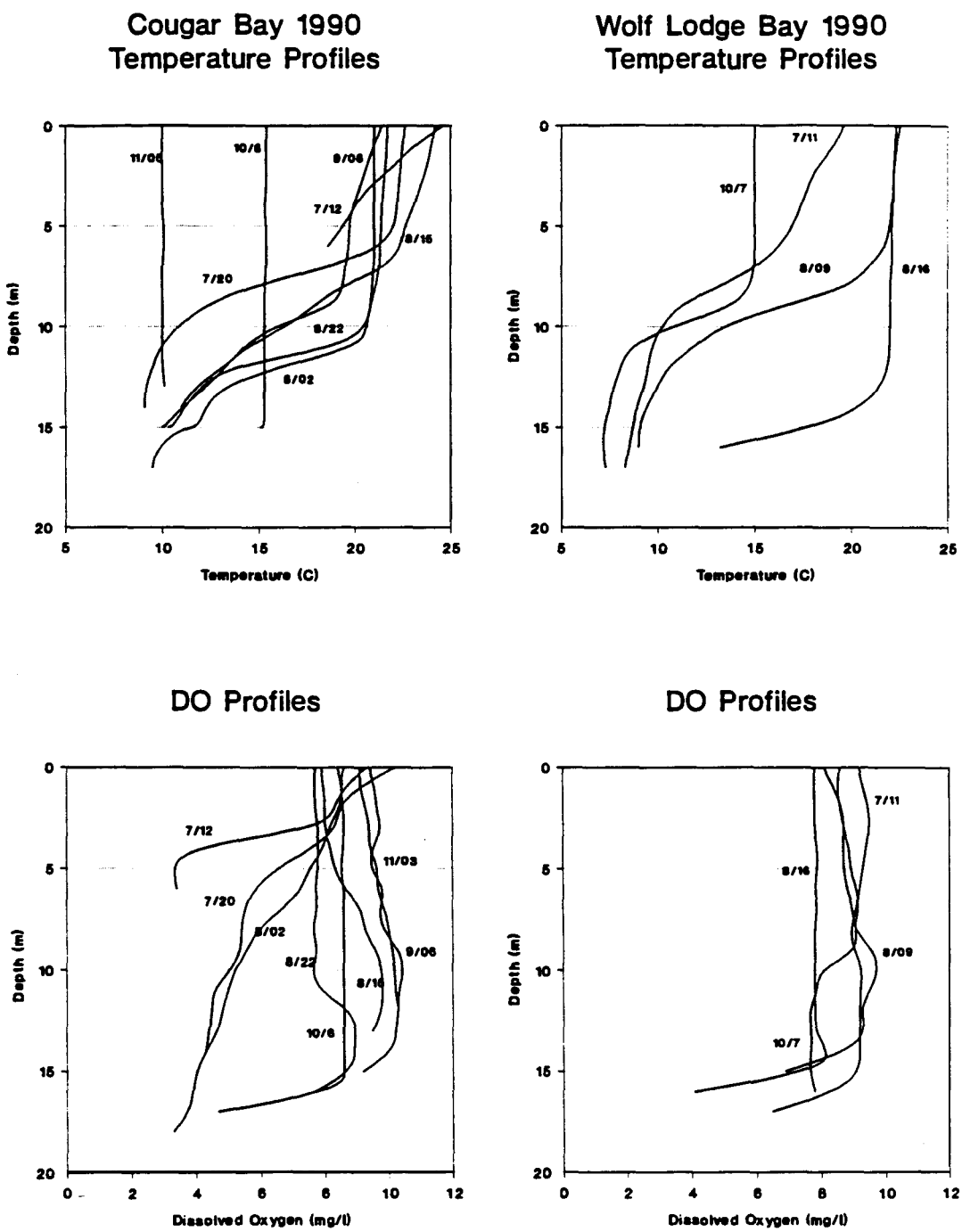
A-2. Temperature and dissolved oxygen (DO) profiles for Killarney Lake (left) and Swan Lake (right) 1989.







A-3. Profiles of temperature (top left), dissolved oxygen (DO) (top right), and conductivity for Cougar Bay on 20 July, 1989.



A-4. Temperature and dissolved oxygen (DO) profiles for Cougar Bay (left) and Wolf Lodge Bay (right) 1990.

APPENDIX B

Northern Pike

Tournament Results

Appendix B. Results of organized northern pike tournaments on the Coeur d'Alene Lake system, Idaho (1989 and 1990).

Tourn Date	#Anglers	Angler Hours	Pike >559mm	Pike per Ang Hour	#Hours per Pike	Pike Mean Wt (g)
2/11/89	20	140	1	.007	140	975
4/21-4/22/89	50	700	9	.013	77.8	2402
9/16-9/17/89	30	540	21	.04	25.7	3200
4/21-4/22/90	64	1152	23	.02	50.1	1980
9/22-9/23/90	22	388	30	.077	12.9	2780

APPENDIX C

Roster of Northern Pike

Implanted with Radio Transmitters

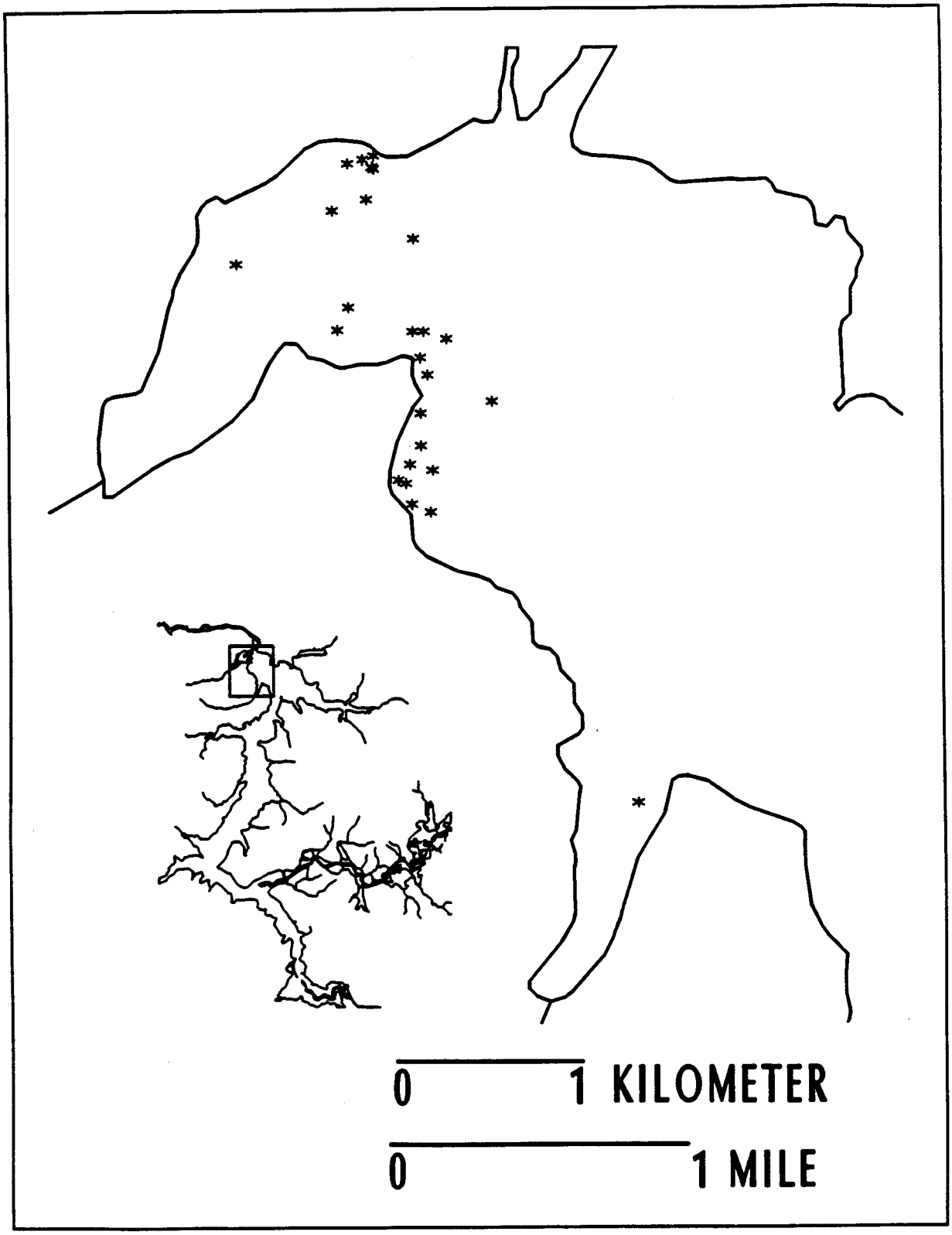
Appendix C. Roster of northern pike implanted with radio transmitters at Coeur d'Alene Lake, 1990.

Fish-Code	Sex	Age	Lenqthm	Weightkq	Date(1990) Implanted	Date(1990) Last Located	Fate
CB1	M	UNK	928	6.8	3/17	10/06	
CB2	M	6	930	7.3	3/18	8/15	Batt Fail
CB3	M	6	874	5.85	3/16	6/02	Ang Hary
CB32	M	3	800	4.75	6/21	9/13	
CB4	F	6	982	9.05	3/20	4/15	Ang Hary
CB42	M	4	815	4.4	4/27	9/13	
CB5	F	5	894	5.3	3/17	8/30	Batt Fail
CB6	M	5	941	8.15	3/18	10/06	
CB7	M	3	791	4.05	3/20	9/13	
CB8	M	7	952	7.9	3/17	9/06	
CB9	F	3	811	5.95	3/18	4/13	Ang Hary
CB92	M	3	825	4.4	4/27	8/15	Batt Fail
WL2	F	UNK	780	6.45	4/28	9/13	
WL3	F	2	645	2.17	4/28	8/09	
WL4	M	4	903	6.9	6/21	8/16	
WL5	M	2	610	1.7	4/29	8/16	
WL6	F	2	650	2.25	4/29	6/19	Ang Harv

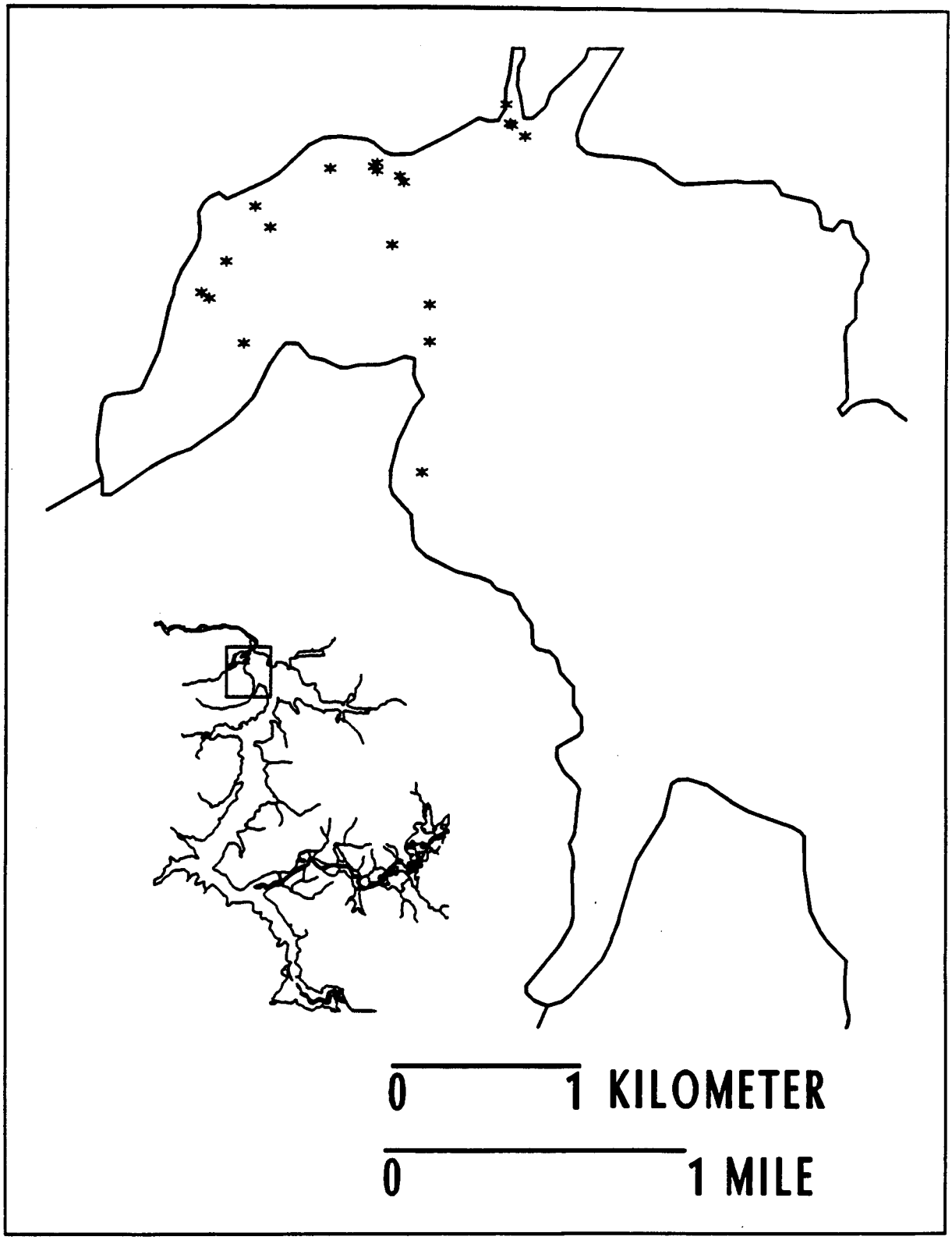
Fish-Code	Sex	Age	Lengthm	Weightkg	Date(1990) Implanted	Date(1990) Last Located	Fate
WL62	F	2	674	2.56	6/28	8/16	Ang Harv
WL7	F	2	660	2.2	4/28	9/13	
WL8	M	2	626	1.95	4/29	8/16	
WL9	M	2	647	2.1	4/28	9/13	

APPENDIX D

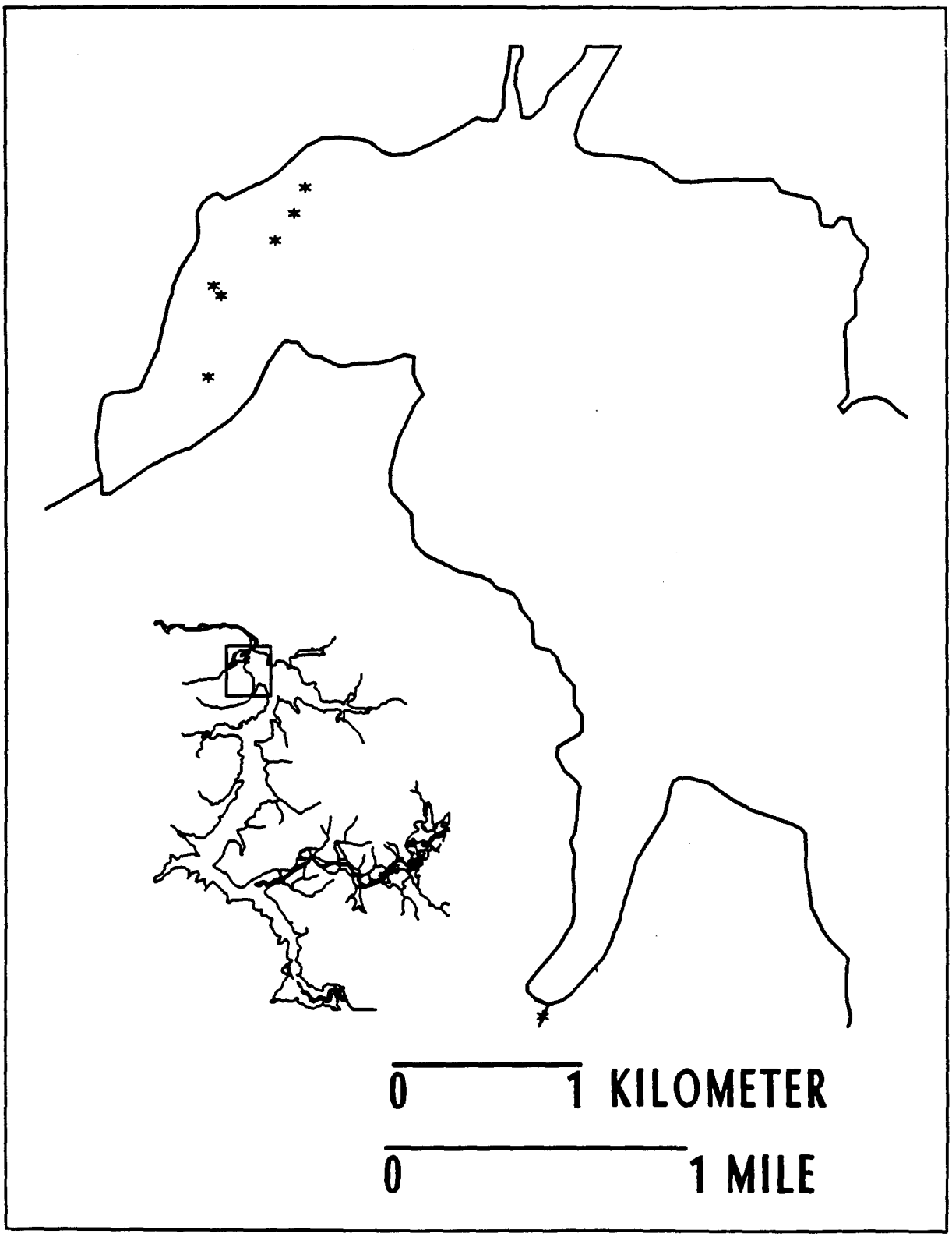
Locations of Radio-Tagged Northern Pike in Coeur d'Alene Lake, Idaho



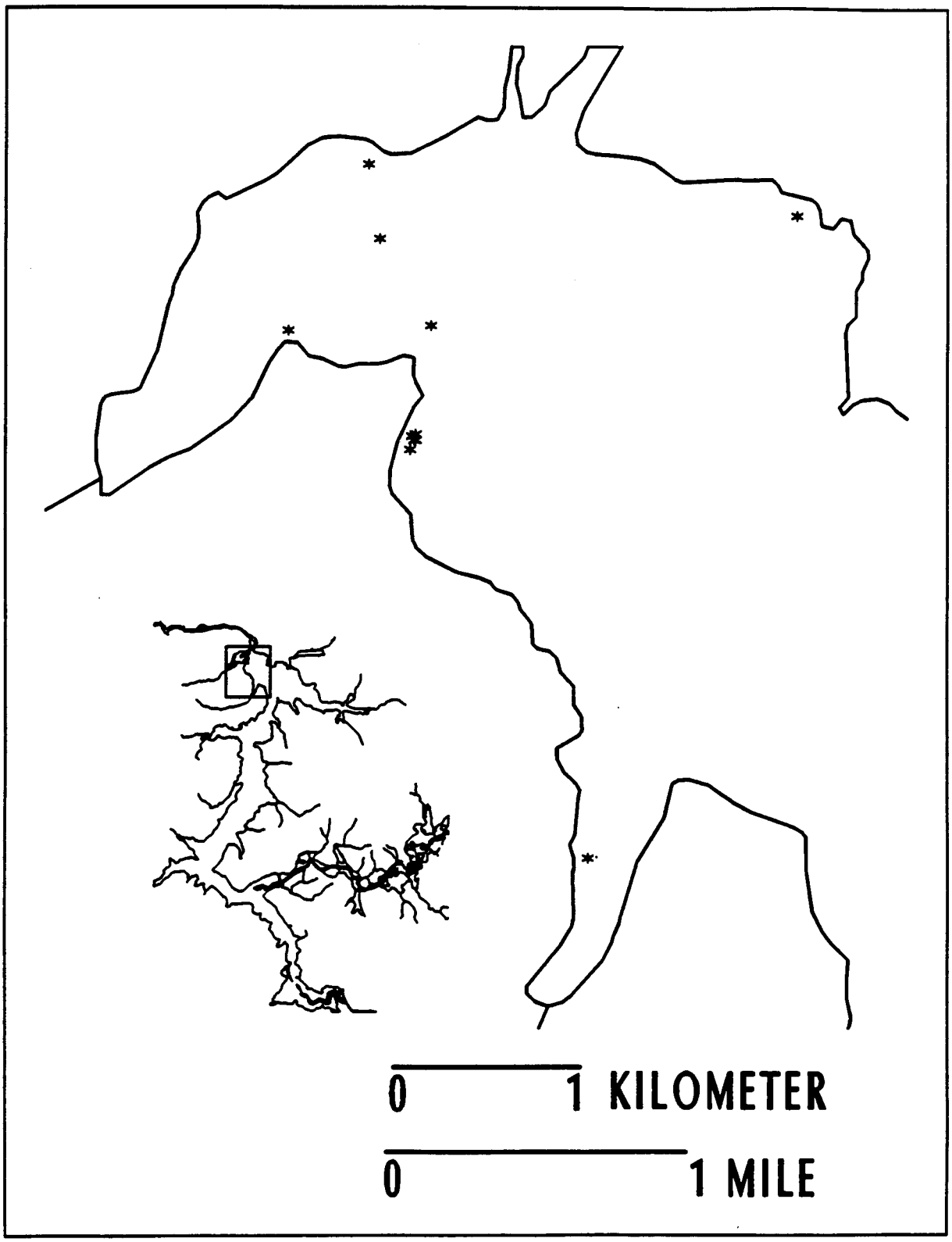
D-1. Locations of northern pike CB1 (6.8 kg male) from 14 April to 6 October 1990. Mean time between locations was 5 days (range 1-8 days).



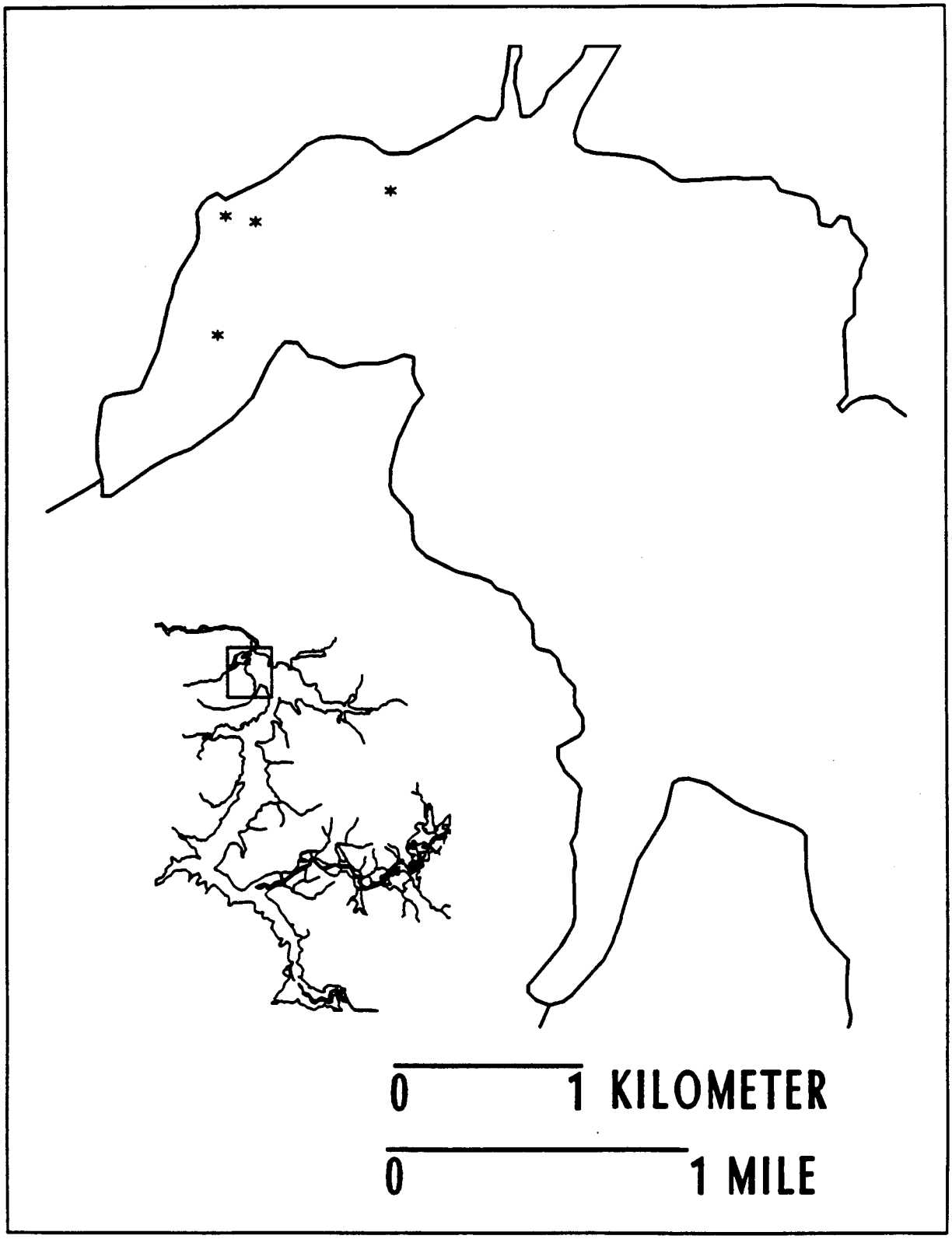
D-2. Locations of northern pike CB2 (7.3 kg male) from 14 April to 15 August 1990. Mean time between locations was 5 days (range 1-8 days).



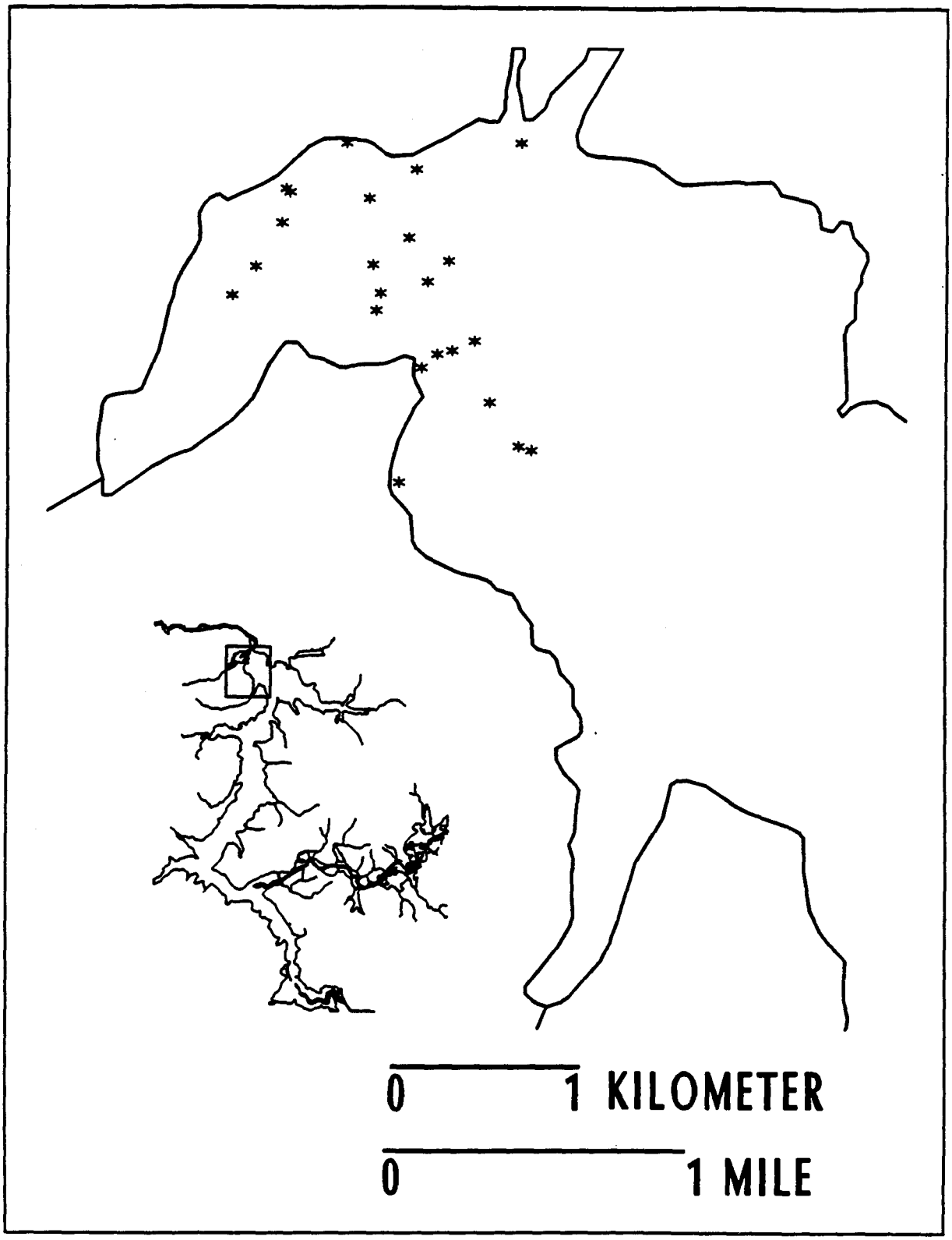
D-3. Locations of northern pike CB3 (5.9 kg male) from 16 April to 2 June 1990. Mean time between locations was 5 days (range 1-8 days).



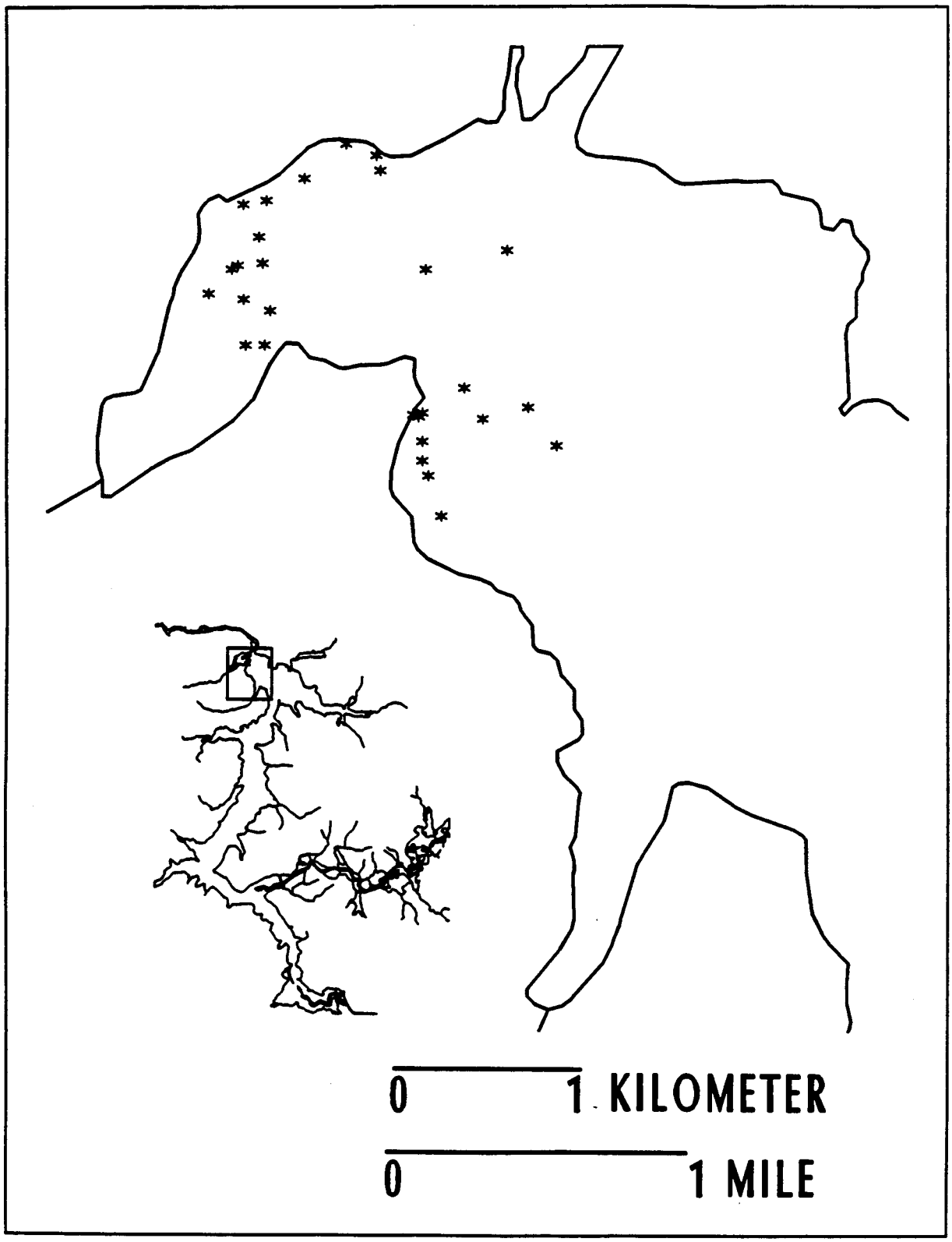
D-4. Locations of northern pike CB32 (4.8 kg male) from 28 June to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).



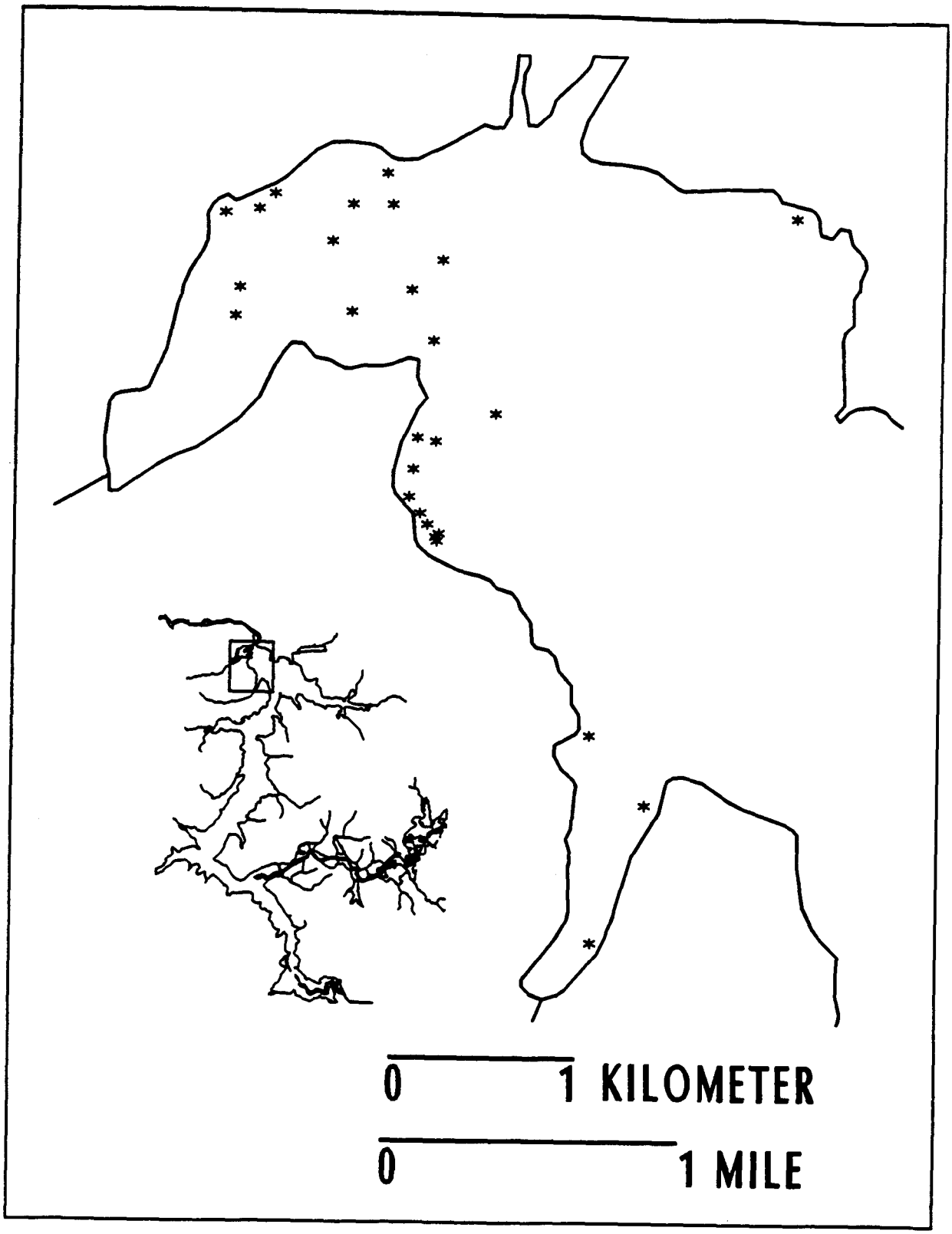
D-5. Locations of northern pike CB4 (9.1 kg female) from 12 April to 16 April 1990.



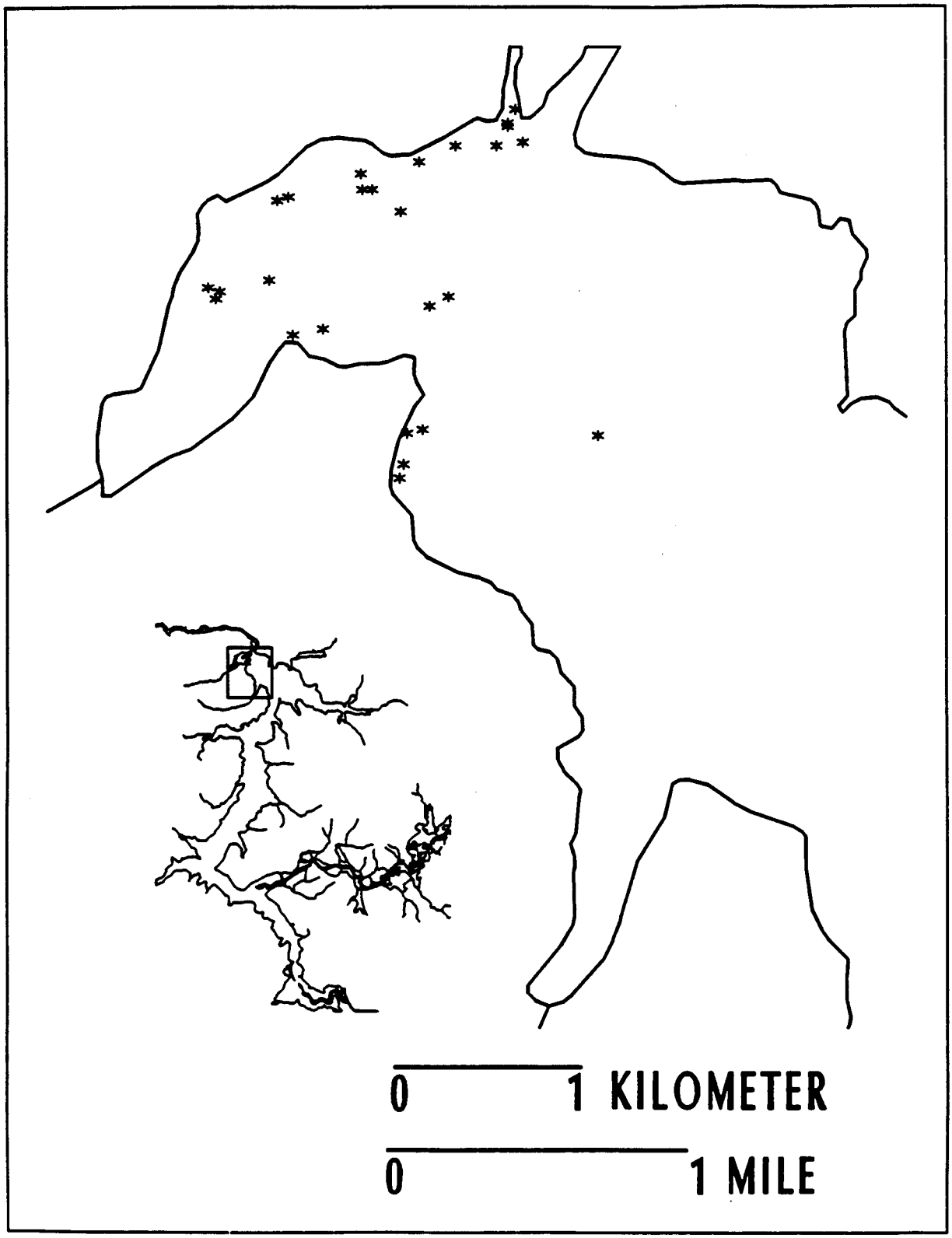
D-6. Locations of northern pike CB42 (4.4 kg male) from 30 April to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).



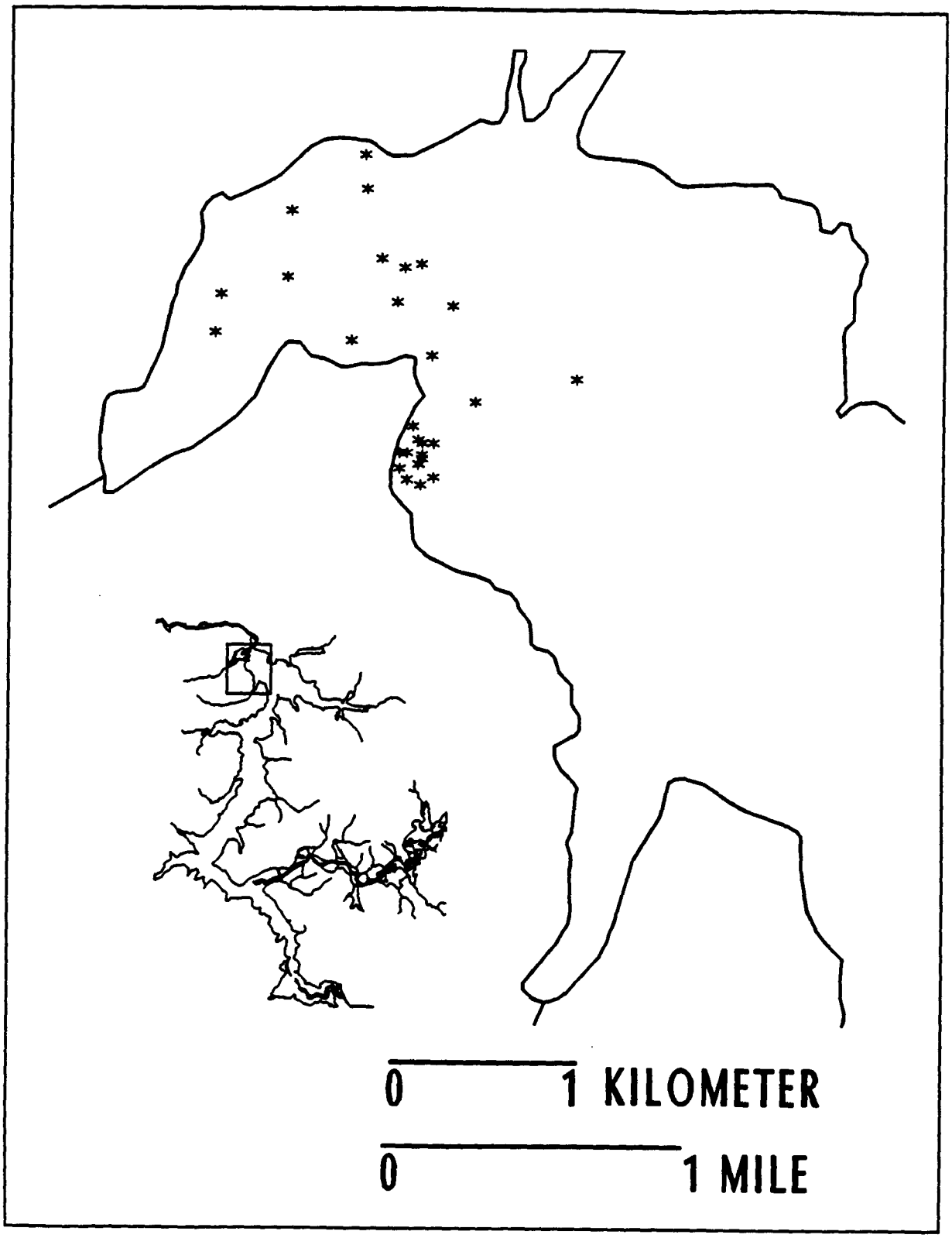
D-7. Locations of northern pike CB5 (5.3 kg female) from 15 April to 30 August 1990. Mean time between locations was 5 days (range 1-8 days).



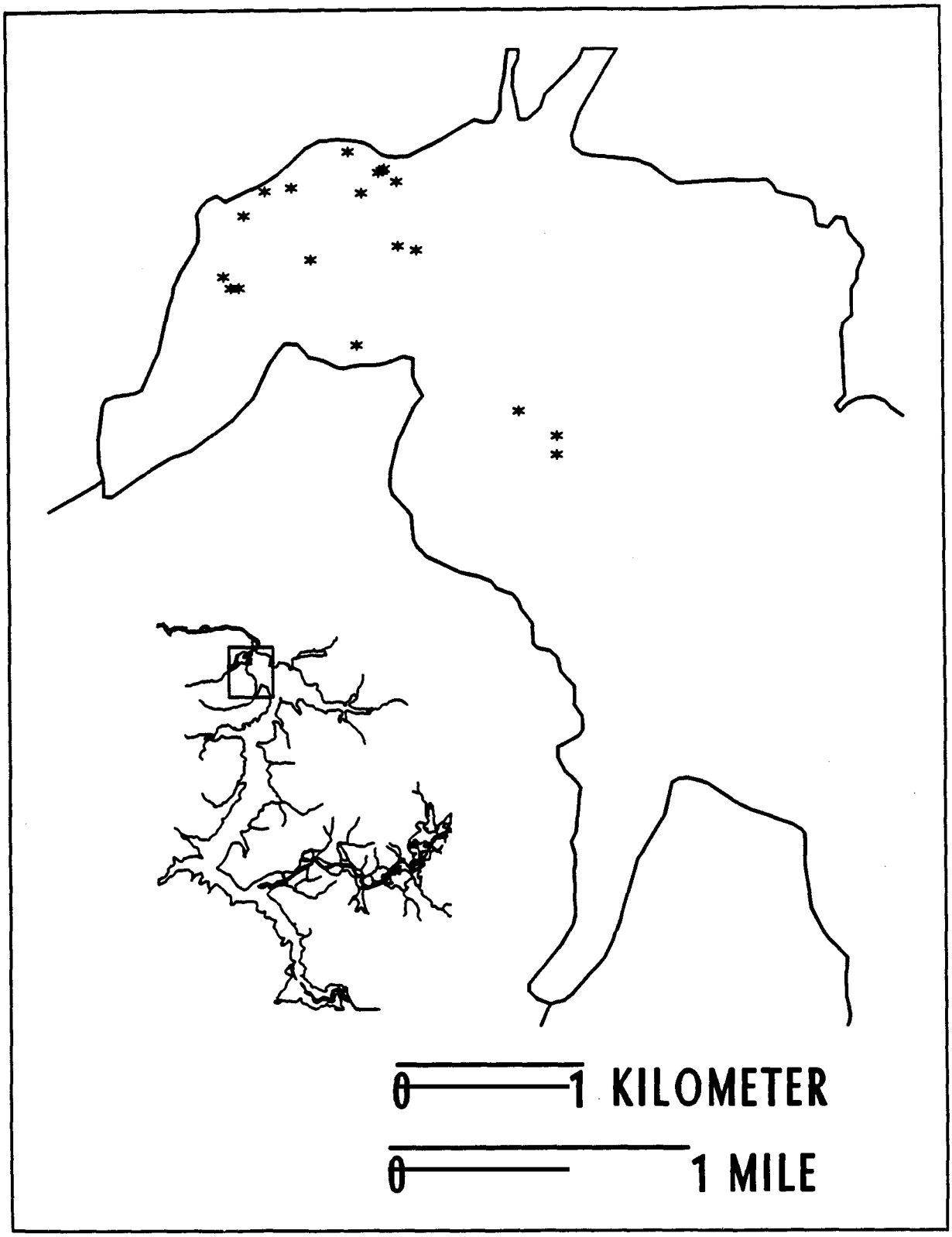
D-8. Locations of northern pike CB6 (8.2 kg male) from 14 April to 6 October 1990. Mean time between locations was 5 days (range 1-8 days).



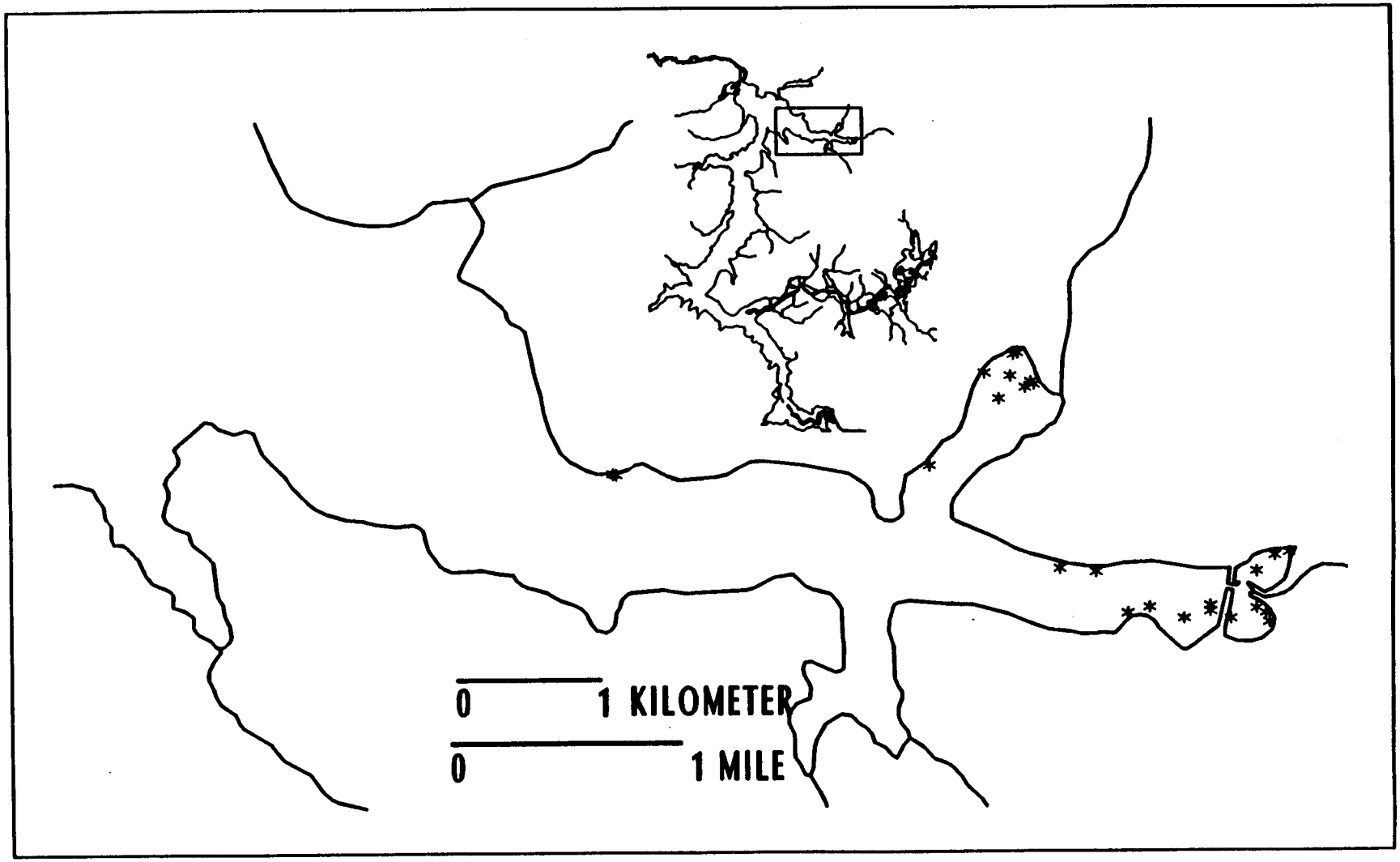
D-9. Locations of northern pike CB7 (4.1 kg male) from 16 April to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).



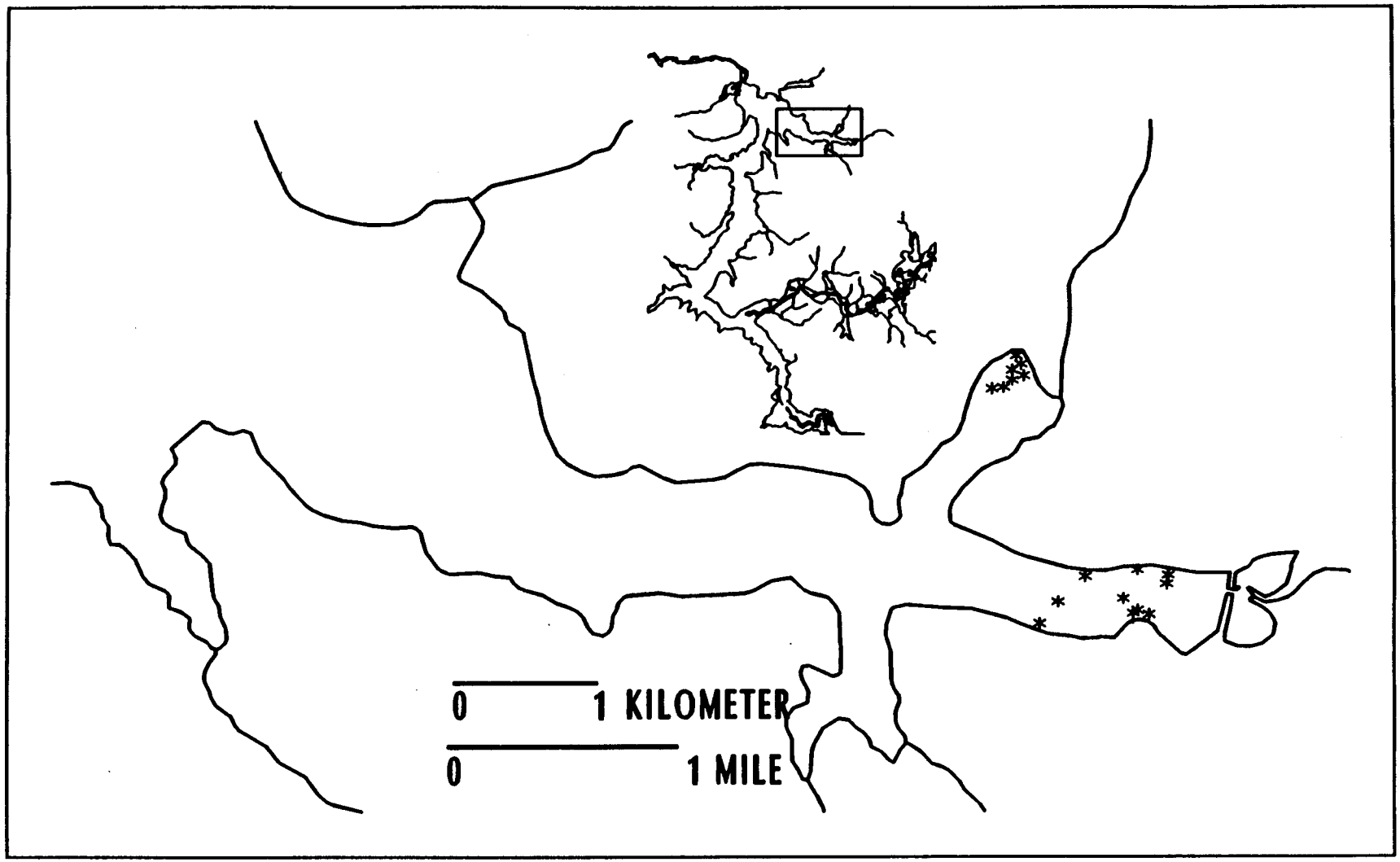
D-10. Locations of northern pike CB8 (7.9 kg male) from 16 April to 6 September 1990. Mean time between locations was 5 days (range 1-8 days).



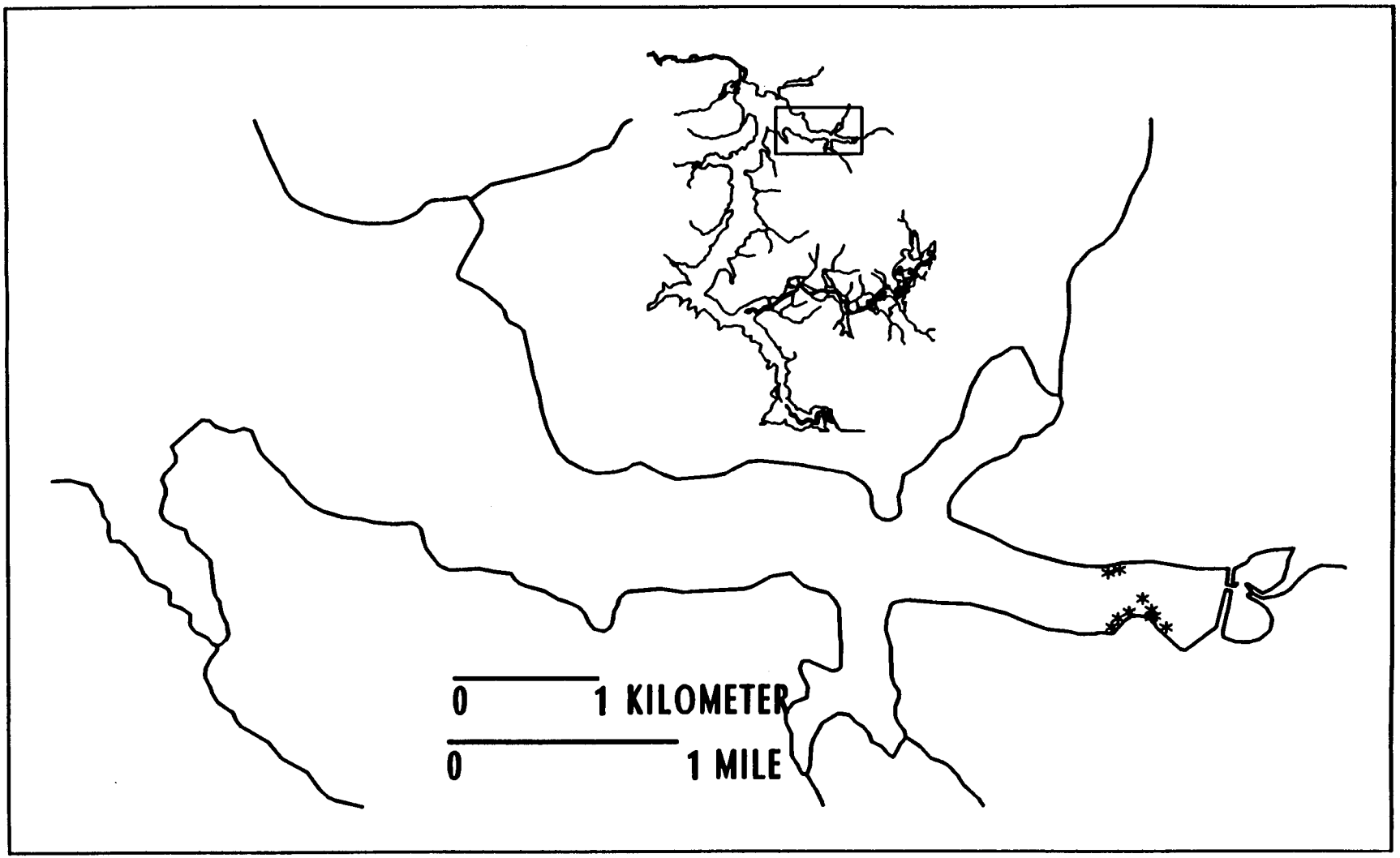
D-11. Locations of northern pike CB92 (4.4 kg male) from 17 April to 15 August 1990. Mean time between locations was 5 days (range 1-8 days).



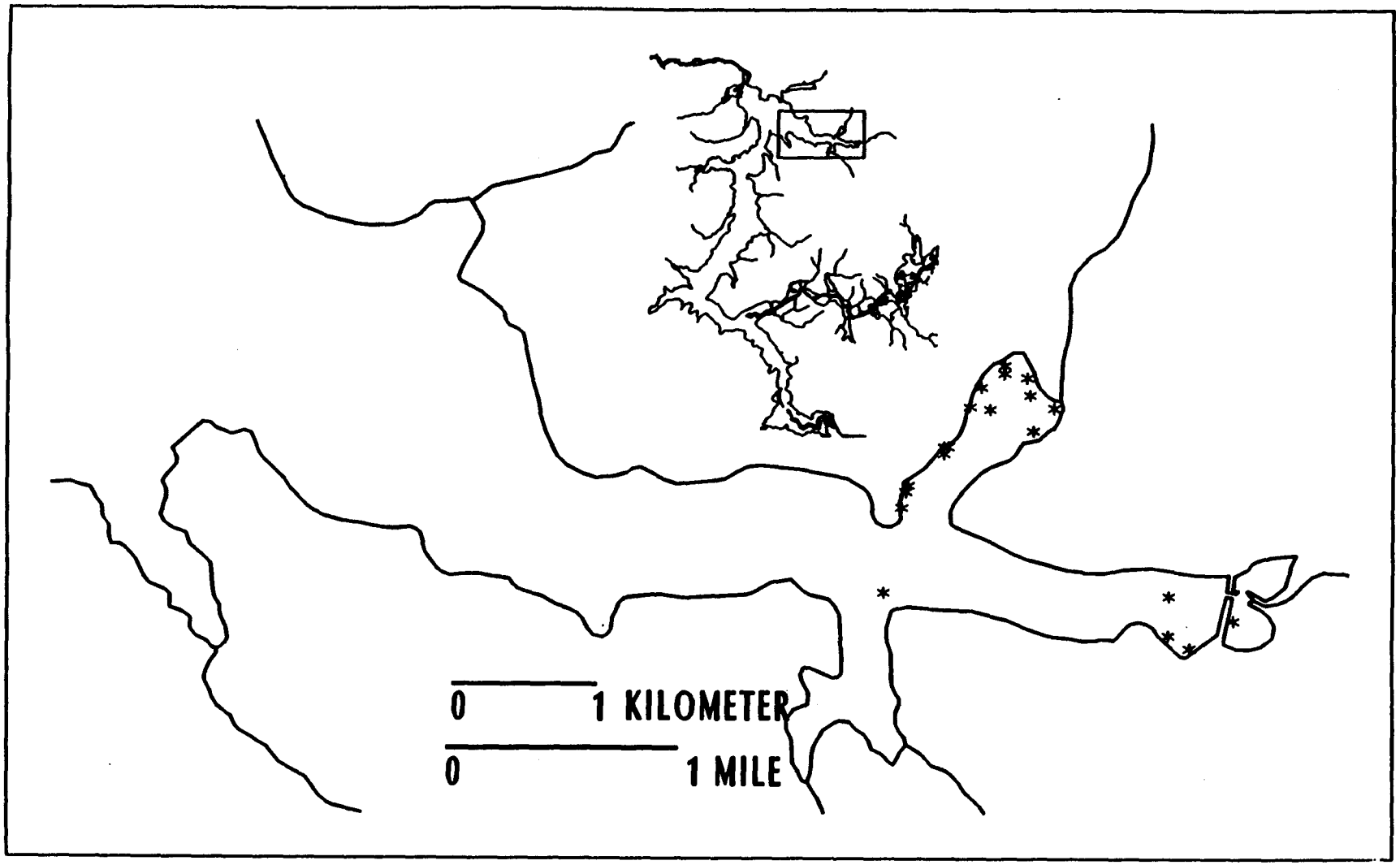
D-12. Locations of northern pike WL2 (6.5 kg female) from 4 May to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).



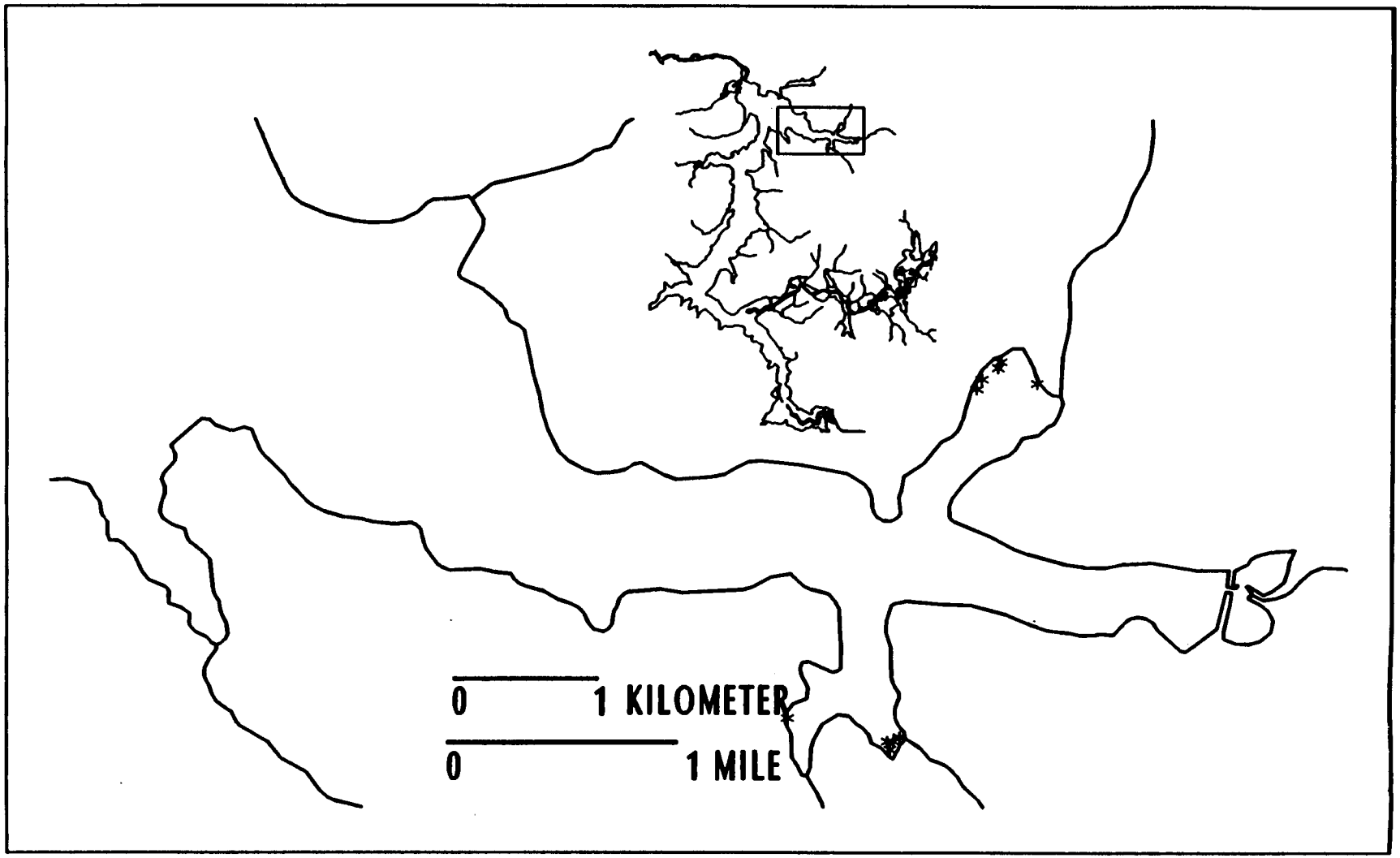
D-13. Locations of northern pike WL3 (2.2 kg female) from 7 May to 9 August 1990. Mean time between locations was 5 days (range 1-8 days.).



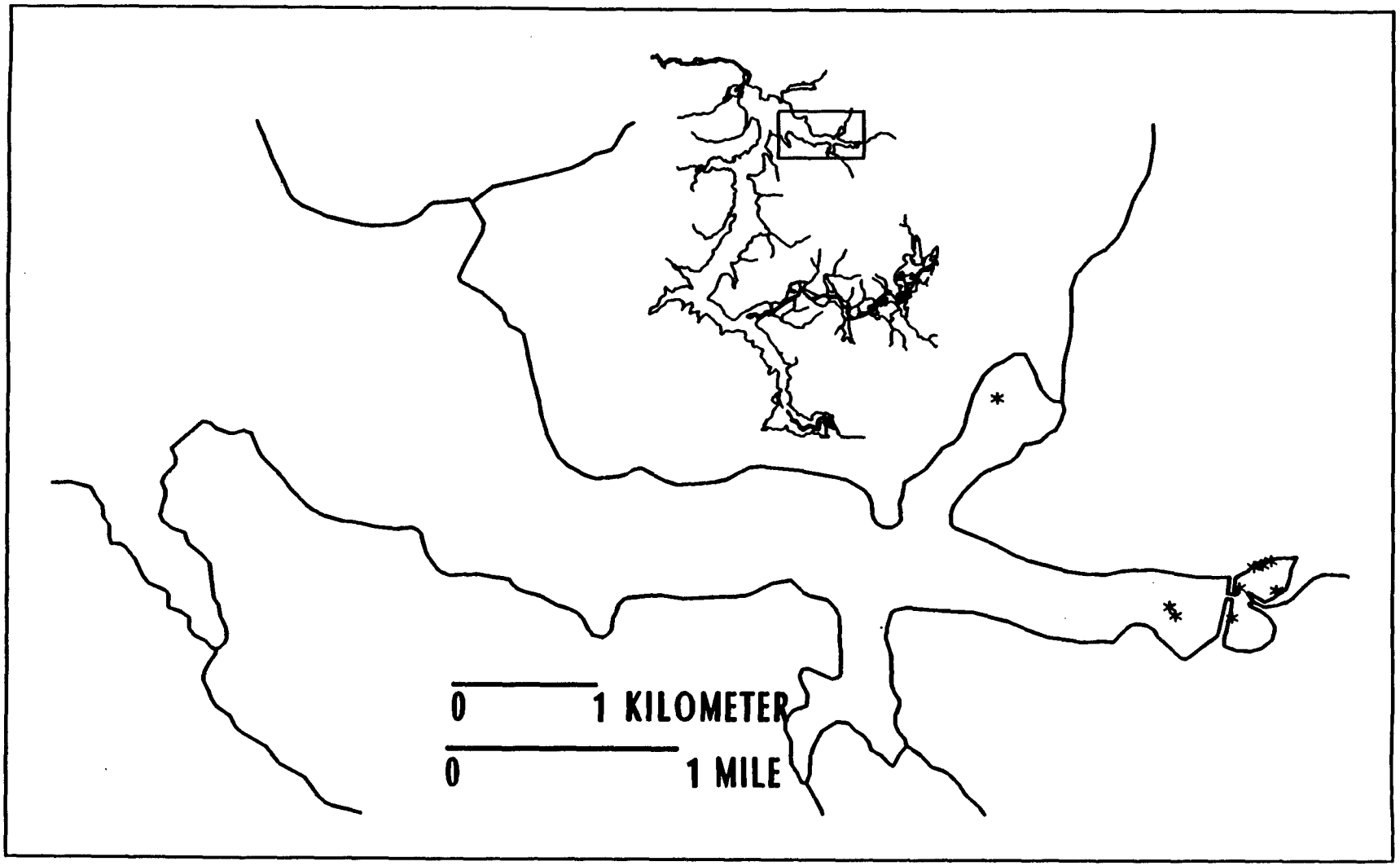
D-14. Locations of northern pike WL4 (6.9 kg male) from 27 June to 16 August 1990. Mean time between locations was 5 days (range 1-8 days).



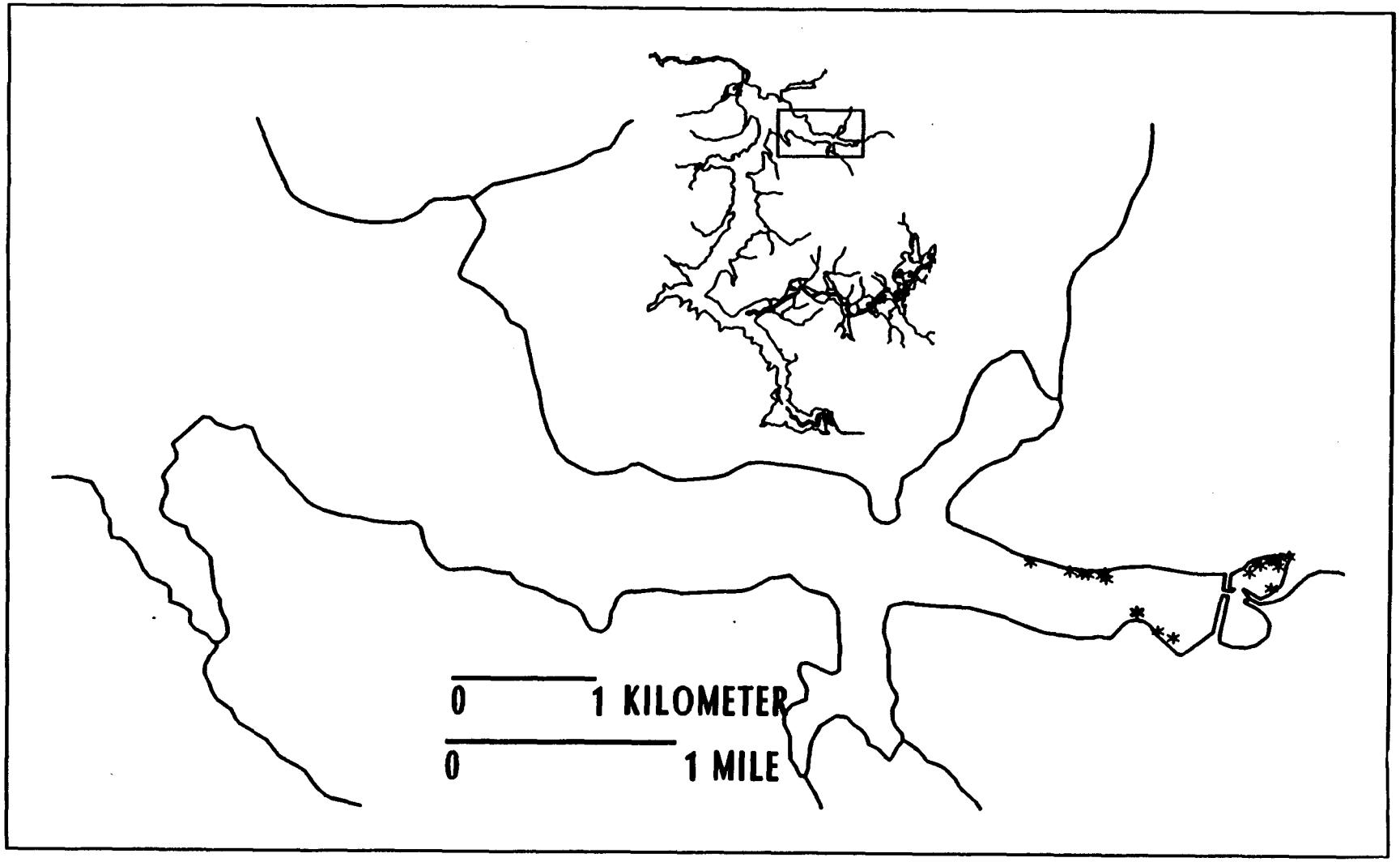
D-15. Locations of northern pike WL5 (1.7 kg male) from 7 May to 16 August 1990. Mean time between locations was 5 days (range 1-8 days).



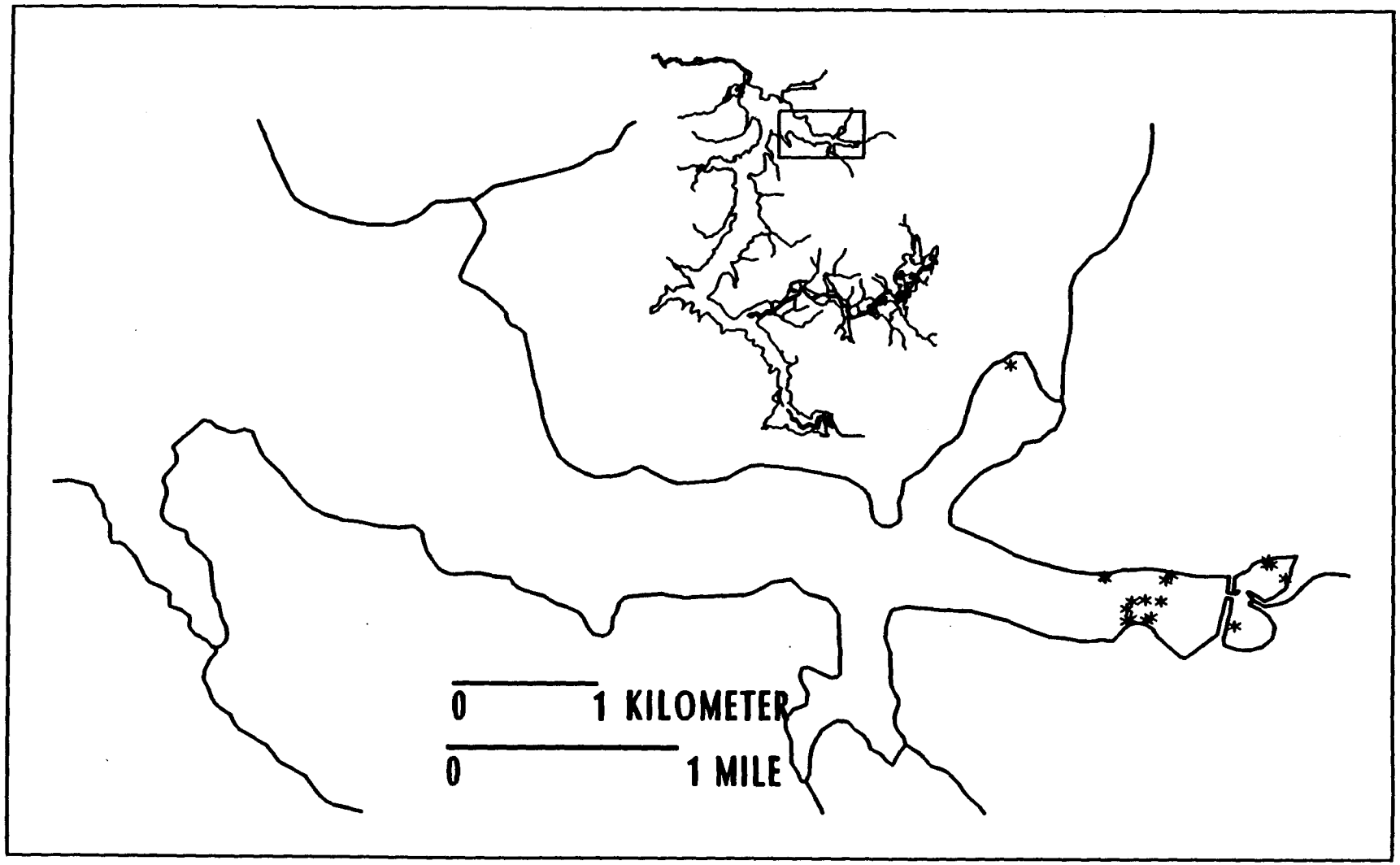
D-16. Locations of northern pike WL6 (2.3 kg male) from 7 May to 19 June 1990. Mean time between locations was 5 days (range 1-8 days).



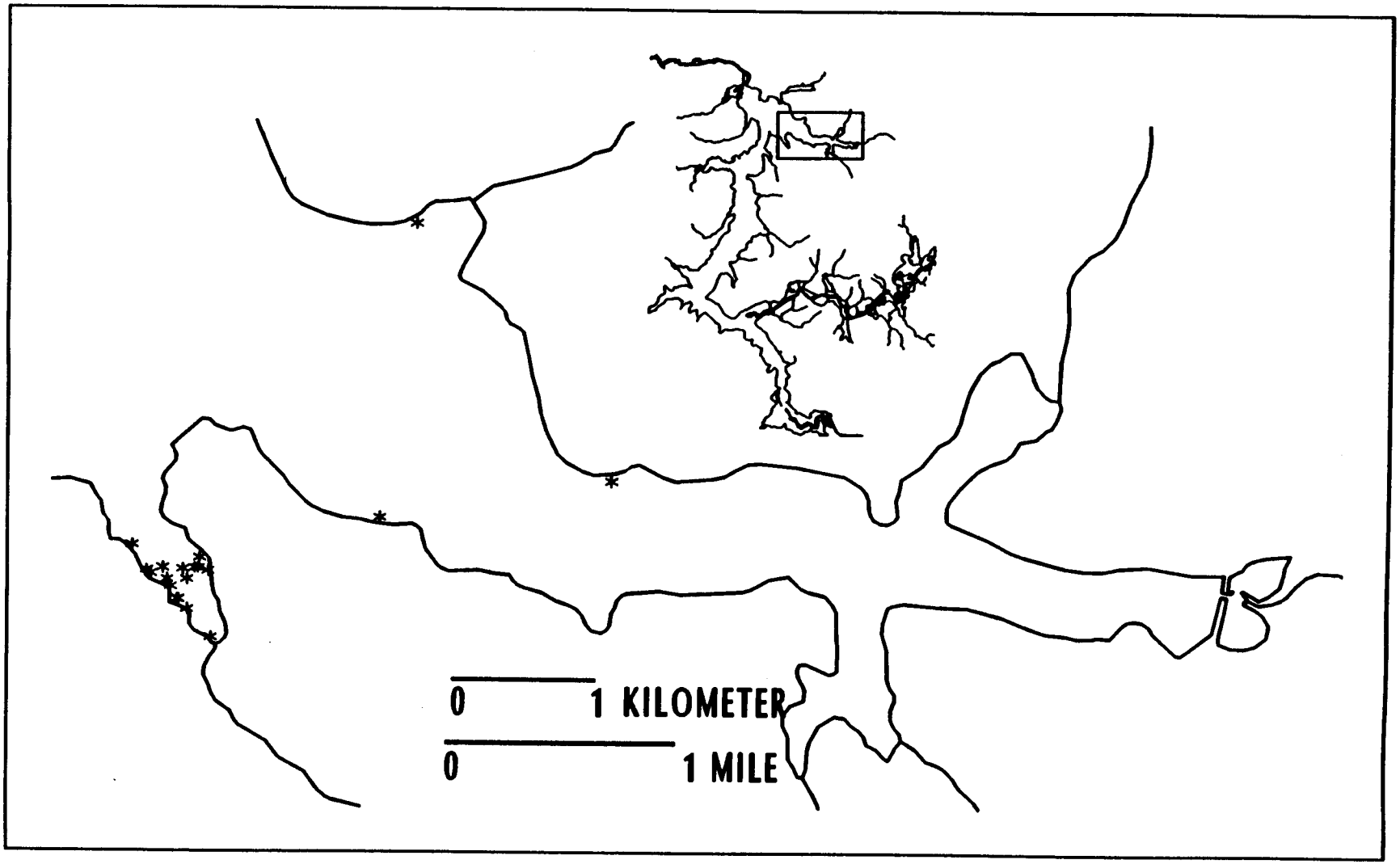
D-17. Locations of northern pike WL62 (2.6 kg female) from 5 July to 16 August 1990. Mean time between locations was 5 days (range 1-8 days).



D-18. Locations of northern pike WL7 (2.2 kg female) from 4 May to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).



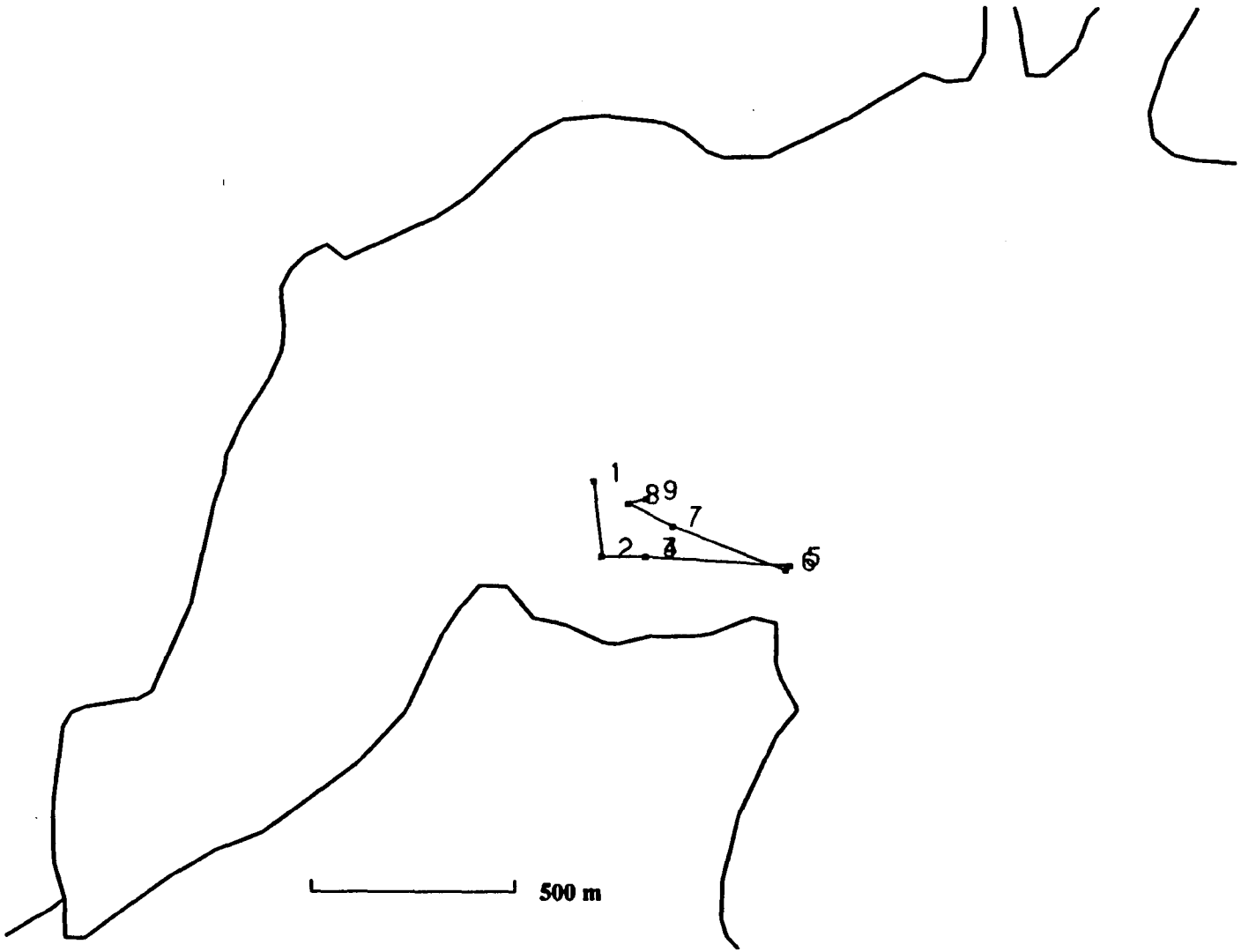
D-19. Locations of northern pike WL8 (2.0 kg male) from 4 May to 16 August 1990. Mean time between locations was 5 days (range 1-8 days).



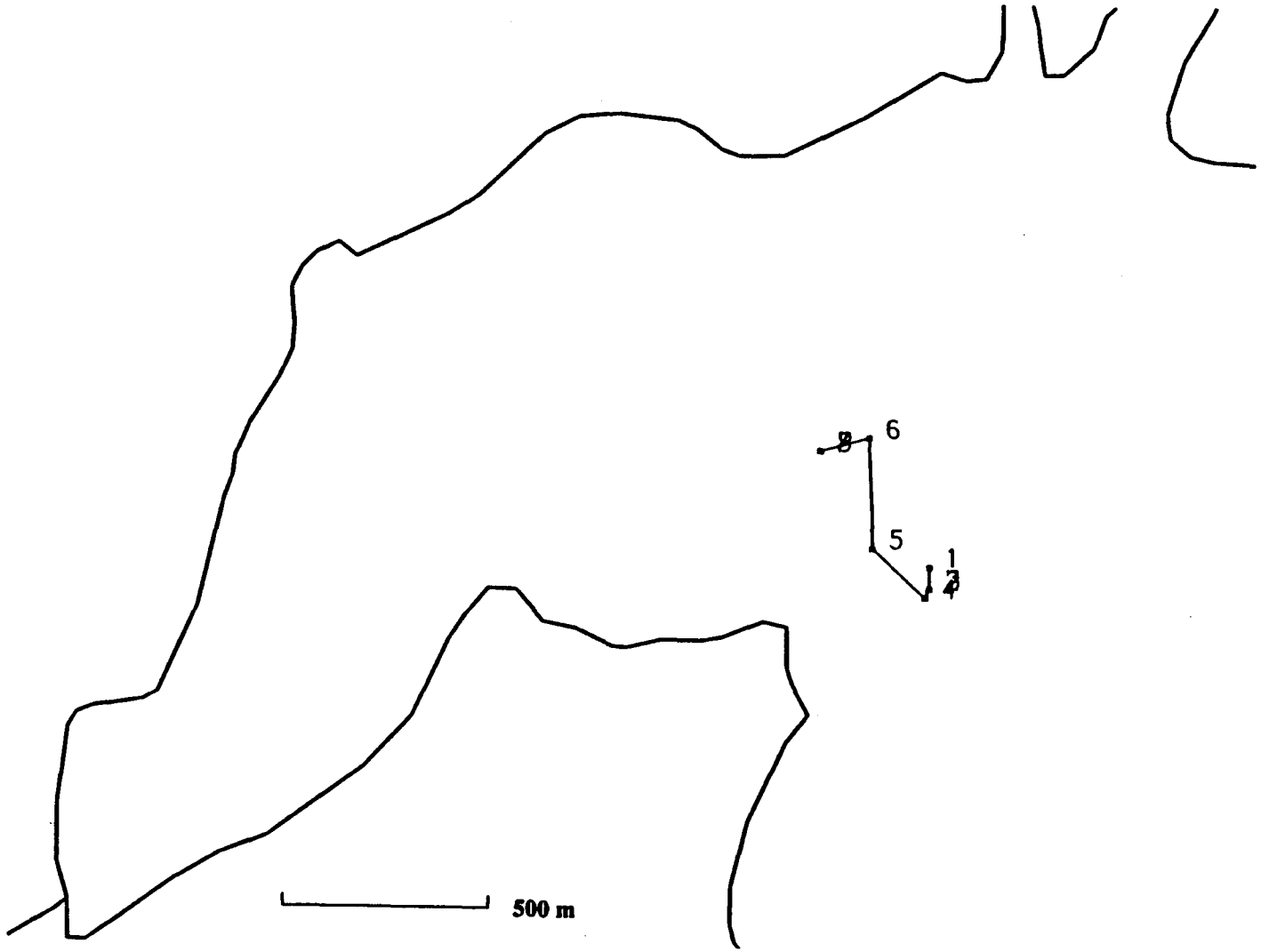
D-20. Locations of northern pike WL9 (2.0 kg male) from 13 May to 13 September 1990. Mean time between locations was 5 days (range 1-8 days).

APPENDIX E

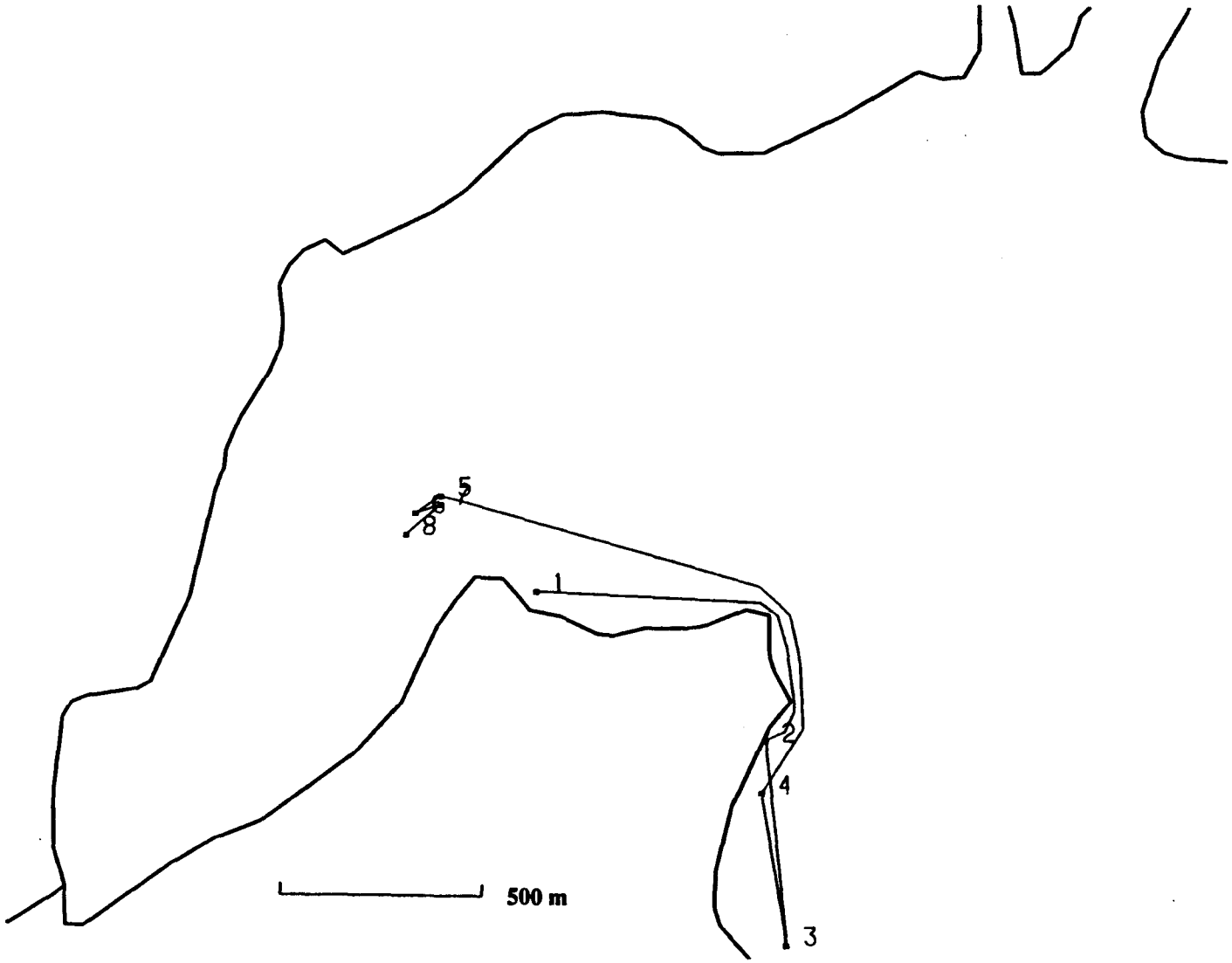
Diel Locations of Radio-Tagged Northern Pike in Coeur d'Alene Lake, Idaho



E-1. Sequential locations of northern pike CB1 (6.8 kg male) from 1831 hours 28 June to 1748 hours 29 June 1990. Locations were made approximately every 3 hours.

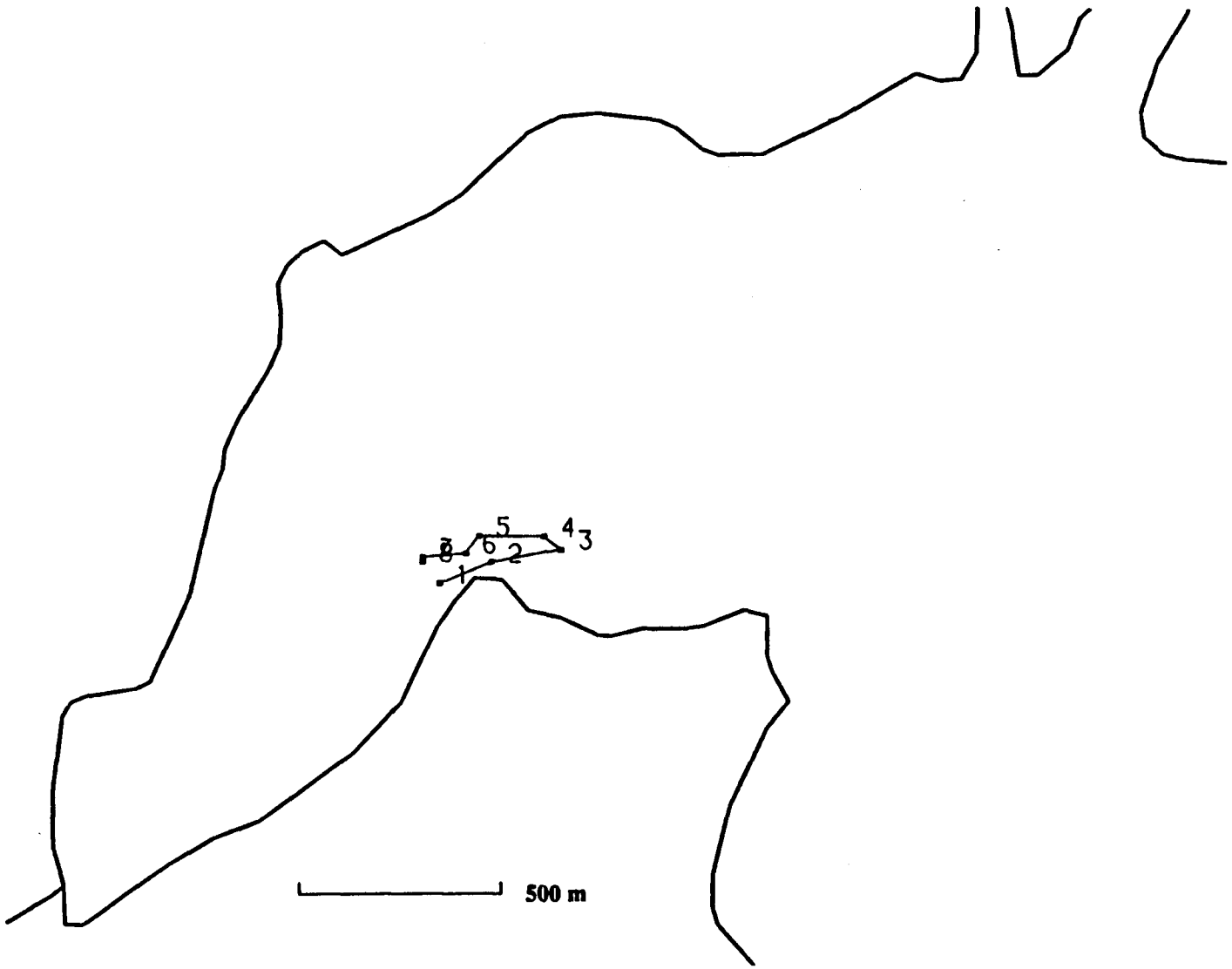


E-2. Sequential locations of northern pike CB42 (4.4 kg male) from 1903 hours 25 July to 1700 hours 26 July 1990. Locations were made approximately every 3 hours.

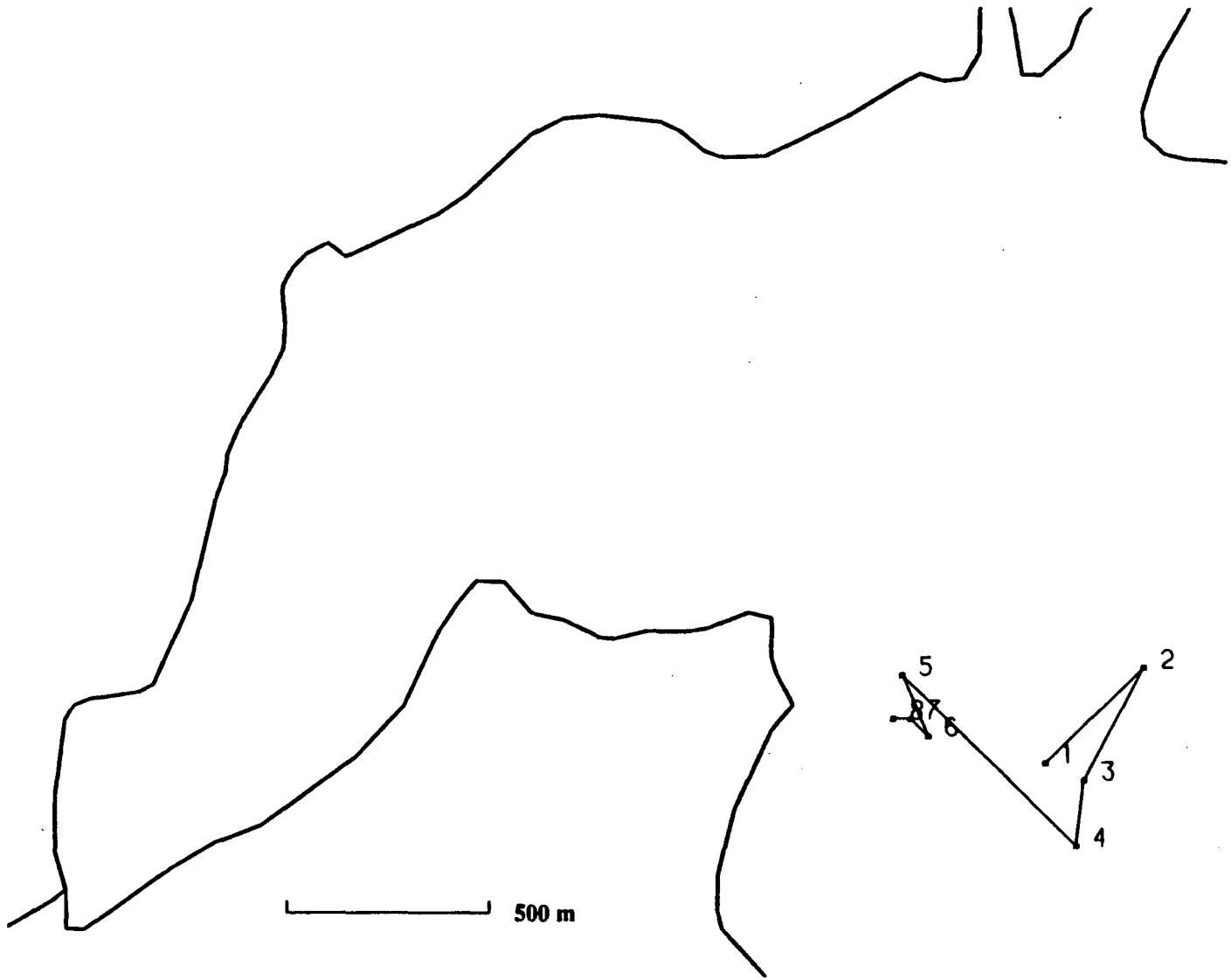


E-3. Sequential locations of northern pike CB5 (5.3 kg female) from 1909 hours 28 June to 1521 hours 29 June 1990. Locations were made approximately every 3 hours.

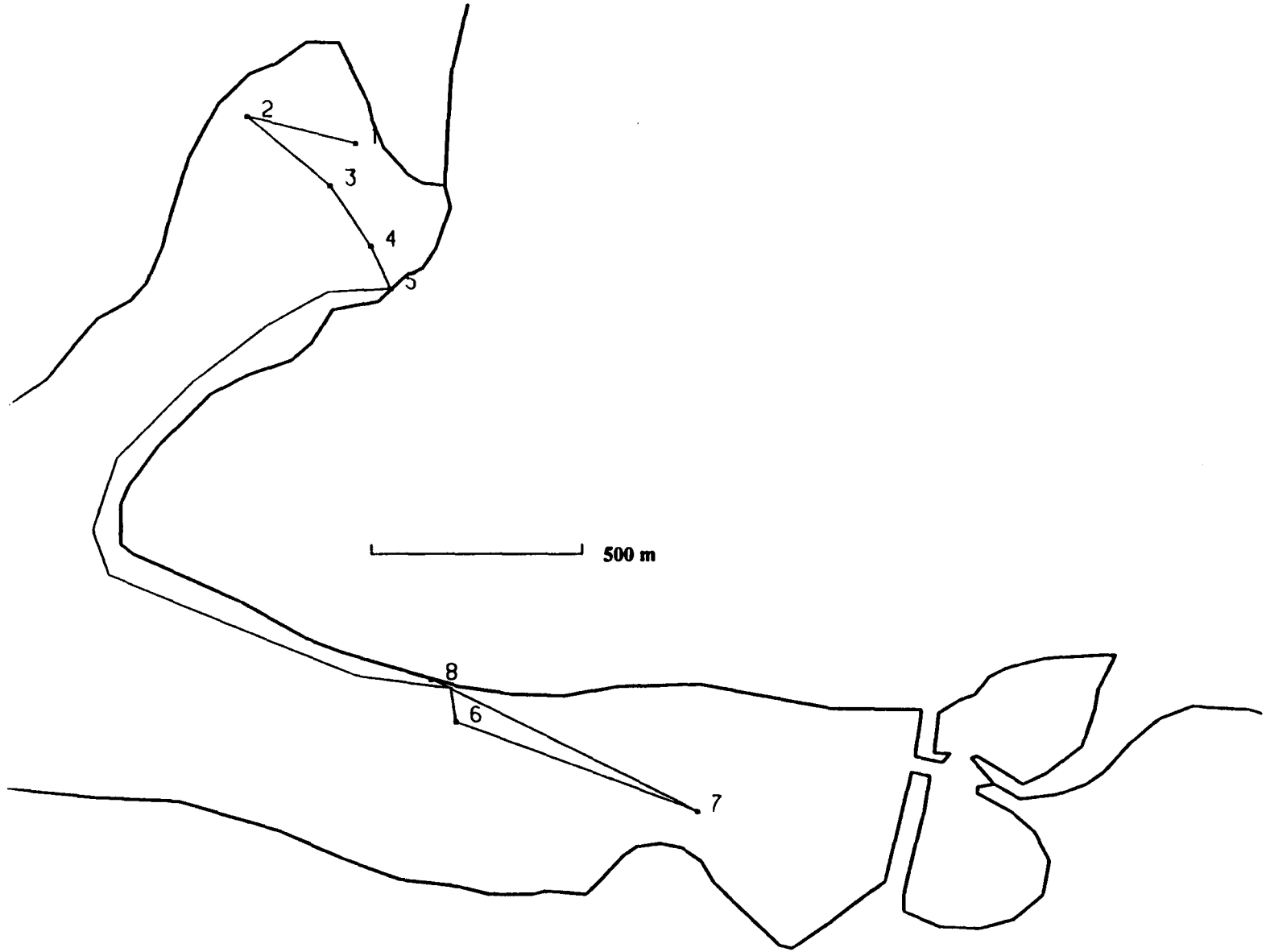
E-4. Sequential locations of northern pike CB5 (5.3 kg female) from 2027 hours 25 July to 0435 hours 26 July 1990. Locations were made approximately every 3 hours.



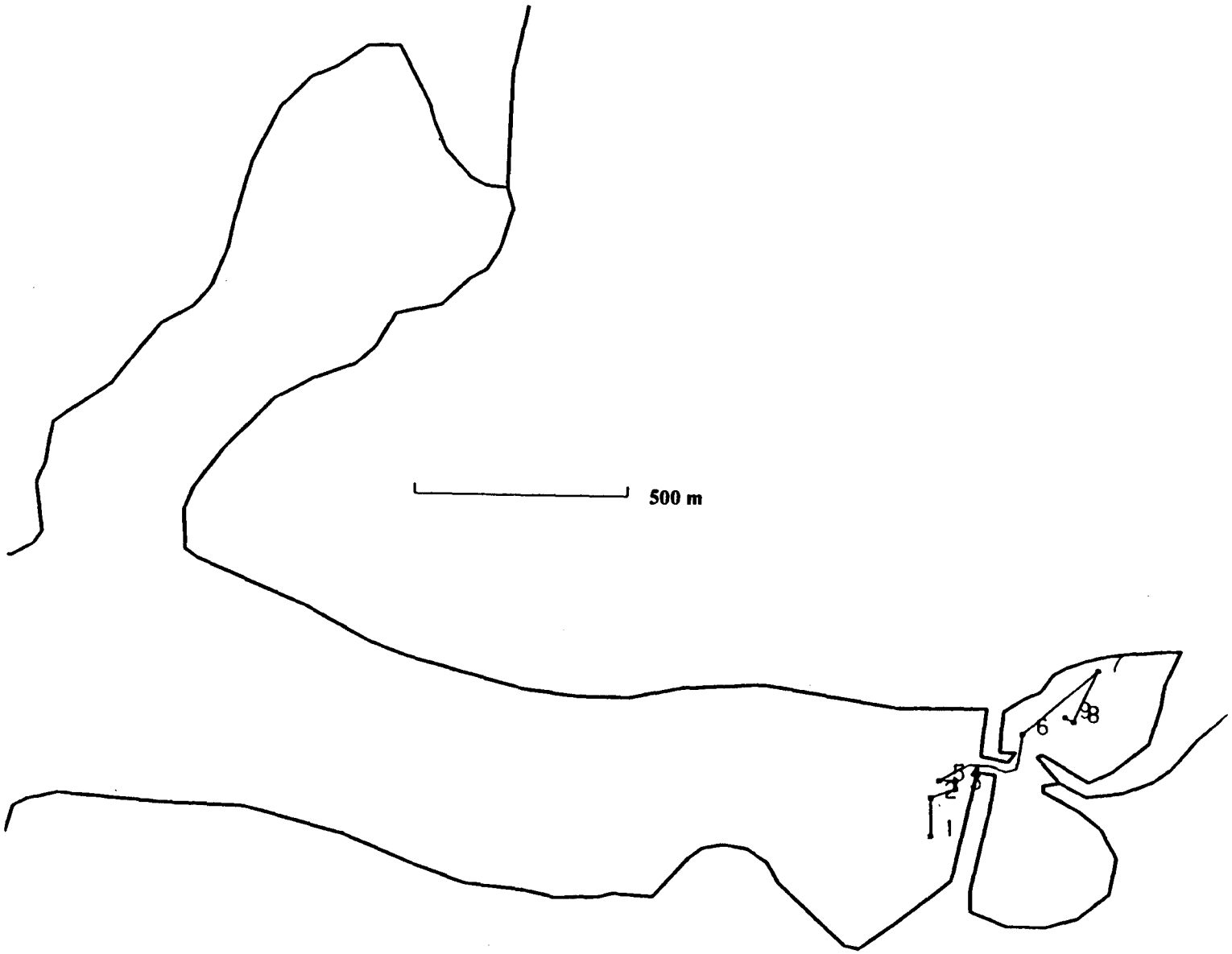
E-5. Sequential locations of northern pike CB7 (4.1 kg male) from 1844 hours 28 June to 1550 hours 29 June 1990. Locations were made approximately every 3 hours.



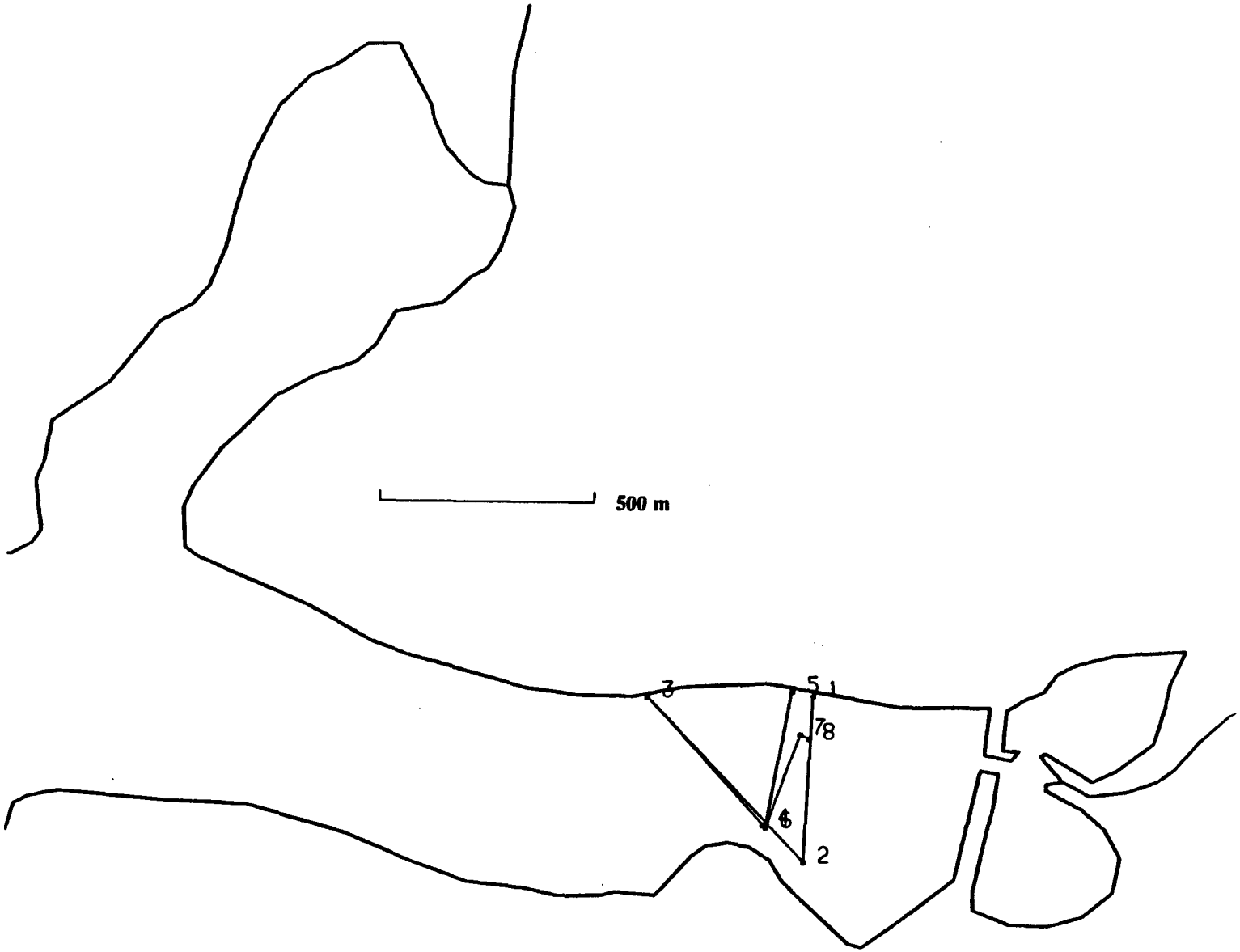
E-6. Sequential locations of northern pike CB8 (7.9 kg male) from 1923 hours 25 July to 1700 hours 26 July 1990. Locations were made approximately every 3 hours.



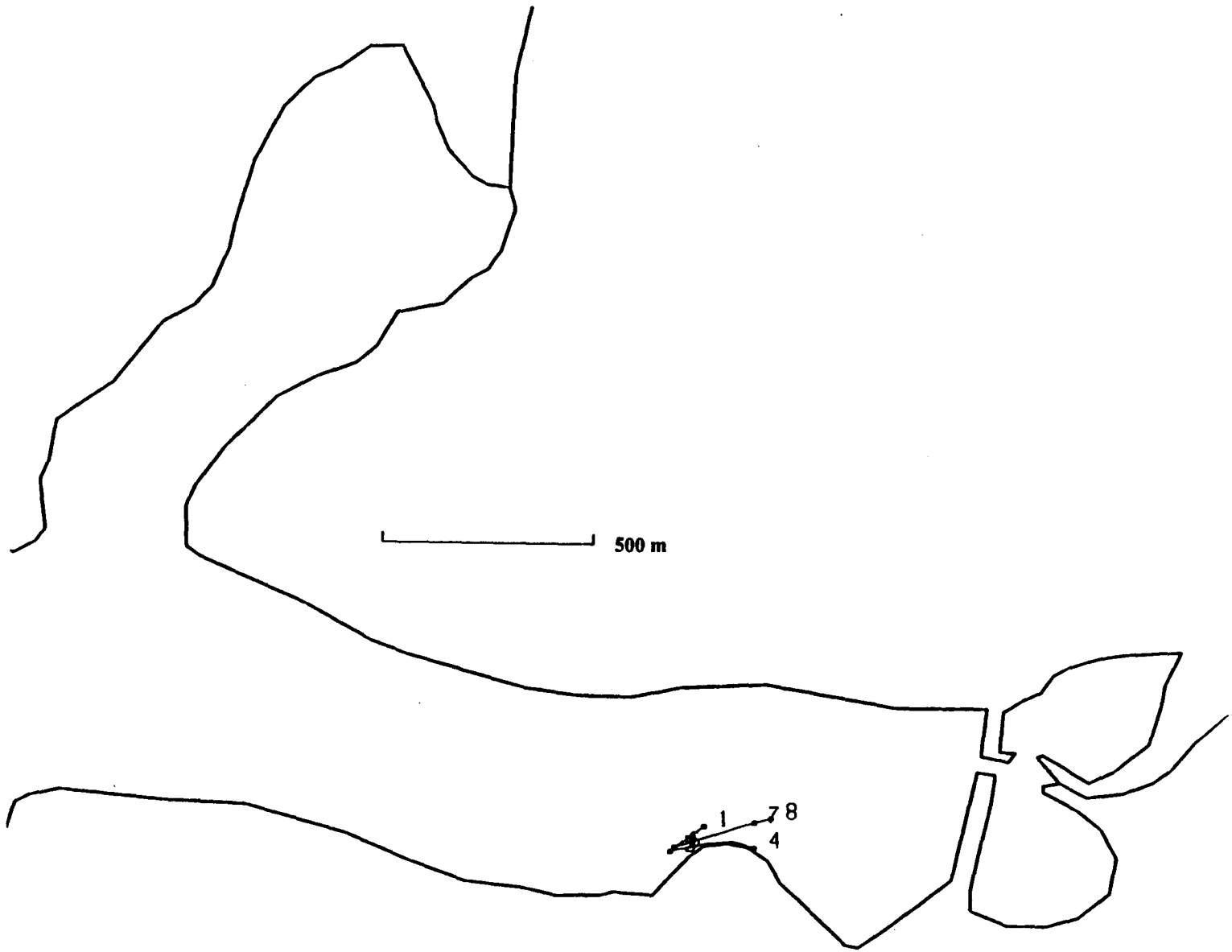
E-7. Sequential locations of northern pike WL2 (6.5 kg female) from 1450 hours 14 June to 1128 hours 15 June 1990. Locations were made approximately every 3 hours.



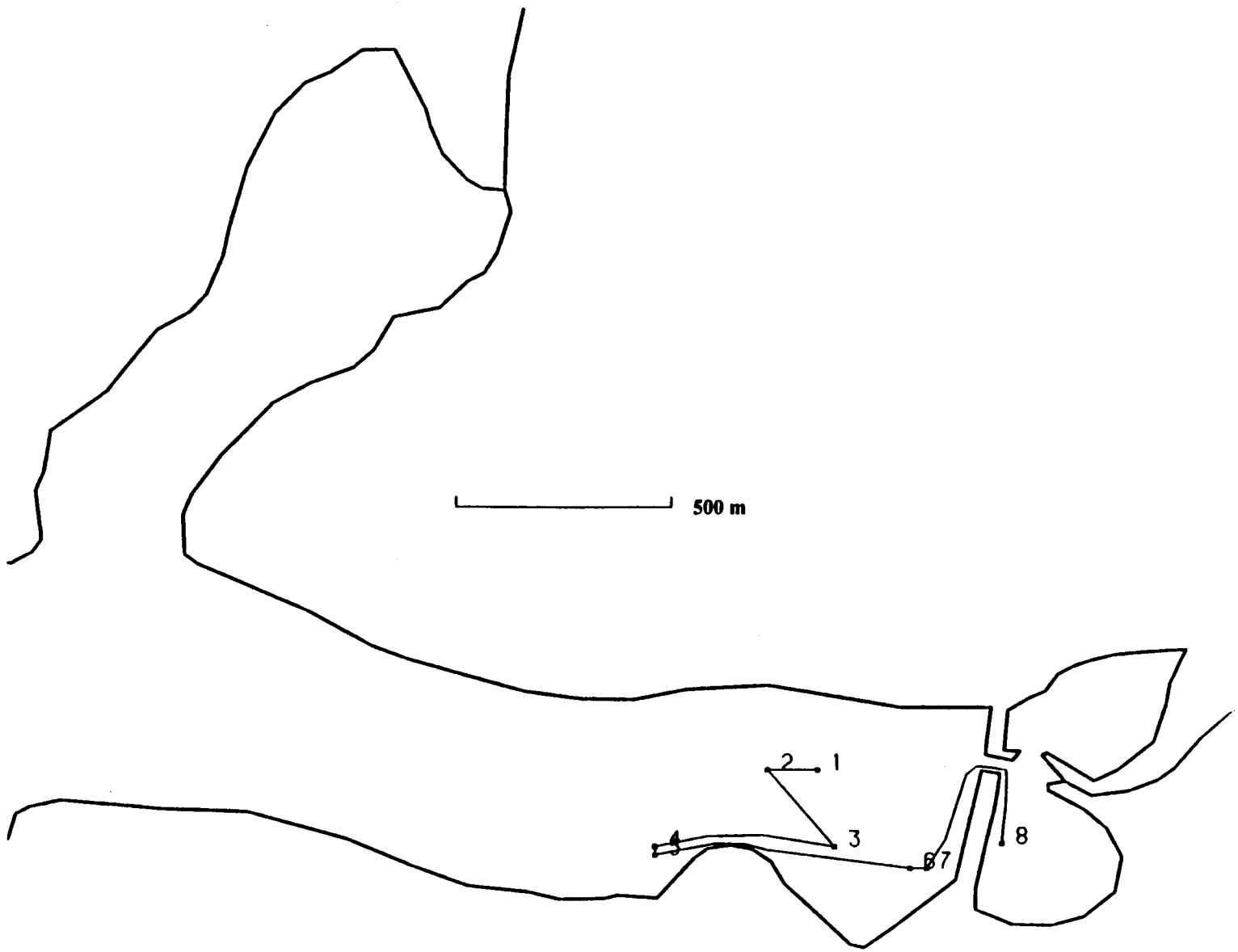
E-8. Sequential locations of northern pike WL2 (6.5 kg female) from 1748 hours 8 August to 1715 hours 9 August 1990. Locations were made approximately every 3 hours.



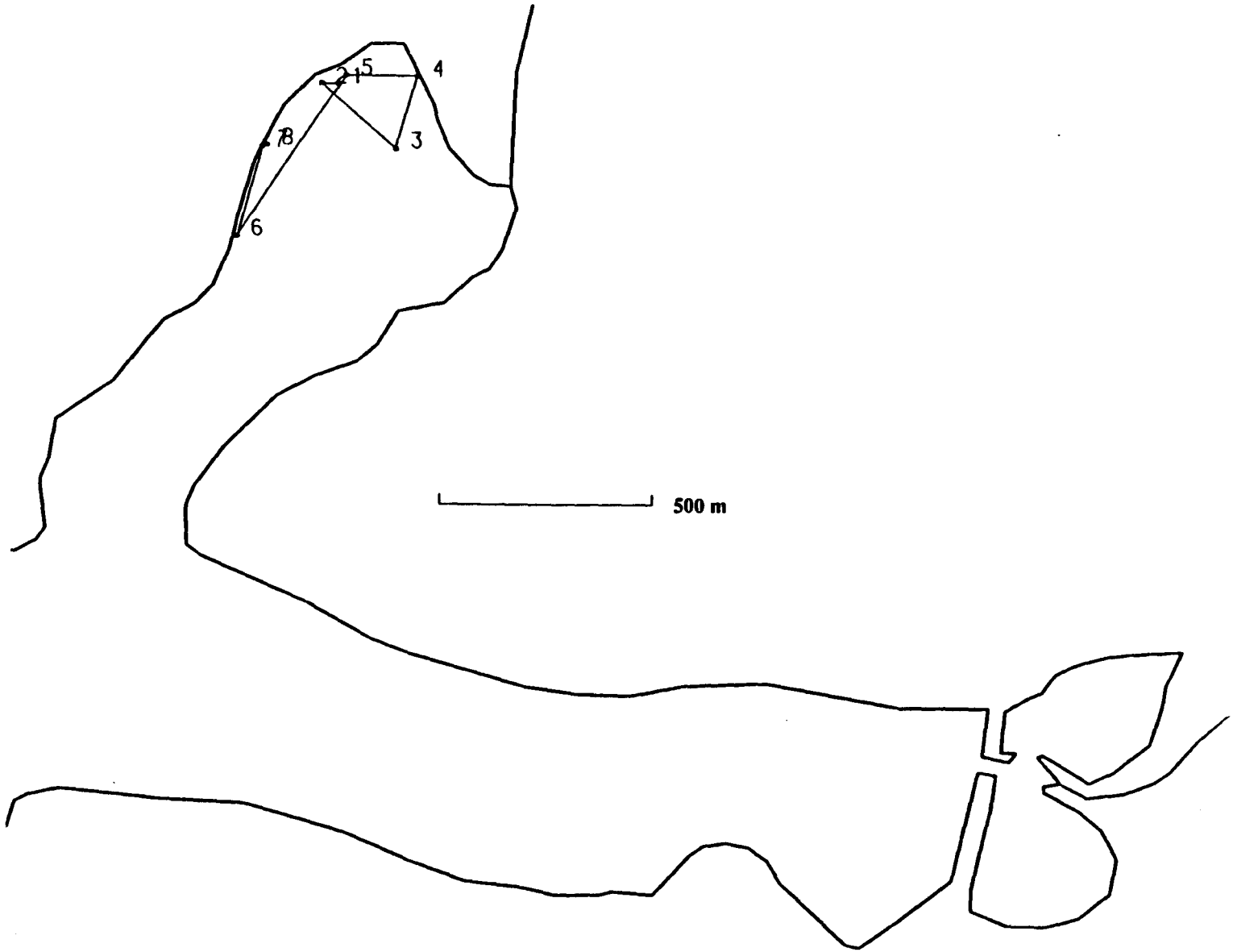
E-9. Sequential locations of northern pike WL3 (2.2 kg female) from 0408 hours 10 July to 2323 hours 10 July 1990. Locations were made approximately every 3 hours.



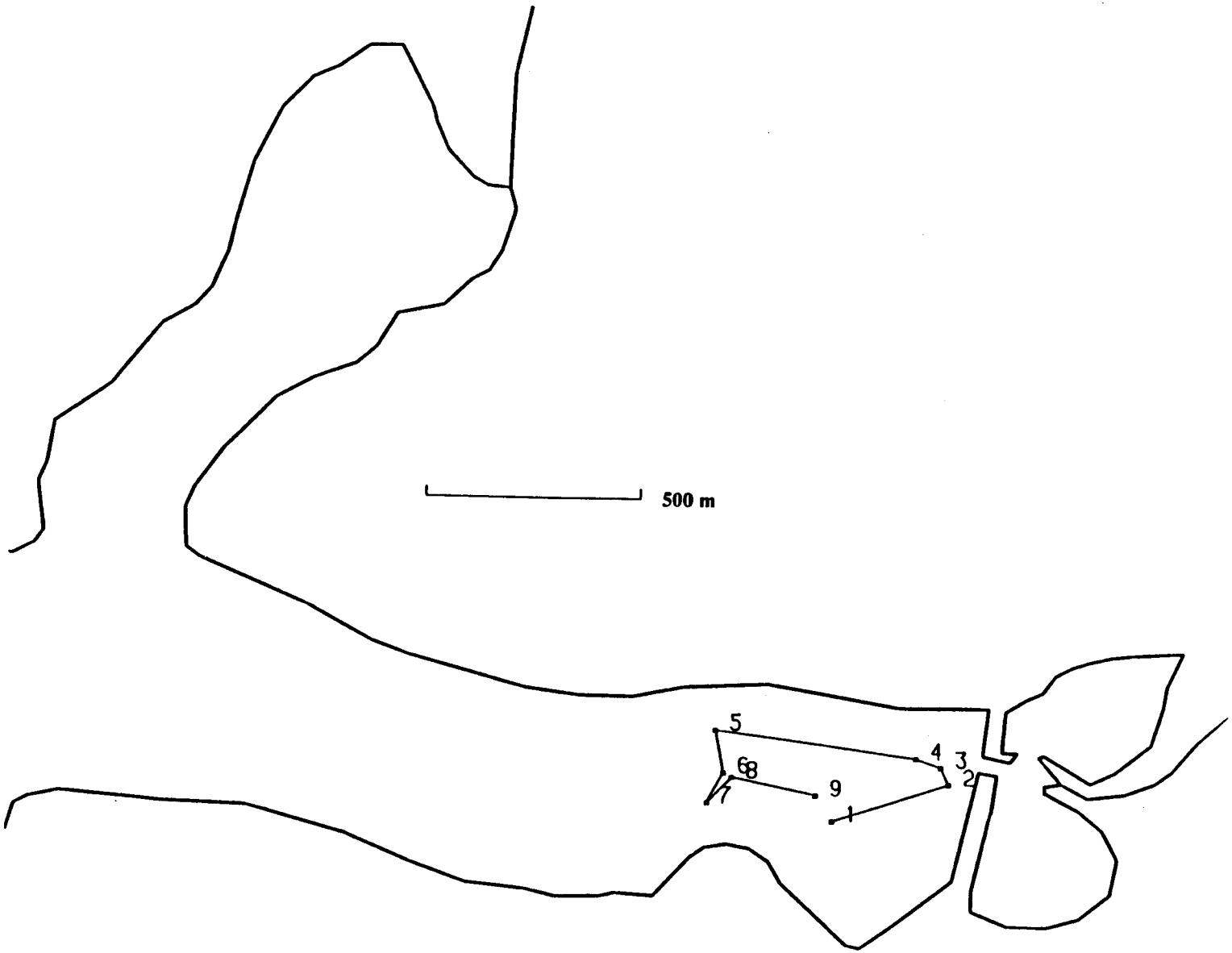
E-10. Sequential locations of northern pike WL4 (6.9 kg male) from 0443 hours 10 July to 2345 hours 10 July 1990. Locations were made approximately every 3 hours.



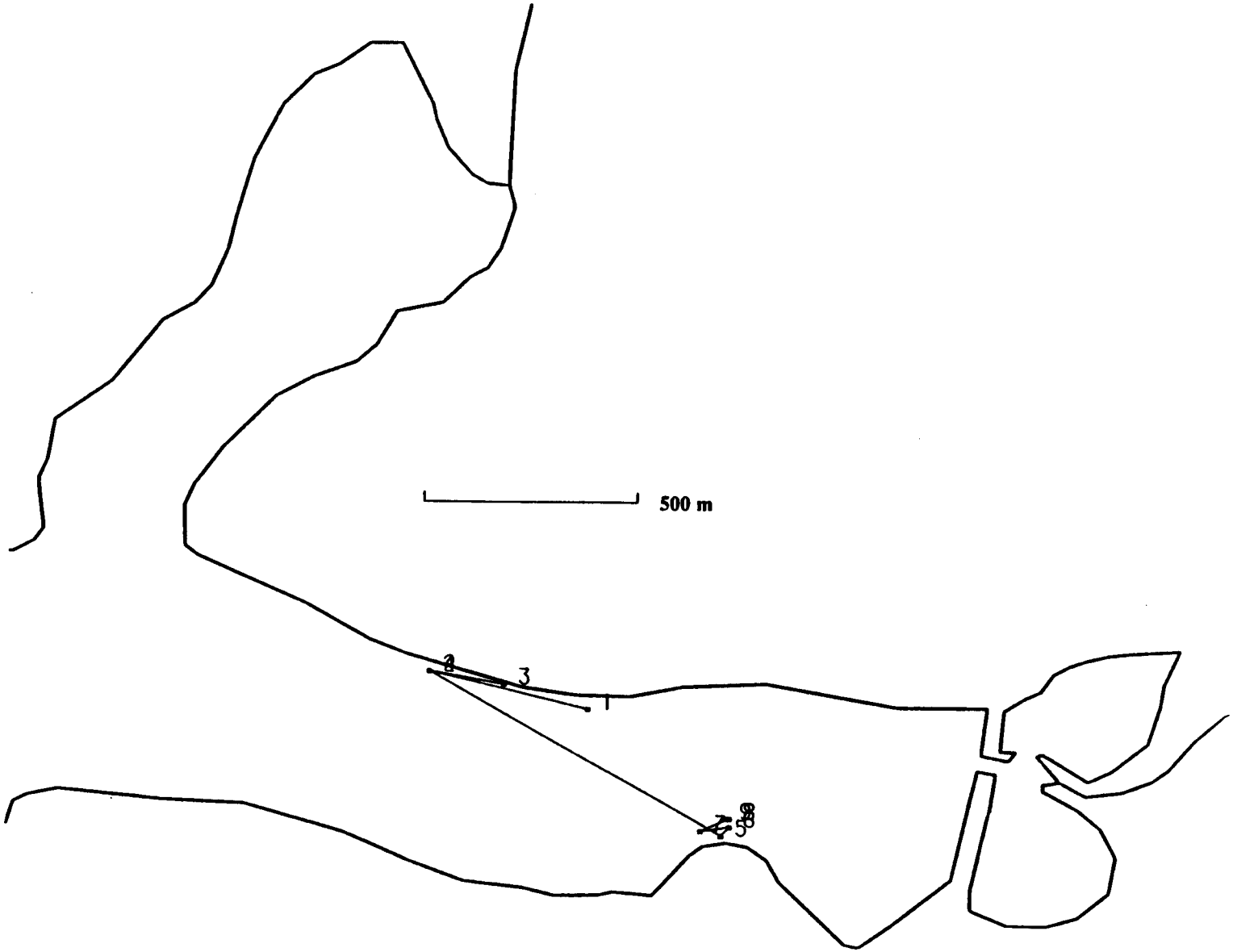
E-11. Sequential locations of northern pike WL5 (1.7 kg male) from 1540 hours 14 June to 1200 hours 15 June 1990. Locations were made approximately every 3 hours.



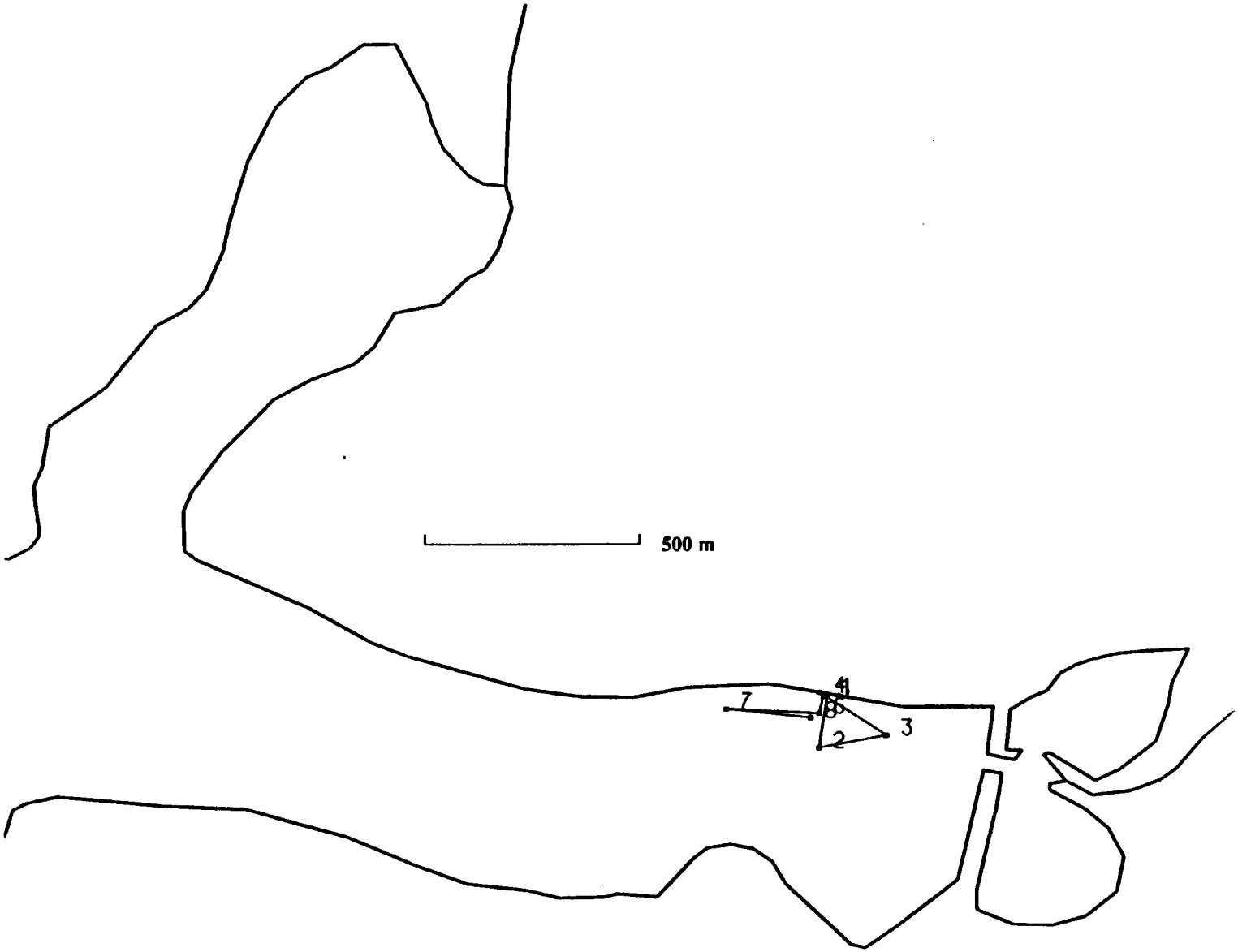
E-12. Sequential locations of northern pike WL6 (2.3 kg male) from 1412 hours 14 June to 1100 hours 15 June 1990. Locations were made approximately every 3 hours.



E-13. Sequential locations of northern pike WL62 (2.6 kg female) from 1730 hours 8 August to 1727 hours 9 August 1990. Locations were made approximately every 3 hours.



E-14. Sequential locations of northern pike WL7 (2.2 kg female) from 1817 hours 8 August to 1739 hours 9 August 1990. Locations were made approximately every 3 hours.



E-15. Sequential locations of northern pike WL8 (2.0 kg male) from 0423 hours 10 July to 2333 hours 10 July 1990. Locations were made approximately every 3 hours.

Submitted by:

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Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
Bureau of Fisheries

Virgil K. Moore
Fisheries Research Manager