Movement of carp in the Lake Winnebago system determined by radio telemetry. No. 134 1982

Otis, Keith J.; Weber, John J.

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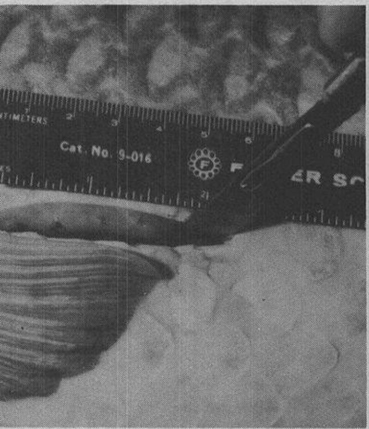
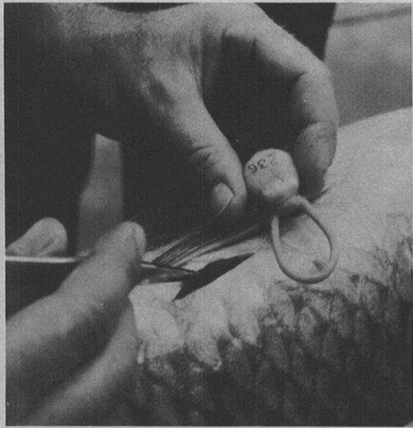
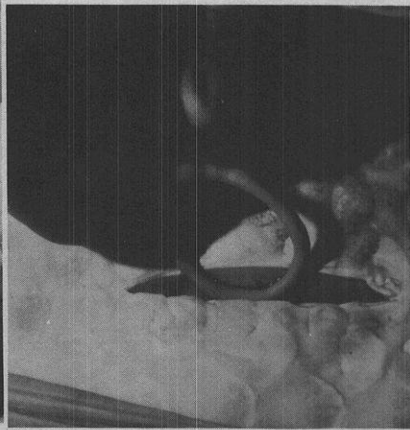
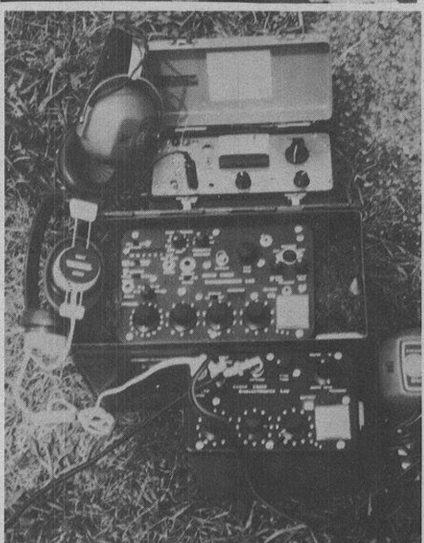
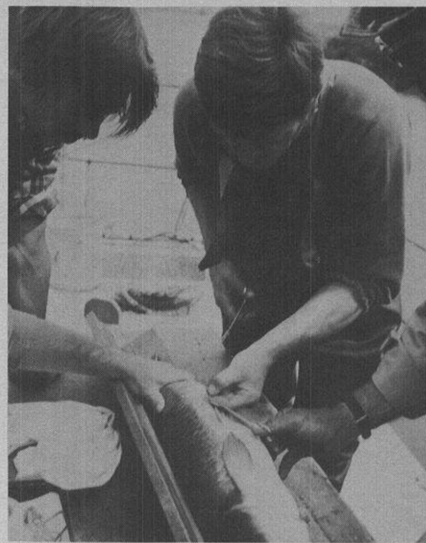
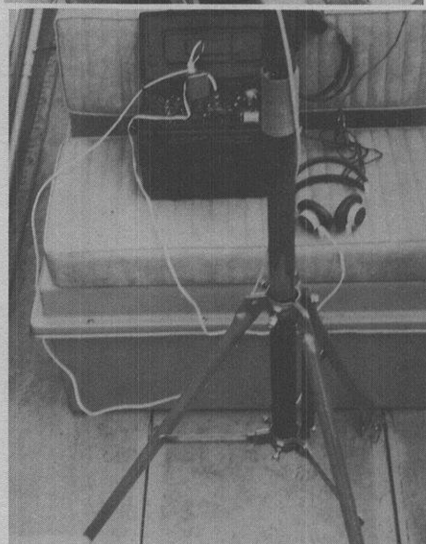
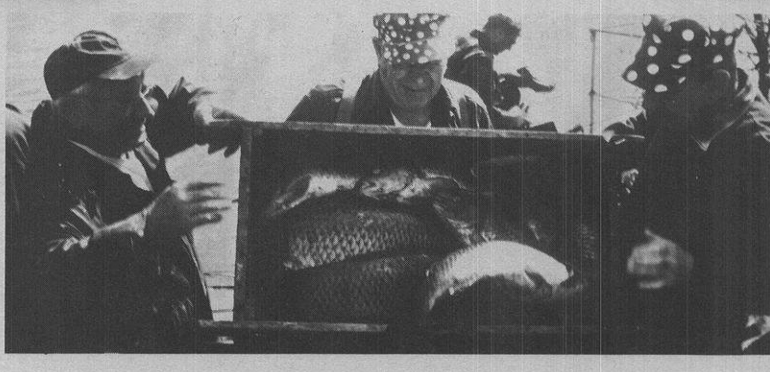


MOVEMENT OF CARP IN THE LAKE WINNEBAGO SYSTEM DETERMINED BY RADIO TELEMETRY

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ABSTRACT

Carp (*Cyprinus carpio* Linnaeus) movement, as determined both by conventional tagging (582 carp) and by radio telemetry (19 carp) with boat, aircraft, and from the ground was found to be influenced primarily by spawning, habitat, and seasonal factors. Carp home ranges during winter months were in the deepest areas of the lakes and were approximately one-third the size of summer home ranges. The least carp movement was noted in January and February. Carp were sensitive to disturbances on the water or ice, and radio-tagged carp appeared to display conditioned behavior to avoid close contacts with the tracking boat, and recapture attempts with an electroshocking boat.

Radio-tagged carp were observed to return to their spawning grounds following intentional displacement. Year-to-year homing tendencies or home range behavior, however, was not observed to be characteristic of carp. Tagged carp were observed to relocate their ranges from year to year within a lake and sometimes from lake to lake.

Radio tracking offers promise for increasing the effectiveness of carp control activities in other waters.

MOVEMENT OF CARP IN THE LAKE WINNEBAGO SYSTEM DETERMINED BY RADIO TELEMETRY

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INTRODUCTION

It has been well documented that carp can cause detrimental changes in a lake or river environment (Wanie and Hopkins 1951, Miller 1952, Jessen and Kuehn 1958, Sigler 1958, Dalquest and Peters 1966, King and Hunt 1967, McCrimmon 1968, Jester et al. 1969, Priegel 1970, Sills 1970). Even though efforts to control carp in Lakes Winnebago and Butte des Morts have been made since 1947 (Table 5), carp are probably partially responsible for increasing turbidity and reducing vegetation in this area. Radio tracking will produce information on the movements and habits of adult carp which will aid in directing management activities.

The study area included Lake Winnebago, 137,708 acres; Lake Butte des Morts, 9,234 acres; Lake Winneconne, 4,507 acres; Lake Poygan, 14,102 acres; and parts of the Fox and Wolf River system adjoining the lake complex (Fig. 1). Lake Winnebago has a maximum depth of 21.0 ft and an average depth of 15.5 ft. The other lakes have maximum depths under 11 ft.

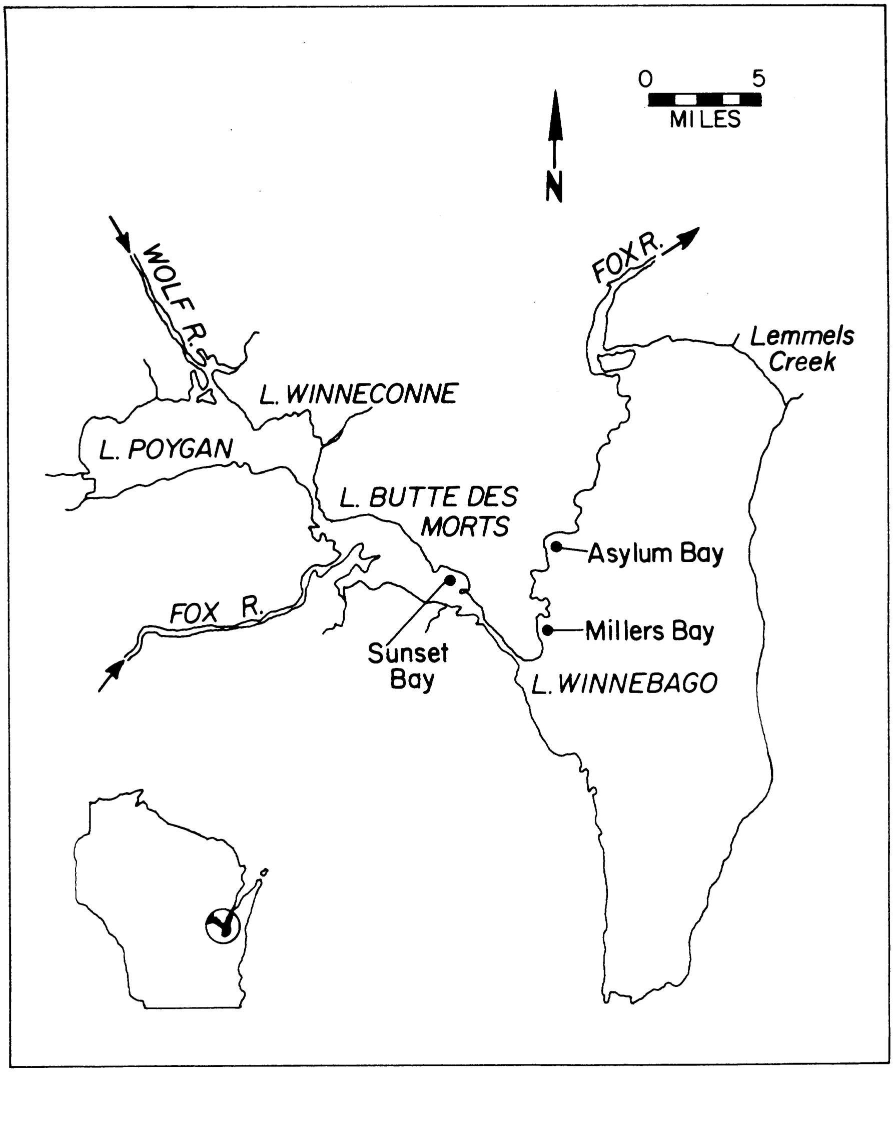

FIGURE 1. *Lakes and rivers in 166,000-acre study area.*

MATERIALS AND METHODS

From 1977 to 1979, 582 carp were collected with ac electrofishing gear, tagged with international orange Floy FD-68 anchor tags, and returned to the lakes in which they were captured: Lake Winnebago, 98 in June 1977 and 139 in October 1979; and Lake Butte des Morts, 154 in June 1978 and 191 in September 1979. Conventional tagging was done in conjunction with radio tagging in order to provide not only a control comparison, but also additional information on carp movement. The tags were inserted, after removing two scales, 2-3 rows below the 5th and 6th soft ray anterior to the posterior margin of the dorsal fin with a Floy FDM-68 tagging gun (Weber 1977).

Nineteen carp were collected by ac electrofishing from 9 June 1978 to 4 October 1979, and were tagged with both Floy FT-4 lock-on loop tags and radios (Fig. 2). Mean total lengths for the 4 male and 15 female radio-equipped carp were 27.3 and 30.0 inches, respectively. The tags were placed 2-3 scale rows below the 3rd soft ray anterior to the posterior margin of the dorsal fin, and inserted completely through the musculature with a needle, locking the tag around the dorsal fin (Weber 1978). Radio transmitters were surgically implanted into the body cavity (Winter 1976, Winter et al. 1978). Fish were anesthetized 10-12 min with 0.36 mg/l of 2-phenoxyethanol, and inverted in a V-shaped trough. After removing 4-6 scales, a 40-50 mm incision was made with a scalpel near the basal anterior half of the pelvic fins (Johnson and Hasler 1977). The site of the incision was changed after June 1978 to the posterior edge of the pelvic fin. This was done to reduce possible interference with the pelvic girdle musculature and vital organs in this region (Weber 1979). Incisions were made with surgical scissors and the radio transmitter inserted with the tuned loop antenna oriented posteriorly. The module was positioned midventral in the peritoneal cavity to avoid contact with the incision.

We found, through our transmitter implant and testing, that the attitude of the loop antenna on the padlock-shaped 20_g AVM SM-1 transmitter had maximum signal strength when oriented in a vertical mode. Factory-made transmitters were modified by taking them apart and reassembling them so as to reverse the antenna orientation. Since maximum signal radiation is off the sides of the loop, and the "null" is straight through the hole of the loop, vertical orientation would direct the signal up to the surface producing a stronger signal. When the transmitter was implanted in the fish, it came to rest midventrally in a horizontal plane. Turning the antenna to a right angle positioned it for maximum output and increased range of signal detection by 100+%.

The incision was swabbed with a 1:1 solution of 70% isopropyl alcohol and hydrogen peroxide, and closed with 6-8 nylon sutures (3-0 dermalon monofilament and 3/8-inch circle reverse cutting needle). Individual sutures were secured with two double-square surgical knots.

Radio transmitters (AVM Instrument Co., Champaign, Ill.) were identified by different frequencies at spaced intervals within the 50 MH_z band. The padlock-shaped transmitters had a rated life of 9-12 months, weighed 20 g in air, and had approximate dimensions of 65 x 25 x 10 mm. Each transmitter was sealed in dental acrylic and beeswax and identified by a number and address inscribed with India ink (Winter et al. 1978, AVM manual 1979).

After surgery, the fish radio-tagged in 1978 were held in oxygenated lake water on a tank truck for a 48-hour recovery/observation period before being released. During this time, radio frequencies and pulse rates of each transmitter were checked and calibrated on an AVM LA-12 receiver. Fish radio-tagged in 1979 were not held for a recovery/observation period, but were released immediately after surgery. A programmable 64-channel manual or scanning receiver (Cedar Creek Bioelectronics Laboratory at Bethel, Minnesota) was used part-

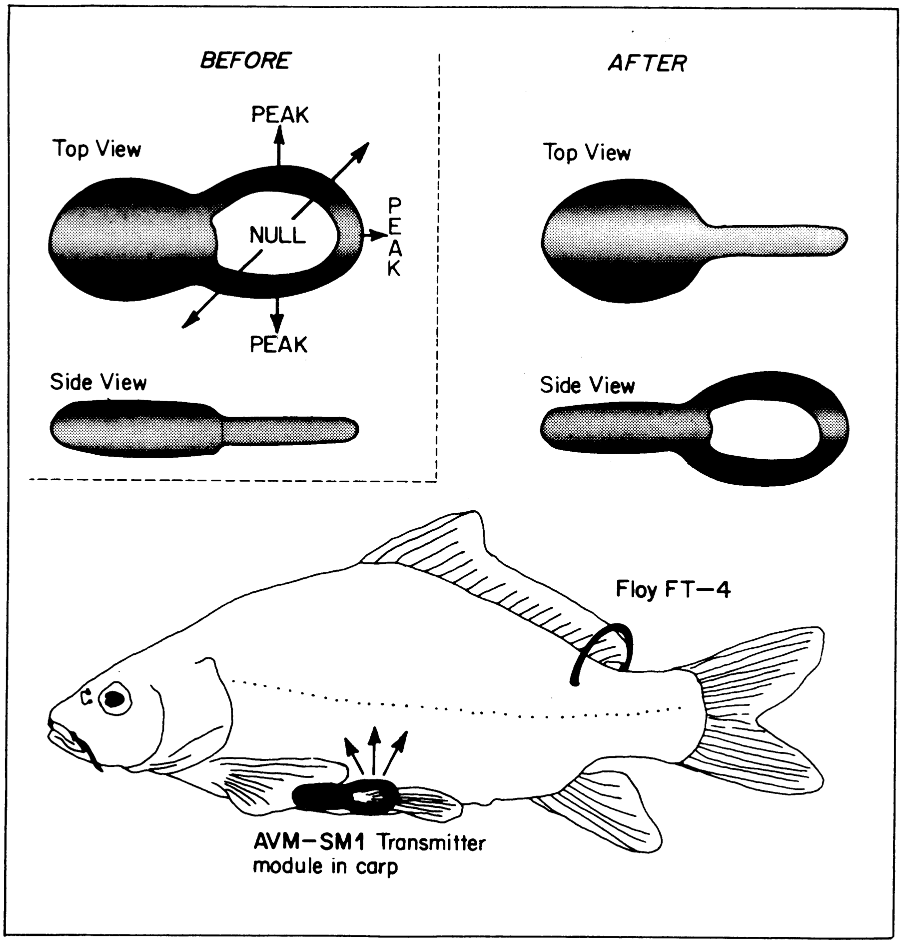

FIGURE 2. *Diagrammatic view of radio transmitters showing turned loop modification and orientation in carp peritoneal cavity. Note that maximum signal strength is directed off sides of loop toward water surface.*

time during the 1979-80 tracking.

Carp were tracked during the open water season by boat, using a 3-element yagi antenna in a vertically polarized position (Fig. 3). The antenna was mounted on a 10-12 ft wood mast set in a tripod, and coupled with either the AVM LA-12 or Cedar Creek radio receiver (both covered 50-51 MH_Z frequency band). Radio locations of fish were determined by triangulation based on azimuth bearings shot from 2-6 boat positions.

When carp could not be found by boat during the open water season they were tracked periodically by single engine aircraft. During winter months aircraft tracking was used almost exclusively (Fig. 4; Weeks et al. 1978). Two 24-inch diameter tuned loop antennae were built by Dav-Tron (Minneapolis, Minn.). The antennae were made of light-gauge (10 mm) aluminum and were mounted under the wings, one parallel to the fuselage and one perpendicular. The wooden arm portion of each unit was secured to the wing struts as far away from the metal on the wings as possible (Weber 1978). Cables from each antenna were wrapped and taped around the struts and drawn through small air vents on each side of the fuselage for attachment to the receiver. Aircraft tracking was tried at altitudes of 20 to 2,500 ft with the best results at 500 ft. The use of aircraft with bi-directional loop antennae allowed for radio-tracking an extensive area in a short period of time. The aircraft also allowed tracking over normally inaccessible areas of thin ice in rivers and main channels of lakes, and during ice-up and ice-out periods.

Some shoreline or ice surface tracking was done using hand-held, bi-directional loop antennae, but the limited transmission range precluded general use of this procedure (Winter et al. 1978).

During open water boat tracking in 1978 the following data were recorded at each radio location: depth, temperature, specific conductance, Secchi disc readings, dissolved oxygen, bottom type and aquatic vegetation types. Data recorded during all types of tracking included: fish radio frequency, location, date, contact time, observers, weather conditions, air temperature, and wind velocity and direction. Individual carp are referred to by the transmitter pulse rate of that fish. Additional information and notes on telemetry appear in the Appendix.

Some terms used in the text pertaining to carp movements are defined as follows:

Winter and Summer: period between total freeze-up and ice-out, and between ice-out and freeze-up.

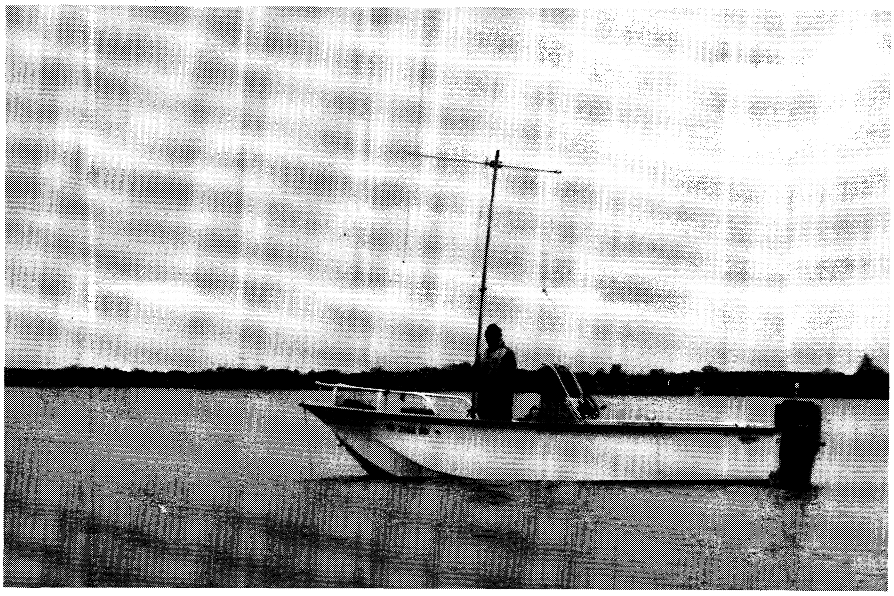

FIGURE 3. *Boat tracking with 3-element yagi antenna.*

FIGURE 4. *Aircraft tracking using 2 tuned loop antennae in parallel and perpendicular alignment to the fuselage.*

Homing: the return of a fish to a home range following experimental or natural displacement (Gerking 1959, Gunning 1963, Gunning and Shoop 1963, Bertmar 1979).

Home range: the area formed by connecting the extreme outermost locations which form the smallest polygon containing all location points during a given time interval. If polygon side cuts across land, the shoreline is used as the boundary (Odum and Kuenzler 1955, Winter 1976).

Primary utilization area: the area within a home range in which most carp movements are made; excludes "excursion" points; often called primary home range (Hayne 1949, Heezen and Tester 1967, Rongstad and Tester 1969, Winter 1977).

Excursion: movements out of the primary utilization area which often make up the periphery of the home range (Winter 1977).

Activity centroid: the geometric center of activity calculated by averaging the X and Y coordinate values for all locations (Hayne 1949, Heezen and Tester 1967, Winter 1977).

RESULTS AND DISCUSSION

EFFECTS FROM IMPLANT SURGERY

Confinement of radio-tagged fish during the 48-hour observation period in 1978 appeared stressful. This was not due to surgery and handling, but because the tags and sutures were subject to significant damage from contact with other carp and the internal structures of the oxygenated holding tank. For these reasons, fish were released immediately after surgery in 1979. Immediate release of flathead catfish after surgery was recommended by Hart and Summerfeldt (1975), and Crossman (1977) felt that both pre-operative and post-operative periods of captivity were unnecessary and probably detrimental for muskellunge. Hasler et al. (1969) recommended an initial confinement period for white bass to regain hydrostatic equilibrium.

There was no apparent stress on the 19 carp from the anesthesia or the handling and surgical procedures used. While Stasko and Pincock (1977) discussed the advantages of internal placement, they also mentioned possible adverse effects from surgery. On the other hand, Johnsen and Hasler (1977) examined a carp after 157 days and found only light scarring from the surgery and no signs of inflammation around the transmitter. In another study, two radio transmitters implanted in carp for more than one year had formed a solid tissue pouch approximately 1 mm thick which adhered to the transmitter (G. Priegel Wis. DNR pers. comm.). No noticeable differences in behavior were noted by other researchers (Ziebel 1973, Crossman 1977, Winter 1977, Prince and Maughan 1978). In studies involving another species, Minor and Crossman (1978) found surgically implanted radio tags did not appear to affect growth or survival of muskellunge recaptured after 15 months.

More females were used for radio implantation for a number of reasons. Female carp were not only larger and longer lived, but it was hoped that they would serve as tracers, leading us to major spawning areas. There was also a difference in the thickness of the ventral abdominal musculature (at site of incision) between the sexes. Flesh thickness was approximately 5-6 mm in females and 8-10 mm in males (Weber 1979). Females also exhibited a lesser degree of internal hemorrhaging than did males, caused not only by the surgery, but also presumably by electrofishing trauma. Gerking (1953) considered the effect of shocking on marked fish to be negligible. Loeb (1958), however, working primarily with carp, said that marked fish may have been weakened by shocking and handling. In this study we felt the combination of less internal hemorrhaging from capture and less bleeding from surgery on thinner musculature, made female carp a better risk than males. Also, once radio transmitters came in contact with blood, a highly conductive medium, they ceased operating. Others have reported that high conductivity can attenuate signal strength in radio transmitters (Winter 1976, Stasko and Pincock 1977, Weeks et al. 1978).

DEPTH DISTRIBUTION AND HABITAT PREFERENCE

Carp spent most of the summer in 3-4 ft of water (Fig. 5). Just prior to ice cover, carp moved into the deeper parts of Lake Butte des Morts and the Fox River channel and overwintered in about 7 ft of water (Fig. 6). They began moving inshore just before ice-out in 1979.

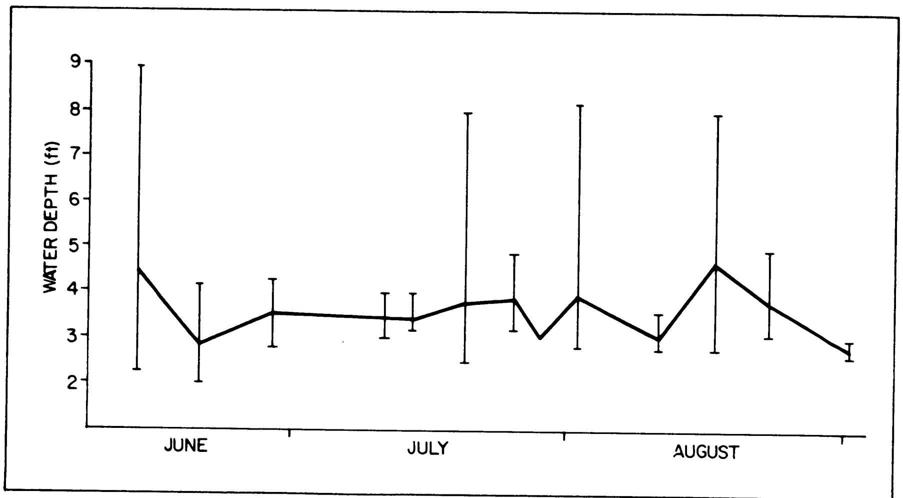

FIGURE 5. *Summer depth distribution of 4 carp radio tagged 9 June 1978. (Each depth average or range represents 1-4 carp contacts/day, and up to 4 combined tracking days; mean = 3.7 ft).*

During the summer, carp were found over 94% of the time in areas of vegetative cover. The association of carp with vegetation in summer has also been noted by others (McCrimmon 1968, Clifford 1973, Johnsen and Hasler 1977). Within beds of submerged vegetation both sexes were located in narrow-leaf pondweed *Potamogeton* sp. (64%), sago pondweed *Potamogeton pectinatus* (31%), and coontail *Ceratophyllum demersum* (5%). To a lesser extent carp used emergent and floating vegetation—reed grass *Phragmites* sp., roundstem bulrush *Scirpus* sp., water lily *Nymphaea varigatum*, arrowhead *Sagittaria* sp., wild rice *Zizania aquatica*, lotus *Nelumbo lutea*, and wild celery *Vallisneria americana*.

MOVEMENTS OF RADIO-TAGGED CARP

Actual and attempted contacts with the 19 radio-tagged carp released in Lake Butte des Morts and Lake Winnebago are summarized in Tables 1-3. Contact success was greater with the boat (40%) than with the aircraft (28%) or shore gear (14%). Mean contact success rate for the study, using all gear, was 34%.

Data for each radio-tagged carp are presented according to date of release to facilitate illustration of movements over a 12-month period.

June, 1978

Four carp (2 males, 2 females) captured in Sunset Bay, Lake Butte des Morts were released on 9 June 1978

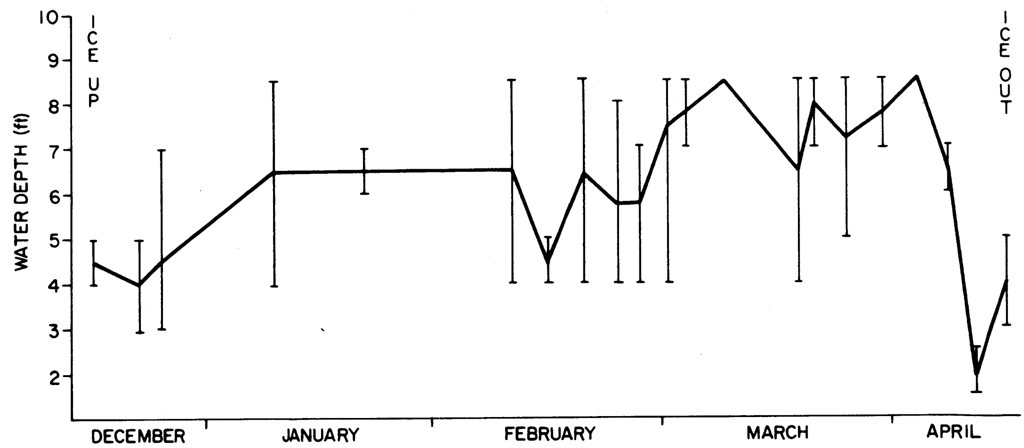

FIGURE 6. *Winter depth distribution during ice cover of 4 carp radio tagged 16 November 1978. (Each depth average or range represents 1-4 carp contacts/day; mean = 7.2 ft).*

TABLE 1. *Summary log of radio contacts for each tagged fish.*

	Date of Release and Fish Frequency																		
	9 June 1978				16 Nov 1978					2 Aug 1979					19 Sep 1979			4 Oct 1979	
	.276	.289	.300	.314	.339	.351	.399	.408	.432	.256	.266	.272	.481	.495	.376	.441	.472	.326	.386
Days of transmission	85	85	75	83	184	149	159	131	*	14*	422	29*	349	6*	335	297	374	1*	267
Total no. contacts	24	27	19	31	22	16	16	11		4	49	8	23	3	27	16	47	1	37
Lake Winnebago	0	0	0	0	1	0	0	0		0	0	0	0	0	0	6	0	1	12
Lake Butte des Morts	24	27	19	31	21	16	16	11		4	49	8	23	3	27	10	47	0	25
Type of contact																			
Aerial	1	3	2	3	21	15	15	10		0	10	1	3	0	3	2	11	0	19
Boat	23	23	17	28	1	1	1	1		4	36	7	20	3	24	14	32	1	17
Shore	0	1	0	0	0	0	0	0		0	3	0	0	0	0	0	4	0	1
Contacts prior to ice cover/total no. days	24/ 85	27/ 85	19/ 75	31/ 83	1/ 1	1/ 1	1/ 1	1/ 1			34/ 120		18/ 120		17/ 72	10/ 72	25/ 72		17/ 57
Aerial	1	3	2	3	0	0	0	0			2		1		0	0	1		1
Boat	23	23	17	28	1	1	1	1			30		17		17	10	23		16
Shore	0	1	0	0	0	0	0	0			2		0		0	0	1		0
Contacts during ice cover/total no. days					18/ 151	15/ 148	13/ 151	10/ 130			9/ 120		2/ 120		0/ 120	0/ 120	12/ 120		10/ 120
Aerial					18	15	13	10			8		2		0	0	9		9
Boat					0	0	0	0			0		0		0	0	0		0
Shore					0	0	0	0			1		0		0	0	3		1
Contacts after ice cover/total no. days					3/ 32	0/ 0	2/ 7	0/ 0			6/ 182		3/ 109		10/ 143	6/ 105	10/ 182		10/ 90
Aerial					3	0	2	0			0		0		3	2	1		9
Boat					0	0	0	0			6		3		7	4	9		1
Shore					0	0	0	0			0		0		0	0	0		0
Last contact date	1 Sep	1 Sep	22 Aug	30 Aug	18 May	13 Apr	23 Apr	26 Mar			26 Sep		15 Jul		18 Aug	11 Jul	26 Sep		26 Jun
	1978				1979					1980									

*Incomplete data: transmitter malfunction or fish died.

TABLE 2. *Number of days per month that radio contacts were attempted by airplane, boat or shore [a (b) s, respectively] for each radio-equipped carp released 9 June and 16 November 1978.*

		.276	.289	.300	.314	.339	.351	.399	.408	.432
1978	June	2 (9)	2 (9)	2 (9)	2 (9)					
	July	2 (12) 1	2 (12) 1	2 (12) 1	2 (12) 1					
	August	(10)	(10)	(10)	(10)					
	September	(1)	(1)	(1)	(1)					
	October	2 (2)	2 (2)	2 (2)	2 (2)					
	November	1 (4) 1	1 (4) 1	1 (4) 1	1 (4) 1	1	1	1	1	1
	December	2	2	2	2	4	4	4	4	4
1979	January	2	2	2	2	2	2	2	2	2
	February	4	4	4	4	5	5	5	5	5
	March	4	4	4	4	7	7	7	7	7
	April	4	4	4	4	6 (1)	6 (1)	6 (1)	6 (1)	6 (1)
	May	3 (3)	3 (3)	3 (3)	3 (3)	4 (4)	4 (4)	4 (4)	4 (4)	2 (3) 1
	June	1	1	1	1	2 (3) 4	2 (3) 4	2 (3) 4	2 (3) 4	
	July	(1)	(1)	(1)	(1)	1 (1) 1	1 (1) 1	1 (1) 1	1 (1) 1	
	August					(5)	(5)	(5)	(5)	
	September	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
Total attempted contacts		27 (43) 2	27 (43) 2	27 (43) 2	27 (43) 2	31 (15) 6	31 (15) 6	31 (15) 6	31 (15) 6	26 (4) 2
Total actual contacts		1 (23) 0	3 (23) 1	2 (17) 0	3 (28) 0	21 (1) 0	15 (1) 0	15 (1) 0	10 (1) 0	0 (0) 0

southeast of Sunset Bay, 2 miles from the capture site, to see if homing would occur. Homing was evident when 3 of these fish were located again at the capture site within one day after release; one did not return to the capture site until 45 days later.

Since these 4 carp remained in a relatively small area of Lake Butte des Morts compared to carp tagged later, an intensive X-Y coordinate grid system was used to designate primary utilization areas and activity centroids. Short-term excursions were not used in home range determinations for these 4 carp, leaving a frequency of occurrence of radio locations within the home range of 92.6% for males and 87.0% for females. For this reason, the home range area figures for June 1978 carp should not be compared with home range figures for carp released later in this study.

These 4 carp were summarized differently because movements of radio-tagged carp after June 1978 were often extensive within a lake or between lakes. The erratic excursions of the later tagged carp across deeper water or along shorelines were difficult to separate in constructing home ranges and primary utilization areas. Also, activity centroids would sometimes fall on dry land or rivers between lakes, which would represent a meaningless data point.

Contact points for individual carp released during the June 1978 period are shown in Figure 7. From these, home ranges and primary utilization areas were delineated. Summer home range was confined to Sunset Bay and ranged from 0.18 mile^2 to 0.30 mile^2, averaging 0.23 mile^2. The primary utilization areas for both sexes combined comprised 45% of the home range areas. Although percentages of contacts in the primary utilization areas were similar for males (81%) and females (89%), these areas were somewhat larger for males (males .12 miles^2 and females .09 miles^2).

Reed grass (*Phragmites*) appeared to offer a barrier between the primary utilization areas near the shore of Sunset Bay and the opening of the bay into Lake Butte des Morts.

Although the activity centroids (Figs. 8, 9) are similar, male carp seemed to show an east-west orientation in their home ranges, while female carp showed a northeast-southwest pattern.

November, 1978

Five female carp were captured and released west of the Highway 41 bridge, Lake Butte des Morts, 16 November 1978. Carp .432 died shortly after release, and the transmitter was found in the spring. The remaining 4 carp were tracked exclusively with aircraft during winter ice cover, 16 December 1978, to ice-out on 17 April 1979 (Tables 1,2). Winter home ranges extended from 1.42 to 3.78 miles^2, averaging 2.41 miles^2 (Fig. 10).

Three of the fish spent early winter below the Wolf River channel inlet in northwest Lake Butte des Morts, but when ice formation was complete by mid-January, they moved to the deepest portion of the lake west of the Highway 41 bridge. The fourth fish joined them in mid-March, near the beginning of ice-out. Ice was completely off Lake Butte des Morts on 16 April 1979 when all carp (except .408 which could not be located) had moved to the upper river channel near the middle of the lake.

Near the end of April, one fish (.339) moved to the south shore of Lake Butte des Morts and final contact was made 18 May 1979 in south Asylum Bay, Lake Winnebago. This downstream movement to Lake Winnebago was the first evidence of movement between the two lakes.

Winter movement for all carp released in November was greatest during early ice cover and again prior to ice-out, but was confined to the deepest southwest portion of the lake in January and February, the time of least carp movement.

TABLE 3. *Number of days per month that radio contacts were attempted by airplane, boat or shore [a (b) s, respectively] for each radio-equipped carp released 2 August, 19 September, and 4 October 1979.*

		.256	.266	.272	.481	.495	.376	.441	.472	.326	.386
1978	August	1 (11) 2	1 (10) 2	1 (11) 2	1 (11) 2	1 (11) 2					
	September	(6)	(7)	(7)	(7)	(4)	(7)	(5)	(8)		
	October	1 (4)	1 (17)	1 (3)	1 (14)	1 (2)	1 (14)	2 (15)	1 (13)	1 (5)	1 (15) 1
	November		2 (4) 1		2 (4) 1		2 (4) 1	2 (4) 1	2 (4) 1		2 (4) 1
	December		4		4		4		3 2		4
1979	January		2		2		2	2	2		2
	February		2		2		2	2	2		2
	March		3 1		3 1		3 1	3 1	3 1	1	3 1
	April		1		1		1	1	1		1
	May		(11) 1		(11) 1		(11) 1	1 (8) 1	(10) 1		1 (8) 1
	June		8 (6)		7 (7)		9 (5)	10 (2)	8 (5)		11 (1)
	July		(7)		(8)		(7)	(5)	(3)		(4)
	August		(6)		(3)		(6)	2 (1)	(6)		
	September		2 (5)				2 (5)	(1)	2 (5)		2 (1)
	October		(1)		(1)		(1)		(1)		(1)
Total attempted contacts		2 (21) 2	26 (74) 5	2 (21) 2	23 (66) 5	2 (17) 2	26 (60) 3	29 (41) 3	24 (55) 5	1 (5) 1	29 (34) 4
Total actual contacts		0 (4) 0	10 (36) 3	1 (7) 0	3 (20) 0	0 (3) 0	3 (24) 0	2 (14) 0	11 (32) 4	0 (1) 0	19 (17) 1

August, 1979

Five carp (2 males, 3 females) were captured and released west of the Highway 41 bridge in Lake Butte des Morts on 2 August 1979. Within 13 days after release, 3 of the fish died, apparently due to their weakened postspawning condition. These fish had also displayed signs of poor recovery from surgery, and slight bleeding when released. They were last contacted heading northwest in Lake Butte des Morts, 0.5-4 miles from the release site.

The 2 remaining females were tracked for 349 days (carp .481) and 422 days (carp .266) (Fig. 11). The new 9-12 month rated transmitters allowed for summer-winter-summer tracking which was not possible for the 1978 releases. Their summer home ranges were in the central and east end of Lake Butte des Morts. After ice cover, 30 November 1979, both had identical overwinter home ranges in the deepest east end of Lake Butte des Morts. Winter home ranges were approximately one-third the size of their summer home ranges.

After ice-out, 28 March 1980, carp .266 occupied a summer home range through September 1980 that was nearly identical to that in 1979. The other female (.481) was not located until mid-July 1980, when three radio locations were made in a small channel off the Fox River below Lake Butte des Morts. Apparently she did not reoccupy her previous summer home range.

September, 1979

Three female carp were captured and released east of the Highway 41 bridge, Lake Butte des Morts, 19 September 1979. There was no initial mortality on these fish and transmitters yielded tracking days of 297 (.441), 335 (.376), and 374 (.472). Movements of these fish over the ensuing 10-13 months were exceptionally erratic (Fig. 12).

Carp .376 was located west of the Highway 41 bridge following release. Although not located during winter tracking, carp .376 was found again in Lake Butte des Morts in mid-June 1980 east of the bridge, where it spent the remaining summer. This apparent lack of year-to-year summer home range was also seen in carp .441 and .472.

Carp .441 moved into east Lake Butte des Morts for one month before the last 1979 contact was made in the Fox River between Lake Butte des Morts and Lake Winnebago. This fish was not found during the winter, but was relocated 14 May 1980 in southern Lake Winnebago. It is probable that this carp overwintered in Lake Winnebago where lake size and depth made radio location difficult.

The most interesting home ranges observed during this study were exhibited by carp .472. Home ranges during the summers of 1979 and 1980 were on both sides of the Highway 41 bridge in eastern Lake Butte des Morts, but they did not overlap. The smaller 1979 summer home range size and lack of overlap may have been due to the shorter time in late summer tracking. This was the only fish in the study to overwinter solely on the east side of the Highway 41 bridge. Although not recorded on Table 1, carp .472 was located 6 times by aircraft from 15 January to 23 February 1981 within the same winter range as that found in 1980.

October, 1979

Two female carp were captured and released in Miller's Bay, Lake Winnebago, one mile north of the Fox River inlet on 4 October 1979. The transmitter became inoperative on one carp immediately after release. The remaining carp (.386) was tracked for 267 days (Fig. 13).

The fish moved south along the west shore of Lake Winnebago, then northwest up the Fox River, and 11 days after release was found in Lake Butte des Morts where it remained throughout the fall. This fish overwintered on both sides of the Highway 41 bridge within a home range typically smaller than that occupied in the summer. On the last day of ice cover, 28

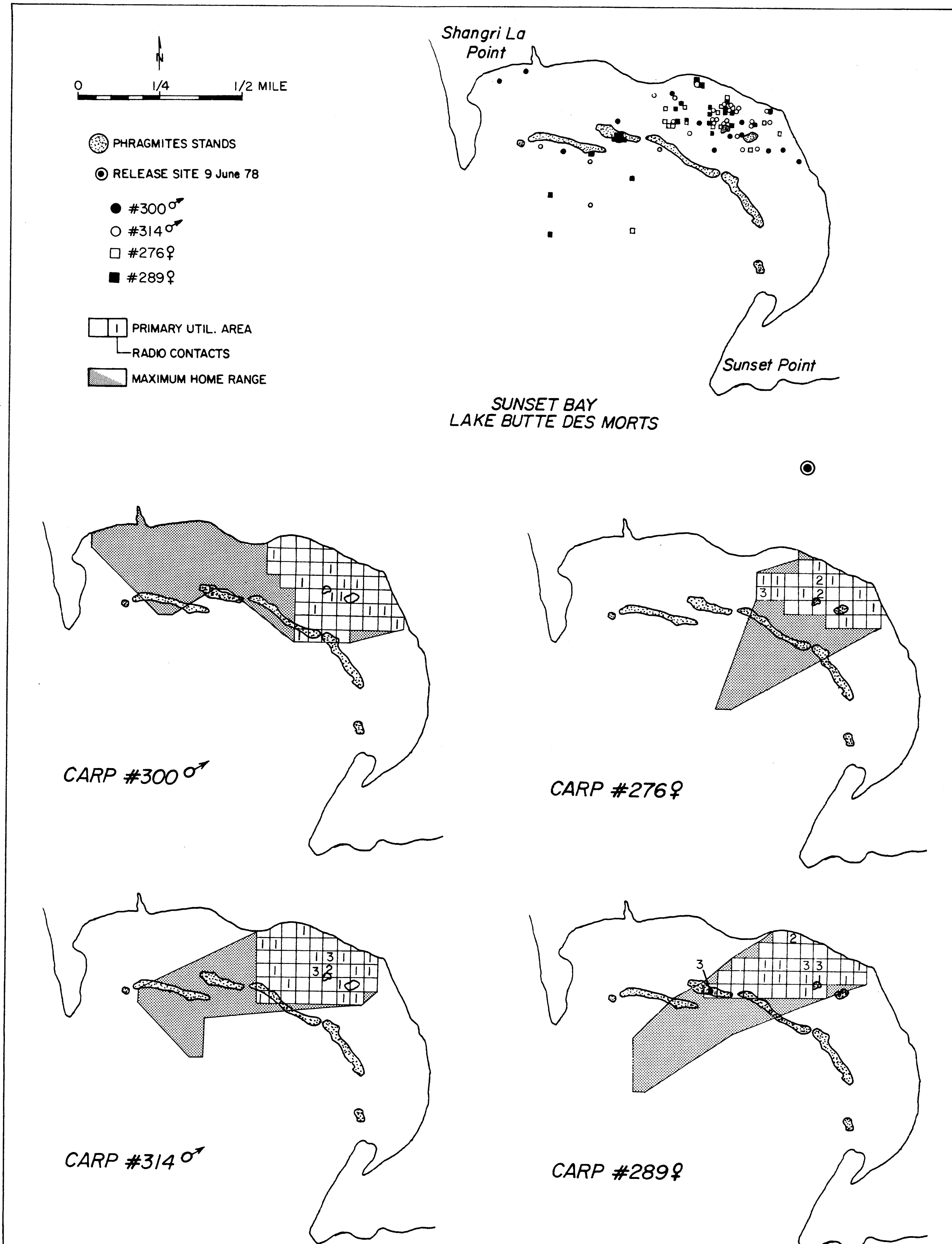

FIGURE 7. *Distribution of individual radio locations for carp released 9 June 1978 in Lake Butte des Morts (above); summer home range and primary use area for individual carp (below).*

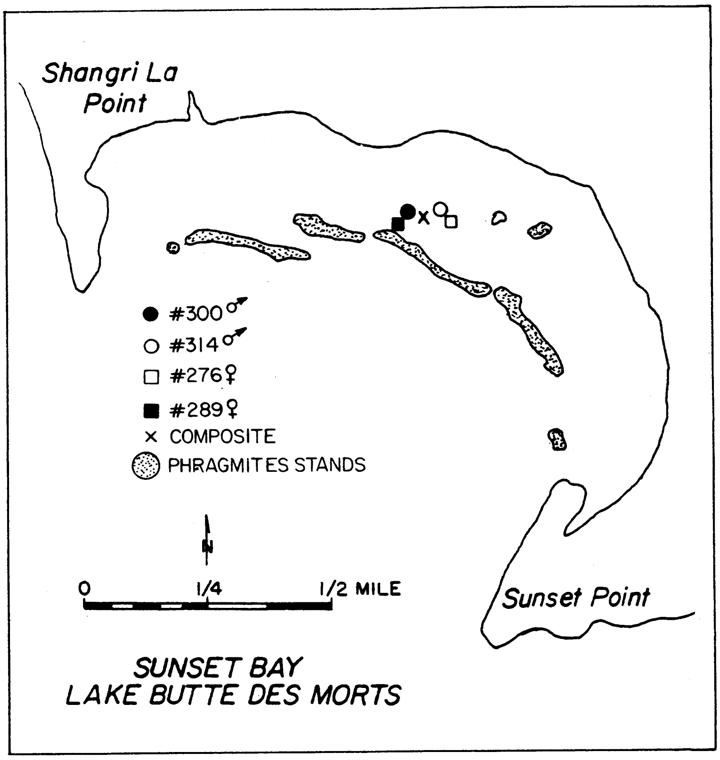

FIGURE 8. *Home range activity centroids for individual carp and for sexes combined, released 9 June 1978 in Lake Butte des Morts.*

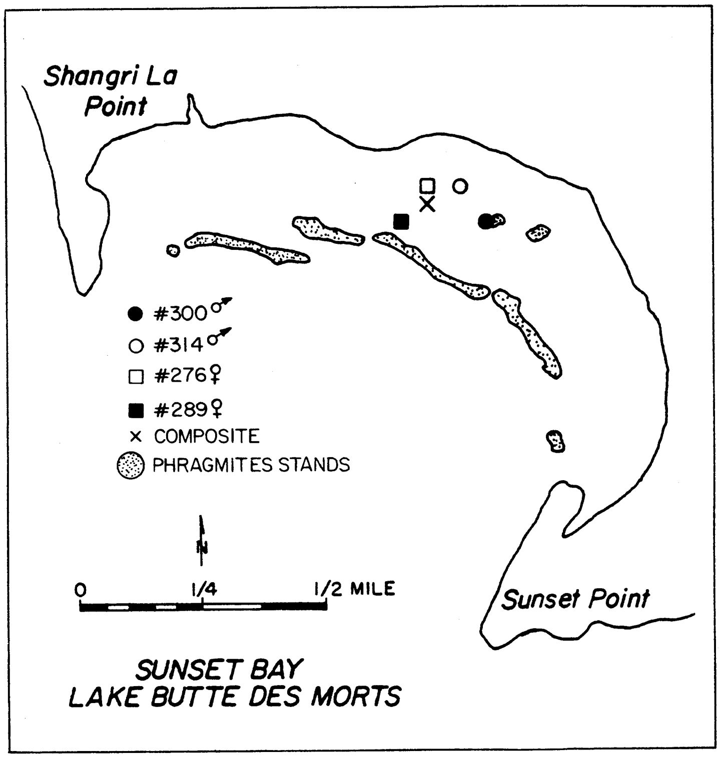

FIGURE 9. *Primary utilization area activity centroids for individual carp and for sexes combined, released 9 June 1978 in Lake Butte des Morts.*

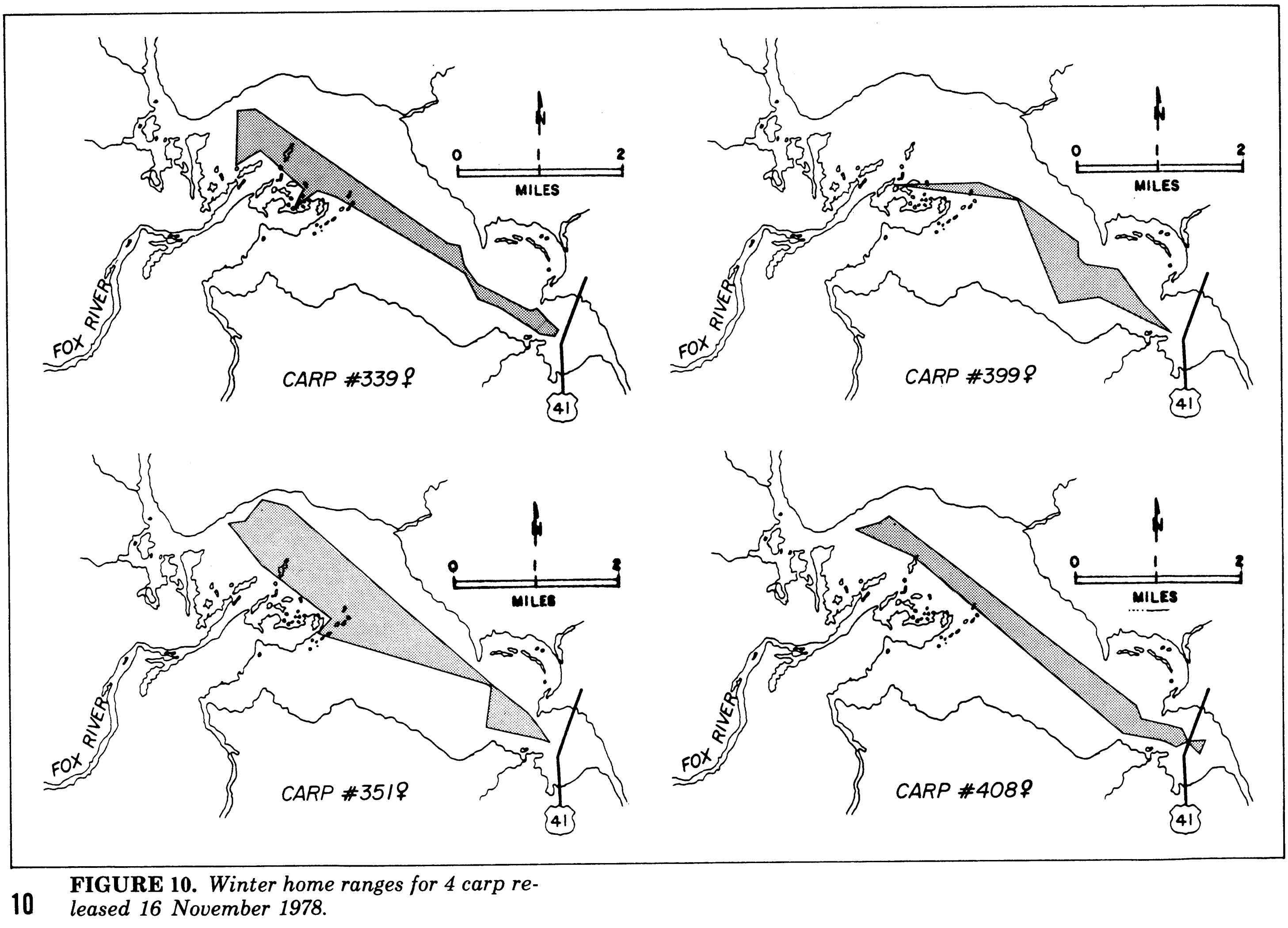

FIGURE 10. *Winter home ranges for 4 carp released 16 November 1978.*

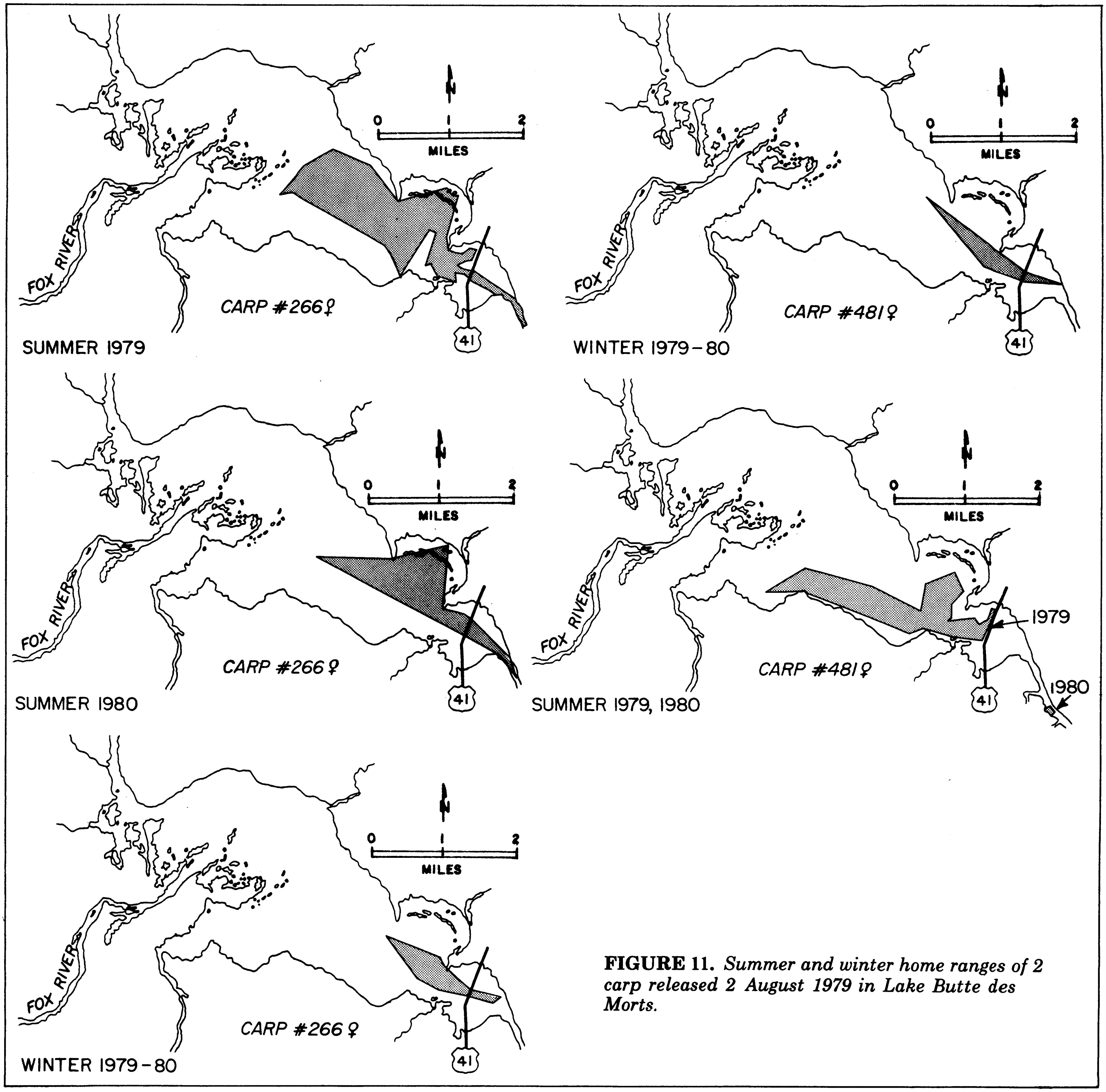

FIGURE 11. *Summer and winter home ranges of 2 carp released 2 August 1979 in Lake Butte des Morts.*

March 1980, it was still in Lake Butte des Morts. On 14 May 1980 this carp had moved to southern Lake Winnebago, a distance of 18 miles.

MOVEMENTS OF ANCHOR-TAGGED CARP

From 1977 to 1979 a total of 24 (3.9%) of the 582 carp tagged with Floy anchor tags was recaptured by commercial fishermen, Wisconsin Department of Natural Resources personnel, and sport fishermen (Table 4).

Priegel and Morrissette (1971) tagged 1,510 carp in Lakes Winnebago and Butte des Morts and recaptured 35 (2.3%) from 1967 to 1969. Although they recorded upriver movements from both lakes, no carp were found moving downriver from Lake Butte des Morts into Lake Winnebago. The present tagging study supports Priegel and Morrissette's (1971) earlier findings; however, one carp did move downriver through and out of Lake Winnebago.

Of the 12 recaptured carp released in Asylum Bay, Lake Winnebago, 10 were recaptured very near their release site ($\bar{x}$ = 0.55 mile). Longer movements were recorded for 2 fish: one traveled 14 miles upstream into Lake Butte des Morts and another was shot by a bow fisherman in Lemmels Creek, a small tributary stream at the north end of Lake Winnebago, 13.5 miles from the release site.

Of the 12 recaptured carp released in Lake Butte des Morts, 8 were recaptured within the lake, averaging 3.8 miles traveled. Four fish were found out of the lake. Two of these were in the Fox River upstream from Lake Butte des Morts, one of which was below the first upriver dam, 19.5 miles from the release site; a third was found

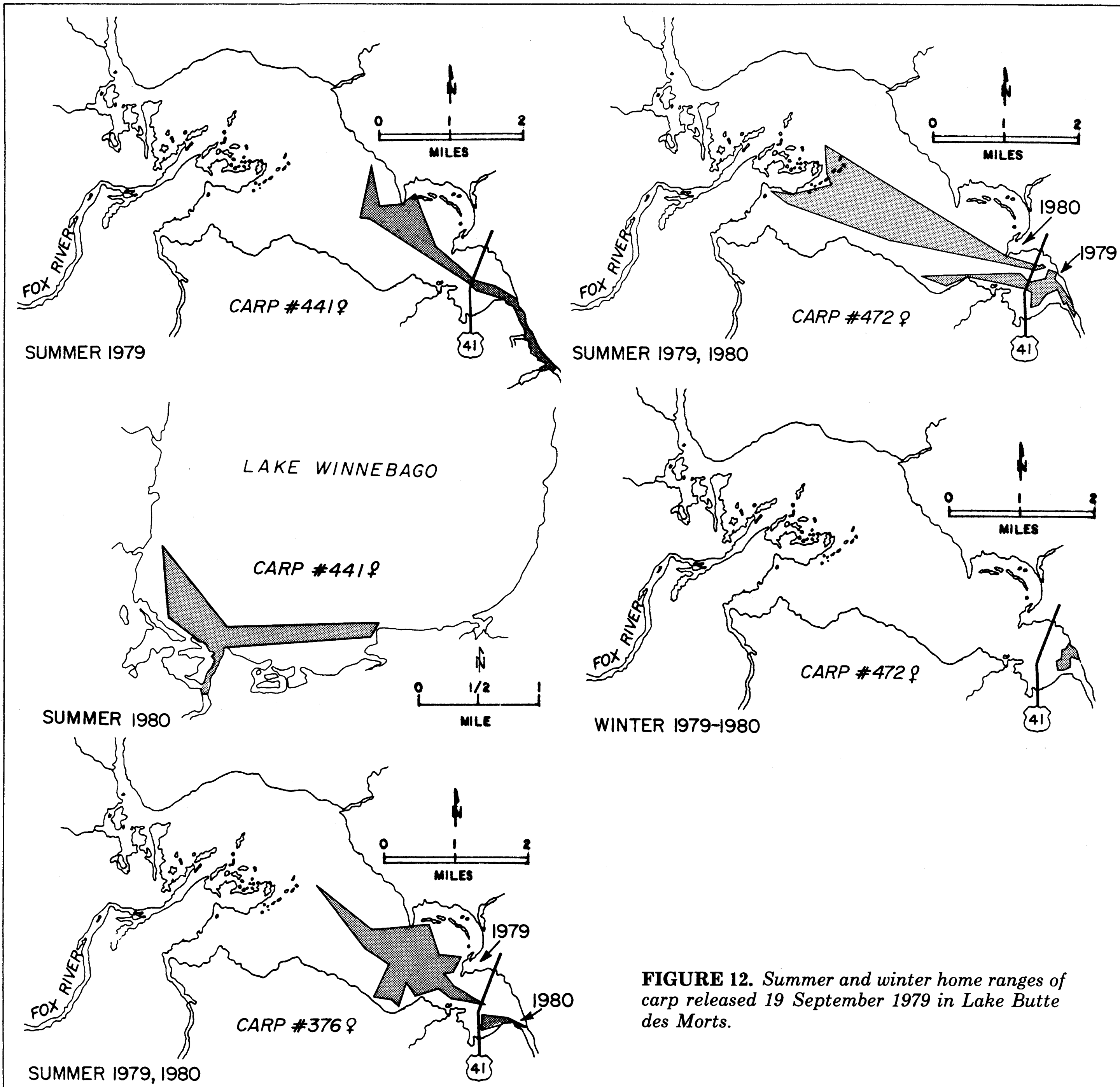

FIGURE 12. *Summer and winter home ranges of carp released 19 September 1979 in Lake Butte des Morts.*

in the Fox River between Lakes Butte des Morts and Winnebago; and the fourth fish, which traveled the farthest distance (21.0 miles), left Lake Butte des Morts, went downstream through Lake Winnebago and over the dam, and was recaptured in the Fox River-Menasha spillway.

Priegel and Morrissette (1971) found a Lake Winnebago-tagged carp traveled 92 miles upriver. Sigler (1958) reported a tagged carp in South Dakota moving 674 miles.

SUMMARY OF CARP MOVEMENT

The movement of carp is influenced by many interrelated factors. In this study it was apparent that spawning, habitat, and seasonal factors played the major roles in carp movement. Tester and Siniff (1973) cited habitat, season, and social interactions as influencing home range movements, and Sigler (1958) found carp movement governed by water temperature, natural wariness, spawning, and migrating tendencies.

Carp in Lake Butte des Morts tended to concentrate in shallow water at spring spawning, scatter and feed in the shallows during summer months, and go into the deepest area of Lake Butte des Morts and the Fox River channel over winter. This pattern compares favorably with numerous other studies on carp movement (Miller 1952, Sigler 1958, Dalquest and Peters 1966, McCrimmon 1968, Jester et al. 1969, Strand and Scidmore 1969, Clifford 1973, Schneberger 1973, Jester 1974, Wichers 1976).

Overwintering in deeper water has been ascribed to colder water tempera-

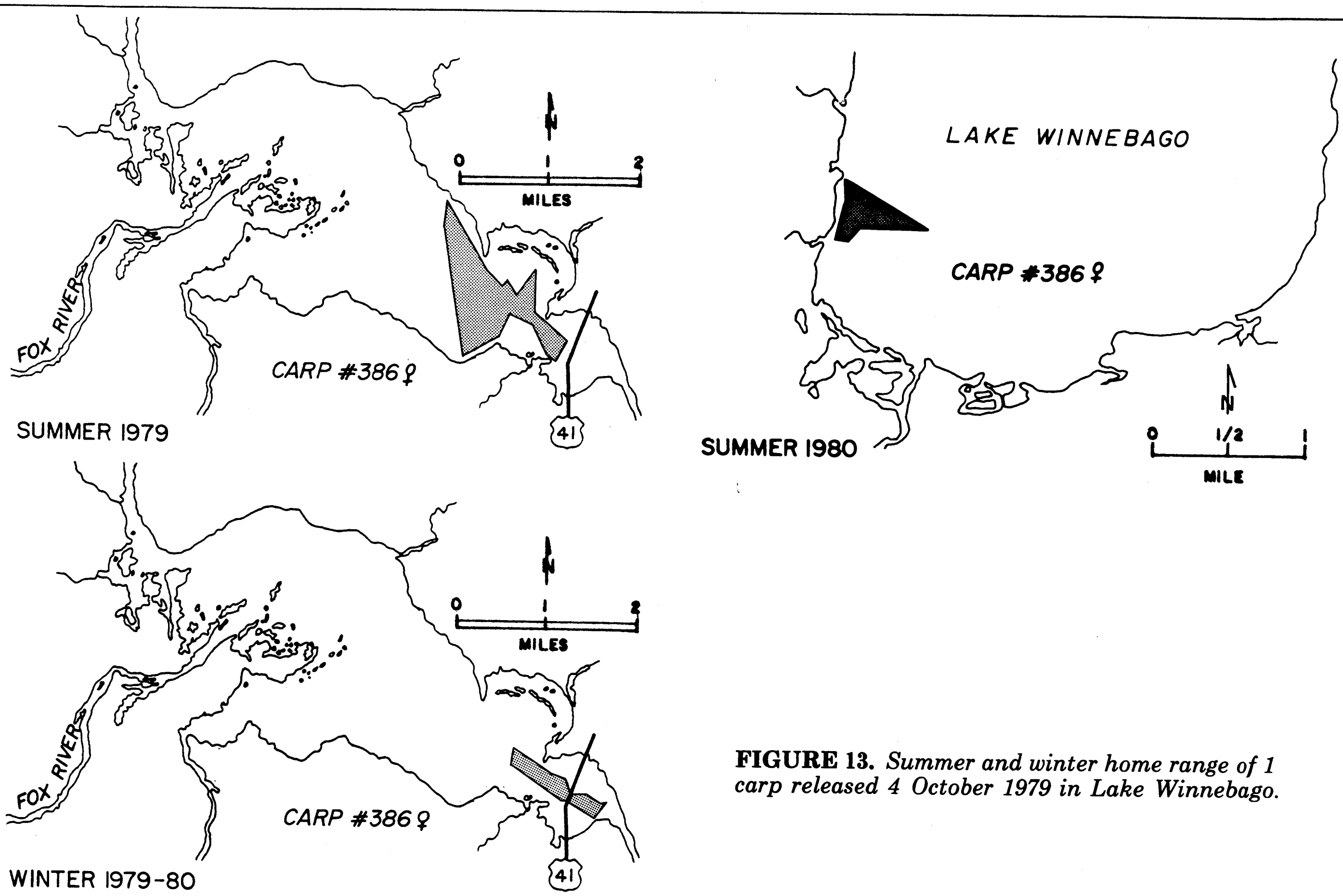

FIGURE 13. *Summer and winter home range of 1 carp released 4 October 1979 in Lake Winnebago.*

TABLE 4. *Recapture data for 24 of 582 anchor-tagged carp, 1977-80.*

Release Area	Recapture Area	Release Date	Recapture Date	No. of Days	Miles* Traveled
Lake Winnebago	Lake Winnebago	24 Jun 77	1 Jun 79	707	0.5
Lake Winnebago	Lake Winnebago	24 Jun 77	13 Sep 77	81	0.0
Lake Winnebago	Lake Winnebago	27 Jun 77	2 Oct 78	462	2.0
Lake Winnebago	Lake Winnebago	27 Jun 77	9 Jun 79	712	2.0
Lake Winnebago	Lake Winnebago	27 Jun 77	1 Jun 79	704	0.5
Lake Winnebago	Lake Winnebago	4 Mar 77	20 Apr 77	47	0.0
Lake Winnebago	Lake Winnebago	4 Mar 77	20 Apr 77	47	0.0
Lake Winnebago	Lake Winnebago	4 Mar 77	7 Jun 78	460	0.5
Lake Winnebago	Lake Winnebago	4 Mar 77	15 Jun 79	833	14.0
Lake Winnebago	Lake Winnebago	4 Mar 77	20 Apr 77	47	0.0
Lake Winnebago	Lake Winnebago	4 Mar 77	20 Apr 77	47	0.0
Lake Winnebago	Lemmels Creek	3 Oct 79	5 May 80	215	13.5
L. Butte des Morts	L. Butte des Morts	7 Jun 78	24 Jul 80	778	1.0
L. Butte des Morts	Upper Fox River	7 Jun 78	10 Jun 78	3	1.0
L. Butte des Morts	Upper Fox River	7 Jun 78	25 Jun 78	18	7.5
L. Butte des Morts	L. Butte des Morts	7 Jun 78	24 Apr 79	319	5.5
L. Butte des Morts	L. Butte des Morts	7 Jun 78	18 Nov 78	164	6.5
L. Butte des Morts	L. Butte des Morts	8 Jun 78	2 Nov 78	147	2.0
L. Butte des Morts	Lower Fox River	20 Sep 79	29 Sep 80	374	21.0
L. Butte des Morts	Upper Fox River	20 Sep 79	1 Dec 79	72	19.5
L. Butte des Morts	L. Butte des Morts	20 Sep 79	4 Sep 80	350	1.0
L. Butte des Morts	L. Butte des Morts	26 Sep 79	20 Oct 79	24	1.0
L. Butte des Morts	L. Butte des Morts	26 Sep 79	12 Nov 79	47	6.5
L. Butte des Morts	L. Butte des Morts	26 Sep 79	16 Dec 80	416	6.5
				$\bar{x}$ = 294	$\bar{x}$ = 4.7

*Miles traveled (distance between release and recapture site) approximated to nearest 0.5 water mile.

TABLE 5. *Harvest statistics for carp removed from Lake Winnebago and connecting waters by state and commercial fishermen, 1947-80.**

	Waters Fished			
	Winnebago	Butte des Morts**	Poygan[1]	Winneconne
Fishing seasons	1947-80	1947-55 1957-80	1947-74 1976-80	1947-48 1957-71 1973-75 1977-80
Total years fished	34	33	33	24
Total harvest (lb)	2,789,603	7,750,354	3,487,241	495,501
Range	30 - 285,663	200 - 513,150	10 - 241,429	500 - 66,400
Avg./year	82,047	234,859	105,674	20,646
Pounds/acre	20.3	839.3	247.3	109.9
Pounds/acre/year	0.6	25.4	7.5	4.6

*These data are almost exclusively from an open water fishery, mainly seining with a few trap net lifts and otter trawling.
**Includes catches made in the upper Fox River from the Lake to Eureka Dam.
[1]Includes periodic catches made in the Wolf River upstream from Lake Poygan to the New London Area.

tures in fall moving carp into deeper areas where water temperatures were warmer (Sigler 1958, Wichers 1976). January and February were found to be the time of least carp movement throughout the study. Winter home ranges were about one-third the size of summer home ranges. Although carp remain active throughout the winter (Strand and Scidmore 1969), their activity in colder water is much reduced and is less influenced by the behavior of other carp (Hunter and Wisby 1964). This subdued activity and tendency to aggregate is affected as in other animals (Rongstad and Tester 1969), by a reduction in feeding (Moen 1953).

Summer movement increased, as was shown by the 3:1 increase in summer over winter home ranges. Neess et al. (1955, 1957) observed marked carp to move freely about 320-acre Lake Wingra, Wisconsin. He noted that, given at least three days, the marked fish will mix randomly with the unmarked part of the population. Gerking (1953) noted the importance of straying fish in the distribution of a population. The ability of carp to move randomly and frequently and often great distances, especially during warmer months, is an effective trait which allows them to relocate and repopulate.

Data collected on the 4 fish released in Sunset Bay, however, suggest that although carp move over a large area in summer, they concentrate in a much smaller portion of their home range most of the time (primary utilization area).

The observed homing tendency in 3 of the 4 carp radio tagged in June 1978 was felt to be directly related to spawning. Following release of these fish, large concentrations of carp were observed in Sunset Bay, a major carp-spawning area in Lake Butte des Morts. The experimental displacement of 4 of these carp captured in Sunset Bay and intentionally released 2 miles to the southeast showed that carp will return to a spawning ground. A similar observation was also made, during spring and summer, by Clifford (1973) in Ocean Lake, Wyoming. He found over 85% of tagged carp were recaptured one year later in the same areas in which they were marked.

Observations on several fish from 1979 to 1980 showed that with one exception, carp shifted their home ranges from one summer to the next.

MISCELLANEOUS OBSERVATIONS ON BEHAVIOR

Except during spawning time, carp were highly sensitive to disturbances on the water or ice, and were wary when recapture was attempted. John Keppler (Wis. DNR pers. comm.) noticed that carp in winter moved inshore in shallow Lake Puckaway (max. depth 5.2 ft - mean depth 3.0 ft) due to snowmobile activity in the center of the lake. Other authors have also found carp to be sensitive to vehicle movement and disturbances on the ice (Strand and Scidmore 1969, Johnsen and Hasler 1977).

During spawning in May and June, an attempt was made to spook carp with the tracking boat, but they either stayed in or moved into dense vegetation and would not move out.

The tracking and shocker boats were used together in mid- to late summer to recapture radio-tagged carp for examination of the incision. Recapture was not possible because the radio-tagged carp were never stationary and appeared to avoid the shocker boat. The carp apparently became conditioned from the previous capture and were more wary. Hunter and Wisby (1964) found that carp used in net avoidance studies showed the greatest learned behavior ability compared to 9 other species of freshwater fish. They further observed that at colder water temperatures carp are less active, and perhaps not as strongly influenced by social behavior. This could help to explain why carp were less influenced by boat activity in spring than in warmer summer water temperatures.

MANAGEMENT IMPLICATIONS

Carp have been harvested from Lakes Winnebago, Butte des Morts, Poygan and Winneconne by state and commercial crews since 1947 (Table 5). An original objective of this study was to locate large seasonal concentrations of carp to facilitate their removal. However, no major carp spawning locations were found that were not already well known, and winter concentration areas in Lake Butte des Morts are presently inaccessible due to thin channel ice. The technique of radio tracking carp tested in this study offers promise for increasing the effectiveness of carp control activities in other waters.

APPENDIX:

Signal Attenuation

Simulated transmitter range testing was done by boat in August and September 1977, and by ground and aircraft during March 1978 ice cover (Weber 1978). During August boat tests on Lake Winnebago, activated transmitters were sealed in plastic bags, placed inside 250-ml Nalgene bottles, and set at depths of 2 and 5 ft below the water surface. Average effective ranges were 0.25 and 0.19 mile at 2 and 5 ft, respectively. During September boat tests on Lake Butte des Morts, activated transmitters were sealed in plastic bags, implanted in the body cavities of 2 dead carp, and again set at depths of 2 and 5 ft below the water surface. Average effective ranges were 0.12 and 0.15 mile at 2 and 5 ft, respectively.

There was a 52% decrease in range at the 2-ft transmitter depth between August and September trials, but little difference in average ranges at the 5-ft depth between test periods. Reduced ranges between 2 and 5 ft would be expected since signal strength and range are inversely related to depth of the transmitter (Stasko and Pincock 1977). The reduction in range at 2 ft between August and September was not considered to be caused by use of dead carp instead of plastic bottles, but rather by signal interference. Ziebel (1973) found no ultrasonic signal attenuation from fish flesh, and Winter (1976) found less than 10% radio signal attenuation from fish flesh. There was signal interference and saturation in the receiver from the following possible sources in the September test area vicinity: commercial aircraft, outboard motors, auxiliary electrical equipment on boats, automotive vehicles, and diesel railroad engines. The interference was probably caused by electrical arcing from spark plugs in the sources mentioned (Winter et al. 1978).

Aircraft telemetry testing was done during maximum ice cover (30 inches) on Lake Winnebago in March 1978 (Weber 1978). Activated transmitters were placed in 250-ml Nalgene bottles and set at depths of 3 and 6 ft below the bottom of the ice. Aircraft tests were designed to check the antennae performance for range, to develop flight patterns and procedures for determining transmitter locations, and to establish a procedure for communication between pilot and tracker. Flight test altitudes of 2,500, 1,500, and 500 ft found respective average ranges of 1.7, 1.1, and 0.5 miles at an airspeed of 85 mph. While greater ranges were obtained at higher altitudes, signal strength was weaker (Weeks et al. 1978). At lower altitudes, signal strength was strongest, providing more accuracy for locating transmitters. Accuracy was within a 264-yd (0.15-mile) radius during air tests. The maximum range for hand-held, bi-directional loop antennae on the surface of the ice was 0.17 and 0.16 mile for transmitters 3 and 6 ft below the bottom of the ice, respectively. Since the 50 MH_Z band is used by ham radio operators, there was some interference in air tracking. Other sources of interference, especially engine noise, were similar to those experienced during boat tracking.

There are many reasons for gear signal attenuation in radio telemetry studies. Other authors have described signal attenuation regarding water conductivity, water depth, and distance (Winter et al. 1978, Winter 1976, Stasko and Pincock 1977) and the thermal and refractive properties of water (Coutant 1976). These conditions are difficult, if not impossible, to surmount, but there are some methods we adopted which increased our success. To reduce error while tracking, both operators wore headphones. Receiver batteries were changed regularly and recharged after 6-8 hours of full use. The maximum signal occurred when the bi-directional loop and yagi antennae were in a plane alignment. Best directional signals, for pinpointing a fish's location, were taken at peak signal with the yagi antenna, and from the null (minimum) signal with the loop antennae (Winter et al. 1978). Transmitter frequency sometimes drifted (ex. 5.470 moves to 50.472) so precision tuning on the receivers was often varied. There appeared to be an upward signal drift trend during winter months when waters were colder, or upon fish release when a water temperature change also occurred. Different operators experienced different hearing ranges and tonal variations. This could account for some of the variance noted in transmitter frequency drift.

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