HOMING BEHAVIOR OF FLATHEAD CATFISH, *PYLODICTIS OLIVARIS* (RAFINESQUE), TAGGED WITH ULTRASONIC TRANSMITTERS

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ABSTRACT

Homing behavior of flathead catfish in an Oklahoma reservoir was observed by tracking fish bearing a 74 kHz transmitter which had been implanted in the peritoneal cavity. Homing is described from 1,190 fixes (site locations) obtained on 22 flathead catfish. The average tracking interval was 18.7 days. Homing occurred in 8 of 12 (67%) fish displaced a distance of 1.3-2.7 km from the site of capture. Average accuracy of homing fish was within 182 m of the original site of capture. One transmitter tagged fish, displaced 1.82 km, returned to the site of capture within 1.7 days. All 12 displaced fish, regardless of whether or not they homed, moved away from their release site before establishing a home range. Most (70%) of the 10 non-displaced fish remained in a well-defined area near the site of release (i.e., the original site of capture) which also provided evidence that the fish recognized a home area. Only 4 of 18 displaced catfish marked with butt-end and anchor tags (i.e., without transmitters) were recaptured, none exhibited homing.

INTRODUCTION

Observations on behavior of displaced fish show that many fish recognize a home area and have the sensory abilities to traverse great distances of presumably unknown area to return to their home (Hasler 1966). Mark-and-recapture procedures generally provide insufficient observations to adequately describe the movements of a free-ranging fish without prodigious effort to obtain recaptures. Where frequent recaptures are possible, as in small streams, behavior of a fish may be altered due to trauma associated with methods of capture. Development of transmitters applicable to placement in or on fish provide an opportunity for continuous surveillance without the disturbance of recapture. We believe telemetry can make a significant contribution to accurate study of homing, home range, activity levels, habitat preference, and correlations between movements and environmental variables.

Movements of flathead catfish in Missouri streams have been observed by mark-and-recapture techniques but homing behavior was not investigated (Funk 1955). Efforts to follow movements of flathead catfish carrying ultrasonic tags in the Missouri River, bordering Nebraska-Iowa, were unsuccessful (Morris 1968). Thus, mark-and-recapture techniques and ultrasonic tracking procedures heretofore applied to studies on flathead catfish in streams have not ascertained the existence of homing ability. In our investigation in Lake Carl Blackwell, Oklahoma, telemetric techniques were used to determine if displaced flathead catfish were capable of returning to their previous home area. Behavior of non-displaced fish were also observed for comparison. Homing is described from 1,190 telemetric observations of site locations of 22 flathead catfish, and observations on 4 of 18 displaced flathead catfish recaptured after tagging with butt-end and anchor tags.

DESCRIPTION OF STUDY AREA

Lake Carl Blackwell (Figure 1), located 12.8 km west of Stillwater, Oklahoma, is an impoundment of Stillwater Creek. The reservoir lies in Payne County, north-central Oklahoma in the Permian red-beds physiographic region. At the time of the study the main east-west axis was 5.3 km long, with several arms extending north and south, and the lake surface was 3.4 m below spillway elevation (284 m above mean sea level). At this lake elevation, the surface area was approximately 850 ha, volume 33.9 million cubic meters, and the average depth 4.0 m.

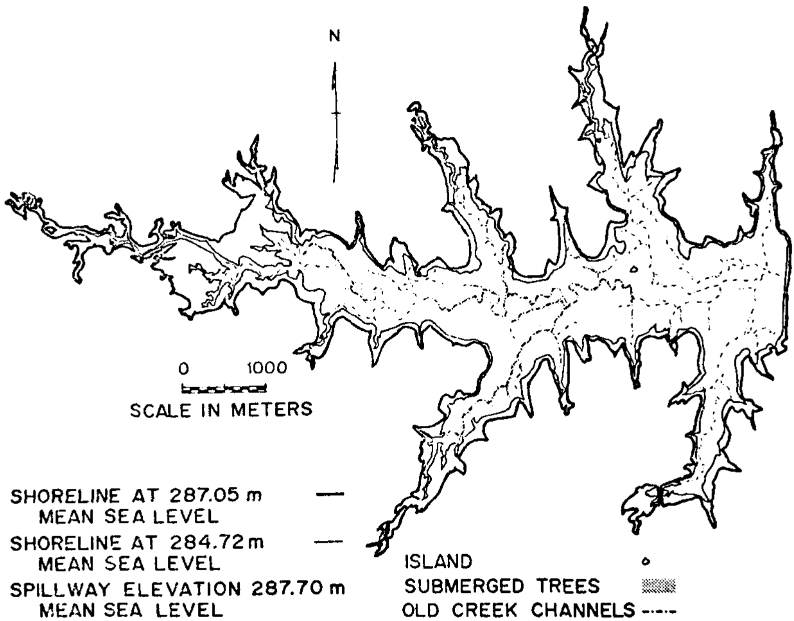

Figure 1. Lake Carl Blackwell showing submerged trees and old creek channels.

METHODS AND MATERIALS

Equipment

Ultrasonic transmitters and receiving equipment were purchased from a commercial source.[1] The 74 kHz/second ultrasonic transmitters were cylindrical in shape, 90 mm long by 19 mm in diameter and, after paraffin coating and with battery, weighed 29.5 g in water and had a spcific gravity of 1.09. The transmitter weight comprised 0.6% of the average weight (5.13 kg) of all 22

[1]Smith-Root Electronics, Seattle, Washington.

flathead catfish. The receiver measured 178 mm long by 165 mm wide by 102 mm high and weighed 1.5 kg (not 6.6 kg as was erroneously reported by Summerfelt and Hart 1972). The hydrophone weighed 2 kg and consisted of a hydrophone cone (maximum diameter 145 mm) positioned on the end of a 156 cm submersible shaft. The performance of this equipment in Lake Carl Blackwell has been described by Summerfelt and Hart (1972).

Capture, Selection, and Tagging of Fish

Flathead catfish were captured from Lake Carl Blackwell in hobbled gill nets. Each fish was tagged for individual recognition at the time of capture with an anchor and a butt-end tag (Summerfelt et al 1972). The anchor tag was placed through an operculum and the butt-end tag was clamped around the base of a pectoral spine. Fish used for mark-and-recapture observations of homing were displaced to another part of the reservoir for immediate release. Fish used for transmitter tracking were selected from fish which lacked gill net lesions or other visible injury. These fish were sexually mature and averaged 720 mm total length and 5.13 kg total weight. Telemetry fish were transported to our laboratory at Oklahoma State University where they were placed in 610 liter tanks with a continuous flow (about 1 liter/minute) of dechlorinated tap water from Lake Carl Blackwell. Transmitters were surgically implanted in the laboratory.

Surgical implantation of transmitters into the peritoneal cavity proved to be a desirable technique for tagging flathead catfish with transmitters (Hart and Summerfelt 1974). Implantation of transmitters by our surgical procedure required removing the fish from the lake, holding it in tanks, and anesthetizing it twice. Elapsed time between capture and release was as much as 10 days, averaging 4.4 days for the first 10 fish and 2 days for the last 12 fish.

Releasing and Tracking Methods

Fish were transported from the laboratory to the lake in a semi-anesthetized condition (12 ppm quinaldine), release at a predetermined location and tracked continuously for at least one hour. Fish were released along the shoreline, or when released offshore they were held in a submersed plastic basket until completely recovered from the anesthetic. Ten fish (designated non-displaced fish) were released near the closest shore to the site of capture. The distance from site of capture to release point averaged 289 meters. The reason fish were not released at the site of capture was to facilitate visual observation of the released fish in shallow water during the initial recovery period. Twelve fish (designated displaced fish) were moved a straight-line water distance of 1.3 to 2.7 km (mean 1.9 km) from the site of capture to ascertain homing ability. The first 8 of the displaced fish were tracked continuously for 48 hours, then their location was checked once every 6 hours. Due to the high cost of continuous surveillance the last 14 fish were checked once every 6 hours after tracking continuously for the first hour.

To track a fish, the last location (fix) noted from the previous check was used as a point to begin searching and a search was made in the apparent direction of travel, as suggested from previous map locations. In cases where a fish was not located at the site of a previous fix, a systematic check was made of other habitats where flathead catfish were frequently found. If both procedures failed to locate the fish, then a systematic transect survey was made for one or two hours daily for a week or more, depending on the probability of the transmitter still functioning.

The transmitter signal was sought by lowering the hydrophone cone about 60 cm beneath the water surface and rotating it 360° while listening for the signal with the aid of earphones. After obtaining a signal, the boat was driven closer to the assumed location, then the hydrophone lowered and the signal sought again.

The procedure was repeated until a maximum signal was obtained directly below the boat. In some cases, it was not necessary to obtain direct positioning over the fish to obtain a location because after obtaining alignment from several positions around the fish, the location became obvious. In rare instances, fish appeared to move away from the boat if appoached too closely, thereafter, location of that fish was approximated within the center of a 25 m^2 block, rather than positioning directly over the fish, After the fish was located, the map location was obtained in one of the following ways: 1) locating the fish directly on the map in reference to transect lines, using a dot to represent the site; 2) estimating distance and direction from a permanent reference site; 3) by triangulation from permanent reference sites and transect lines.

The number of fixes obtained for a single fish depended on how long the fish had been at large. During continuous tracking, the search and location procedure gave as many fixes as needed to record the movement of the fish. When monitoring was reduced to four daily checks for site location, a search was maintained until a fix was obtained, then the observer searched for the next fish; however, when a fish was moving, the observer stayed with the fish for up to an hour, giving additional fixes.

Using four quarterly observations, 1,565 fixes would have been the maximum number obtained on the 22 fish considering the average longevity of the transmitters. Not all scheduled checks were made because fish were occasionally lost and inclement weather or equipment malfunction eliminated 25% of the scheduled checks. The quarterly tracking procedure did yield 1,190 fixes for 22 fish, 75% of the possible maximum number.

Average tracking time for a fish was 18.66 days, 7.55 days less than the expected transmitting life determined in a performance evaluation of the transmitters (Summerflet and Hart 1972). The discrepancy between the length of time the fish were followed and the expected transmitting life indicated most fish were lost before the transmitter ceased to function. Losing a fish with a functional transmitter probably occurred when a fish got beneath stumps or longs, or within a deep, narrow submerged creek channel where lateral signal transmission would be attenuated or completely blocked.

Precision of Techniques

The precision of map locations recorded while tracking fish was influenced by discrepancy between true and apparent location of the fish, and precision of the observer in reconnoitering and transposing a fix to a map point. Based on observations of the azimuth deviation in ponds (Summerfelt and Hart 1972) and observations in ponds on movement of transmitter tagged flathead catfish which also had a bobber-tag, we assumed a linear precision on the reservoir within 5 meters, making location precision an area of 25 m^2. This is a minimal precision influenced somewhat by wave action and signal echoes. However, the dot size on the map (scale = 15.81 m/mm, or ca 250 m^2 per mm^2) was about 0.7-1.0 mm diameter, which covered 96 to 196 m^2 of lake area. The slight error in locating the fish was only 13 to 26% of the map area occupied by the dot representing a fix, therefore, this type of error appears inconsequential in comparison to the error in transposing the observed location to the map.

The error in transposing lake locations to the map may have been as much as 2 mm on the map (ca. 32 m) for a single transposition. However, in subsequent locations within 300 m of a previous map location, the error would be less than 1 mm map distance (15.81) because the new map location could be accurately placed by relating it to a previous map location.

Determination of Homing

Homing of fishes has been assessed in several ways, homing of stream fishes has often been assessed by recapturing the fish in a "home pool". Anadromous fish are usually considered to have homed if they are recaptured in a stream where they have been captured prior to seaward migration. Homing of lake and reservoir fishes have often been associated with capturing a fish on a particular spawning ground from one year to another. Determination of homing of a reservoir fish using telemetric techniques presents a unique problem since there are no *a priori* factors which determine how close the fish must come to its original capture location before declaring it as having "homed".

Gunning (1959) defined homing as returning to a home range. We adopted Gunning's definition and assessed homing on the basis of a type of circular home range described by Dice and Clark (1953) and Calhoun and Casby (1958). Recapture radii were determined by first giving each fix a Cartesian coordinate (x and y value). Then all x and all y values are averaged to yield a mean x and mean y location, the center of activity. Finally, the recapture radii are determined by measuring the distance between each fix to the center of activity. All recapture radii for a single fish are then arranged in ascending order and a radius of sufficient length is selected which will contain 95% of all radii for that fish. When this was done for all fish, the mean of this distance was the average home range radius (494 meters), and a displaced fish was considered to have homed if it returned to an area within 494 m of the original capture location.

RESULTS

Adjustment Period

Analysis of daily home range for the first 11 days after release indicated abnormally large movements during the first 1.5 days (Figure 2). Movements within 1.5 days apparently constitute an adjustment period when behavior appears atypical. Shepherd (1973) evaluated transmitter attachment and fish behavior and reported data which suggests rainbow trout released in tanks have an adjustment period of approximately 1 day. In the present study, movements in the 1.5-day adjustment preiod are not included in determinations of home range radii.

Homing

Most of 22 transmitter tagged flathead catfish accurately homed while mark-and-recapture observation of 18 displaced fish gave no indication of homing. Eight (67%) of the 12 displaced fish and 8 (80%) of the 10 non-displaced fish homed (Table 1). The average homing accuracy, the distance from the original capture location to the closest fix, was within 182 m for displaced fish and 588 m for non-displaced fish. Using conventional mark-and-recapture techniques, only 4 of 18 displaced fish were recaptured and none exhibited homing behavior. Although a major gill-netting effort was underway during the period of study to estimate flathead catfish population density by mark-and-recapture methods. only 1 of 12 displaced transmitter tagged fish was recaptured.

A good characterization of homing ability was demonstrated by a female flathead catfish (code 226) which returned to the same location where it was originally captured (Figure 3). Displaced a distance of not less than 1817 m, it homed a straight-line distance of 2316 m within 39.5 hours (58.6 m/hr), but within 47 m of the initial recapture site within only 16.7 hours (183.2 m/hr), but passed about 174 m beyond it. In its homing journey the fish selected the deeper (3 m) but longer passage around the outside of an island rather than a shorter route through shallow water (0.5 m). Observations on depth distribution indicate that flathead catfish rarelv travel into water of depths less than 3.5 m in Lake Carl Blackwell (Summerfelt et al. 1972).

Table 1. Homing behavior, displacement distance, and closest fix (the linear distance from the original capture location to the closest fix) of displaced and non-displaced Lake Car Blackwell flathead catfish.

Displaced fish							Non-displaced fish						
Code	Sex	Homing behavior	Behavior pattern	Displacement distance (m)	Closet fix (m)	Tracking time (days)	Code	Sex	Homing behavior	Behavior pattern	Closest fix (m)	Tracking time (days)
211	M	yes	3	2237	316	26.1	311	M	no	3	1249	11.1
212	M	yes	3	1960	24	16.8	312	M	yes	2	134	7.4
213	M	yes	4	1739	494	22.9	313	M	yes	1	55	15.7
221	F	no	3	1407	1091	7.7	314	M	yes	1	308	10.4
222	F	no	5	1289	648	25.8	321	F	yes	2	340	8.0
223	F	yes	4	2174	117	5.4	322	F	no	3	3241	26.9
224	F	no	3	1858	822	35.1	323	F	yes	2	63	33.5
225	F	yes	4	1700	71	23.9	324	F	yes	1	190	26.3
226*	F	yes	3	1817	0	1.9	325	F	yes	5	206	7.8
227	F	yes	4	1858	277	19.8	326	F	yes	1	95	9.5
228	F	yes	3	2672	126	6.4						
231	?	no	4	1486	783	19.3						

*Fish 226 was sacrificed after injuring itself in a gill net 1.9 days after release.

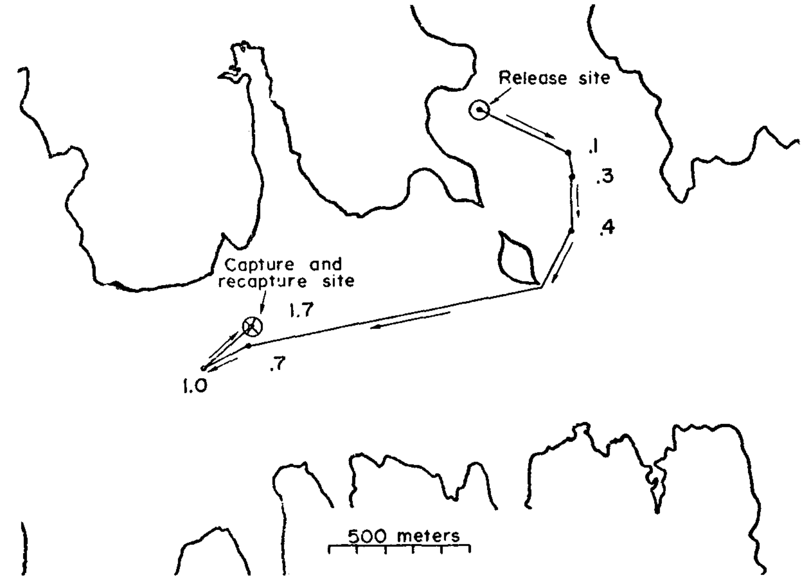

Figure 3. Homing of a displaced female flathead catfish (fish code 226). Numbers represent days after release.

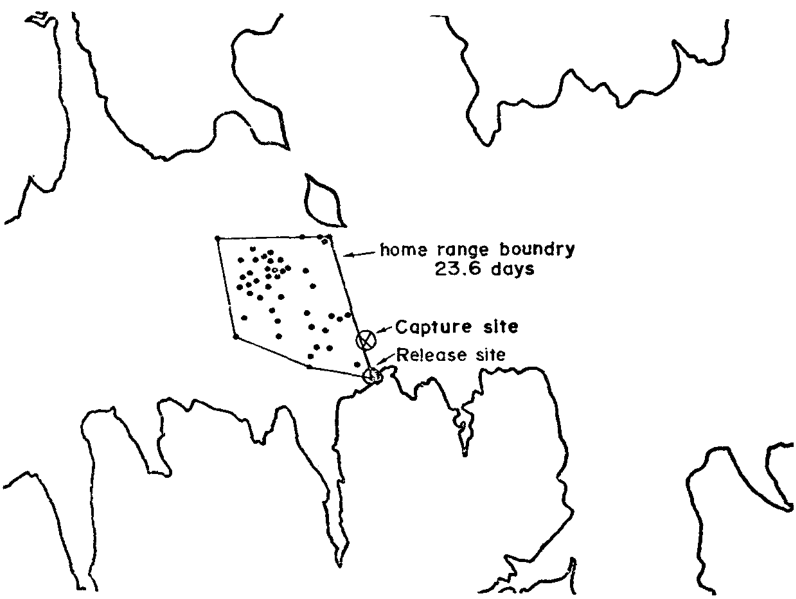

Figure 4. Behavior pattern category 1 (fish code 326). Fish established home range near site of release and stayed within the home range.

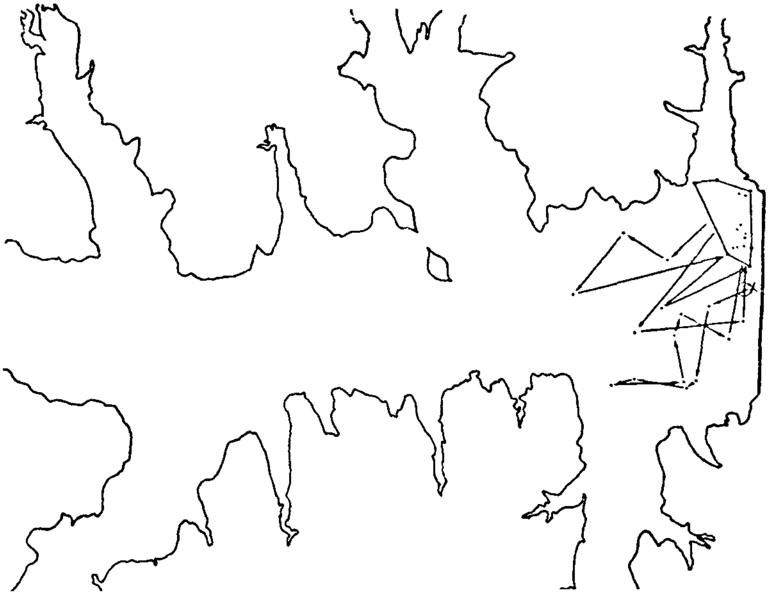

Figure 5. Behavior pattern category 2 (fish code 312). Fish established home range near site of release but made sallies. Fish spent 74% of tracking time within the home range boundry. Release site represented by "X" and original capture location represented by "⊗".

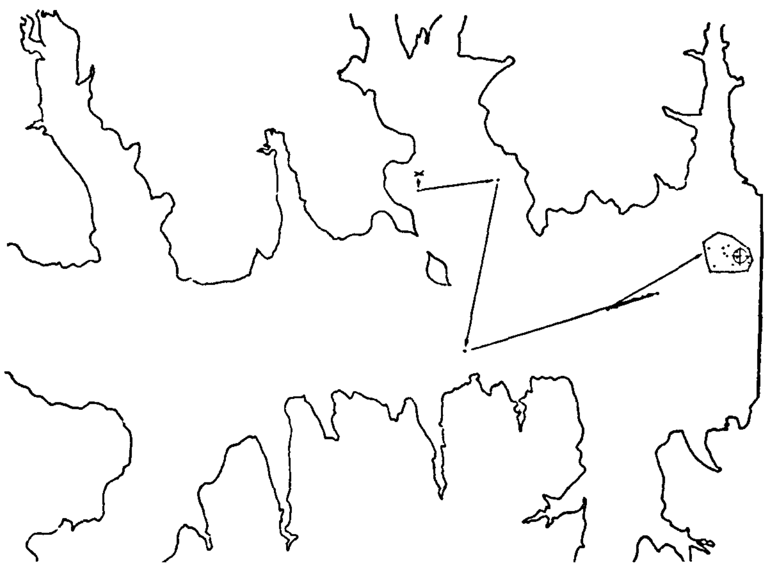

Figure 6. Behavior pattern category 3 (fish code 212) which traveled from release site and established a home range which included the original capture site. Four of eight fish which would be placed in this category homed. Release site represented by "X" and original capture location represented by "⊗".

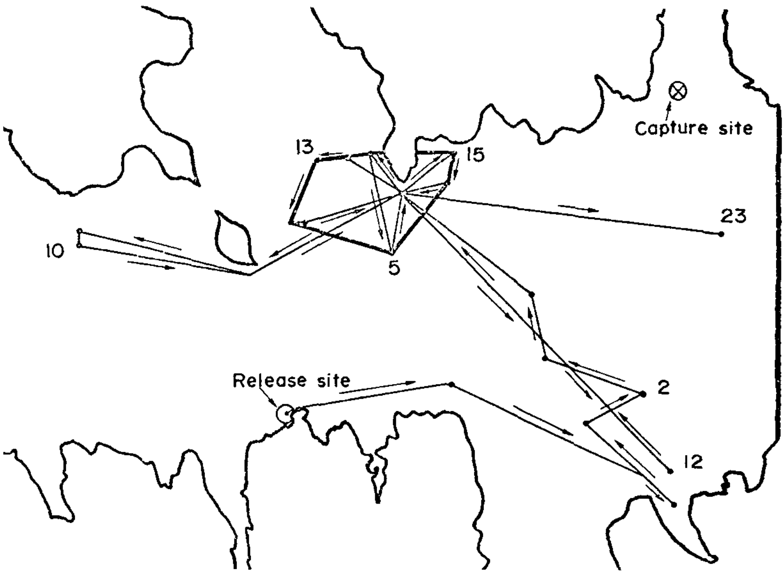

Figure 7. Behavior pattern category 4 (fish code 213). Fish left release area, established a home range, but made lengthy sallies. Numbers represent days after release.

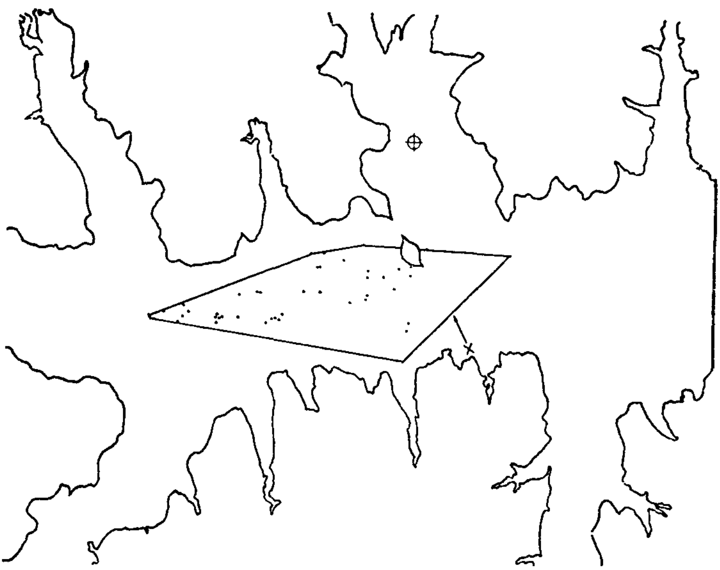

Figure 8. Behavior pattern category 5 (fish code 222). Fish established a large home range and made extensive movements within the home range. Release site represented by "X" and original capture location represented by " ".

Major Behavior Patterns

Behavior patterns of transmitter tagged fish were categorized as follows: 1) established a small home range close to the release site and stayed within the home range (Figure 4); 2) as in behavior pattern 1, but made sallies (defined by Burt 1943) outside the home range (Figure 5); 3) left the release area, traveled extensively, then established a small range and stayed within the home range (Figure 6); 4) as in behavior pattern 3, but made sallies outside the home range (Figure 7); and 5) established a large home range and made widely extended movements within it (Figure 8). All displayed fish, regardless of whether or not they homed, moved away from their release site before establishing a home range, thus exhibiting behavior patterns 3, 4 and 5 (Table 2). Most non-displaced fish (70%) which established a home range exhibited behavior patterns 1 or 2, indicating a familarity with the release site. Non-displaced fish apparently remembered evironmental stimuli of the release area as those of their previous home range and re-established a home range in the same area. The type 3 and 4 behavior of displaced fish suggests a searching behavior of fish seeking its previous home or other suitable habitat.

Table 2. Number of fish in each stratified group exhibiting one of five major behavior patterns (behavior patterns described in text) with the number of fish that homed in parenthesis.

Description of behavior pattern	Behavior category	Displaced fish	Non-displaced fish
Remained near release site			
Restricted movements	1	0	4(4)
Took sallies	2	0	3(3)
Departed from release site			
Restricted movements	3	6(4)	2(0)
Took sallies	4	5(4)	0
Random movements	5	1(0)	1(1)

Site Recognition

Another type of homing behavior, not true homing in the sense that a fish returns to its home range, is that of a fish returning to a site previously used. These trips require environmental recognition since the fish returns to exactly the same location, within our precision, after excursions (sallies) up to 1.4 km linear distance. Nineteen of 22 fish exhibited this type of homing behavior. Fish code 213, a displaced male, is a good example of this type of behavior (Figure 7). Fish 213 appeared to have established a second home range in an area not including its original capture site and took sallies outside this home range, presumably searching for its original home range.

DISCUSSION

The inability to continuously track a fish has been the greatest obstacle restricting accurate homing studies, but this problem has largely been solved with the development of ultrasonic transmitters (Trefethen 1956), albiet longer life transmitters (at least 12 months) are needed to track fish through annual activity cycles. Provided the method of transmitter attachment and tracking is suitable, ultrasonic transmitters present the opportunity for continuous surveillance from a remote location thus allowing the fish to behave normally.

Gunning (1959) defined homing as returning to a home range and for reservoir or lake fishes this is more realistic than limiting homing only to those displaced fish which returned to the original capture site. Ideally, the home range of each fish should be known before displacement, but knowledge of average home range dimensions of the species in a given environment will have to be substituted, since generally it is unfeasible to first determine a fish's home range, recapture it, then displace it to determine its homing ability. We believe it is best to define homing as return of a displaced fish to an area within a specified radius of its original capture site. We defined this radius as the average recapture radius containing 95% of all observations for all fish studied in this reservoir. In many previous studies, homing was assessed when a fish returned to a home pool, stream, or spawning ground without knowing home range dimensions of the species under investigation.

Homing ability of flathead catfish was demonstrated after being removed from the lake for at least two days. Time elapsed between capture and release ranged from 2 to 10 days with an average of 3 days for all 22 fish. During the time interval the fish were removed from the lake, they were anesthetized twice, hauled in covered containers in trucks and boats twice, and held in two different tanks. Even after these experiences most displaced fish exhibited homing after an initial adjustment or reorientation period of 1.5 days. Eight of 10 non-displaced fish demonstrated recognition of their previous home area by re-establishing a home range in the area of their release and consequently the area of their previous home range. All of 12 displaced fish left the release area before establishing a home range, again indicating memory of their previous home range and a desire to return to it.

Most displaced and non-displaced flathead catfish which established a home range returned to a given site within that home range more than once. Reuse of a specific site within the home range suggests a highly developed sense of environmental recognition and occurrence of preferred use-areas. Of the three fish that did not show this behavior, two homed; i.e., in the sense that they returned to within 494 m (the average of the 95% recapture radius) of their original capture site. Therefore, 21 of 22 fish showed some type of homing behavior.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. J. Mamm. 24: 346-352.

Calhoun, J. B. and J. U. Casby. 1958. Calculation of home range and density of small mammals. U. S. Public Health Serv., Public Health Monogr. No. 55. U. S. Govt. Printing Office, Washington, D. C. 24 pp.

Dice, L. R. and P. J. Clark. 1953. The statistical concept of home range as applied to the recapture of the deermouse (*Peromyscus*). Contribution Lab. Vertebr. Biol., Univ. Mich. No. 62. Ann Arbor, Mich. 15 pp.

Funk, J. L. 1955. Movement of stream fishes in Missouri. Trans. Amer. Fish. Soc. 85: 39-57.

Gunning, G. E. 1959. The sensory basis for homing in the longear sunfish, *Lepomis megalotis* (Rafinesque). Invest. Indiana Lakes and Streams 5(3): 103-129.

Hart, L. G. and R. C. Summerfelt. 1974. Surgical procedures for implantation of ultrasonic transmitters into flathead catfish (*Pylodictis olivaris*). In preparation.

Hasler, A. D. 1966. Underwater guideposts. The University of Wisconsin Press, Madison, Wisconsin. 155 pp.

Houser, A. 1960. The effect of homing on channel catfish population estimates in large reservoirs. Proc. Okla. Acad. Sci. 40(1959): 121-133.

Morris, L. 1968. Flathead catfish investigations in the Missouri River. Nebraska D-J Project No. F-4-R-5, Job Progress Report, Jobs II-a, b and c, pp. 7-14.

Shepherd, B. 1973. Transmitter attachment and fish behavior. Underwater Telemetry Newsletter, Tracking Aquatic Animals 3(1): 8-11.

Summerfelt, R. C. and L. Hart. 1972. Performance evaluation of a 74 kilocycle/second transmitter for behavioral studies on reservoir fishes. Proc. S. E. Assoc. Game & Fish Comm. 25(1971): 607-622.

Summerfelt, R. C., L. Hart, and P. R. Turner. 1972. Flathead catfish movements. Natl. Marine Fish. Serv. U. S. Dept. of Commerce, P. L. 88-309, Completion Rept. for Okla. Proj. 4-60-R. Multilithed. 76 pp.

Trefethen, P. S. 1965. Sonic equipment for tracking individual fish. U.S. Fish and Wildlife Service. Special Scientific Report--Fisheries. 179:1-11.