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Intra-Stream Movement and Distribution of Channel Catfish

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SYNOPSIS. Channel catfish were marked and tagged in a 20-mile stretch of the lower Des Moines River. The experimental area was separated into eight segments of 2.5 miles each. Dispersion of recaptured fish from these segments was used to describe movement. Of the 4,988 catfish tagged, 345 were recaptured in the following two years. Approximately 50% of the recaptured fish did not move from the segment in which they were originally marked. Moving catfish were distributed in a normal fashion in upstream and downstream directions. Mean distances of movement was 5.6 miles downstream and 5.1 miles upstream. The greatest distances recorded were 70 miles downstream and 155 miles upstream. Description of catfish movement and the probability of movement in either direction are discussed. Equations for the computation of the number of tagged fish in any of the segments before sampling are presented. The effects of movement on population estimates are discussed.
INDEX DESCRIPTORS: channel catfish, movement, Des Moines River, fish tagging method.

Investigations of intra-stream distribution and movement of channel catfish in the Des Moines River were initiated in 1964. The original purpose of the study was to obtain information on the natural movement of catfish. A secondary purpose was to determine the effects of natural movement on numerical population estimates in short study areas within streams where loss of marked fish outside the arbitrary boundaries would preclude recovery and dilute the marked:unmarked ratio, resulting in over estimation.

Previous investigators found wide variation in movement of channel catfish. Factors responsible for the variability were stream size, location of the study area within the stream basin, alteration of stream course, man-made and natural barriers and resident or transported fish.

Previous studies were conducted in the upper Des Moines River by Harrison (1953) and Muncy (1958). Harrison (1953) reported a rather sedentary catfish population that exhibited random movement mostly < 1 mile in distance. Muncy (1958) found about 73% of the tagged channel catfish moved < 5 miles in the first year and 68% moved for about the same distance during the second year. The direction of movement was about equal in upstream and downstream directions. Hubley (1963) reported 49% downstream movement, 19% upstream movement and 24% non-movement of resident catfish in the Mississippi River. Transported fish showed greater tendency for movement, but the distance traveled remained generally < 5 miles. Welker (1967) found approximately the same directional dispersion in the Little Sioux River, Iowa, but tagged catfish moved much greater distances in the rechanneled portion of the stream. About 83% of the tagged channel catfish in his study were recaptured > 25 miles from the release site. He attributed most of this movement to severe lowering of water levels during an extended drought where flow in the upper reaches of the stream became interrupted. McCammon and LaFaunce (1961) and Humphries (1965) reported random movement of tagged catfish in California and Georgia streams.

Funk (1955) discussed the theory of two discrete stream populations of channel catfish, where a sedentary portion of the population occupied territories and niches within the habitat. The mobile population had vast multiple directional movement either seeking a niche or ignoring establishment of a territory. Movement patterns of catfish tagged by Funk (1955) were quite similar to other studies, except in headwater regions where there was pronounced downstream movement. State-wide, 37% of the tagged catfish showed no movement, 33% moved upstream, 21% moved downstream and 9% had complex movement requiring initial downstream movement followed by upstream movement in a tributary stream.

A 20-mile segment of the Des Moines River near Knoxville in Marion County was chosen for study. The stream lies in a broad alluvial valley, winding from bluff to bluff in a series of sharp bends. Width of the river ranged from 200 to 500 ft. The stream is characterized by short riffles and long sluggish pools with numerous protective drifts of lodged, floating logs, fallen trees and debris. Many large sand bars are exposed during low flow. The study area was permenantly flooded by Red Rock Reservoir in 1969.

METHODS AND PROCEDURES

In 1966, 4,988 channel catfish > 9 inches total body length were marked and tagged in the 20-mile experimental area. Marking consisted of inserting a small (1/8 x 3/8 inch) serially numbered aluminum strip through a small incision into the body cavity and removing the adipose fin for rapid external identification. The tag was placed forward of the incision with small forceps which prevented accidental loss of the tag through the incision before it healed.

The study area was divided into 8 segments of 2.5 miles each. These segments were consecutively numbered from 1 through 8 from the upstream boundary. Baited hoop nets were raised daily, except on weekends, and the total length, weight, sex and station number recorded for each fish that was caught and tagged. The nets were located near the center of each segment and were not moved throughout the entire 5-month study period.

Recaptured fish were classified as non-moving, upstream movement and downstream movement. The former were fish recaptured in the identical segment in which they were marked, and the latter two classes required movement of at

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least one segment. Although movement of 1.25 miles would actually place a mobile catfish into the adjoining segment, recapture in the segment would require movement of 2.5 miles because all nets were placed near the center of the stations. The station number where tagging occurred and other data for the number of days at large and length and weight gained were also recorded. Simultaneous marking and recapture continued from June through October in the first year. Additional tagged fish were also recovered during intensive netting in 1967 at the same stations, but no further tagging was completed.

DESCRIPTION OF THE MOVEMENT PATTERN OF TAGGED FISH

The greatest problem in describing movement patterns of tagged channel catfish was estimating the probability of movement k sections from the location of tagging. Due to the nearly equal tagging effort between segments of the study area and because sampling was restricted wholly to the 20-mile area, the probability of movement must be determined directly from the recovery data. Several tags were returned by anglers from outside the study area, but these were used only to establish maximum distance of movement and were not used in the description of intra-stream distribution.

All data from recaptured fish were separated into a frequency distribution representing non-movement, upstream movement (+) and downstream movement (-) where the $_j{}^{th}$ movement was described by

$$_j = 1 \rightarrow -7 \text{ section}$$
$$_j = 2 \rightarrow -6 \text{ section}$$
$$\vdots$$
$$_j = 15 \rightarrow +7 \text{ section.}$$

The frequency distribution of movement for recaptured fish approximated a normal curve, with a very slight skewness in the downstream direction. Recaptured catfish showed only minor differences in upstream and downstream movement. Movement of 1 segment showed the same frequency (56) in both directions. For movement 2 and 3 sections, downstream movement had a slightly higher frequency (12 and 18, 13 and 6), respectively. After this distance sample size was too small for comparison, but they appear approximately equal in both directions.

In order to describe the intra-stream distribution and movement of tagged channel catfish the following assumptions were necessary: (1) movement of tagged fish was random about a mean, where the mean might deviate from 0 if initial displacement was the result of tagging or if tagging was conducted during a period of natural displacement; (2) there was no purposeful directional movement, such as migration; (3) a negligible number of tagged fish moved more than $\pm$ 7 sampling segments after tagging, which would place them outside the boundaries of the study area and unavailable for *recapture*, regardless of the location of original capture; (4) post-tagging movement was independent of tagging station and movement can be measured as a discrete random variable in units of segments; (5) the population density remained nearly constant within each station, although the population may be partially composed of different individual fish; (6) there was no source of tagged or marked fish outside the boundaries, and if so they could be easily separated; and (7) fish movement could occur in an upstream or downstream direction, but could not occur in both directions for the same fish.

The movement distribution curve was originally established for the entire study area and later applied to individual segments. Individual sampling stations were treated as the center point from which all movement originated and yielded eight distribution curves, all of which were assumed to have a common mean and variance.

ESTIMATION OF THE NUMBER OF TAGGED FISH AT TIME OF SAMPLING

In an open water system, such as stream habitat, with no physical barriers between the sampling stations there is continual change of at least part of the marked catfish population from one section to another. As long as movement is not of sufficient distance to place the fish outside the study area boundaries, they remain available to recapture. Adjustment for immigration and emigration in each segment was necessary before sampling was completed. Of most concern was dilution of the marked:unmarked ratio which resulted from fish moving outside the study area, and not changes in the actual population density. The latter was assumed to be constant without concentration of fish due to movement into a particular section of the stream.

The number of marked fish available to recovery in the i^{th} segment must initially be the number marked and released and adjusted for upstream and downstream movement which would place the fish into a different segment, bring in marked fish from adjoining stations or move tagged fish completely out of the sampling area. The number of marked fish lost due to movement was adjusted by progressively reducing the number originally marked and released according to the estimated loss. Adjustment was not required for recruitment or mortality since the population estimates were conducted on a cumulative bi-weekly sample which would tend to nullify the effects of each other.

The following notations were used in the determination of the number of fish in each segment before sampling:

t_i = Number of fish released in section i immediately before a given sampling period, and was the summation of the number of marked fish released at different periods [$i = 1(1)8$].

T_i = Number of marked fish estimated to be in section i immediately before a given sampling period [$i = 1(1)8$].

P_i = Probability of a marked fish being i sections away from the section in which it was tagged and released [$i = 1(1)15$] and coded as before.

The estimated number of tagged fish entering and leaving the i^{th} section was

$$T_1 = \sum_{i=1}^{8} t_i P_{(9-i)} - t_1 \sum_{i=1}^{15} P_1$$

$$T_2 = \sum_{i=1}^{8} t_i P(10-i) - t_2 \sum_{i=1}^{15} P_i$$

$$\vdots \qquad \qquad \vdots$$

$$T_8 = \sum_{i=1}^{8} t_i P(16-i) - t_8 \sum_{i=1}^{15} P_i$$

Since upstream and downstream movement are nearly equiprobable and the probability of movement versus non-movement was also nearly equal it was assumed there was no dilution resulting from disproportionate movement and the difference in fish leaving and entering the study area can be written

$$D = \sum_{i=1}^{15} P_i - P_8 = 0$$

Then, the estimated number of tagged fish within the boundaries of the study area in the n^{th} sampling period can be expressed as

$$T_j = \sum_{i=1}^{8} t_i P_i - \sum_{j=1}^{15} P_j$$

TAGGED FISH RECOVERY AND THE EFFECTS OF MOVEMENT

Of the 4,988 channel catfish marked and tagged in the study area, 345 or 6.9% were recaptured during the following two years. In the first year when marking and recovery of tagged fish were simultaneous, 163 or 3.3% were recaptured. The following year no further tagging was done, but intensive netting in the study area produced a total catch of 12,198 catfish and 182 were recovered.

The pattern of catfish movement was quite similiar to other investigations. Movement was also similar in both years. Tagged fish that did not move from the segment in which they were tagged comprised 49.5% of the recoveries in the first year and 49.0% in the second year. During the first year, 50.9% of the mobile tagged fish moved in a downstream direction for a mean distance of 5.1 miles. The following year 51.2% of the fish that moved went in the downstream direction a mean distance of 4.9 miles. Upstream movement occurred for 39.1% of the mobile catfish in the first year and 48.8% in the second year. The average distance of upstream movement was 5.9 and 5.4 miles, respectively. Angler returns were received from as far as 70 miles downstream and 155 miles upstream. Over the two year period of study the probability of non-movement was 0.4950, and its complement 0.5050 represented movement in either direction. The probability of movement k sections was: 1 section, 0.2949; 2 sections, 0.0867; 3 sections, 0.0461; 4 sections, 0.0360; 5 sections, 0.0157; 6 sections, 0.0156; 7 and 8 sections, 0.0050 (Figure 1).

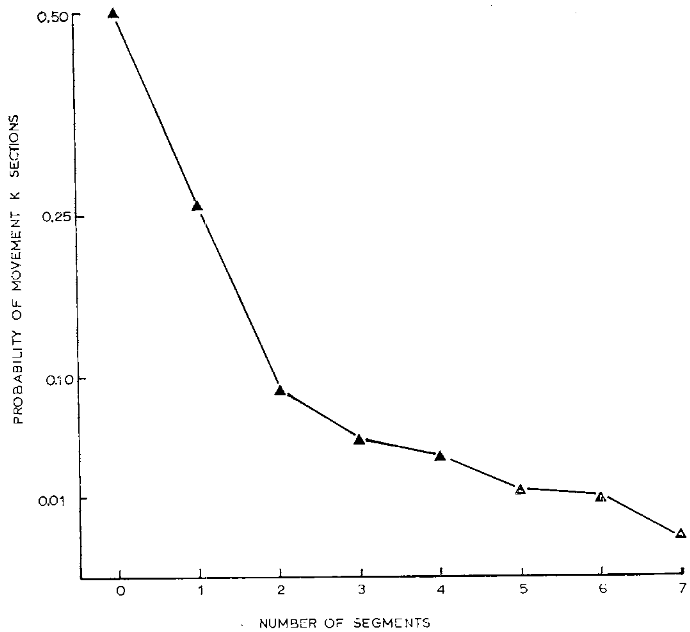

Fig. 1. Probability of movement k sections in an upstream and downstream direction of channel catfish.

The original number of fish marked in the individual segments of the study area ranged from 113 in station 2 to 1,367 in station 7 (Table 1). Computation of the loss of marked fish revealed 516 moved outside the boundaries leaving 4,472 available to recovery. Loss of tagged fish outside the study area was proportionately greater from segments that formed the upstream (1) and downstream (8) boundaries. In station 1 loss of marked fish by movement in either direction was equal to the summation of the probability of movement eight segments [$i = 1(1)8$] in the upstream direction and the probability of movement eight segments [$i = 8$] downstream. The original number of catfish tagged in this station was 516. A total of 261 moved out of the segment, of which 132 were outside the boundaries and 129 were located in other segments. An additional 92 tagged fish moved into the section from other segments. The estimated number of tagged fish available for recapture in the section was 348.

Multiple census population estimates from Chapman (1952) were computed from the ratio of marked:unmarked fish in bi-weekly samples in the first year. The final cumulative yield was 113,383 ± 4,868 catfish in the 20-mile study area. Adjusting this estimate for the loss of marked fish from

TABLE 1. NUMBER OF CHANNEL CATFISH MARKED AND RELEASED IN EACH SEGMENT OF THE STUDY AREA AND THE ESTIMATED NUMBER AVAILABLE FOR RECAPTURE AFTER ADJUSTMENT FOR MOVEMENT.

Segment *N*	N *Marked and Released*	N *non-moving*	N *Moving from* K^{th} *Sections*	Est. N *Moving out of area*	Est. N *In other Sections*	Est. N *Moving into* K^{th} *Sections*	Est. N in K^{th} *Section at (t)*
1	516	256	261	132	129	92	348
2	113	56	57	11	46	272	328
3	938	464	474	54	420	188	652
4	490	243	247	21	226	347	590
5	774	383	391	34	357	279	662
6	599	297	302	38	264	368	665
7	1,267	627	640	153	487	197	824
8	291	144	147	73	74	259	403
Sum	4,988			516			4,472

movement outisde the boundaries reduced the density to 103,358. At the 95% level, this estimate would vary not more than 4,438 fish. Overall the loss of marked fish by movement over estimated the population density by about 10%.

DISTANCE TRAVELED AND LENGTH OF TIME AT LARGE

The distance traveled by tagged channel catfish in relation to the length of time between marking and recovery was important in studying intra-stream distribution and movement. If mobile catfish were constantly moving there would be a simple linear relationship between the two variables. To test this hypothesis the dependent variable distance traveled was regressed on the number of days at large for both upstream and downstream directions. Both regressions had negative coefficients and showed no significant linear trend. The recovery data indicated the distance traveled by a mobile catfish increased systematically for a maximum of 90 days after which the distance moved became less.

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