1967

Movement of Forage Fishes in a South Dakota Stream

Thomas P. Felix

MOVEMENT OF FORAGE FISHES IN A SOUTH DAKOTA STREAM

BY

THOMAS P. FELIX

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Wildlife Management, South Dakota
State University

1967

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Head
Wildlife Management Department

ACKNOWLEDGEMENTS

I wish to express most sincere appreciation to my major adviser, Dr. Richard A. Tubb, and to Dr. Alfred C. Fox, for their helpful field assistance, direction, and constructive criticisms in the preparation of this manuscript. I am also indebted to Dr. Felix Harrison Hsia and Dr. Lee Tucker for their guidance in the statistical analysis of data. I sincerely thank fellow graduate students Larry Kallemeyn, Artwin Schmidt, James Congdon, Thomas Clifford, Steve Gloss and James Sinning for their tireless field endeavors which made this study possible. Financial aid was provided by the Cooperative Fishery Unit at South Dakota State University.

ABSTRACT

Movement patterns of Semotilus atromaculatus, Rhinichthys atratulus, Campostoma anomalum and Catostomus commersoni were investigated in an eastern South Dakota stream for a period of one year. Electrofishing, fin clipping and a multiple census method were employed. Population structures were estimated for each species. Populations were considered unstable due to the occurrence of appreciable emigration and immigration between sampling periods. Differential size class mobility was established for all species.

Species exhibited upstream movement tendencies during the summer and more random movement tendencies during the fall. Size classes of S. atromaculatus, R. atratulus and C. anomalum showed differential upstream movement affinities. Considerable growth recruitment occurred in the smaller size classes. Greater mobility of larger size classes of all species was found.

Marking mortality was considered negligible for S. atromaculatus, C. anomalum and C. commersoni but highly significant for R. atratulus. Upstream summer migrations and downstream winter migrations were the general movement trends of all species. All species were classified as semimobile because of mobile and sedentary qualities.

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INTRODUCTION

Few movement studies have been conducted on stream forage fish populations. In contrast, several investigations have been conducted on movements of larger stream fishes (Gerking, 1950, 1953, 1959; Funk, 1955; Scott, 1949; Miller, 1954, 1957). Fish movement studies are invariably associated with marking or tagging programs. The small size and population density of forage species has prohibited extensive studies. One exception is McCleave's (1964) study of the mottled sculpin (*Cottus bairdi*).

No movement studies of forage fishes in eastern South Dakota have been undertaken. Migratory, seasonal and other movements of these fishes are not well known. Knowledge of forage fish movements are valuable, especially in streams having a sport fishery potential. Seasonal locations of fish concentrations, relative movements of utilizable size classes, and the sedentary or mobile qualities of forage fishes have been given little consideration before initiation of stocking programs. If predatory sport fishes displaying limited movement or home range affinities are to be stocked, information on immigration, emigration and species stability of available forage populations is desirable.

The headwater portion of the South Fork Yellowbank River of eastern South Dakota is considered a potential brook trout fishery, but has not previously been exploited as a sport fishery (Kallemeyn, 1967 unpublished). A study was initiated in June, 1966 to study forage fish movements before the introduction of brook trout. Four forage fishes (*Semotilus atromaculatus*, *Rhinichthys atratulus*, *Campostoma anomalum*, *Catostomus commersoni*) were selected for intensive study. Objectives were (1) establishment of population structure for each species (2) determination of general movement patterns (3) estimation of relative movement of intraspecific size classes and (4) determination of species stability.

DESCRIPTION OF STUDY AREA

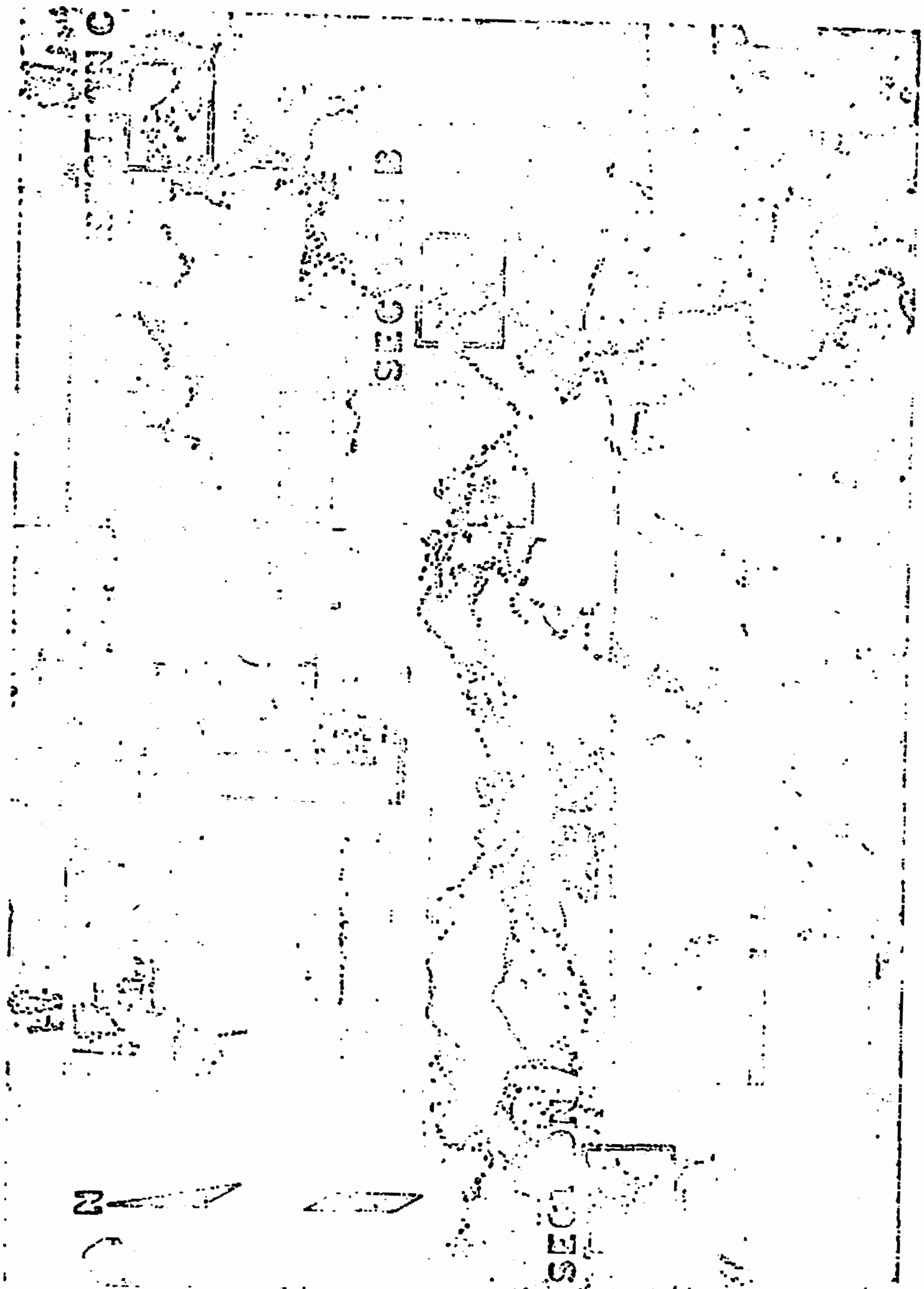
The South Fork Yellowbank River originates from springs along the northern boundary of Deuel County in east-central South Dakota. The stream is aptly named since iron precipitates impart a yellowish hue to the banks and stream bed. It flows generally eastward into Minnesota and eventually empties into the Minnesota River (Fig. I).

The study area was confined to the upper 4 miles of the South Fork Yellowbank. The average stream width from stream source to mile 2 is approximately 8 ft. and from mile 2 to mile 4 the average width is 12 ft. Riffle depth averaged 2 inches and pool depth averaged 30 inches with a few pools nearly 50 inches deep.

Springs occur along the 4 mile study section but the majority occur near the source. The stream originates in a coteau area and meanders through a mixed-hardwood forest. Heavy shade cover exists over the first 2 mile portion of the stream. The lower 2 miles consists primarily of open pasture with isolated shade areas.

Stream substrate consists of coarse glacial moraine material varying from a rubble substrate in the riffles to a sandy substrate in the pools. A few large, deep pools contain mud, silt and detritus in small amounts. Suspended inorganic material tends to settle out rapidly due to the coarse nature of such material. The water remains exceptionally clear during all seasons of the year except when livestock activity and heavy rains occasionally cause temporary turbidities.

Figure I Aerial Photograph of Study Area



Scale: 1 inch = 0.32 mi.

Discharge of the stream is approximately 3.8 cubic ft/sec and remained fairly constant throughout the study with several exceptions (Kallemeyn, 1967, unpublished). Heavy summer rains increased water flows for short periods. Rain in late September and early November snowfalls resulted in increased flows until heavy ice formation in late November and early December. Water flows decreased gradually during hot, dry periods of July and August, and abruptly following formation of a 3 to 5 inch ice cover in early December. Increased flow occurred during a late December thaw, causing water to flow over the ice in certain areas. By early January 5 to 12 inches of ice covered all but the upper 0.5 miles of the stream resulting in decreased and constant flow throughout the winter.

Water temperature varied considerably throughout the duration of the study. Two temperature gradients were observed, and were referred to as Gradient I and Gradient II, summer and winter gradients respectively (Table 1). It was assumed that the shade cover was responsible for maintaining low summer temperatures in the upper 2 miles of the study area because water temperature rose quite rapidly within the next 400 yards of open pasture beyond mile 2.

Water temperature gradually decreased in downstream areas in late September. Little temperature difference occurred between the upper and lower two mile sections, and essentially no temperature gradient existed. A temperature gradient opposite to Gradient I was noted by the first week in November, after the first snowfall and formation of a partial ice cover.

TABLE 1

Summer and Winter Temperature Gradients of the Study Area

Gradient I.		June - Mid-September	
	Source (canopy closed)	2.0 mi. downstream (canopy terminates)	4.0 mi. downstream (canopy open, day-time measurements)
Period			
June-July	11-18°C	15-26°C	18-30°C
August-mid-Sept.	10-15°C	10-23°C	16-23°C

Gradient II.		November-March	
	Source (no ice cover)	0.5 mi. downstream (ice cover)	0.5-4.0 miles (ice cover)
Period			
Nov.-March	2-6°C	0°C	0°C

Gradient II extended for only 0.5 miles. Snow, ice, and sub-zero air temperatures resulted in rapid cooling of the water from an average temperature of 4.2°C at the source to 0°C within 0.5 miles. The downstream portion of the study area remained frozen over with a constant water temperature of 0°C except for isolated spring areas. Both gradients were due to nearly constant spring temperatures of 6 to 10°C.

A small tributary 2.5 miles downstream from the source was found to increase July and August daytime water temperature of the mainstream 1°C. Mainstream and tributary water temperatures were constant during the winter months.

Indigenous fish populations of the stream consisted mostly of forage species. Forage and predator fishes are indicated in Table 2. An indigenous predator present throughout the year was the larger size classes of the creek chub, *Semotilus atromaculatus*. No permanent barriers to fish movement existed throughout the 4 mile study area.

TABLE 2

Indigenous Fish Species of South Fork Yellowbank River Listed in Approximate Order of Decreasing Abundance

Forage Species	Predators
1. Shortnose dace, *Rhinichthys atratulus* (Hermann)	1. Creek chub, *S. atromaculatus* (Mitchill) larger size classes all year.
2. Stoneroller, *Campostoma anomalum* (Raf.)	2. Northern pike, *Esox lucius* L. spring and summer only.
3. Fathead minnow, *Pimephales promelas* Raf.	3. Black bullhead, *Ictalurus melas* (Raf.) summer only.
4. Creek chub, *Semotilus atromaculatus* (Mitchill)	
5. Common shiner, *Notropis cornutus* (Mitchill)	
6. White sucker, *Catostomus commersoni* (Lacépède)	
7. Sand shiner, *Notropis stramineus* (Cope)	

TABLE 2. (continued)

Forage Species	Predators
8. Emerald shiner, *Notropis atherinoides* Raf.	
9. Hornyhead chub, *Hybopsis biguttata* (Kirtland)	
10. Johnny darter, *Etheostoma nigrum* Raf.	
11. Brook stickleback, *Culaea inconstans* (Kirtland)	
12. Black-sided darter, *Percina maculata* (Girard)	
13. Iowa darter, *Etheostoma exile* (Girard)	

LITERATURE REVIEW

A number of investigations have been conducted on movement of fresh water fishes. Most of these investigations (in lakes and large rivers) are inappropriate for the purposes of this study. Movement of stream fish is unique. The small size of a stream restricts movement of fish populations to essentially an upstream-downstream phenomenon. Lateral movements between banks is not significant since such movements involve negligible distances. Ability of fishes to negotiate riffle areas varies considerably with water volume. Physical factors causing non-random movement include isolated pools and long intervening riffle areas. Non-random movement may also be caused by such biological factors as competition for available niches.

Spacial or competitive restrictions are less severe in large rivers and lakes. In such bodies of water lateral and vertical movements, in addition to upstream and downstream movements, become significant. When comparing stream environments to lake and large river environments, fish movement essentially changes from a one-dimensional aspect with a single upstream-downstream axis to a three-dimensional, multiaxial aspect. For this reason, only the literature on stream fish movement is presented.

One characteristic of stream fish populations which should be kept foremost in mind when undertaking a movement study is that the populations of stream areas may change from day to day. Population increases are caused by natality, ingress, and stocking. Mortality, egress, and harvest tend to decrease the population (Cleary and Greenbank, 1954).

Scott (1949) discussed the distributional pattern of stream fish populations. He pointed out that a uniform distribution of these populations does not exist and should not be expected, due to the diversity of habitats. He referred to "nodes of abundance" corresponding to the occurrence of optimal conditions for a particular species. Nodal areas may be deep pools, shallow sand-gravel complexes, or riffle areas. At any instant in time the population consists of a series of relatively dense groups, corresponding to the nodes, separated by areas of less favorable habitat and consequently relatively sparse groups. Cleary and Greenbank (1954) suggested that stratified sampling should be employed to minimize sampling error due to clumping.

The one-dimensional directional nature of stream fish movement was elaborated on by Funk (1955). In addition to upstream and downstream movement, Funk described a complex movement. He defined complex movement as movement in one direction followed by movement in the opposite direction by the same individual. Complex movement can be detected only when the initial movement of the fish is downstream and the following upstream movement occurs up a tributary stream.

A serious limitation to the mark-recapture method of evaluating stream fish movement is obvious. The only information available to the investigator is the location of marking and recapture sites. Funk (1955) and Cleary and Greenbank (1954) both emphasized this limitation. Location of release and recovery give an indication of only net travel, and give no clues to intermediate upstream and downstream movements. Consequently, no indication of how far the fish actually traveled between sampling periods is obtained. Errors of this type are substantially reduced when complex movements between streams are recognized, but recognition of such movements is limited to streams with extensive tributary systems. Superimposing another mark on individual fish recaptured at sites other than the original marking location may give insight to the nature of complex movements. By this method, movement in one direction and subsequent movement in the opposite direction can be detected. An intervening sampling period is necessary, since it is obvious that detection of a complex movement of a fish in the same stream between two consecutive sampling periods is impossible.

Gerking (1950, 1953, 1959) studied movement and homing instincts of Centrarchids and Catostomids. Definite home ranges for stream fishes were found to exist. Riffle areas served as home range boundaries. Fish populations were not found to travel freely up and down the stream. Between 70 and 80 percent of the marked fish were found in the locality of marking upon subsequent sampling. Home ranges of suckers varied from 200 to 400 ft. Strays, consisting generally of larger fish, were noted. He speculated that fishes identified home ranges by scent.

McCleave (1964) showed that the mottled sculpin, Cottus bairdi, displayed limited movement and established home ranges. Eighty percent of the fish were recaptured in either original or adjacent sections of marking. He estimated a maximum home range of 150 ft. It was suggested that overlapping home ranges may decrease the apparent home range size. Homing tendencies, upon displacement, were not observed.

The rock bass, Ambloplites rupestris, was investigated by Scott (1949). Fish showed a strong tendency to remain in the locality of marking, occasionally for as long as 2 years. Upstream and downstream movement was approximately equal. The greatest number of recoveries were noted at the point of original tagging and fewer at upstream and downstream sites, forming an approximately normal distribution. Fish were considered to range through no more than a mile of stream within the course of 2 years. No extensive redistribution during the 3 year study occurred, inspite of great variation in environmental conditions. Scott referred to the rock bass as a sedentary species.

Shuck (1943), in a population study of the wild brown trout, Salmo trutta, in Montana, discovered little movement. Ninety percent of the trout were taken in the sections where they were tagged. The remaining

10 percent were distributed equally upstream and downstream. Tag returns by fishermen indicated that 64 percent of the trout were taken in the sections where they were tagged, and that the remaining 36 percent had moved only short and approximately equal distances upstream and downstream.

Movement of the cutthroat trout, Salmo clarki, was investigated by Miller (1954, 1957). He found that home ranges did not exceed 20 yards in length. Sixty-seven percent of recaptured fish were found to be in home pools. The remaining 33 percent drifted downstream. The latter were all small fish thought to have been injured during tagging.

Homing experiments involved retention of fish upstream and downstream from their home ranges. Fish were retained at different distances for varying periods of time. He proposed that fish homed by scent since very few moved in the wrong direction when released downstream, but one-third moved in the wrong direction when released upstream. Odors were considered to drift downstream with the current. The ability to home was thought to be partially a function of distance and time.

Contrary to Miller's findings, Bjorn and Mallet (1964) concluded that cutthroat trout showed little tendency to occupy a restricted home range for any length of time. Only 25 percent of the tagged trout were recovered in the release area. The greater majority of the remaining 75 percent were recovered more than 2 miles upstream and downstream.

Movements of Centrarchids were investigated by Larimore (1952). _Micropterus dolomieui_ exhibited limited movement, since 80 percent of the smallmouth bass were recaptured in marking localities. Homerange affinities were shown to exist. The redear sunfish, _Lepomis microlophus_, showed less ability to home than the smallmouth bass, which Larimore attributed to the relative swimming ability of the two species.

Bangham and Bennington (1939) noticed low recapture percentages at marking sites. Recaptures of the white sucker, _Catostomus commersoni_, were infrequent. They suggested that low recovery percentage may have been due to tag loss. Percentage of the total catch of rock bass, smallmouth bass and white sucker varied considerably in the same 1 mile section at successive samplings, indicating unstable populations. A high percentage of recaptures was found to be inversely related to length of time intervals between samplings. Considerable mobility involving emigration and immigration of individuals was suspected. Mortality of these species during a single season is too low to account for the decreasing recovery percentages. Some recoveries were as much as 10 miles from tagging sites.

Funk (1955) attempted to clarify the controversial findings of other workers. He proposed a hypothesis whereby every fish species consisted of sedentary and mobile groups. Species were classified as sedentary, mobile, or semimobile species, depending upon the relative predominance of the two groups. Funk stated that this concept provides a logical explanation to many observed phenomena and contradictory findings. The hypothesis implied that the home range concept applied only to the sedentary groups of a species. If most sampling is done near the mark and release sites a strong bias in favor of restricted movement is introduced. All accessible waters should be sampled with equal intensity as far as possible. Funk used a creel census covering an entire river system to evaluate movement. He reported that all four of the most numerous species in his study contained higher percentages of mobile fish in the spring than in the summer. Three species were more mobile in the intermediate age groups. Funk's interpretation was that intermediate age groups were trying to establish themselves and moved away from areas where larger fish were already established. In support of Funk's hypothesis, Larimore (1952) noted that certain smallmouth bass in any pool were temporary residents. Individuals 9 inches or less in length tended to wander more than larger fish. Gerking's (1950, 1953, 1959) observations of only large stray fish contradicts the hypothesis. Funk noted that mobile or semimobile species such as the carp, Cyprinus carpio, became more mobile when released in unpreferred habitats, or when released in preferred but unstable habitats.

Two types of movement were recognized by Funk (1955): random movements in a limited area and movements resulting in travel through a considerable distance of stream. Fishes exhibiting predominantly limited movement were considered sedentary. Semimobile fishes exhibited both types of movement, and fishes moving appreciable distances from sampling areas were classified as mobile. In support of his hypothesis, Funk cited the well-known phenomenon of rapid repopulation of decimated areas. Repopulation of such areas would occur very slowly except for the existence of mobile groups within species.

Observations of the effects of water temperature on stream fish movement has been largely confined to introduced populations. Cooper (1953) and Newell (1957) noted greater movement of stocked brook, brown, and rainbow trout populations, predominently downstream, during cold water plantings than during warm water plantings. The apparent effects of water temperature on directional movement of introduced fish may be due to other factors. Bangham and Bennington (1939) stated that native stream fish were acclimated to their habitat and were consequently less mobile than introduced fish. Competition from established indigenous fishes may also affect movement of introduced populations.

Bjorn and Mallet (1964), investigating the movements of cutthroat and dolly varden trout, found that both species exhibited upstream movement in spring and early summer and downstream movement in fall and winter. Forty-eight percent of the fish tagged upstream in summer were recovered downstream in winter. Conversely, over 60 percent of the fish tagged downstream in winter were recovered upstream the following spring and summer. All 118 fish recovered downstream from their original release sites had been tagged and released during summer and early fall.

No general statement can be made concerning the relation between stream stability and fish movements. Newell (1957) stated that no correlation existed between water levels and stocked trout movements. Other workers have shown a high correlation between stream stability and fish movements. Larimore (1952) reported that smallmouth bass did not return to home pools after displacement during low water levels, and Fajen (1962) noted that smallmouth bass moved from shifting pools but remained in stable pools. In a study of 14 species of darters Winn (1958) showed that water level influenced directional movements. Effects of changing water flows are minimized in spring fed streams with nearly constant flows and relatively stable substrate.

The presence of certain fishes in tributary streams may be a direct consequence of their spawning migrations. The white sucker, Catostomus commersoni, ascends small streams to spawn in rapids but is not abundant in these streams after spawning (Reighard, 1920). Shetter (1938) reported two definite movement periods for the white sucker, April-May and September-October. The stoneroller, Campostoma anomalum, has also been found to ascend small streams to spawn where it is most abundant during March and April (Smith, 1935).

Summarizing directional movement, studies have shown that indigenous fish populations exhibit approximately equal upstream and downstream movements. Introduced species have shown a consistent tendency to move downstream.

Efficient management of predatory fishes demands a knowledge of the quantity of forage fishes available to the predators. Large sampling errors may be introduced into estimates of stream forage fish populations without a knowledge of forage fish movements. This study was undertaken to provide basic information on movement patterns of some common forage fishes of eastern South Dakota. It is hoped that knowledge obtained from the investigation of these patterns will improve management of sport fishery streams in South Dakota.

METHODS, PROCEDURES, MATERIALS

The 4 mile study area was chosen during the first two weeks in June. A length of 4 miles was arbitrarily selected using the following two criteria: (1) four miles was considered a minimum distance to adequately evaluate extensive movement, (2) the area downstream from the 4 mile boundary was considered atypical.

Three sections of equal length in the study area were selected for intensive study, marked with stakes, and designated as sections A, B and C, upstream to downstream respectively. Sections were spaced as equidistantly as possible throughout the 4 mile study area. Accessibility considerations determined the spacing to some extent. The sections were selected to have similar pool-riffle development and to include all types of stream habitat, in accordance to the suggestions of Cleary and Greenbank (1954). Riffle areas were taken as the boundaries whenever possible (Gerking, 1953). Section A was located 0.3 miles downstream from the source of the stream, section B 2.5 miles downstream from section A, and section C 0.5 miles downstream from section B. Complex movements between the tributary and the main stream were investigated. Accordingly, a fourth section, section D, was located on the tributary 250 ft. from its mainstream confluence. Since the confluence occurred immediately above section B, complex movements were detectable between sections A and D only.

The study was designated to determine two types of fish movement in addition to complex movement, extensive movement between sections and limited movement within a section. For detection of limited movement within sections, each section was subdivided into three equal subsections designated subsections one, two and three, upstream to downstream respectively. Sections A, B and C were each 600 ft. in length. Section D, established to detect extensive and complex movements, was only 200 ft. long. Stream portions of 100 ft. immediately upstream and downstream from sections A, B and C were sampled at each sampling period, with the exception of the initial period, to evaluate limited movement among subsections. Thus at each sampling period three 800 ft. portions of the main stream were sampled.

The sampling scheme employed was essentially a compromise between the methods of Funk (1955) and Gerking (1950, 1953, 1959). Funk's methods involved equal sampling of all waters in the study area, whereas Gerking's methods involved sampling of only mark-release areas. Both workers agreed that mobile and sedentary intraspecific groups existed, but disagreed on the relative proportions of each. Funk maintained that data from methods similar to Gerking's were biased in favor of sedentary groups, while Gerking maintained that Funk's creel census data were biased in favor of the strays or mobile groups. T eliminate bias, spot checks were made between the intensively sampled study sections of the stream.

Fish were collected by electrofishing. Both A.C. and D.C. were used in the study. Mortality was high with the A.C. shocker used during the first two sampling periods. Replacement by a D.C. shocker decreased mortality nearly 100 percent.

Sampling and marking operations were initiated during the last week in June. A potential of 100 volts with an amperage varying from 1.0 to 3.0 amps proved to be most effective in stunning fish without mortality. No apparent harm to the fish was noticed, except for an infrequent spinal curvature described by Hauck (1947) and Omand (1950). Electrodes used were of the brail type.

Essentially the same shocking proceedure was used at each sampling period for each section. Sections were shocked one subsection at a time, including the 100 ft. areas immediately upstream and downstream after the initial sampling period. Shocking proceeded upstream to avoid turbidity problems. Block nets were placed at the upstream and downstream boundaries of each subsection before shocking to prevent intersubsectional movements. Upstream block nets proved to be most important since the stream was narrow enough in almost all instances to prevent fish from getting behind the workers. After a subsection was shocked, fish were placed in a live car and allowed to recover.

The shocking team consisted of three men. In pools and wide areas, the stream was shocked in a crosswise fashion. The negative brail was inserted into pools and under banks, while the positive brail was operated to draw fish from hiding places. The more frequent narrow areas of the stream were effectively shocked in small, lengthwise portions, the operator of the positive brail positioning himself upstream. Fish recovery was usually immediate with the exception of larger fish. In most instances, recovery of all fish took place within 5 minutes.

After recovery, fishes were marked by the fin clip method. Ricker (1956) proposed four qualifications of a good marking program: (1) the mark should not affect mortality or behavior of fish, either immediately or cumulatively, (2) the mark should render the fish no more or less liable to capture, (3) the mark should render the fish readily identifiable by the markers, (4) the mark should be retained by the fish indefinitely. The method was chosen primarily on the first of the above criteria. The small size of the majority of the fish in the study precluded the use of tags which might have resulted in high mortality or considerable impairment of movement. Finclipped fish appeared to be no more or less subject to stunning by the shocker than unclipped fish. The clip, when properly applied, was readily observed by all workers. Some fin regeneration occurred, but marks remained obvious throughout the study.

Ricker (1956) recommended sampling of populations before the initiation of a fin clip study to determine the natural incidence of the mutilation proposed. No previous samplings were made prior to the initiation of fin clipping due to time considerations.

However, few incidences of natural fin loss or mutilation were observed. Fin clips were readily distinguished from natural loss or deformation, since clips were invariably associated with unique regeneration patterns and formations of scar tissue. All fish exhibiting natural fin losses were excluded from the study after length-frequency data was obtained.

The technique used in fin clipping varies according to the amount of regeneration desired. If minimal regeneration is desired the fin should be cut as closely to the body as possible without causing injury (Stuart, 1958). Scott (1949) found no regeneration if fins were clipped close enough to the body to remove the bases of all fin rays. When fins were clipped at varying lengths, recaptured fish showed varied amounts of fin regeneration, ranging from no regeneration to almost complete regeneration.

Eipper and Forney (1965) indicated that adverse effects of fin mutilation on survival or behavior were minimized with partial clips. Due to the delicate nature of the smaller size classes of fishes in the study, avoidance of mortality was considered to be a greater problem than inability to recognize fish with regenerated fins. Therefore, the partial fin clip method was used.

Sections A, B and C had separate marking schemes and subsections had variations of the different schemes. Caudal-pectoral clips were used in section A, with subsection A-1 having a caudal-right pectoral mark, A-2 a caudal mark only, and A-3 a caudal-left pectoral mark. Section B had a dorsal-pectoral marking scheme and the subsectional marking scheme of median and paired fins was identical to that in section A. In section C caudal-pelvic clips were used. Subsectional variations in the marking of median and paired fins in subsections 1 and 3 were identical to those in sections A and B. Subsection C-2 was designated with a caudal-dorsal mark to distinguish it from subsection A-2. Section D on the tributary was designated by a double pectoral clip.

A slight error was introduced into the study by the use of the above marking schemes. A few fish escaped from the hands of the workers with only a partial mark. It is possible that some of the recoveries in the next sampling period were escapees from a previous sampling period with an incomplete mark. Escapees may have been recorded as having moved from a different section or subsection, when in reality no such movement occurred.

Extensive movement was defined as movement from original sampling sections. Extensive movement occurred when recoveries were found in other sections, between sections, or upstream and downstream from sections A and C respectively. Limited movement was defined as movement within the 800 ft. sampling sections in which the fish were marked.

Stream areas upstream from section A, between sections A and C and downstream from section C were spot checked for marked fish. Spot checking was accomplished by use of seal salutes, small weighted explosives which temporarily stunned fish in immediate areas, and by electrofishing.

Fish were marked at each of the first four shockings. The procedure used was essentially a multiple census procedure. Strong suspicion of a mobile population precluded the use of the Schnabel and Peterson formulae for analyses of population sizes. Nevertheless, the multiple census method was considered appropriate and necessary to evaluate movement. All fish above 5-6 cms were marked. This limit was set on the criterion of marking efficiency. No fish in the 100 ft. areas upstream and downstream from sections were marked.

Sampling periods were originally planned to occur at 2 week intervals. Time and manpower considerations resulted in several of the successive sampling periods occurring at 3 and 4 week intervals. Six sampling periods were completed before freeze-up in November. Length-frequency data for determination of population structure was obtained for three complete sampling periods and part of a fourth. Movement data was obtained for all six sampling periods.

During each sampling period, marked recoveries were recorded so that the original location of marking, location of recapture, direction of movement and approximate distance moved could be determined. Fish were identified and measured in order to establish size classes within species.

Fish exhibiting limited or no movement were remarked with the marking scheme of their original subsection, if appreciable regeneration had occurred. Marked fish were released in the subsection of recovery rather than in original subsections. McCleave (1964) released recaptured fish in their original subsections of capture and marking instead of in subsections of recovery to gain insight to the problem of overlapping home ranges. However, I considered transportation of fish from one area to another to be a disruption of natural movement.

Fish moving to different sections, i.e., exhibiting extensive movement, were remarked with the marking scheme of the recovery subsection. Relatively few fish were discovered which exhibited extensive movement. Fish with more than one marking scheme were immediately conspicuous. Examination of fish with superimposed marking schemes made possible determinations of complex movements of individual fish between two nonconsecutive sampling periods.

Species population structures were determined from length-frequency data. All marked fish, unmarked live discards under 5-6 cms and dead fish were included.

At the completion of each sampling period, marked fish moving into and out of sections and subsections, and dead marked fish, were accounted for before calculation of total numbers of marked fish for subsequent sampling periods. Fish which had been previously marked but which could not be found in the 800 ft. areas were recorded as missing fish.

Winter Movement

The onset of sub-zero temperature and a heavy ice cover in sections B and C precluded further shocking. Section A, near the source, remained open most of the winter but heavy intermittent snow bridges and the desire to use a constant unit of effort in all sections led to the use of minnow traps. The traps were cylindrical, slightly wider in the middle than at the ends. The measurements were 16 1/2 inches by 8 inches, tapering to 7 inches at the ends. Both ends were funneled inward towards a 1 1/8 inch orifice. The ends and adjoining halves of the traps were of plastic material, while the bodies of the traps consisted of 1/4 inch wire mesh.

Traps were baited with bread and set in the pool areas of all sections except section D, which was frozen to the bottom. Due to thick ice cover, placement of traps was possible only in pool areas in sections B and C. Eight traps were placed in each section, one in each of the 100 ft. areas and two in each subsection. Spacing was designed to represent each successive 100 ft. as evenly as possible. Occassionally, uneven occurrance of deep water necessitated uneven spacing.

Traps were inspected at two week intervals, and essentially the same proceedure of recording data was used as in the previous electrofishing sampling. No fish were marked during winter samplings.

Mortality Experiments

No mortality of fin clipped trout was reported by Stuart (1958). Cooper (1953) noted a greater return of fin clipped than tagged trout, suggesting lower mortality in the fin clip method. Shetter (1950) found no significant mortality of fin clipped lake trout fingerlings, Salvelinus namaycush.

Ricker (1949), investigating the effects of fin removal on survival and growth, reported that the instantaneous mortality rate of marked fish was increased approximately 50 percent. It was suggested that removal of a second fin decreased survival percentage and nearly doubled instantaneous mortality. Over-wintering mortality was greater for marked fish. The severness of the handicap was thought to vary among species. Total mortality was low, and growth was not retarded.

During the summer, downstream block nets were left in the stream on several occasions for periods ranging from 1 to 10 days in an attempt to detect dead marked fish floating downstream. During the winter, fin clip mortality experiments were conducted with the use of sealed minnow traps. Ten fish representative of each of the species studied were placed in each of two sealed minnow traps after having been shocked. The fish in one trap were fin clipped using clips from each of the marking schemes employed in the study. The fish in the other trap, the control group, were not fin clipped. Fish remained in the traps for 3 weeks. The experiment was repeated twice.

Simultaneously, 10 fish which had been trapped rather than shocked were sealed in a third trap and compared with the control group in the fin clip study to detect shocking mortality. This experiment was also repeated twice.

Statistical Methods

The statistical analysis used in this paper was taken from Yamane (1964). The terms significant and highly significant refer to the 5 percent and 1 percent levels of significance respectively. Yates continuity correction has been used for Chi-square tests when 1 degree of freedom existed. The correction is essentially a downward adjustment to reduce the number of rejections of null hypotheses. Size classes were combined in Chi-square tests when expected values of classes were appreciably less than five, since the approximation to the Chi-square distribution becomes poor at this level.

RESULTS

The relative frequency of occurrence of fishes in the study area and the combined frequency of the four species studied are presented in Table 3. Frequencies were derived by enumeration of all fish taken in the three sections during four successive sampling periods. The four species selected for intensive study were chosen on the basis of abundance and durability. The fathead minnow was more abundant than either the creek chub or the white sucker, but the small size and delicate nature of the species prohibited marking. Immediate shocking and handling mortality for the common shiner was also quite high.

TABLE 3

Relative Frequency of Occurrence of Fishes in Study Area

Species in Decreasing Order of Abundance	Freq. (in %)	Comb. Freq. of the 4 species
* Shortnose dace, Rhinichthys atratulus	30.49	65.16
* Stoneroller, Campostoma anomalum	22.62	
Fathead minnow, Pimephales promelas	19.80	
* Creek chub, Semotilus atromaculatus	8.78	
Common shiner, Notropis cornutus	8.65	
* White sucker, Catostomus commersoni	3.27	
Sand shiner, Notropis stramineus	2.09	
Emerald shiner, Notropis atherinoides	1.63	
Horney-head chub, Hybopsis biguttata	1.05	
Other	1.11	
(Includes Culaea inconstans, Etheostoma nigrum, Percina maculata, Etheostoma exile and predators listed in Table 2)		

* Species in study.

Population structures for each of the four species, expressed as relative abundance of size classes within species, are presented in Fig. II. Histograms were constructed from length frequency data of summer and fall size classes. Values were computed by enumeration of size class frequencies for sampling periods during seasons.

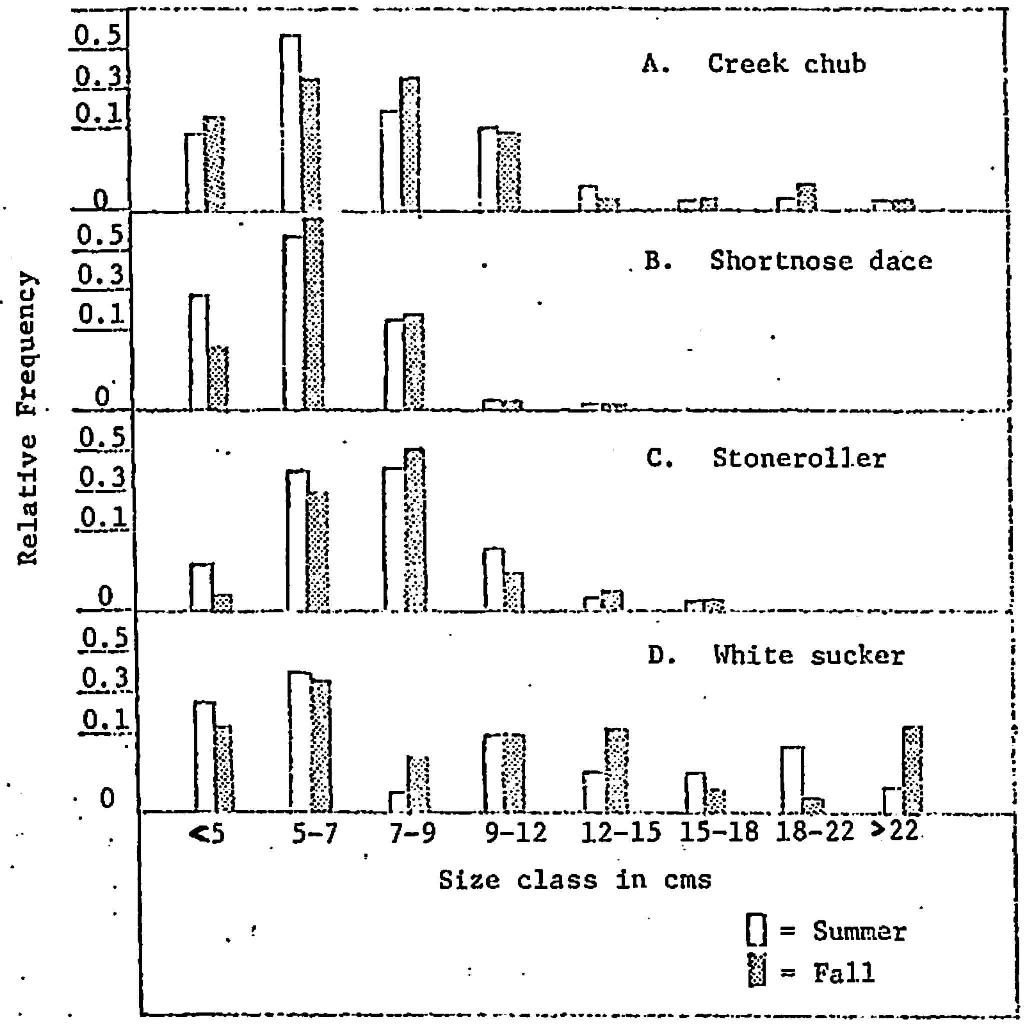
A notable change among the smaller size classes occurred from summer to fall. Varying summer growth rates apparently resulted in noticeable recruitments into the next larger size classes by fall. Fig. IIA indicates a decrease during the fall in the 5-7 cms size class of creek chubs followed by an increase in the 7-9 cms size class. A similar relationship between the less than 5 cms, 5-7 cms and 7-9 cms size classes of shortnose dace, stonerollers and white suckers is depicted in Fig. II.

Less summer-fall variation occurred in the larger size classes, with the exception of the white sucker. The slight variation in larger size classes was quite likely due to sampling error, and implied a lack of seasonal growth recruitment into or among larger size classes.

Movement in General

Recovery percentages can be used to estimate the degree of movement, especially when the multiple census method with additional marking at successive sampling periods is used. Accuracy of the estimate is increased when almost all markable fish in the

Figure II Population Structure of the Four Species, Average for All Sections



sampling sections are fin clipped. Ratios of marked to unmarked fish at succeeding sampling periods can be taken as a measure of degree of emigration and immigration, barring natality and mortality. Table 4 indicates recovery percentages for sampling periods two through five (the periods preceeded by marking).

TABLE 4

Average Recovery Percentages of the Four Species at Successive Samplings

Sampling Period	Percent Recovery of Marked Fish			
	C. Chub	Sn. Dace	Stoneroller	W. Sucker
2	17.60	15.16	15.31	34.04
3	12.32	15.38	6.02	12.98
4	13.98	16.08	10.58	9.87
5	13.54	10.33	11.05	6.18
Average	14.36	14.96	10.74	15.76

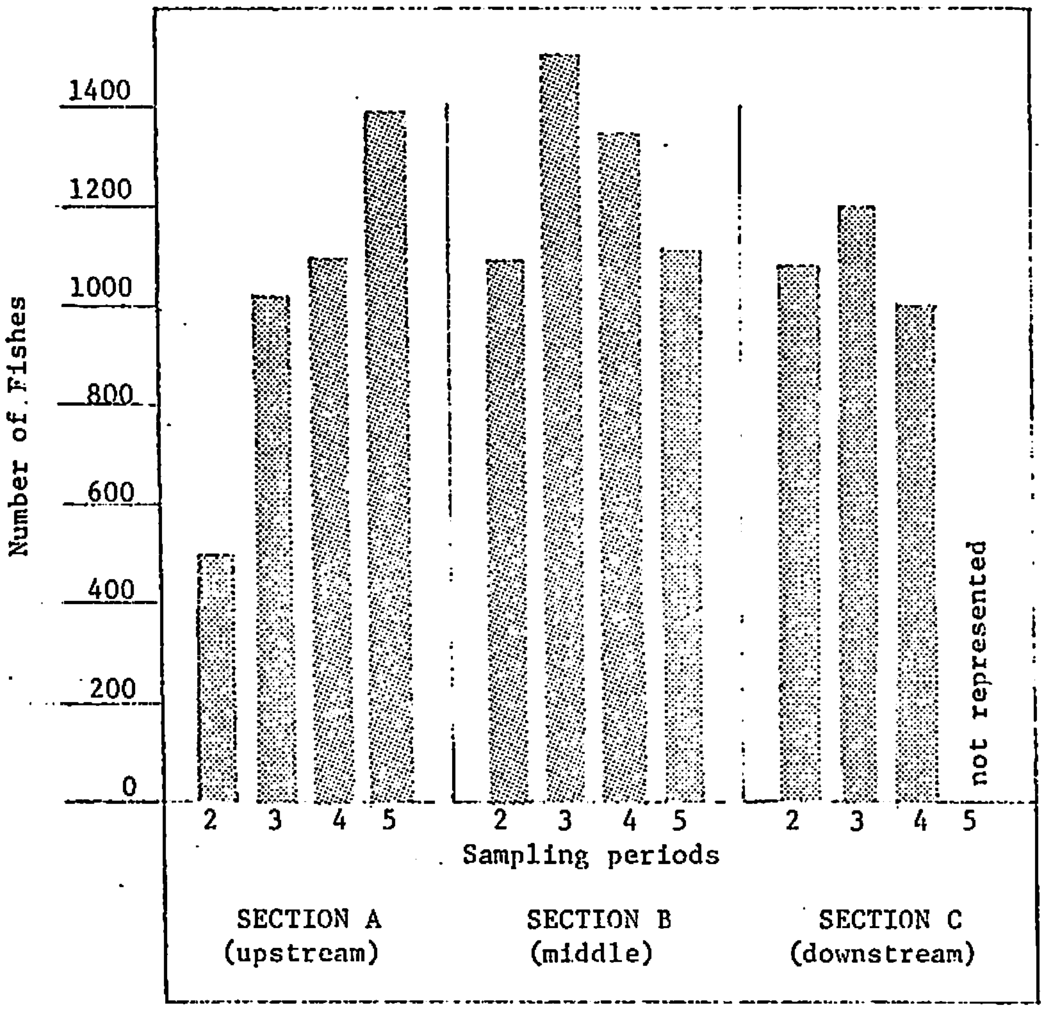
It was evident that a high and constant ratio of unmarked to marked fish occurred at each period. Implications were that considerable immigration and emigration occurred. Increases in the total number of fish in the sections, or insufficient decreases to represent a high mortality percentage (approximately 86 percent), indicated immigration in the absence of recruitment from natality. Recruitment from natality during a 2 to 4 week interval was not suspected. An emigration of 86 percent could not be established, but evidence of extensive movement confirmed some emigration.

The degree of fluctuation in the total number of fish in stream sections at successive sampling periods was taken as a measure of stability and mobility of the populations. An increasing and subsequently decreasing population could result from a unidirectional migration of fish. Fig. III illustrates the observed situations in stream sections A, B and C. Populations were not stable between sampling periods and an upstream migration, starting at the second sampling (July) and reaching a peak at the third sampling (August) was apparent. Increased populations were evident near the head waters (section A) at samplings three, four and five. A mass of fish passing through sections B and C in August was apparent.

Variation in the percentages of individual species in the total catches of stream sections at successive samplings was considered an indication of species stability and mobility. It is evident from Table 5 that percent-composition of the four species varied in the three sections between sampling periods. This was interpreted as evidence of unstable species populations.

Chi-square tests of homogeneity of each section were performed to determine the significance of the variation apparent in Table 5. Expected values of species frequency for each section were determined from $E = n_i\hat{p}$, where n_i = total number of fish of all species in the section at a particular sampling and $\hat{p} = m/n$, where m = total number of a particular species encountered in the section throughout four samplings and n = total number of fish of all species encountered throughout four samplings. Chi-square values were obtained from $\sum_{i=1}^{4} (O-E)^2/E$, where O and E are observed and expected values, i = one

Figure III Total Number of the Four Species Found in Sampling Sections at Successive Sampling Periods



sampling period. The null hypothesis assumed that each section was homogeneous with respect to percent composition of a species at successive sampling periods. The hypothesis does not imply that the sections were homogeneous with respect to each other. Rejection implied instability of a species in a particular section. Results are presented in Table 6.

TABLE 5

Species Percent-Composition Variation in Sampling Sections at Successive Sampling Periods

Sampling Period	Percentage of Total Catch		
	Sect. A	Sect. B	Sect. C
A. Creek Chub			
2	6.9	17.33	8.25
3	7.04	6.15	10.23
4	6.17	8.87	11.25
5	6.09	9.32	---
B. Short Nose Dace			
2	31.9	18.93	9.8
3	57.88	17.74	17.69
4	57.49	19.12	22.35
5	61.73	13.93	---
C. Stoneroller			
2	.15	24.67	31.44
3	.96	19.07	33.38
4	7.22	32.12	38.25
5	20.94	35.23	---
D. White Sucker			
2	.15	5.73	5.67
3	.25	4.23	3.51
4	.85	4.11	4.48
5	.97	5.92	---

TABLE 6

Chi-square Analysis of Homogeneity of Species Percent-Composition at Successive Sampling Periods

Species	Sec.	No. of Sampling Periods	% of Freedom	Chi-square value	Conclusion
C. Chub	A	4	3	1.52	Stable
	B	4	3	143.23	Unstable**
	C	3	2	8.13	Unstable*
Sn. Dace	A	4	3	140.13	Unstable**
	B	4	3	18.52	Unstable**
	C	3	2	90.33	Unstable**
Stoneroller	A	4	3	540.90	Unstable**
	B	4	3	144.19	Unstable**
	C	3	2	10.90	Unstable**
W. Sucker	A	4	3	12.82	Unstable**
	B	4	3	10.47	Unstable*
	C	3	2	9.41	Unstable**

* Significant.
** Highly significant.

On the basis of Chi-square tests all species were considered unstable to varying degrees (Table 6). The creek chub appeared to be the most stable, being highly unstable in only one section. White suckers were highly unstable in two sections and shortnose dace and stonerollers were highly unstable in all sections.

Funk (1955) recognized sedentary and mobile groups within species and seasonal changes in relative proportions of the two groups. Analysis of summer and fall recovery data yielded the following proportions of summer and fall mobile groups (Table 7). All fish found outside subsections of original marking were considered mobile.

TABLE 7

Seasonal Mobile Species Proportions

Species	Proportion Mobile		Z-value
	Summer	Fall	
Creek chub	0.30	0.36	1.318
Shortnose dace	0.36	0.43	1.647*
Stoneroller	0.53	0.61	2.000*
White sucker	0.59	0.45	13.207**

An increase in fall mobile proportions for three species and a decrease for the fourth was indicated. The comparison of two percentages method, where $Z = p_1 - p_2 / \sqrt{\hat{\pi}(1-\hat{\pi})(1/n_1+1/n_2)}$ was used to evaluate the significance of the seasonal change. Z is the normal area table deviate, which has a significant value of 1.645 and a highly significant value of 2.325. Values p_1 and p_2 are the summer and fall mobile sample proportions respectively, as determined from recovery data. The estimated annual mobile population proportion, $\hat{\pi}$, was determined from $\hat{\pi} = k_1+k_2/n_1+n_2$, where k_1 and k_2 were the respective numbers of summer and fall mobile fish and n_1 and n_2 were the respective summer and fall sample sizes. Z values in Table 7 indicated a significant increase in fall mobile sample proportions of shortnose dace and stonerollers and a highly significant decrease in this proportion for white suckers. Seasonal change in the mobile sample proportion of creek chubs was not significant.

Percentages of species populations showing limited, extensive, and no movement are presented in Table 8. Percentages were based on the total number of recoveries, both extensive and limited, throughout the summer-fall samplings. Percent mobile was taken as the average between the summer and fall mobile sample proportions (Table 7), since these proportions were determined from equitable samples from populations of approximately equal size.

TABLE 8

Sedentary and Mobile Species Percentages

Species	% Sedentary	% Mobile	% Limited Movement	% Extensive Movement
Creek chub	66.80	33.20	28.92	4.28
Shortnose dace	60.47	39.53	34.95	4.58
Stoneroller	43.37	56.63	53.50	3.13
White sucker	47.92	52.08	42.73	9.35

A classification of the four species as mobile, semimobile, or sedentary according to Funk's criteria is quite arbitrary. Each of the species had an appreciable percentage of the fish displaying limited movement, suggesting a semimobile classification. However, since limited movement as defined here involves movement through only 800 ft. of stream, many workers might consider it negligible. Only a small percentage of fishes were mobile if limited movement is disregarded. This suggests sedentary classifications for all species.

Directional Movement

A Chi-square analysis of directional movement for both seasons is presented in Table 9. The "closeness of fit" test was used. Only moving populations were considered. Random directional movement was assumed, hence expected values for upstream and downstream movement were half the total number of moving fish. Upstream frequencies were consistantly higher than expected during the summer.

TABLE 9

Chi-square Analysis of Seasonal Species Movement

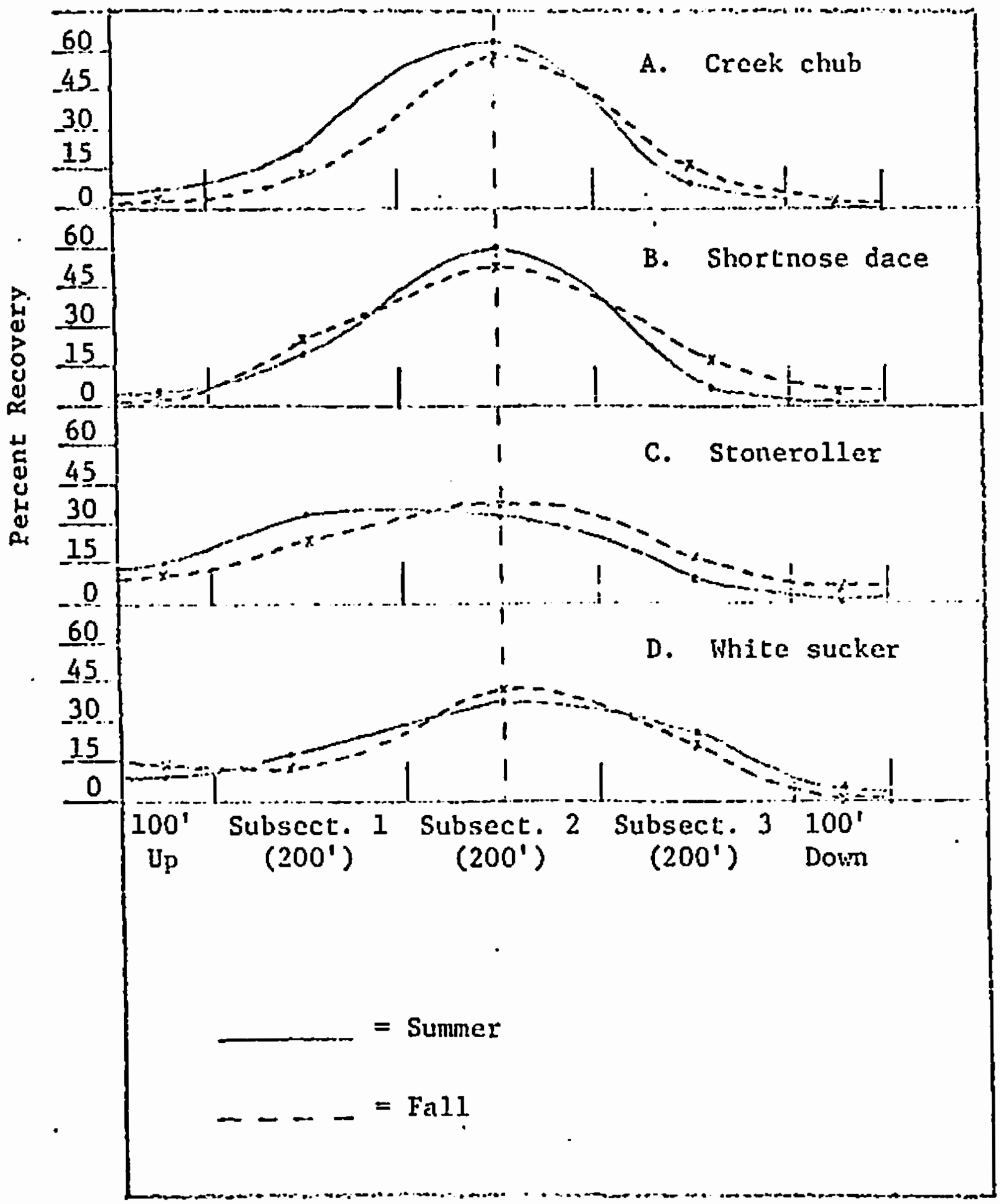
Species	Number Moving	Down Obs.	Up Obs.	Exp. Down and Up	% of Freedom	Chi-square Value
A. Summer						
C. Chub	69	25	44	34.5	1	4.69*
Sn. Dace	119	35	84	59.5	1	19.38**
Stoneroller	137	22	115	68.5	1	61.78**
W. Sucker	54	17	37	27.0	1	6.68**
B. Fall						
C. Chub	74	36	38	37.0	1	.01
Sn. Dace	94	39	55	47.0	1	2.09
Stoneroller	235	93	142	117.5	1	9.80**
W. Sucker	13	4	9	6.5	1	1.23

Summer upstream movement was significant for creek chubs and highly significant for the other three species. Lack of downstream movement was equally significant (Table 9A). Fall directional movement was not significant for creek chubs, shortnose dace and white suckers. Upstream fall movement of the stoneroller was highly significant. Increased downstream movement during the fall for all species was inferred since all fall downstream observed values increased with the exception of the white sucker. Apparent deviation of the white sucker from the trend may have been due to chance, since fall recovery frequency for this species was low.

Apparently a predominent summer upstream trend gradually disappeared, resulting in approximately random fall movement. A graphic representation of frequency of locations of recoveries of the middle subsection of all sections during the two seasons further illustrates movement tendencies of the four species (Fig. IV). Scott (1949) mentioned that the greatest number of recoveries were noted at original tagging sites and fewer at up-stream and downstream sites, forming an approximately normal distribution. This is to be expected assuming random directional movement. If upstream or downstream movement predominates, a skewed recovery distribution would be expected.

Greater areas under upstream portions of summer recovery distribution curves of creek chubs, shortnose dace and stonerollers indicated a predominant upstream trend (Fig. IV). Fall recovery distribution curves approached the normal curve, since upstream and downstream areas under the curves were approximately equal. More random directional movement was inferred during this period. Seasonal movement trends were not graphically evident for white suckers. Low recovery frequency of white suckers may have been

Figure IV Summer and Fall Recovery Distributions for the Four Species, Average of Middle Subsections for All Sections



responsible. For the other three species, the graphic presentation supports the Chi-square analysis.

Movement in Relation to Water Temperature

An approximately linear relationship was observed between decreasing water temperatures and decreasing percentages of upstream movement of creek chubs and stonerollers (Table 10).

TABLE 10

Relationship of Upstream Movement and Water Temperature

Sampling Period	Percent Upstream Movement	Water Temp. in °C
A. Creek chub		
2	75.0	21.3
3	63.3	18.0
4	60.3	16.2
5	56.5	10.2
6	22.6	4.2
B. Stoneroller		
2	81.3	24.5
3	89.0	20.5
4	82.2	18.0
5	68.8	10.5
6	49.7	3.0

Percentages and temperatures for the creek chub were averaged for all sections, those for the stoneroller were averaged for sections B and C. Stonerollers were not abundant in section A until the latter part of the study. Linear regression equations were determined by the least squares method. For the creek chub, the equation was $Yc = 16.20 + 2.79X$, where Yc is the percent of upstream movement and X is the water temperature. The regression equation for the stoneroller was $Yc = 50.49 + 1.55X$. Similar linear relationships between water temperatures and directional movements were not observed for shortnose dace and white suckers.

Movement in Relation to Time

A linear relationship between the length of time intervals between successive markings and recovery percentages was noted. Higher recovery percentages were found for shorter time intervals. Average recovery percentages for all species at varying time intervals are listed in Table 11. Intervals were the shortest, mean, and longest intervals between markings (average of all sections).

TABLE 11

Marked Recovery Percentages as a Function of Time

Species	Recovery percentages after an interval of:		
	16.3 Days	26.5 Days	53.3 Days
Creek chub	18.3	14.1	5.9
Shortnose dace	17.3	12.4	2.3
Stoneroller	18.9	8.8	4.7
White sucker	34.5	9.8	3.4

A greater dispersion with time was evident, barring mortality. Linear regression equations were calculated (Table 12). Yc = recovery percentage, X = time interval between markings. The relationships were inverse, consequently the slopes were negative. The validity of regression equations in Table 12 is questionable because equations were derived from only three values and the b values were not tested to be significantly different from zero.

TABLE 12

Regression Equations: Time vs Percent Recovery

Species	Yc = a + bx
Creek chub	Yc = 23.3 - .33x
Shortnose dace	Yc = 23.5 - .40x
Stoneroller	Yc = 21.6 - .34x
White sucker	Yc = 38.9 - .72x

Relative Movement of Size Classes

Total recovery of size classes within a species for all sampling periods was analyzed by the Chi-square "closeness of fit" test. The null hypothesis assumed equal movement of all size classes. Accordingly, expected recovery frequencies of size classes equalled size class marking frequencies, and were obtained by multiplying the total number of recoveries of the species by size class marking frequencies. It was assumed that unequal size class movement resulted in recovery frequencies lower-than-expected for more mobile size classes and recovery frequencies higher-than-expected for less mobile size classes. The basis for this assumption was a high rate of egression of more mobile marked fish from the sampling area, resulting in increased concentrations of less mobile marked fish at subsequent sampling periods. Relative marking frequencies, observed and expected recovery frequencies, Chi-square values and Exp/Obs ratios are presented in Table 13.

TABLE 13

Chi-square Analysis of Relative Recovery of Size Classes

Size Classes	5-7cms	7-9cms	9-12cms	12-15cms	15-18cms	18-22cms	22cms
A. Creek chub							
Rel. Mark. Freq.	.5138	.2743	.1406	.0381	.0121	.0121	.0086
Exp. Rec. Freq.	218.37	116.58	59.71	16.19	5.14	5.14	3.66
Obs. Rec. Freq.	55	138	158	39	12	11	12
Chi-square Value	485.25**	3.94*	161.80**	32.14**	9.15**	6.68**	18.91**
Recovery Ratio (E/O)	3.97	.84	.38	.42	.43	.47	.31
(5-7 and 7-9 combined = 1.73)							
B. Shortnose dace							
Rel. Mark. Freq.	.5994	.3942	.0062				
Exp. Rec. Freq.	324.27	213.26	3.35				
Obs. Rec. Freq.	120	409	12				
Chi-square Value	128.68**	179.66**	22.33**				
Recovery Ratio (E/O)	2.70	.52	.28				
C. Stoneroller							
Rel. Mark. Freq.	.3984	.4885	.0958	.0162			
Exp. Rec. Freq.	258.56	317.04	62.17	10.51			
Obs. Rec. Freq.	23	348	235	40			
Chi-square Value	214.61**	3.02	480.75**	82.75**			
Recovery Ratio (E/O)	11.24	.91	.26	.26			
(5-7 and 7-9 combined = 1.55)							
D. White sucker							
Rel. Mark. Freq.	.4482	.0344	.1091	.1091	.0977	.1494	.0517
Exp. Rec. Freq.	56.47	4.33	13.75	13.75	12.75	18.82	6.51
Obs. Rec. Freq.	1	1	12	36	32	30	14
Chi-square Value	54.96**	2.56	1.44	36.00**	31.49**	6.64**	8.62**
Recovery Ratio (E/O)	56.47	4.33	1.15	.38	.40	.63	.47
(5-7, 7-9 and 9-12 combined = 5.32)							

Unexpected recovery of creek chub size classes was evident (Table 13A). Smaller and intermediate size classes, 5-7 cms and 7-9 cms, had lower-than-expected recovery frequencies, suggesting greater mobility for these size classes. The Chi-square value for the 5-7 cms size class was highly significant. All larger size classes had highly significant higher-than-expected recovery frequencies, implying less mobility.

Higher mobility for shortnose dace in the 5-7 cms size class and lower mobility in the 7-9 cms and 9-12 cms size classes were apparent (Table 13B). Size classes 7-9 cms and 9-12 cms were the larger size classes for this species. Chi-square values were highly significant.

Stonerollers (Table 13C) showed highly significant lower-than-expected recovery frequencies in the 5-7 cms size class, a difference not significant in the 7-9 cms size class, and higher-than-expected recovery frequencies in the larger size classes which were highly significant. High mobility in smaller size classes, lower mobility in larger size classes, and an intermediate degree of mobility in the 7-9 cms size class, approaching the expected value, were implied from Chi-square values.

White suckers showed a relationship similar to stonerollers except that the 7-9 cms and 9-12 cms size classes displayed insignificant deviations. This was interpreted as intermediate mobility for these size classes.

From results of Table 13 high mobility among small size classes and low mobility among large size classes was suggested. Intermediate mobility for intermediate size classes was noted for two species. It should be noted that the intermediate size class of the creek chub nearly showed the same relationship as that of stonerollers and white suckers. Higher mobility in the 7-9 cms size class of creek chubs was just barely significant. The 5-7 cms size class of the shortnose dace, the smallest of the four species, was actually the intermediate size class.

Apparent differential size class mobility interpreted from unexpected recovery may have been caused by differential marking mortality or unequal growth recruitment among size classes. Exact evaluations of degrees of differential mobility, differential mortality and/or recruitment by growth were not possible. Greater fin clip mortality among smaller size classes was likely. Growth recruitment between small size classes and between small and intermediate size classes was highly probable. Fig. II indicates considerable seasonal recruitment among these size classes. However, recruitment by growth between sampling periods with 3 to 4 week intervals was considered to be much less than that depicted in Fig. II.

If mortality in all size classes and recruitment by growth from the smallest to the next largest size class can be removed, differential size class mobility can be established. These two factors were removed in the analysis of recovery data containing members of the 5-7 cms size classes. Only surviving fish were recovered, and no fish smaller than 5-7 cms were marked. A Chi-square test of independence was used. The null hypothesis was that no differential mobility occurred, hence movement was independent of size class. Movement was designated event A and occurrence in a size class event B. Assuming independence, the probability of A and B occurring together was $P(A) \cdot P(B)$. $P(A) = n_A/n$, where n_A = total number of fish of a particular species that moved. $P(B) = n_B/n$, where n_B = total number of fish occurring in a particular size class. The total number of a species recovered = n. Expected values were determined from $P(A) \cdot P(B)(n) = n_A n_B/n^2 \cdot n = n_A n_B/n$. Results are presented in Table 14.

Differential size class mobility was highly significant for all species. Lack of recovery in the smaller size classes of the white sucker indicated differential mobility only in the intermediate (9-12 cms) and larger size classes. Only a dependent relationship between size class and movement was established. No indication of relative degree of mobility of large and small size classes existed. Table 15 presents the results of separate Chi-square independence tests on smaller (includes intermediate) and larger size classes of two species, to determine existance of a dependent relationship in both classes. Shortnose dace have been omitted since only three size classes for this species existed. White suckers were omitted because small size classes were not represented in recovery data (Table 14).

TABLE 14

Chi-square Analysis of Differential Size Class Mobility Based on Recovery Frequencies

Species	Size Class	Obs	Exp	$\frac{(O-E)^2}{E}$	% of Freedom	Chi-square Value
C. Chub	5-7cms	21	6.9	28.810	4	192.1**
	7-9	31	10.2	42.422		
	9-12	51	16.7	70.453		
	12-15	20	6.6	27.212		
	15-over 22	17	5.6	23.207		
Sn. Dace	5-7	53	28.6	20.822	1	2291.8**
	7-12	140	9.0	2271.98		
Stoneroller	5-7	16	9.2	5.034	3	383.7**
	7-9	210	178.5	5.562		
	9-12	117	67.4	365.013		
	12-15	26	15.0	8.073		
W. Sucker	5-7	not represented				
	7-9	not represented				
	9-12	12	6.9	3.771	3	20.8**
	12-15	20	11.6	6.081		
	15-18	15	8.7	4.568		
	18-over 22	21	12.2	6.331		

TABLE 15

Chi-square Analysis of Differential Mobility of Small and Large Size Classes

Species		Chi-square Value
	Smaller size classes	
Creek chub	(5-9 cms)	100.6**
Stoneroller	(5-9 cms)	53.5**
	Larger size classes	
Creek chub	(9- 22 cms)	96.4**
Stoneroller	(9-15 cms)	2081.3**

Smaller and larger size classes of both species showed highly significant differential mobility. A dependent relationship was established.

Recovery ratios (Table 13) were considered fair approximations of relative mobility of larger size classes. Assumptions were (1) fin clip mortality was low for larger fish and (2) recruitment of marked individuals into a size class by growth between sampling periods was negligible or equaled abandonment of that class by growth. Studies by Shetter (1950) and Stuart (1958) have shown that the first assumption was valid. Indirect evidence formed the basis for the second assumption. A decreasing change in growth rate with increasing age has been well established for fish (Lagler et al., 1962). Recruitment into smaller size classes by growth should exceed growth abandonment of these classes because of a large decrease in growth rate within the size classes. Conversely, growth recruitment into larger size classes should not exceed growth abandonment of these size classes because of a small decrease in growth rate within the size classes. All size classes intervals must be approximately equal for the assumption to be valid.

Negligible fin clip mortality and recruitment by growth cannot be justified for smaller size classes. Since high mortality and unequal growth recruitment and abandonment may have occurred, assessment of relative mobility of smaller size classes was not justified by the above assumptions.

Another method which can be used to determine relative mobility of size classes of the four species is examination of distances moved by size classes. Distance moved by a particular fish in limited recovery was taken as half the difference between the minimum and maximum distances the fish traveled from the subsection of marking to the subsection of recovery. Complex movements were excluded. Percentages of the total number of moving recoveries in each size class moving different distances is presented in Table 16.

TABLE 16

Relationship of Species Size Classes to Distances Traveled

Species	Size Class in cms	Percent of Recoveries Moving Distances: <200 ft.	<300 ft.	≥300 ft.	≥400 ft.	≥500 ft.
C. Chub	5-7	15.63	81.25	18.74	12.49	3.12
	7-15	13.63	74.99	22.72	21.58	3.40
	15-22	38.46	38.46	46.15	61.53	not rep.
Sn. Dace	5-7	8.33	91.66	8.33	2.08	2.08
	7-9	32.07	68.81	31.12	18.86	7.54
	9-12	not rep.	60.00	40.00	20.00	20.00
Stoneroller	5-7	41.66	74.99	24.99	16.66	8.33
	7-9	21.47	70.24	29.66	18.70	4.90
	9-15	20.83	70.83	29.17	16.66	not rep.
W. Sucker	5-7	not rep.				
	9-15	12.12	78.78	21.22	12.12	3.03
	15-over22	18.42	52.63	47.10	41.10	21.05

Several generalizations can be made from results of Table 16. A consistantly low percentage of recoveries in all species were found to move less than 200 ft., indicating that all size classes generally moved more than 200 ft. between sampling periods. Creek chubs, shortnose dace, and white suckers showed a high percentage of fish moving less than 300 ft. in the lower size classes, but a decreasing percentage of fish moving this distance in the intermediate and larger size classes. In general, the three species exhibited increasing percentages of fish moving distances equal to or greater than 300, 400, and 500 ft. in the larger size classes. No relationship between size class and distance moved was apparent for stonerollers.

With the exception of stonerollers, the above generalizations imply greater relative mobility of larger fish. Results may also be interpreted in terms of a home range concept, i.e., home range size increases with increasing fish size. Relative mobility as used here refers only to distance moved and not to migratory tendencies.

Both the home range and greater-relative-distance-moved interpretations for larger size classes imply expected higher recovery percentages of smaller size classes at subsequent samplings. Less mobile smaller fish would tend to be more concentrated in marking areas due to low egression rates. The exact opposite was observed. Possible reasons were: high fin clip mortality in the smaller size classes, recruitment by growth of the smaller size classes into intermediate size classes, or extensive movement (emigration) of a large mobile proportion of the smaller size classes from the sampling areas, or a combination of all three.

The possibilities are reduced to recruitment by growth and/or emigration if mortality was negligible.

Mortality

Establishment of the existance of negligible or high mortality is essential to relative mobility assessments of small and intermediate size classes. Results of all mortality experiments indicated no mortality. In my opinion the tests were not reliable. The absence of dead fish in block nets below sampling sections did not conclusively indicate a lack of mortality. Fish dying in pools may not have floated downstream. Predatory mammals and birds may have removed dead fish from pools and block nets. During the winter all marked fish in minnow traps survived, but size classes were not well represented and the summer heat factor during handling and clipping was absent.

A more realistic and all-inclusive mortality estimate was derived from recovery data. Recovery percentages of fish marked with 1-fin clip and fish marked with 2-fin clips were compared. If appreciable handling and fin clip mortality among small and intermediate size classes occurred, doubling the handicap and increasing handling time considerably should have significantly increased mortality. Since the majority of the fish marked consisted of small and intermediate size classes, an appreciably decreased recovery percentage should have been noted in 2-clip subsections.

Ricker (1949) stated that instantaneous mortality doubled and survival percentage was lowered with the application of a second fin clip.

In Table 17 the average recovery percentages of 1-clip subsections, A-2 and B-2, have been compared with the average recovery percentages of 2-clip subsections, A_1B_1 and A_3B_3. Percentages were computed from recovery data of all six sampling periods.

TABLE 17

Comparative Recovery Percentages of 1-clip and 2-clip Subsections

Species	Percent Recovery In A_2 and B_2 (1-clip)	Percent Recovery In A_1B_1 and A_3B_3 (2-clip)	Z Value
C. Chub	40.00	40.54	.250
Sn. Dace	45.08	28.17	6.538**
Stoneroller	27.76	26.48	.757
W. Sucker	37.25	27.22	1.477

The comparison of two percentages method was used to evaluate the difference. The null hypothesis was that recovery percentages of 1 and 2-clip subsections was not significantly different, i.e., no marking mortality occurred. Rejection implied mortality. Highly significant marking mortality of shortnose dace and insignificant marking mortality of creek chubs, stonerollers and white suckers is evident from Z values in Table 17.

Since Table 17 is the most accurate estimation of mortality available for the study, relative mobility assessments of size classes based on recovery Exp/Obs ratios in Table 13 are valid for creek chubs, stonerollers, and white suckers. However, the recruitment by growth factor must be properly evaluated. Relative mobility assessments for shortnose dace size classes are not valid. Lack of expected high recovery percentages of smaller size classes based on the interpretation of greater mobility of larger size classes cannot be explained by mortality for three species. The possibilities are reduced to emigration and/or growth recruitment.

Directional Size Class Movement

Directional size class movement was analyzed during summer and fall by the Chi-square "closeness of fit" test. Expected values were determined from the assumption of random directional movement of size classes. Pooled Chi-square tests were used to accentuate consistent but insignificant directional discrepancies of independent size class tests. Size classes with no recoveries are indicated (Table 18).

Significant upstream summer movement was apparent for 9-12 cms creek chubs (Table 18). The pooled Chi-square value indicated significant species upstream summer movement, since examination of the directional discrepancies of all size classes revealed an upstream trend. Fall directional movement was not significant for creek chubs.

TABLE 18

Chi-square Analysis of Differential Directional Size Class Movement

Species	Size Class	Obs. Down	Exp. Down	Obs. Up	Exp. Up	% of Freedom	Chi-square
A. Summer							
C. Chub	5-7 cms	5	6.5	8	6.5	1	.308
	7-9	3	5.0	7	5.0	1	.900
	9-12	7	14.0	21	14.0	1	6.036*
	12-over 22	8	8.0	8	8.0	1	1.776
	Pooled	23	33.5	44	33.5		6.582*
Sn. Dace	5-7	12	14.5	17	14.5	1	.552
	7-9	22	44.0	66	44.0	1	21.012**
	9-12	not represented					
	Pooled	34	58.5	83	58.5	1	20.454**
Stoneroller	5-9	16	45.0	74	45.0	1	36.106**
	9-12	4	18.0	32	18.0	1	20.250**
	12-15	0	4.5	9	4.5	1	7.110**
	Pooled	20	67.5	115	67.5	1	66.864**
W. Sucker	5-7	not represented					
	7-9	not represented					
	9-12	4	6.0	8	6.0	1	.750
	12-15	4	6.5	9	6.5	1	1.340
	15-18	4	6.0	8	6.0	1	.750
	18-22	6	9.5	13	9.5	1	2.764
	Pooled	18	28.0	38	28.0	1	7.141**
B. Fall							
C. Chub	5-9 cms	14	14.5	15	14.5	1	.034
	9-12	14	11.5	9	11.5	1	.347
	12-15	4	5.5	7	5.5	1	.181
	15-over 22	6	5.0	4	5.0	1	.100
	Pooled	38	36.5	35	36.5	1	.122
Sn. Dace	5-7	8	12.0	16	12.0	1	2.042
	7-12	28	26.0	24	26.0	1	.170
	Pooled	36	38.0	40	38.0	1	.210
Stoneroller	5-7	4	5.5	7	5.5	1	.362
	7-9	43	62.5	82	62.5	1	11.552**
	9-12	35	40.5	46	40.5	1	1.234
	12-15	11	8.5	6	8.5	1	.940
	Pooled	93	117.0	141.0	117.0	1	9.846**
W. Sucker	12-over 22	4	6.0	8	6.0	1	.750

Shortnose dace, 7-9 cms, showed highly significant summer upstream movement. Directional movement of 5-7 cms shortnose dace was not significant. However, a highly significant pooled test accentuated the consistent upstream discrepancies for both size classes. Fall directional movement was not significant.

All size classes of the stoneroller exhibited highly significant summer upstream movement. Fall upstream movement for the 7-9 cms size class was highly significant. A highly significant pooled test suggested that upstream movement for the species during the fall was predominent, though not as pronounced as summer upstream movement.

Larger size classes of the white sucker showed insignificant directional movement during both seasons, but the highly significant pooled test of Table 18A accentuated a consistent upstream summer trend.

Pooled test results in Table 18 are consistent with the species directional Chi-square analysis of Table 9. Therefore, directional size class movement can be related to movement of the total fish population of the study area. The four species comprised the majority (65.16 percent) of the population. Consequently, it is highly probable that the upstream summer migration depicted in Fig. III consisted primarily of stonerollers (all size classes) and dace (mostly 7-9 cms size class), these two species being most abundant. Creek chubs, 9-12 cms, probably contributed to a lesser extent. Pooled test results present the possibility that all size classes of the four species may have been involved to varying degrees.

Fig. III shows a steadily increasing population of the four species in section A, supporting the upstream migration claim. A similar population increase could result from growth recruitment. However, sections B and C did not show the same consistent population increase, which would be expected if growth recruitment were the cause. Further evidence of upstream migration of stone-rollers, shortnose dace, and white suckers can be seen in Tables 5 and 6. Percentage of total catch of these three species in section A was highly unstable (Table 6). Percentages increased steadily throughout the sampling periods (Table 5). Growth recruitment was dismissed as a possible cause, since similar increases were not observed in sections B and C.

Increased fish populations and increased species percent composition resulting from downstream migration into section A from headwaters were unlikely because of the headwater location of section A. Increased concentrations due to upstream migration into headwater areas seemed more logical.

Extensive Movement

Relatively few individuals were found which exhibited extensive movement (Table 19). Due to low recovery, results were not statistically analyzed, and reliability of size class recovery percentages was questionable. A complimentary relationship between low recovery percentage of small size classes in limited movement and high recovery percentage in extensive movement was not established. Conversely, the opposite was not demonstrated for larger size classes. Such relationships would have supported the argument for greater relative mobility of smaller size classes. Results imply that intermediate and large size classes were more mobile than small size classes, supporting the argument for greater relative mobility of larger size classes.

TABLE 19

Percent Recovery of Size Classes in Extensive Movement

Species	Total No. Found	% in Small Size Class	% in Interm. Size Class	% in Large Size Class
Creek chub	19	15.7	26.3	57.9
Shortnose dace	26	42.3	53.8	3.8
Stoneroller	21	23.8	28.6	47.6
White sucker	13	0	0	100

Only two fish were found to display complex movements. A white sucker from A-1 moved downstream 2.5 miles to the tributary and up the tributary approximately 300 ft. during the summer. A stoneroller from B-2 moved upstream 2.5 miles to section A-3 during the summer and was found downstream in section B-1 the following winter.

Superimposition of sectional marking schemes resulted in recognition at successive sampling periods of fish which moved from one section to reside in another. A creek chub moved downstream from A_3 to B_3 and remained in B_3 for two consecutive sampling periods. Another creek chub moved upstream 0.5 miles from D-2 to B-3 and remained for two consecutive sampling periods. Fish showing complex movements and fish moving from one section to reside in another were of larger size classes.

Winter Data

Very few marked fish were found during the winter. Traps were highly selective for small and intermediate size classes. No statistical analysis was attempted. A large concentration of stonerollers was found in traps of section C. Two stonerollers had moved downstream from section B and one from section A. The stoneroller exhibiting complex movement moved downstream to section B from section A during the winter. A winter downstream movement trend of this species was possible. Evidence of winter downstream movements of creek chubs, shortnose dace and white suckers was not found.

DISCUSSION

In general, Fig. II is thought to be a reliable approximation of population structure for fishes 5 cms and larger. Funk (1949) has stated that the electrofishing technique results in a fairly complete enumeration of fish populations in portions of small streams. The techique has one disadvantage since it is not selective for fish less than 5 cms. Fishes of this size were observed to swim away from electrodes unaffected. It is my opinion that this size class was underestimated for all species, especially during the summer before growth recruitments to the 5-7 cms size classes occurred.

Interpretations of considerable emigration and immigration from results of Table 4 appear to be valid except for shortnose dace, since an analysis of recovery percentages of 1 and 2-clip subsections indicated marking mortality was not significant (Table 17). Increased fish populations and low mark-recapture ratios during one or two sampling periods could be explained by growth recruitment. Recruitment of the less than 5 cms size class into the 5-7 cms size class may have occurred at some time during the study. However, growth recruitment was probably not responsible for constant low recovery percentages (approximately 14 percent) extending from late June to early November. Spring sampling confirmed that the year classes spawned the previous spring for all species were less than 5 cms.

All four species are spring spawners. Emigration was established from extensive movement recoveries, low recovery frequencies of marked fish of species displaying no marking mortality, and frequent occurrence of limited movement exceeding 500 ft. Immigration was established from the presence of large percentages of unmarked intermediate and large fish at successive sampling periods, which could not have been due to natality or growth recruitment during a 3 to 4 week period.

Predominantly unstable species populations in all sections indicated movement. Population increases followed by decreases were noted in two of the three sections. Under these conditions, population changes due to growth recruitments were not likely. Low recovery percentages caused by high natural mortality was doubtful for the species concerned during the five month period. Examination of size classes throughout the study indicated that the life span of all species exceeded 5 months. Natural predation was believed to be minimal due to the scarcity of predacious fishes.

It is possible that a large percentage of the four species were mobile and that limited recovery observations involved only sedentary groups. A more plausible interpretation was advocated by Gerking (1959). He stated that quantitative expressions of degree of straying described the techniques of the investigator as well as the behavior of the fish. Accordingly, use of larger sampling sections might have resulted in larger recovery percentages and lower mobility and instability estimates. Few intersectional movements were observed between sections B and C, which were only 0.5 miles apart. If large percentages of species populations were mobile, an appreciably greater number of intersectional recoveries should have been noted. The assumption that most of the unrecovered fish had moved less than 0.5 miles upstream and downstream from sections seemed more logical. Thus extension of sampling areas to 2000 or 3000 ft. should have greatly increased recovery percentages. With this interpretation, movement tendencies indicated by analysis of limited recovery data of 800 ft. sections were considered as characteristic of the whole population and not just a sedentary group. However, relative stability estimates may not have been accurate. Relative species stability estimates for small stream sections are always less than estimates for large stream sections. Variation is due to sampling inconsistancies and limited movement habits resulting in slight differences in species distribution at successive sampling periods. Such variation is less for larger sections because slight distributional differences and species percent-composition discrepancies resulting from sampling inconsistancies are minimized. Bangham and Bennington (1939) reported considerable variation in percent-composition of white suckers in 1 mile sections at successive sampling periods, but percent-composition of creek chubs did not vary. These findings are in partial agreement with my findings.

Statistical analysis indicated that creek chubs were more stable than white suckers (Table 6). Instability implications of Chi-square homogeneity tests in Table 6 resulting from analysis of relatively small sample sizes and areas must be accepted with some reservation.

Significantly greater fall mobility was established for shortnose dace and stonerollers (Table 7). It is suggested that increased mobility was apparent rather than actual because of more random fall movement. Summer recovery of moving fish was largely confined to upstream areas of sections due to an upstream movement trend. Many mobile fish immediately beyond the upstream boundaries may not have been accounted for. Fall recovery of moving fish was more evenly distributed throughout the sections. Effective recovery areas for moving fish were increased, resulting in higher recovery frequencies of mobile fishes and consequent greater mobile sample proportions. Insignificant seasonal change in mobile sample proportions of creek chubs was probably due to a less significant and less apparent upstream summer trend (Table 9, Fig. IV). Approximately normal seasonal recovery distributions and only slight seasonal directional movement variations for white suckers do not explain the highly significant fall decrease in the mobile sample proportion of this species.

In view of the above considerations, fall mobile sample proportions (Table 7) may be more accurate mobile population proportion estimates for species than seasonally averaged values (Table 8), with the exception of the white sucker. Funk's (1955) findings that mobile proportions were higher in the spring and summer support the claim that the fall increase was only apparent. They also explain the fall decrease in the mobile proportion of white suckers.

Classification of the four species as mobile, semimobile or sedentary is controversial. Low recovery percentages at successive sampling periods in the absence of mortality suggest a high percentage of mobile fish and a mobile classification. The interpretation that most unaccounted for fish were probably located within 0.5 miles upstream and downstream from sections, based on low intersectional recovery between B and C, suggests a sedentary classification. Percent-mobile and percent-sedentary sample proportions of Table 8 imply semimobile classifications. Evidence of mass summer and winter directional migration tendencies of all species again suggests mobile populations. Increased concentration in headwater areas during mid and late summer, followed by decimation of headwater areas in winter and early spring with concurrent heavy downstream (from the study area) concentrations were observed. Populations may have been sedentary in headwater areas during part of the summer, sedentary in downstream areas during part of the winter, and quite mobile during transitional or interseasonal migrations between summer and winter locations. Sedentary-mobile classifications of fishes exhibiting such annual movement tendencies may be artificial. Nevertheless, evidence of sedentary and mobile qualities for all species during the study indicates that a semimobile classification for all four species is appropriate. Mobile and sedentary population proportions apply to species populations only when mass migrations are not taking place.

Directional movement was well established (Table 9 and Fig. IV). An upstream summer trend which changed to an approximately random fall trend confirmed an increasing fall downstream movement. It is speculated, in view of winter downstream movement tendencies exhibited by stonerollers, that a winter downstream trend occurred. Upstream summer movement and downstream winter movement were reported by Bjorn and Mallet (1964). Results of April electrofishing indicated decimated headwater areas and high concentrations of stonerollers and creek chubs in areas downstream from the study area. Low fall recovery of white suckers throughout the study area, an absence of white suckers in headwater areas during the winter and an increased concentration of suckers in headwater areas in April supported a post-fall downstream migration of this species. The interpretation is in agreement with Reighard's (1920) and Shetter's (1938) observations.

A possible explanation for decreased fall upstream movement was presented in Table 10 and the following regression analysis.

Upstream movement appeared to be dependent on water temperature for two species, but many other factors such as photo period responses due to seasonal change and inherent biological "clocks" were not considered. Thus an exact causual relationship was not proposed. It is suggested that the regression equations may prove useful in practice. The explanation of the exact relationship between water temperature and upstream movement is lacking.

An obvious limitation to application of regression equations of time vs. percent recovery (Table 12), implying greater dispersal with time, is the life span of the fish. Proposed equations may be of value in short term mark-recapture studies. Due to high marking mortality, the equation is not recommended for shortnose dace.

Differential mobility of all size classes was established by Chi-square tests of independence (Table 14 and 15). Differential size class mobility was based on Chi-square independence tests of expected and observed recovery frequencies of Table 13. Recovery frequencies were associated with greater relative mobility of smaller size classes. An analysis of distances moved by size classes (Table 16) indicated greater mobility of larger size classes. However, from an inspection of percentages in Table 16, it can be seen that application of a Chi-square independence test would also establish a dependent relationship between size class and distance moved. Thus differential size class mobility was established regardless of which relative mobility of size classes argument was accepted. Relative mobility of size classes was not established with certainty. Analysis of recovery Exp/Obs ratios supports the argument of greater mobility of smaller size classes (Table 13). A comparison of distances moved by size classes supports the argument for greater mobility of larger size classes (Table 16).

Relative size class mobility has been established from Table 13 with proper consideration of recruitment by growth. Greater relative mobility of smaller size classes was established, but relative mobility of each size class was not established. Low Exp/Obs ratios of larger size classes were taken as evidence of less mobility. It was assumed that growth recruitment between small size classes greatly exceeded growth abandonment. Therefore, respective recoveries ratios of small size classes were not indicative of relative mobility. However, when small and intermediate size classes were combined (Table 13), high Exp/Obs ratios indicated greater relative mobility of this size class complex. Negligible recruitment of this size class complex to larger size classes was assumed. The assumption seemed valid for a 3 to 4 week interval. The argument applies to creek chubs, stonerollers and white suckers. Due to marking mortality, similar interpretations based on recovery frequencies are not justified for shortnose dace size classes.

The argument for greater mobility of larger size classes is based on the results of Tables 16 and 19. With the exception of stonerollers, Table 16 indicates that larger size classes moved relatively greater distances than smaller size classes. The interpretation is consistant with Larimore's (1952) suggestion that greater mobility may be due to relative swimming ability.

Acceptance of greater mobility of larger size classes implies that higher recovery frequencies of small size classes should have been observed. Mortality, emigration and growth recruitment were proposed to explain the lack of such recovery. Mortality was shown to be negligible for three species. Extensive movement of large proportions of the 5-7 cms size class from sampling areas was not confirmed (Table 19). Low recovery frequency for all species decreases the reliability of Table 19, but no other information on relative extensive size class movement existed. Therefore, considerable growth recruitment between the 5-7 cms and 7-9 cms size classes appeared to be the most logical explanation.

Relative mobility of large and small size classes appears controversial. Gerking (1950, 1953, 1959) noted a predominance of large stray fish. Greater mobility of small size classes has not been found in the literature. Higher percentages of intermediate and large size classes displaying extensive movement (Table 19) support Funk's and Gerking's findings. The greater mobility of larger fish apparent in Table 16 agree with Larimore's suggestion.

Greater relative mobility of larger size classes was advocated in this study for the following reasons: Distances traveled (Table 16) were direct evidence of greater mobility of larger size classes. Inferences of greater mobility of small size classes based on recovery ratios in Table 13 were indirect evidence because definite proof of fish locations was not available. The argument for negligible marking mortality and the assumption of negligible growth recruitment between the small-intermediate size class complex and the larger size classes may not be entirely valid. The argument for greater relative mobility of larger size classes is supported in the literature (Gerking 1950, 1953, 1959; Larimore 1952).

Conclusions regarding mortality of 1 and 2-clip subsections are only valid if increasing handling time and doubling the handicap increased mortality. The assumption is logical and is supported by Ricker (1949).

Upstream summer movement tendencies of creek chubs and shortnose dace were largely confined to movements of a single size class (Table 18). However, pooled tests closely agreeing with species directional movement depicted in Table 9 and Fig. IV, indicated nearly all size classes displayed some summer upstream tendencies. Apparently all size classes of stonerollers and white suckers contributed to upstream summer movement.

The argument that increasing fish populations in section A is evidence of upstream movement rather than downstream movement from headwaters is logical. Steadily increasing populations in section A due to downstream movement would be possible only if a barrier to continued downstream movement below the section existed. The obvious upstream barrier to continued upstream movement, resulting in increasing fish concentrations, was the spacial limitation of the headwater area.

Low frequency of extensive recovery may have been due to less intensive sampling of intervening areas rather than to low frequency of occurrence of extensive movement. Most sampling was done in sampling areas because of time considerations. Bias in favor of sedentary fish was quite possible. Accordingly, the classification of semimobile rather than sedentary seemed even more appropriate (Funk, 1955).

Several suggestions are offered to improve future studies of this nature. Of prime importance is a more efficient and less time consuming marking program. Methods, including florescent sprays, dyes and chemicals for immersion staining techniques and tatooing or radioactive tracers may become more appropriate as they are refined (Arnold, 1966).

Construction of large screen-lined holding pens which could be placed in pool and riffle areas so that natural substrate overlies the bottom screen is suggested. Large numbers of marked and unmarked fish should be placed in experimental and control pens respectively. Species and size classes should be well represented, except for large predatory size classes of creek chubs. Size class marking frequencies should be accurately recorded. Knowledge of marking mortality and growth recruitment between size classes could then be obtained.

Sampling areas should be no less than 1 mile in length. Resulting determinations of species stability, relative amounts of extensive and limited movements, and relative distances moved by size classes would be more accurate. The fate of the 5-7 cms size class between sampling periods would also become more apparent.

Intervening areas should be sampled with equal intensity. Electrofishing and marking should start immediately after the spring runoff when upstream areas are decimated to ascertain upstream spring and early summer migrations. Winter minnow traps should be considerably larger with an increased orifice. A two year study is recommended.

SUMMARY

1. Population structures of Semotilus atromaculatus, Rhinichthys atratulus, Campostoma anomalum, and Catostomus commersoni were estimated. Relative frequencies of the less than 5 cms size classes were thought to be underestimated for all species. Seasonal recruitment by growth occurred mainly in the smaller size classes during the study.

2. Considerable immigration and emigration occurred in all sections between sampling periods. Effects of natality, growth recruitment and natural and marking mortality were shown to be secondary to actual movement.

3. Species populations were found to be unstable between sampling periods. Stonerollers and shortnose dace were more unstable than white suckers and creek chubs. Creek chubs were most stable. Conclusions were based on small sample sizes and areas and were subject to considerable error. Based on recovery data, the majority of all fish moved less than 0.5 miles upstream and downstream from sampling sections between samplings.

4. Mobile and sedentary species groups were recognized during non-migratory periods. Shortnose dace, stonerollers and white suckers showed significant seasonal changes in mobile sample proportions. The evidence suggests that increased seasonal changes, because of upstream summer migratory trends, were apparent rather

than actual. Fall mobile sample proportions for creek chubs, stonerollers and shortnose dace were considered more accurate population estimates than seasonally averaged values. The white sucker showed a decreased fall mobile sample proportion.

5. All species were classified as semimobile due to evidence of both mobile and sedentary annual movement tendencies.

6. A linear relationship between decreasing upstream movement and decreasing water temperature was found for creek chubs and stonerollers. A causual relationship was not advocated, but the regression equations may have practical applications.

7. An inverse linear relationship between dispersion and time was suggested. Practical usage of regression equations for creek chubs, shortnose dace and stonerollers is recommended for short term studies.

8. Differential mobility of size classes, and a dependent relationship between size class and movement, was established.

9. Evidence for two contrasting arguments of relative size class mobility was presented. Respective arguments were greater mobility of smaller size classes and greater mobility of larger size classes. Due to more direct evidence and agreement with the literature, greater mobility of large size classes was advocated.

10. Marking mortality for creek chubs, stonerollers, and white suckers was insignificant; similar mortality for shortnose dace was highly significant.

11. Growth recruitment into the next largest size class was considered the most logical explanation for the low observed recovery frequencies of the 5-7 cms size classes.

12. An upstream summer movement trend was found for all species. Fall species directional movement was found to be more random. Downstream winter trends were proposed from results of winter data, observations of decimated winter and early spring headwater areas, and concurrent observations of concentrated downstream populations. Differential directional size class movement was established for creek chubs and shortnose dace during the summer. Differential directional size class movement was not observed for stonerollers and white suckers during the summer. Pooled tests indicated that all size classes of all species were involved in summer upstream movement. Fall differential directional size class movement was not significant for creek chubs, shortnose dace and white suckers, but upstream movement of the 7-9 cms size class of stonerollers was highly significant. In general, fall downstream movement increased. Evidence for a steady summer upstream migration of all species towards headwater areas was presented.

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