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PRE- AND POST-SPAWNING MOVEMENTS OF WALLEYE, *Stizostedion vitreum*, IN SOUTHERN INDIAN LAKE, MANITOBA

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ABSTRACT

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The pre- and post-spawning movements of two walleye, *Stizostedion vitreum* (Mitchill), populations from streams tributary to Southern Indian Lake, Manitoba, were studied from 1975 to 1978 by the capture of all fish ascending spawning streams in the spring, tagging of walleye on the spawning runs, and utilization of recapture information from the commercial fishery. Walleye ascended streams to spawn in the spring while Southern Indian Lake was ice covered. A stream temperature of 5°C was the minimum threshold for upstream movement and temperature reversals below 5°C caused a cessation of upstream movements. Stream discharges did not affect upstream movements. The spawning runs were composed predominantly of males and the male to female ratio was highest (up to 52 to 1) near the peak of the runs. Modal ages in the spawning populations were 9 or 10.

Fish were concentrated after spawning in shallow bays adjacent to spawning streams in late spring and early summer. Rates of dispersal away from spawning streams were highly variable between individual fish but the greatest overall degree of dispersal occurred in late summer, when walleye were captured by the commercial fishery in open, deeper areas of the lake. Movements of individual fish of up to 160 km were recorded and movements of 100 km were not uncommon. The pattern of recaptures in fall and winter suggests that walleye tend to start moving back to spawning areas soon after the summer.

Rates of homing to spawning streams were quite low, averaging 20%. However, the rates of return of fish to the general vicinity of spawning streams were much higher, averaging 62%.

The walleye populations spawning in the two study streams, which are 75 km apart by shortest water distance, appear to be distinct, showing different modal ages, different growth rates, differences in scale characteristics and little gene flow between them, as indicated by the recapture of fish tagged on one spawning stream at the other spawning stream at a later year.

Key words: spawning; migrations; lakes; reservoirs (water); homing behavior; sex ratio; age; growth.

RESUME

Bodaly, R. A. 1980. Pre- and post-spawning movements of walleye, *Stizostedion vitreum*, in Southern Indian Lake, Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 931: v + 30 p.

On a étudié, de 1975 à 1978, les mouvements avant et après la fraye de deux populations de doré jaune, *Stizostedion vitreum* (Mitchill), provenant de cours d'eau tributaires du Southern Indian Lake, au Manitoba, en capturant tous les poissons remontant les cours d'eau au printemps, en marquant les dorés jaunes en remonte et en utilisant des informations sur les recaptures fournies par la pêche commerciale. Le doré jaune remonte les cours d'eau pour frayer au printemps alors que le Southern Indian Lake est encore recouvert de glace. Une température de l'eau des rivières de 5°C constitue un seuil minimal pour la remonte, et une baisse de la température par rapport à ce seuil cause un arrêt des remontes. Le débit des cours d'eau n'affecte pas la remonte. Les reproducteurs en remonte étaient en majorité des mâles, et le rapport mâles/femelles était le plus élevé (jusqu'à 52 pour 1) près du sommet des remontes. L'âge modal de la population de reproducteurs était 9 ou 10 ans.

Après la fraye, les poissons se rassemblent dans les baies peu profondes proches des rivières à frayères, à la fin du printemps et au début de l'été. Les taux de dispersion par rapport aux frayères sont extrêmement variables d'un spécimen à l'autre, mais le degré général de dispersion le plus élevé est noté à la fin de l'été, au moment où le doré jaune est capturé par les pêcheurs professionnels loin des rivages dans les eaux plus profondes du lac. On a relevé pour certains poissons des déplacements allant jusqu'à 160 km, et des déplacements de 100 km n'étaient pas rares. Le schéma des recaptures de l'automne et de l'hiver semble indiquer que le doré jaune commence à se diriger vers ses frayères peu de temps après la fin de l'été.

Les taux de retour au cours d'eau de naissance sont assez bas (20% en moyenne). Toutefois, le taux de retour du poisson au voisinage de son cours d'eau de naissance est beaucoup plus élevé (62% en moyenne).

Les populations de doré jaune qui frayent dans les deux cours d'eau étudiés, qui se trouvent à 75 km de distance par la voie d'eau la plus courte, semble être distinctes, car elles presentent des ages modaux différents, des taux de croissance différents, des différences dans les caractéristiques des écailles et peu d'échanges génétiques, comme le montre la recapture dans un cours d'eau de poissons marqués à l'autre cours d'eau dans une année antérieure.

Mots-clés: reproduction; migrations; lacs; réservoirs (d'eau); maintien de remontée; rapport des sexes; âge; croissance.

INTRODUCTION

The pre- and post-spawning movements of the walleye, *Stizostedion vitreum* (Mitchill), have been studied extensively in the United States, in the southern half of the natural range of the fish (Eschmeyer 1950; Smith et al. 1952; Carbine and Applegate 1946; Olson and Scidmore 1962; Forney 1963; Priegel 1970). About 83% of walleye habitat is in Canada (excluding the Great Lakes) and 95% of the commercial walleye yield is from Canada (Carlander et al. 1978), yet there have been few studies of walleye spawning movements in the northern parts of its range. Rawson's (1957) report on the walleye of Lac La Ronge, Saskatchewan, is still the only extensive study of walleye spawning movements in northern Canada.

The object of this study was to examine the spawning and post-spawning movements of walleye populations from two spawning streams tributary to Southern Indian Lake, Manitoba. Upstream spawning movements, stream conditions during spawning migrations, dispersal after spawning and rate of return to the spawning streams in successive years were documented. Walleye are known to home to particular spawning sites on a year-to-year basis although this homing behavior seems to be weakly developed (Smith et al. 1952; Olson and Scidmore 1962; Rawson 1957; Stoudt 1939; Crowe et al. 1963; Forney 1963). Olson et al. (1978) have hypothesized that walleye reproductive homing is an adult learned behavior as opposed to the natally imprinted homing of Pacific salmon. However, there are few quantitative estimates of the degree of walleye reproductive homing (Olson and Scidmore 1962). Also, estimates of the rate of homing of spawning walleye depend on whether homing is defined as a return to a particular stream or only as a return to a general area. Furthermore, return to a general area may occur without spawning taking place as spawning may not be annual in some northern populations. This study documented the return of fish to the general area where tagged as compared to the specific stream where tagged by the use of observations on both spawning stream recaptures and commercial fishery recaptures.

STUDY AREA

Southern Indian Lake is located in north-central Manitoba, Canada (57°N, 99°W; Fig. 1) on the Churchill River. It is a riverine lake which has been manipulated extensively for the diversion of most of the flow of the Churchill River for hydro-electric purposes. Before diversion, the Churchill River (mean flow 1000 m^3 sec^{-1}) entered Southern Indian Lake at its southwest corner, flowing through most basins of the lake and flowing out at Missi Falls (Fig. 1). A control structure at Missi Falls was closed in June 1976 and an operating level 3 m above former mean elevation was reached in September 1976. Partial diversion of Churchill River flow through an artificial channel off the South Bay basin of Southern Indian Lake started in summer 1976 and full operating diversion of 850 m^3 sec^{-1} was reached by fall 1977.

Southern Indian Lake is a large lake with a post-flooding surface area of 2530 km^2 and post-flooding mean depth of 10 m (Cleugh et al. 1974). Lake level is regulated within a 1 m operating range.

The walleye spawning populations of two streams tributary to Southern Indian Lake, Sandhill and Poplar streams, have been studied (Fig. 1). Sandhill stream is the larger stream; flows during May have ranged from 1.3 to 7.8 m^3 sec^{-1}. Flows on Poplar stream during May have ranged from 0.3 to 3.3 m^3 sec^{-1}. The two spawning streams are approximately 75 km apart by the shortest water route. Prior to flooding, Sandhill stream had several series of rapids over large boulders. The first series of rapids was approximately 5 km from the head of Sandhill Bay. Flooding in late 1976 brought the lake level to between the first and second series of rapids. Before flooding, Poplar stream had two series of rapids. The first rapids were approximately 5 km from the head of Poplar Bay. The 1976 flooding brought the lake level to between the first and second series of rapids.

MATERIALS AND METHODS

Very soon after ice left Sandhill and Poplar streams (while ice was still covering Southern Indian Lake proper) a one-directional weir was constructed across the stream below the first set of (unflooded) rapids. Before flooding (1975 and 1976), the trap site was downstream of all stream rapids whereas after flooding (1977 and 1978) the trap site was upstream of the first flooded rapids but downstream of all unflooded rapids. The weir consisted of an open-topped box of cedar and wire mesh construction with a vertical opening approximately 15 cm wide on the downstream side. During normal operation, wire mesh wings from each side of the weir box to the shore directed all fish moving upstream into the weir box. During periods of very high flow, the weir wings were opened to prevent injury to fish moving downstream and to prevent the weir from washing downstream.

All fish entering the weir box were counted and released upstream of the weir. All walleye, to a maximum number that could be handled each day were tagged with white or orange Floy (spaghetti) tags bearing the words "Fisheries Reward" and a numerical code unique to each fish. Commercial and sport fishermen were paid a $1.00 reward for each tag returned with information as to place and date of capture of tagged fish. Walleye tagged and recaptured were weighed to the nearest 25 g, fork length was determined to the nearest 0.5 cm and sex was determined by type of gonadal product expelled upon squeezing the abdomen. The sex of almost all walleye sampled could be determined in this way. The overall sex ratio for each year's spawning run was determined as the products of the sex ratio of the daily sample of tagged and re-captured fish and the total of each day's run, summed over all days of the year's run.

Walleye from Sandhill stream in 1978 and from Poplar stream in 1977 and 1978 were aged from sections of dorsal spines (Campbell and Babaluk 1979). Fish were stratified sampled by 25 cm length classes up to a maximum of 20 fish per length stratum (Ricker 1975). Total age distribution were calculated from total length distributions and age distributions within each length stratum.

Total walleye spawning runs were observed and enumerated by weir operations in 1976, 1977 and and 1978. In 1975, the first portion of the upstream movements of walleye on Sandhill stream was missed. At the Poplar stream in 1975 the upstream movement of walleye was missed, however some fish were tagged while moving downstream after spawning.

Stream temperatures were monitored by mercury maximum/minimum thermometers. Stream flows were estimated by various methods, depending on the amount and type of data available. Relative stream height (approximate) only was taken for Sandhill stream in 1975. In 1976-1978 daily discharges were calculated from level readings taken manually (daily or more often) or continuously. For Poplar stream in 1976 and 1977 and for Sandhill stream in 1976, daily discharges were calculated from the equation $Q = cLH^{1.5}$ (where Q = discharge, c = a constant, L = width of stream, and H = depth of water). The constant, c, was derived from one metering of actual stream flow. For Sandhill stream in 1977, daily discharges were calculated from a Manning equation of the form $Q = \frac{1.49}{n} wd^{1.67} s^{.5}$ (where Q = discharge, n = a coefficient of bottom roughness, d = depth of water, w = width of stream, and s = slope of stream bed). Calculation of n was based on one measurement of Q, w, d and s; d varies directly with gauge height. For Poplar and Sandhill streams in 1978, daily flows were calculated from a stage-discharge regression ($Q = ah^b$) based on five meterings of actual stream flow from 0.5 to 1.5 $m^3 sec^{-1}$ on Poplar stream and from 2.4 to 4.5 $m^3 sec^{-1}$ on Sandhill stream.

RESULTS

UPSTREAM MOVEMENT OF FISH

Large numbers of fish were found to be migrating upstream on Sandhill and Poplar streams soon after ice left the streams and while Southern Indian Lake was still ice covered. Four species of fish were caught in the traps: walleye, northern pike (*Esox lucius* L.), longnose sucker (*Catostomus catostomus* (Forster)) and white sucker (*Catostomus commersoni* (Lacepede)).

Spawning migrations of walleye, pike, longnose sucker and white sucker up Sandhill and Poplar streams occurred exclusively in the month of May (Fig. 2-8). Movement of fish began from the 5th to the 15th of May and was largely finished by the 15th to the 30th of May. Duration of the migration was from 10 to 18 days. The total numbers of walleye, pike and longnose sucker captured on Sandhill stream, the larger of the two streams, were consistently larger than numbers caught on Poplar stream (Table 1). The total numbers of white sucker caught on the two streams were similar. Walleye numbers have varied considerably over the four years of trap operation with a considerable decline in total numbers at both streams in 1978. The number of pike captured have shown a consistent increase from 1975 to 1978.

The upstream movement of fish was associated with rising stream temperatures and stable stream flows (Fig. 2-8). Walleye movement was usually minimal until stream temperature reached at least 5°C. In 1977, when the stream temperature rose quickly and steadily and stream flow was relatively constant at moderate flow, the number of walleye moving upstream per day reached a peak 3-4 days after the start of movement and dropped steadily after this peak (Fig. 4 and 7). Peak numbers of migrating walleye in 1977, at both Sandhill and Poplar streams, were associated with stream temperatures of about 10 C. After the peak of migration in 1977, the numbers of walleye caught per day dropped to near zero in about 5 days.

Temperature alone appears to control walleye movements, while stream flow alone does not play a part. The onset of cool weather after the start of walleye spawning runs caused a slowing or complete stoppage of the run. Cooler weather caused decreases in stream temperatures and was usually associated with precipitation (snow or rain) which caused increases in stream discharge. However, cool stream temperatures unassociated with higher stream discharge appeared to discourage upstream movement of walleye. For example, at Poplar stream in 1976, walleye movement ceased on the 9th and 10th of May when stream temperature decreased, despite the fact that stream discharges were similar to those when the two subsequent peaks in walleye movement occurred. Also, the higher stream discharges which occurred coincidentally with lower water temperatures on 16-17 May, 1978 at Sandhill stream were apparently not a factor in slowing fish movements since the peak of the walleye migration in 1977 at Sandhill stream (Fig. 4) occurred at approximately the same discharges. Breaks in the walleye spawning runs generally occurred when stream temperature decreases were associated with discharge increases (Fig. 2, 3, 5 and 8). Such temporary stoppages of runs occurred in 3 of the 4 years that traps were operated on Sandhill and Poplar streams. The upstream movement of fish resumed when weather conditions improved and stream temperatures increased and stream flow decreased. It is known from tagging that some walleye moved downstream during periods of high water, when trap wings were usually opened. returning upstream when stream conditions improved.

The patterns of movement of pike, longnose sucker and white sucker were similar to those for walleye, although upstream pike movement generally reached a peak before, and at lower stream temperatures, than peak movements of other species. Peak movements of the four species generally occurred within 4 days of each other although on Sandhill stream in 1976, pike and white sucker peaks occurred about 9 days before longnose sucker and walleye peaks.

The upstream movement of fish followed distinct daily patterns. Captures of pike in upstream traps were largely restricted to the light period, while catches of walleye occurred almost exclusively during the dark. Both species of suckers were caught largely during the afternoon and evening periods.

SEX RATIOS

The overall sex ratio in walleye spawning runs was always strongly in favor of males but varied considerably from year to year, ranging from 3.95 to 7.51 males per female (Table 2). There appears to be a relationship between the total size of the spawning run and the sex ratio at Sandhill stream, the larger the spawning run, the greater the male to female ratio (Table 1 and 2). No comparable relationship is evident for Poplar stream.

Consistent trends in the sex ratio over the spawning run were noted only in 1977, the only year during which the run was not interrupted by cool weather (Table 3). Male to female ratios were moderately high at the beginning of the run, rose to extremely high ratios just before peak numbers were captured and declined gradually thereafter until ratios of one or less males per female occurred at the end of the run.

SIZES

The length frequency distributions for male walleye caught in spring spawning runs were similar both between years and between streams (Fig. 9). The modal length group was usually 400-424 mm fork length and only on Sandhill stream in 1975 did the modal length group differ. The average size of female walleye was considerably larger than that for males (Fig. 10). The modal length group for females was always either 425-449 or 450-474 mm fork length. The modal length group for Poplar stream females was 450-474 mm fork length for all three years while the modal length group for Sandhill stream females was 425-449 mm for two years and 450-474 mm for two years.

Consistent trends over the course of the spawning run in the average size of walleye moving upstream were evident only for the 1977 season. The average size of males on both Sandhill and Poplar streams increased from the beginning of the spawning run to a maximum at or just before peak numbers of walleye were moving upstream (Table 4). Average size of males showed a general decrease for the remainder of the spawning run. At Sandhill stream, the maximum average size of female walleye occurred on the first day that significant numbers of females were moving upstream (Table 4) and average sizes decreased thereafter. No size trends were evident in the female walleye spawning run up Poplar stream in 1977.

GROWTH

The growth of male walleye was best described by second order polynomial regressions (Fig. 11). The growth equations for male fish are as follows:

Poplar 1977: Fork length (mm) = $-1.95 \times age^2 + 54.73 \times age + 82.5$

Poplar 1978: Fork length (mm) = $0.19 \times age^2 + 18.12 \times age + 266.3$

Sandhill 1978: Fork length (mm) = $1.38 \times age^2 + 45.34 \times age + 115.6$

These equations were not compared statistically, however the growth of male walleye taken from Poplar stream in 1977 and from Sandhill stream in 1978 appears very similar whereas male walleye taken from Poplar stream in 1978 show a larger size at the younger age groups (Fig. 11).

The growth of female walleye was best described by linear regressions of size on age. The growth equations for female fish are as follows:

Poplar 1977: Fork length (mm) = $5.17 \times age + 401.5$

Poplar 1978: Fork length (mm) = $7.48 \times age + 380.8$

Sandhill 1978: Fork length (mm) = $12.79 \times age + 332.2$

Female walleye showed different growth patterns as compared to males (Fig. 11). Female fish were larger than males of the same age. These differences were large at younger ages (5-10) but tended to decrease with increasing age. The growth regressions for female walleye from Poplar stream in 1977 and 1978 were significantly different (analysis of covariance, $F_{1,91} = 4.98$, $p<0.05$) but were more similar to each other than to the growth regression for female walleye taken from Sandhill stream in 1978.

AGE STRUCTURE

The modal age for male and female walleye caught at Poplar stream was 9 for both the 1977 and 1978 samples (Fig. 12 and 13). The modal age for male and female walleye caught at Sandhill stream in 1978 was 10 (Fig. 12 and 13).

The youngest fish found to be mature were five year-old males and females while the oldest male and female fish were 16. Age distributions for both Sandhill and Poplar samples were quite irregular, perhaps due to uneveness of year class strengths or variable mortality between years or year classes. Chi-square values for tests of the assumptions of calculating a single survival estimate from the descending limb of the age frequency distribution by comparison of the best survival estimate and Heincke's estimate of survival (Robson and Chapman 1961) were significant in four of six cases tested (Table 5). Survival estimates fell within the range 0.2 to 0.5. Survival of male walleye appeared to be greater than survival of female walleye. In the only two calculations for which non-significant χ^2 values resulted, survival of male fish from Poplar in 1977 was estimated to be 0.51 and from Sandhill in 1978 to be 0.47 (Table 5). Estimates of female survival where non-significant χ^2 values resulted were 0.22 for Poplar stream in 1977 and 0.37-0.39 for Sandhill stream in 1978.

TAG LOSS

The loss rate of tags by walleye was usually low, but was quite high for the 1978 recaptures (Table 6). Tag loss was judged by the observation of tagging scars and evidence of the removal of scales and/or spines for aging in succeeding years on spawning streams. Tag loss averaged about 9% over the three years of observation while broken tags averaged about 1%. High tag loss was restricted to fish recaptured in 1978 (Table 6) and most of the fish showing lost tags were probably fish originally tagged in 1977. The majority of fish showing lost tags in 1978 at Poplar stream were identified as fish first tagged in 1977 by evidence of the removal of a dorsal spine for aging. Although not all walleye tagged at Poplar stream in 1977 could be identified in this way since not all fish had dorsal spines removed, probably almost all cases of tag loss identified at Poplar stream in 1978 were fish tagged in 1977 because of the very low incidence of tag loss recorded for fish tagged in 1975 and 1976 (Table 6). Similarly, the majority of cases of tag loss identified at Sandhill stream in 1978 were probably walleye originally tagged in 1977 because the incidence of tag loss detected in recaptures in 1976 and 1977 was only about one-third the rate recorded in 1978. Apparently poor tagging techniques by field personnel in 1977 was the cause of high tag loss rates in 1978 recaptures.

RATES OF EXPLOITATION

Rates of exploitation, as determined from rates of tag returns from the commercial fishery, have varied greatly from year to year although they have been relatively similar for the two spawning stream populations in a given year (Table 7). Exploitation was highest in 1977 when it averaged 0.48 for the Poplar and Sandhill stream populations. Exploitation was lowest in 1975 when only 3% of tags were returned. Actual exploitation in 1975 was probably somewhat higher than this figure because of the unfamiliarity of commercial fishermen with the tag return reward program. After 1975, cooperation with commercial fishermen was excellent and almost all recaptures from the fishery were probably reported. Over the period 1975 to 1978, when rates of exploitation are known, there is a general agreement between the whole lake walleye yield for Southern Indian Lake and the rate of exploitation on the Sandhill and Poplar walleye populations although there was no significant linear relation (Table 7). Total walleye catch for Southern Indian Lake over the period 1968 to 1978 has been extremely variable, ranging from zero to almost 137,000 pounds (Table 7). Average catch over this period was 53,200 pounds while the average catch over the period 1975 to 1978 was 73,600 pounds.

POST-SPAWNING MOVEMENTS

The dispersal over the summer of walleye tagged in May on the two Southern Indian Lake spawning streams was wide ranging (Fig. 14 and 15). The longest tag movement recorded was a fish tagged on Sandhill stream and recaptured in Granville Lake, Manitoba, upstream on the Churchill River, a distance of approximately 160 km by water. The fish had been at large for approximately three years. Another fish moved from Sandhill stream to Leaf Rapids, upstream on the Churchill River, a distance of about 130 km by water in approximately 14 months. The fastest fish movement recorded was a walleye tagged on the 18th of May on Sandhill stream and recaptured at the northern end of Southern Indian Lake, 100 km away by the shortest water route, on June 30th of the same year. Movements of 100 km within four months after tagging were fairly common.

Walleye tagged at Sandhill stream appeared to disperse more widely during the summer than walleye tagged at Poplar stream (Fig. 14 and 15). Walleye tagged at Poplar stream were recaptured mainly in and near South Bay, and northwards to Sandhill Bay with few fish being caught in more remote parts of the lake (Fig. 16). The pattern of dispersal after diversion of the Churchill River of walleye tagged at Poplar stream was similar to the pattern before Churchill River diversion, despite the fact that the major dispersal route of these fish was The Channel which carried negligible flow before diversion and considerable flow (850 m^3 sec^{-1}) after diversion (Fig. 1). Walleye tagged at Sandhill stream were recaptured in almost all parts of Southern Indian Lake and upstream on the Churchill River (Fig. 14). The overall pattern of dispersal of walleye tagged at Sandhill stream appeared to be similar before and after Churchill River diversion. With the exception of one recapture approximately 10 km south of South Bay, no walleye were recaptured outside the Churchill River basin on the diversion route; however, there is very little fishing pressure in this area.

The geographic pattern of walleye tag recaptures showed a general enlargement away from the spawning streams over the summer period (Fig. 16 and 17), but individual fish showed a great variance in the rate of dispersal with some fish moving away from their spawning stream quite rapidly and others moving little over the summer (Fig. 16 and 17). These individual differences may be related to sex, with male walleye tending to stay close to spawning areas and female walleye dispersing immediately following spawning, as has been shown for Athabasca River walleye (W.A. Bond, pers. comm.). Fish tagged at Sandhill stream and recaptured in the month of June were mainly (99%) caught within Sandhill Bay (Fig. 16A). Only one of the walleye caught outside Sandhill Bay in the month of June was a fish which was tagged in the year of recapture. In the month of July, most tagged walleye were still caught within Sandhill Bay but an increased proportion (10%) were caught outside the bay (Fig. 16B). Most of the fish caught outside Sandhill Bay in July were tagged in the same year as recaptured. Fish tagged at Sandhill stream showed an increased dispersal away from Sandhill Bay in August (Fig. 16C) when 91% of fish were caught away from Sandhill Bay. For the remainder of the ice-free season, September and October, the pattern of tag recaptures appears less dispersed than in late summer (Fig. 16D).

A similar pattern of gradual dispersal away from the spawning stream was evident for fish tagged at Poplar stream (Fig. 17). In the month of June almost all tags (98%) were caught within Poplar Bay. In July, the majority of walleye were still recaptured in Poplar Bay but an increased proportion were caught away from Poplar Bay. Most of the walleye recaptured in August (56%) were caught away from Poplar Bay. The pattern of recaptured fish caught in September and October (Fig. 17D) appears to be less dispersed than in August.

Few walleye have been recaptured during the winter. Almost all of the tagged fish caught during the winter were captured in The Channel near the town of South Indian Lake (Fig. 1) where fishing for domestic consumption is carried out.

RETURN OF TAGGED FISH TO THE SPAWNING STREAM

Calculation of the proportion of tagged fish that return to the spawning stream where tagged in later years is dependent on estimates of the mortality of tagged fish over the period between tagging and recaptures. The following survival estimates were used in determining homing patterns.

	Sandhill	Poplar
1975	0.55	0.55
1976	0.40	0.50
1977	0.30	0.30

These estimates will be considered more fully in the Discussion.

Rates of return of fish to the spawning stream of original capture one year after tagging ranged from 7 to 36% with an average for both streams over three years of observation being about 20% (Table 8 and 9). Average rates of homing in the first year and over all years were similar for Poplar and Sandhill fish. A pattern of increased rates of homing to the stream where tagged in the first year after tagging over the three years of study is evident (Table 8 and 9).

Usually less than half of tagged walleye recaptured inside Sandhill and Poplar Bays by the commercial fishery in early summer were fish that had been recaptured on the spawning stream fence (Table 8 and 9). In other words, many fish return to (or never leave) the general area of the spawning stream where they were tagged in a previous year but do not ascend the stream to spawn. An average of about 30% of walleye tagged on Sandhill stream which returned to (or stayed in) Sandhill Bay in later years ascended Sandhill stream to spawn (Table 8). The comparable figure for Poplar stream fish was about 40% (Table 9).

The estimates of the proportion of tagged fish that returned to (or never left) the vicinity of Sandhill and Poplar streams in later years, whether they ascended the stream where originally tagged or not, averaged 62% for both streams with a range of 18 to 131% (Table 8 and 9). The mean for Sandhill stream was 77% while the mean for Poplar stream was 47%. These figures could be calculated since the identity of all tagged fish ascending Poplar and Sandhill streams to spawn in 1976, 1977 and 1978 was known and since the proportion of tagged walleye caught inside Sandhill Bay and Poplar Bay in early summer which actually ascended the spawning streams to spawn was also known. These calculations assume that fish that ascended the stream to spawn had the same probability of being caught in the commercial fishery as fish that did not.

A small number of walleye, tagged in one spawning stream were recaptured at the other study stream in a later year (straying). Two fish, tagged at Sandhill stream have been recaptured at Poplar stream while six fish from Poplar have been recaptured at Sandhill stream. The rate of straying for fish tagged at Sandhill stream was 0.1% and that for fish tagged at Poplar stream was 0.3%, utilizing survival estimates as given in Tables 8 and 9.

DISCUSSION

STREAM CONDITIONS DURING UPSTREAM SPAWNING MOVEMENTS

The movement of walleye up spawning streams from adjacent lake areas in the spring appears to be initiated and controlled solely by water temperature. Temperatures of about 5°C appear to be the threshold for the initiation of upstream movement with peak numbers of migrating walleye being associated with stream temperatures of about 10°C. Walleye appear to have similar temperature requirements for upstream spawning migrations throughout its range (Herman 1947; Rawson 1957). In large northern lake systems, these temperature requirements mean that spawning migrations up tributaries occur with the lake proper still ice covered (Herman 1947; Rawson 1957; Bidgood 1967). Any reversals of stream temperature below the 5 C threshold after the spawning run has started result in a slowing or stopping of upstream fish movement (Fig. 2, 3, 5, 6, and 8). Derback (1947) recorded the discouraging effect of a weather reversal on tributary spawning walleye from Heming Lake, Manitoba. Similarly, Stoudt (1939), Rawson (1957) and Johnson (1971) have noted the prolongation of walleye spawning runs under cooler weather conditions and concentration of runs in years where water temperatures rose quickly. Stream discharges do not appear to affect walleye upstream spawning migrations, although increases in flow were often associated with decreases in stream temperatures. Longnose and white sucker and northern pike appear to react to stream conditions in a similar manner to walleye.

SEX RATIO AND SIZE TRENDS DURING THE WALLEYE SPAWNING RUN

The pattern of a moderate male to female ratio at the start of the walleye spawning run, rising to very high ratios just before peak fish movements and a gradual decline to approximately equal numbers of males and females at the tail of the run has not been observed before. Both Rawson (1957) and Johnson (1971) noted very high male to female ratios at the start of the run and more moderate ratios (5:1 in the case of Rawson) in the main part of the run. It is not possible to compare directly sex ratios over the course of a migration to a spawning site to sex ratio changes at a particular spawning site. However, most studies concerning sex ratios on walleye spawning beds have noted that males tend to arrive first and stay longer and that females tend to stay on the spawning site for shorter periods, probably only for actual spawning (Eschmeyer 1950; Priegel 1970; Payne 1964), and the Southern Indian Lake (Table 3) and Lac La Ronge (Rawson 1957) findings are in agreement with these studies.

The trends observed in the sizes of male and female walleye over the course of the spawning run have not been observed before. These differences were relatively small, however, and their significance is not clear.

GROWTH, AGE STRUCTURE AND SURVIVAL ESTIMATES

Rate of growth of male walleyes from Southern Indian Lake was moderate, being similar to that for Oneida Lake, N.Y. (Forney 1963) and Red Lake, Minn. (Smith and Pycha 1961) but slower than for Lac La Ronge, Sask. (Rawson 1957). Growth of female walleye from Southern Indian Lake was unusual in that fish were relatively large at younger ages but showed relatively small yearly growth increments over all ages captured (Fig. 11). Size at age 10 was much smaller than walleye aged 10 from Lac La Ronge (Rawson 1957) or Oneida Lake (Forney 1963). Perhaps female walleye from Southern Indian Lake show fairly rapid growth in early years with a dramatic slowing of growth at maturity.

The walleye populations of Southern Indian Lake are relatively old with modal ages of 9 or 10 (Fig. 12 and 13), being comparable to Lac La Ronge walleye which show modal ages of 8 to 10 (Rawson 1957). More southerly walleye populations tend to be younger. Priegel (1970) noted modal ages of 6 to 7 for Lake Winnebago, Wisconsin walleye while Johnson (1971) found modal ages were 4 to 5 for males and 7 to 8 for females in Little Cut Foot Sioux Lake, Minn. In Oneida Lake, modal ages were 5 to 7 for males depending on year class strengths and were 5 to 9 for females (Forney 1963). Combined male and female age frequency distributions for Bay of Quinte, Ontario, walleye showed age 3 or 4 to be modal (Payne 1964).

The estimation of annual survival rates has importance in the calculation of rates of homing. In this study, a large majority of homing fish were males and this discussion will, therefore, center on male survival rates. Both estimates for male samples for which the assumptions of calculating a single annual survival rate from a catch curve did not appear to be violated (samples from Poplar stream in 1977 and Sandhill stream in 1978) were close to 0.5 (Table 5). However, levels of exploitation, which probably affect annual survival rates, have not been constant over the period 1968 to 1978 (Table 7). Ricker (1975) has shown that survival rates estimated from catch curves reflect survival rates operative when the year classes were being recruited into the catchable population. The descending limb of the catch curve from the sample of male walleye from Poplar stream in 1977 included fish which were 9 to 14 years old. These were recruited into the spawning popluation at ages 6 to 8 over the period 1969 to 1976. Average walleye yields for all of Southern Indian Lake over this period was 53,000 lbs. Similarly, fish on the descending limb of the catch curve for the male sample from Sandhill stream in 1978 were recruited into the spawning population at age 6 to 9 over the period 1968 to 1977. Average walleye yield for all of Southern Indian Lake over this period was 54,000 lbs, a yield very similar to the comparable figure for Poplar stream. As annual mortality estimates from catch curves were very similar for the two populations (~0.5), they seem to respond similarly to similar average whole-lake commercial yields. The average whole lake walleye yield over the period 1975 to 1978, for which tag estimates of exploitation rate are available, was about 74,000 lbs and the average rate of exploitation (μ) for both Sandhill and Poplar streams over this period was 0.27 (Table 7), if it assumed that actual μ values for 1975 were about 0.10. It is therefore assumed that average μ values over the period of recruitment of the male Sandhill and Poplar stream samples (1968 to 1977) are somewhat lower than 0.27 since average commercial yield was somewhat less than for the period 1975 to 1978 when exploitation was known to be 0.27. Annual survival of about 0.5 is therefore assumed to be in response to an exploitation rate of about 0.25.

The relation between fishing mortality and natural mortality is unknown, however, the following simplifying assumptions could be made. Total annual mortality could be constant regardless of changes in fishing mortality because total annual mortality could be completely compensating with one fish dying in the fishery increasing the chances of other fish living. Alternatively, it could be assumed that fishing mortality acts on the population immediately following spawning (see Discussion: Post-spawning dispersal patterns) and that a natural mortality of, say, 0.4 acts on the survivors over the remainder of the year. If the latter assumption approximates reality, then annual survival rates for the Sandhill and Poplar walleye populations are:

	Sandhill	Poplar
1975	0.55	0.55
1976	0.40	0.50
1977	0.30	0.30
1978	0.46	0.42

POST-SPAWNING DISPERSAL

The walleye is well known to be a wide-ranging fish. In all studies of walleye movements in fairly small lake systems, with the longest axis of the lake up to about 40 km, walleye have been shown to disperse all over the lake (Eschmeyer and Crowe 1955; Smith et al. 1952; Carbine and Applegate 1946; Rose 1949; Stoudt 1939; Forney 1963). For larger lake and river systems, including Southern Indian Lake, movements up to and exceeding 75 km are not uncommon (Eschmeyer and Crowe 1955; Carbine and Applegate 1946; Bidgood 1967; Rawson 1957; Ryder 1968; Doan 1942; Payne 1964).

The pattern of recaptured fish depends in part on the actual movements of the fish and in part by the pattern of commercial fishing. In Southern Indian Lake, fishing specifically for walleye is done only in late spring and early summer in shallow bays off the main basins adjacent to known spawning streams. Fishing for walleye starts as soon as regulations allow (generally 1st June or 1st July) and by the month of August, very few fishermen continue to fish for walleye in these bay areas, saying that catches fall off as the summer progresses. Walleye are caught incidentally in the lake whitefish fishery conducted in summer and winter away from the lake shore in relatively deep (15-20 m) water.

In Southern Indian Lake, there are concentrations of walleye in bays adjacent to spawning streams in late spring and early summer. Most late spring and early summer recaptures were from Sandhill Bay and from the Poplar Narrows area (Fig. 16 and 17) and fishermen apparently take advantage of these concentrations of fish at this time of the year. By late summer, the fish have dispersed sufficiently that commercial fishing in areas adjacent to spawning streams is no longer profitable. Most recaptures in late summer come from open water, deeper areas of the lake as incidental catches in the whitefish fishery, indicating that the walleye tend to disperse away from areas adjacent from spawning streams into the deeper waters of the lake. The patterns of fish dispersal away from spawning areas in Southern Indian Lake are very similar to those reported by Rawson (1957) for Lac La Ronge.

There was a large amount of variation in the rate of dispersal of individual fish away from the spawning site. By late summer, many fish had moved extensively over Southern Indian Lake while many others had apparently not left the bay areas adjacent to spawning streams (Fig. 16 and 17). In most other studies of lake systems where spawning sites were close to the lake in which walleye fed during the summer, this variation in the dispersal rate of individual fish away from spawning areas has also been noted (Eschmeyer 1950; Eschmeyer and Crowe 1955; Bidgood 1967; Rawson 1957; Forney 1963). Where walleye dispersal has been studied in systems where spawning sites were far removed along a river system from the lake of summer feeding, a relatively rapid and complete movement of fish back to the lake was noted immediately after spawning (Herman 1947; Ferguson and Derksen 1971). Payne (1964) also noted a fairly rapid post-spawning movement of many tagged walleye out of the Bay of Quinte, presumably because they were seeking the cooler waters of Lake Ontario.

The pattern of tag recapture for the fall period gives an indication of a less dispersed pattern than during the late summer (Fig. 16 and 17). This may be due to fish moving out of deeper waters and, therefore, being less vulnerable to the whitefish fishery or it may be due to movements of some fish back towards spawning areas. Payne (1964) found indications of returns of fish tagged in the Bay of Quinte at spawning back to the bay from Lake Ontario starting in September. Similarly, Wolfert and Van Meter (1978) found that Lake Erie walleye started returning to spawning areas in late summer and autumn.

There have been no tag recaptures from the winter whitefish fishery conducted from January to March. The walleye catch from the winter fishery has traditionally been less than 5% of catch (Weagle and Baxter 1973). Some tagged walleye are caught in shallow, bay areas during domestic fishing in the winter. In Lac La Ronge, walleye are found only in shallow, bay areas during the winter and are, as in Southern Indian Lake, generally absent from deeper areas of the lake during winter (Rawson 1957).

HOMING

Walleye are known to utilize the same spawning areas in successive years in preference to other available areas (Smith et al. 1952; Olson and Scidmore 1962; Rawson 1957; Stoudt 1939; Crowe et al. 1963; Forney 1963) and this tendency has been termed homing. The tendency to home is apparently weakly developed in walleye but calculated estimates of homing depend on exactly how homing is defined. Homing could be defined strictly as the return of fish to a particular spawning stream or shoal or defined less rigorously as the return of fish to a particular region, stream system, or series of streams. In order to estimate homing rates, spawning runs must be completely enumerated for marked fish on a year-to-year basis, using marks from which the homing history of individual fish can be determined. Also, appropriate survival estimates must be available in order to estimate homing. Olson and Scidmore (1962) defined homing as return of marked fish to a river inlet on a small Minnesota lake of area about 7 km^2. Homing in the first year following tagging was about 30% with application of an appropriate survival estimate. Homing in the first year following tagging for both study streams tributary to Southern Indian Lake averaged 20%.

The rates of walleye homing to a particular stream or shoal are influenced by the degree of permanent dispersal away from the vicinity of the stream or shoal, by the tendency of fish to utilize alternate streams or shoals near the particular site under study and by whether spawning is annual for all fish. Fish that leave the general vicinity of a particular spawning site and do not return by the following spring have no opportunity to spawn at that spawning site and in Southern Indian Lake about half the walleye tagged at Poplar and Sandhill streams leave the Sandhill and Poplar Bay areas and do not return in later years (Tables 8 and 9). This type of permanent dispersal probably varies depending on the size and nature of the aquatic system being considered, tending to be greater in larger lake and river systems such as Southern Indian Lake, than in smaller lake and river systems.

Not all fish that return to (or never leave) the general vicinity of the stream where tagged will spawn in that particular stream in a given year (Table 8 and 9) and this may be due to fish not spawning every year, to the use of alternate streams or shoals in the area, or both. Walleye are not obligate stream spawners and individual fish could be spawning in a particular stream one year and a nearby shoal the next. Also, walleye are known to utilize alternate streams within close proximity of each other (Smith et al. 1952; Stoudt and Eddy 1939; Crowe et al. 1963; Forney 1963).

The use of alternate streams or shoals within a particular area by individual fish may underly the great variation in the total numbers of walleye spawning in Sandhill and Poplar streams from year to year. Conditions in particular streams with regard to flow or temperature may be more favorable or attractive to fish in certain years so that greater numbers of fish are enticed into that particular stream. Two apparent relationships have been noted in the literature between the size of walleye stream runs and conditions in a particular stream on a year-to-year basis. Olson and Scidmore (1962) noted an apparent relationship between stream flow and the size of a walleye spawning run, observing greater numbers of walleye when stream flows were higher. Johnson (1971) presented data for 17 years of a walleye spawning run, giving total size of the run and overall sex ratio. There is a significant correlation between these two parameters with high M:F ratios tending to occur in years with a relatively large spawning run. There is a suggestion of correlations between the size of walleye spawning runs at Sandhill and Poplar streams and both stream flows and overall sex ratio, especially if the catches of 1977 and 1978 are considered to have been reduced due perhaps to fishing pressure or the flooding of the first spawning rapids in both streams.

DISCRETENESS OF SANDHILL AND POPLAR POPULATIONS

The Sandhill and Poplar walleye populations are evidently far enough away from each other that they remain largely genetically discrete. The rate at which walleye stray between two spawning sites is apparently dependent in part on the distance between the sites. Straying has been observed previously only between spawning sites that are relatively close together, that is less than 20 km apart (Stoudt and Eddy 1939; Crowe et al. 1963; Forney 1963; Rawson 1957), with the exception of the record of straying between two streams on the Red Lakes, Minn. system that are 70 km apart (Smith et al. 1952). Other studies of spawning sites located a long distance apart (50-60 km) found no straying between the sites (Priegel 1967; Crowe et al. 1963). The Southern Indian Lake spawning streams are about 75 km apart and straying between them was present but at a very low level. Thus, there is evidently a very low level of gene flow between the two spawning populations.

The lack of extensive gene flow between the Sandhill and Poplar walleye populations has apparently led to a number of genetic and/or environmentally based differences between them. Thus the age distributions (Fig. 12 and 13) and growth rates for females (Fig. 11) are different for the two populations. Also, in attempting to age these fish from scales, it was noted that the distinctness of the annuli was markedly different for fish from Sandhill stream as compared to fish from Poplar stream.

The tendency of walleye to home repeatedly to a particular spawning site is a force that promotes the differentiation of various spawning populations, allowing for the possibility of adaptation to local ecological conditions. The fact that Southern Indian Lake is a large, riverine system probably tends to allow for extensive dispersal and, therefore, tends to promote mixing between spawning populations relative to other systems which have been studied.

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REFERENCES

BIDGOOD, B.F. 1967. Ecology of walleyes in Richardson Lake - Lake Athabasca. Alberta Fish Wildl. Div. Fish. Sect. Res. Rep. 1: 20 p.

CAMPBELL, J.S., and J.A. BABALUK. 1979. Age determination of walleye, *Stizostedion vitreum vitreum* (Mitchill), based on the examination of eight different structures. Can. Fish. Mar. Serv. Tech. Rep. 849: iv + 23 p.

CARBINE, W.F., and V.C. APPLEGATE. 1946. Recaptures of tagged walleyes, *Stizostedion v. vitreum* (Mitchill), in Houghton Lake and the Muskegon River, Roscommon County, Michigan. Copeia 1946(2): 97-100.

CARLANDER, K.D., J.S. CAMPBELL, and R.J. MUNCIE. 1978. Inventory of percid and esocid habitat in North America. Am. Fish. Soc. Spec. Publ. 11: 27-38.

CLEUGH, T.R., H.A. AYLES, and W. BAXTER. 1974. The morphometry of Southern Indian Lake: Present conditions and implications of hydroelectric development. Lake Winnipeg, Churchill and Nelson Rivers Study Board, Tech. Rep. App. 5, Vol. 1. 15 p.

CROWE, W.R., E. KARVELIS, and L.S. JOERIS. 1963. The movement, heterogeneity, and rate of exploitation of walleyes in northern Green Bay, Lake Michigan, as determined by tagging. Int. Comm. Northwest Atl. Fish. Spec. Publ. 4: 38-41.

DERBACK, B. 1947. The adverse effects of cold weather upon the successful reproduction of pickerel, *Stizostedion vitreum*, at Heming Lake, Manitoba, in 1947. Can. Fish Cult. 2: 22-23.

DOAN, K.H. 1942. Some meteorological and limnological conditions as factors in the abundance of certain fishes in Lake Erie.

Ecol. Monogr. 12: 293-314.

ESCHMEYER, P.H. 1950. The life history of the walleye in Michigan. Mich. Dep. Conserv. Inst. Fish. Res. Bull. 5: 99 p.

ESCHMEYER, P.H., and W.R. CROWE. 1955. The movement and recovery of tagged walleyes in Michigan, 1929-1953. Mich. Dep. Conserv. Inst. Fish. Res. Misc. Publ. 8: 32 p.

FERGUSON, R. G., and A.J. DERKSEN. 1971. Migrations of adult and juvenile walleyes (*Stizostedion vitreum vitreum*) in southern Lake Huron, Lake St. Clair, Lake Erie and connecting waters. J. Fish. Res. Board Can. 28: 1133-1142.

FORNEY, J.L. 1963. Distribution and movement of marked walleyes in Oneida Lake, New York. Trans. Am. Fish. Soc. 92: 47-52.

HERMAN, E.F. 1947. Notes on tagging walleyes on the Wolf River. Wis. Conserv. Bull. 12(4): 7-9.

JOHNSON, F.H. 1971. Numerical abundance, sex ratios, and size-age composition of the walleye spawning run at Little Cut Foot Sioux Lake, Minnesota 1942-1969, with data on fecundity and incidence of *Lymphocystis*. Minn. Dep. Nat. Resour. Div. Fish. Game Sect. Fish. Invest. Rep. 315: 9 p.

OLSON, D.E., D.E. SCHUPP, and V. MACINS. 1978. An hypothesis of homing behavior of walleyes as related to observed patterns of passive and active movement. Am. Fish. Soc. Spec. Publ. 11: 52-57.

OLSON, D.E., and W. J. SCIDMORE. 1962. Homing behavior of spawning walleyes. Trans. Am. Fish. Soc. 91: 355-361.

PAYNE, N.R. 1964. The life history of the walleye, *Stizostedion vitreum vitreum* (Mitchill), in the Bay of Quinte. M.A. thesis, Univ. of Toronto, Toronto, Ont.

PRIEGEL, G.R. 1967. The movement, rate of exploitation and homing behavior of walleyes in Lake Winnebago and connecting waters. Wisconsin, as determined by tagging. Wis. Acad. Sci. Arts Lett. 56: 207-223.

___________. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Wis. Dep. Nat. Resour. Tech. Bull. 45: 105 p.

RAWSON, D.S. 1957. The life history and ecology of the yellow walleye, *Stizostedion vitreum*, in Lac La Ronge, Saskatchewan. Trans. Am. Fish. Soc. 86: 15-37.

RICKER, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191: 382 p.

ROBSON, D.S., and D.G. CHAPMAN. 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 91: 181-189.

ROSE, E.T. 1949. The population of yellow pikeperch (*Stizostedion v. vitreum*) in Spirit Lake, Iowa. Trans. Am. Fish. Soc. 77: 32-41.

RYDER, R.A. 1968. Dynamics and exploitation of mature walleyes, *Stizostedion vitreum vitreum*, in the Nipigon Bay region of Lake Superior. J. Fish. Res. Board Can. 25(7): 1347-1376.

SMITH, L.L., L.W. KREFTING, and R.L. BUTLER. 1952. Movements of marked walleyes, *Stizostedion vitreum vitreum* (Mitchill), in the fishery of the Red Lakes, Minnesota. Trans. Am. Fish. Soc. 81: 179-196.

SMITH, L.L., and R.L. PYCHA. 1961. Factors related to commercial production of the walleye in Red Lakes, Minnesota. Trans. Am. Fish. Soc. 90(2): 190-217.

STOUDT, J.H. 1939. A study of the migration of the wall-eyed pike (*Stizostedion vitreum*) in waters of the Chippewa National Forest, Minnesota. Trans. Am. Fish. Soc. 68: 163-169.

STOUDT, J.H., and S. EDDY. 1939. Walleye pike tagging study, 1937-1938, Chippewa National Forest. Trans. North Am. Wildl. Conf. 4: 305-310.

WEAGLE, K.V., and W. BAXTER. 1973. The fisheries of Southern Indian Lake: Exploitation and reproduction. Lake Winnipeg, Churchill and Nelson Rivers Study Board, Tech. Rep. App. 5, Vol. 1. 163 p.

WOLFERT, D.R., and H.D. VAN METER. 1978. Movements of walleyes tagged in eastern Lake Erie. N.Y. Fish Game J. 25(1): 16-22.

Table 1. Total numbers of walleye, northern pike, longnose sucker and white sucker caught in upstream traps in early May spawning runs, Sandhill and Poplar streams, 1975-1978.

Stream	Year	Walleye	Northern Pike	Longnose Sucker	White Sucker
Sandhill	1975	>8263 [a]	84	579	1321
	1976	2356	155	121	785
	1977	3682	1917	507	2840
	1978	1870	3463	357	5119
Poplar	1976	1904	25	0	565
	1977	1868	372	24	4969
	1978	617	453	2	1869

[a] First part of walleye spawning run missed.

Table 2. Estimated overall male:female ratios in walleye spawning runs, Sandhill and Poplar streams, 1975-1978.

Stream	1975	1976	1977	1978
Sandhill	7.08	4.16	6.18	3.95
Poplar	-	7.15	4.40	7.51

Table 3. Male:female ratios during walleye spawning runs, (and number sampled), Sandhill and Poplar streams, 1977. Peak numbers of walleye were trapped 9-10 May.

May	Sandhill Stream	Poplar Stream
6	3:1 (4)	-
7	7:1 (38)	14:1 (15)
8	18:1 (188)	52:1 (106)
9	12:1 (451)	11:1 (487)
10	6:1 (406)	3:1 (285)
11	8:1 (294)	2:1 (199)
12	4:1 (184)	2:1 (97)
13	1:1 (72)	2:1 (53)
14	1:1 (26)	1:1 (2)
15	½:1 (19)	

Table 4. Daily average sizes (mm) during walleye spawning runs, Sandhill and Poplar streams, 1977. Peak numbers of walleye were trapped 9-10 May. Sample size in brackets.

May	Males		Females	
	Sandhill	Poplar	Sandhill	Poplar
6	418 (29)			
7	423 (100)	416 (14)		
8	429 (100)	420 (100)	477 (10)	
9	424 (100)	425 (100)	463 (34)	452 (39)
10	417 (100)	420 (100)	458 (54)	444 (66)
11	413 (100)	412 (100)	455 (34)	447 (59)
12	410 (39)	410 (65)	448 (48)	447 (31)
13	399 (12)	415 (34)	444 (32)	448 (19)
14			445 (14)	
15			448 (12)	

Table 5. Annual survival estimates (S) and χ^2 values for the assumptions of catch curve mortality rate calculations (Robson and Chapman 1961) for Poplar stream walleye, 1977 and 1978 and Sandhill stream walleye, 1978.

	Poplar 1977		Poplar 1978		Sandhill 1978	
	M	F	M	F	M	F
S (best estimate)	0.53	0.33	0.34	0.37	0.42	0.37
S (Heincke's estimate)	0.51	0.39	0.39	0.51	0.33	0.36
χ^2_1	2.76$^{N.S.}$	7.51*	8.64*	13.06*	22.36*	0.31$^{N.S.}$
S (best estimate; after removal of modal age class)	0.55	0.22	0.23	-	0.47	0.39
S (Heincke's estimate; after removal of modal age class)	0.60	0.19	0.18	-	0.45	0.45
χ^2_1	6.72*	2.10$^{N.S.}$	3.87*	-	0.85$^{N.S.}$	2.90$^{N.S.}$

* : Significant χ^2 at $p < 0.05$

N.S.: Indicates not significant χ^2 at $p > 0.05$

Table 6. Percent of fish with lost and broken tags as compared to the total number of walleye recaptured, Sandhill and Poplar streams, 1976-1978.

Recaptured	1976		1977		1978	
	Lost	Broken	Lost	Broken	Lost	Broken
Sandhill	0	0	5	1	13	2
Poplar	0	3	<1	0	35	0

Table 7. Total commercial walleye yield from Southern Indian Lake summer fishery, 1968-1978, and rate of exploitation for walleye tagged on Sandhill and Poplar streams, 1975-1978.

	Whole Lake Walleye yield (lb) (dressed weight)	Rate of Exploitation (μ)	
		Sandhill	Poplar
1968	34,800		
1969	20,400		
1970	43,000		
1971	102,600		
1972	35,100		
1973	54,900		
1974	Nil		
1975	34,400	0.03	0.03
1976	136,600	0.30	0.16
1977	81,700	0.46	0.50
1978	41,700	0.24	0.30

Table 8. Estimated number and proportion of tagged walleye homing to Sandhill stream and Sandhill Bay area and proportion of commercial recaptures in Sandhill Bay area spawning in year of recapture, 1975-1978. Annual survival rates of 0.55, 0.40, and 0.30 are assumed for the period 1975-1978.

		# tagged fish assumed to be alive at start of year	# stream recaptures	estimated proportion of tagged fish homing to stream	# of commercial recaptures in Sandhill Bay in early summer	Proportion of commercial recaptures in Sandhill Bay in early summer which were captured on stream in year of recapture	estimated # of tagged fish homing to Sandhill Bay area	estimated proportion of tagged fish homing to Sandhill Bay area
1975 Tag Pool (1320 Fish Tagged)	1976 returns	726	54	0.07	81	0.20	273	0.38
	1977 returns	290	52	0.18	69	0.22	239	0.82
	1978 returns	87	26	0.30	35	0.23	114	1.31
1976 Tag Pool (1417 Fish Tagged)	1977 returns	567	102	0.18	130	0.32	316	0.56
	1978 returns	170	27	0.16	29	0.31	87	0.51
1977 Tag Pool (1968 Fish Tagged)	1978 returns	590	212[a]	0.36	145	0.34	606[a]	1.03

[a] corrected for tag loss rates

Table 9. Estimated number and proportion of tagged walleye homing to Poplar stream and Poplar Bay area and proportion of commercial recaptures in Poplar Bay area spawning in year of recaptures in Poplar Bay area spawning in year of recapture, 1975-1978. Annual survival rates of 0.55, 0.50, and 0.30 are assumed for the period of 1975-1978.

		# tagged fish assumed to be alive at start of year	# stream recaptures	estimated proportion of tagged fish homing to stream	# of commercial recaptures in Poplar Bay in early summer	Proportion of commercial recaptures in Poplar Bay in early summer which were captured on stream in year of recapture	estimated # of tagged fish homing to Poplar Bay area	estimated proportion of tagged fish homing to Poplar Bay area
1975 Tag Pool (947 Fish Tagged)	1976 returns	521	69	0.13	11	0.27	253	0.49
	1977 returns	260	32	0.12	28	0.68	47	0.18
	1978 returns	78	8	0.10	9	0.22	36	0.46
1976 Tag Pool (1599 Fish Tagged)	1977 returns	800	199	0.25	210	0.44	391	0.49
	1978 returns	240	38	0.16	27	0.33	114	0.48
1977 Tag Pool (1065 Fish Tagged)	1978 returns	320	91[a]	0.28	39	0.33	223[a]	0.70

[a] corrected for tag loss rates

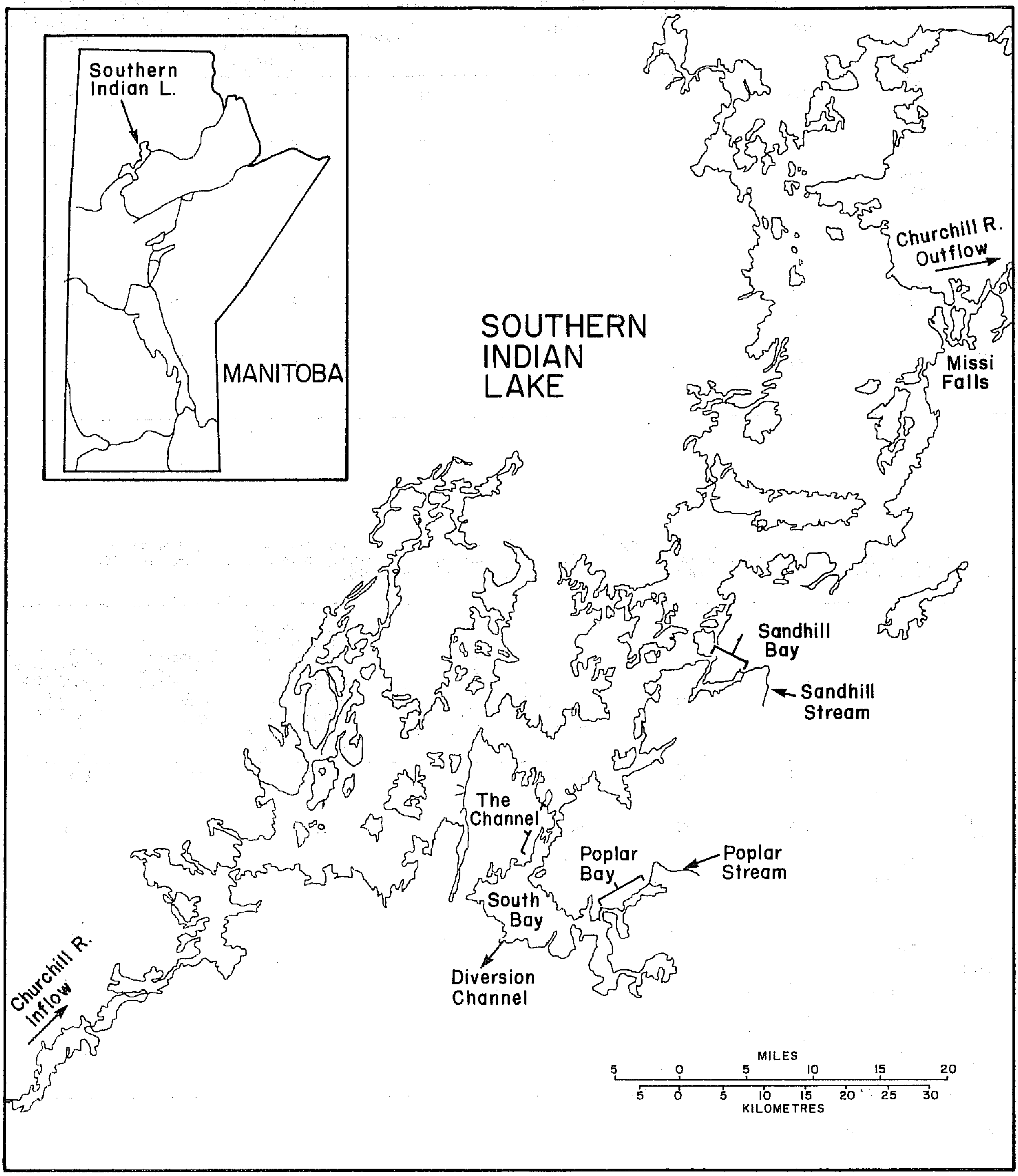

Fig. 1. Southern Indian Lake study area.

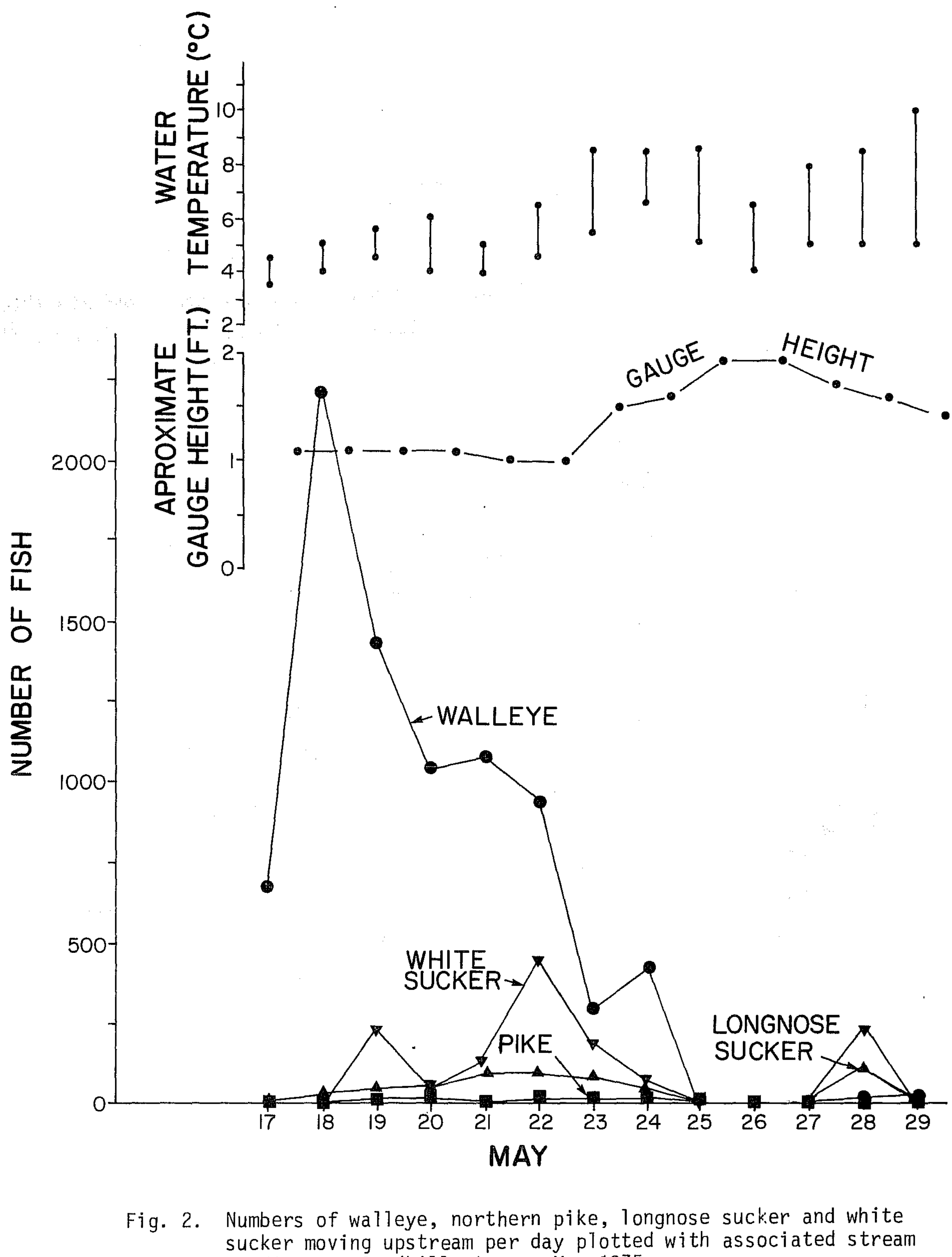

Fig. 2. Numbers of walleye, northern pike, longnose sucker and white sucker moving upstream per day plotted with associated stream conditions, Sandhill stream, May 1975.

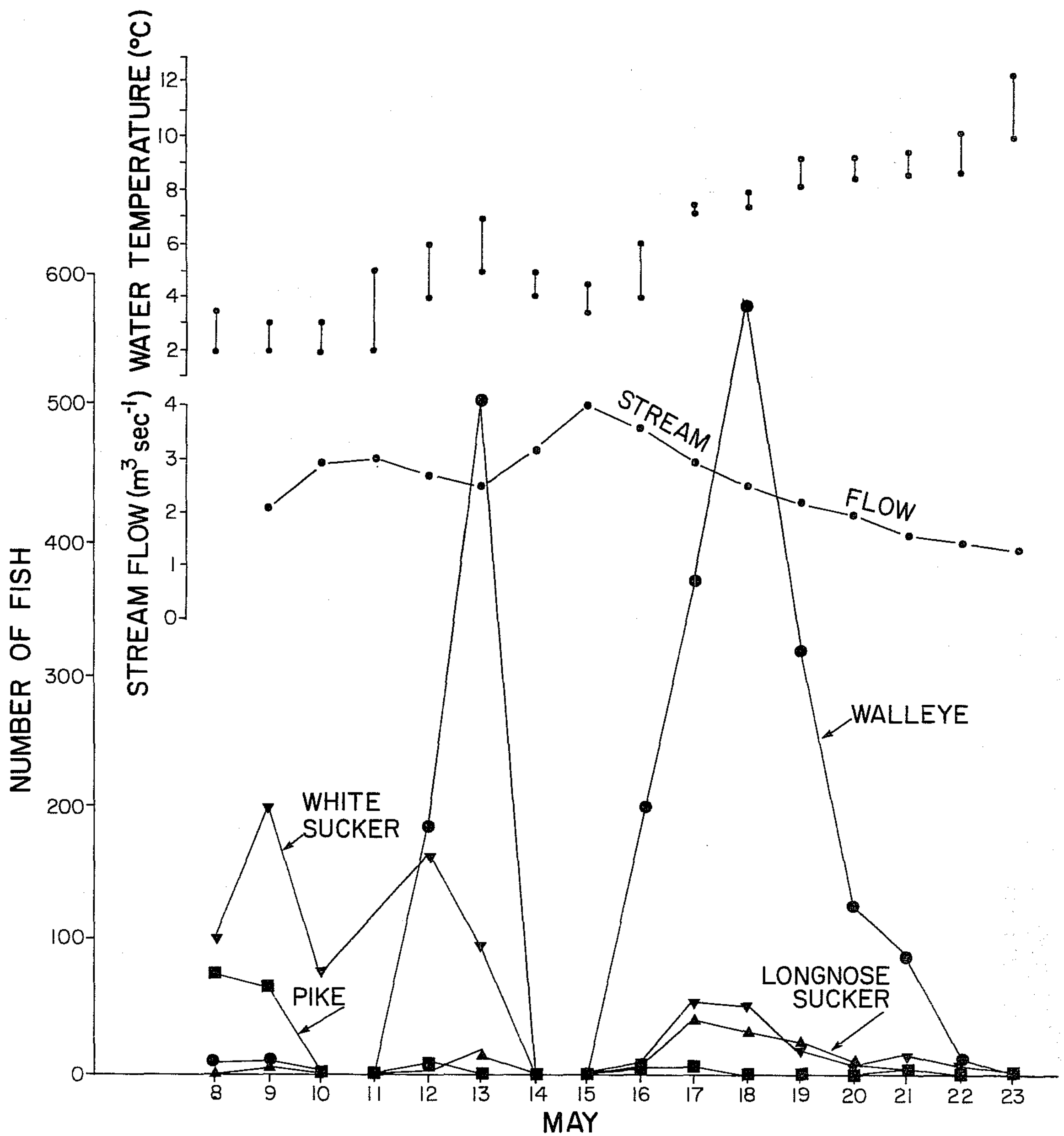

Fig. 3. Numbers of walleye, northern pike, longnose sucker and white sucker moving upstream per day plotted with associated stream conditions, Sandhill stream, May 1976.

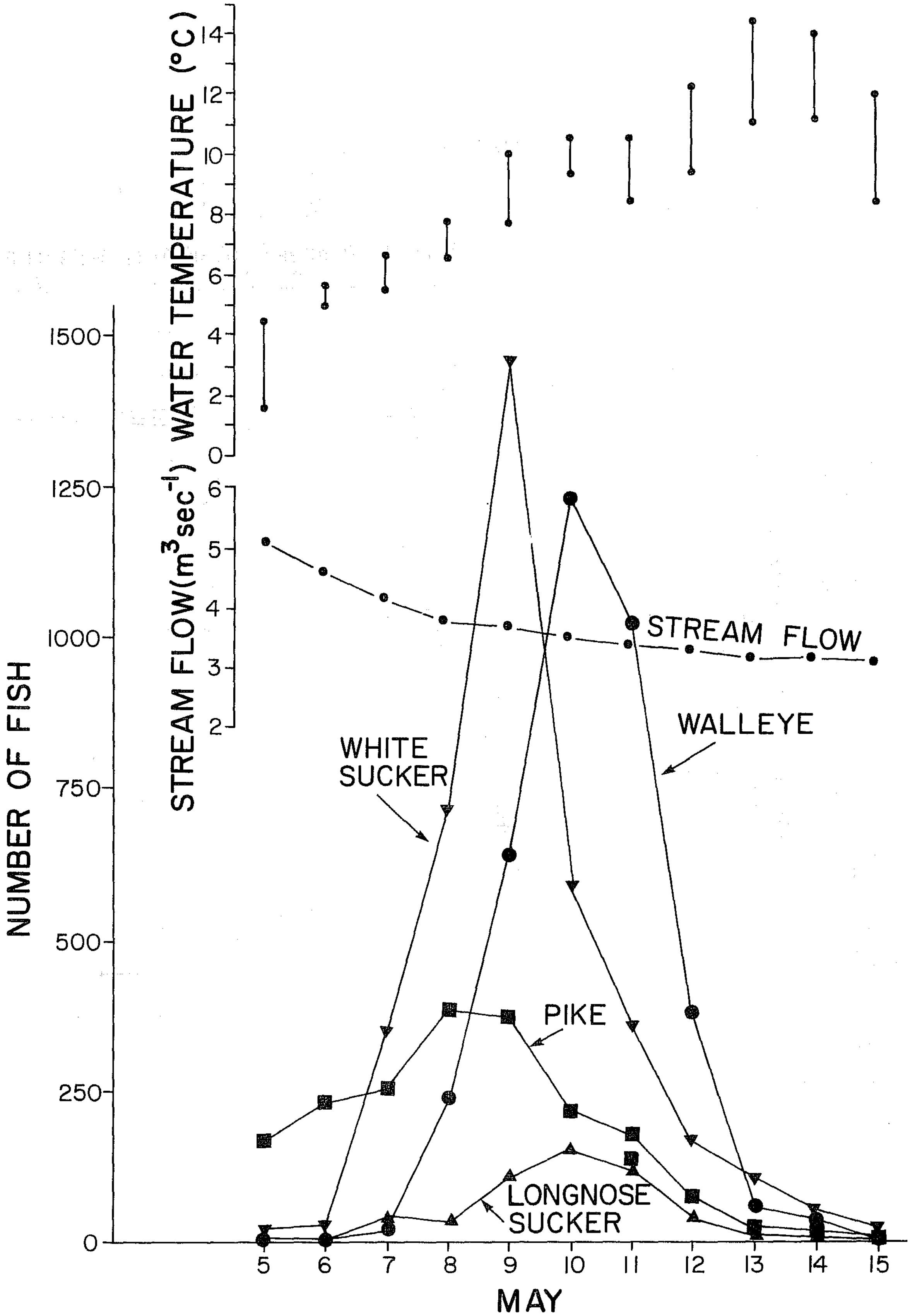

Fig. 4. Numbers of walleye, northern pike, longnose sucker and white sucker moving upstream per day plotted with associated stream conditions, Sandhill stream, May 1977.

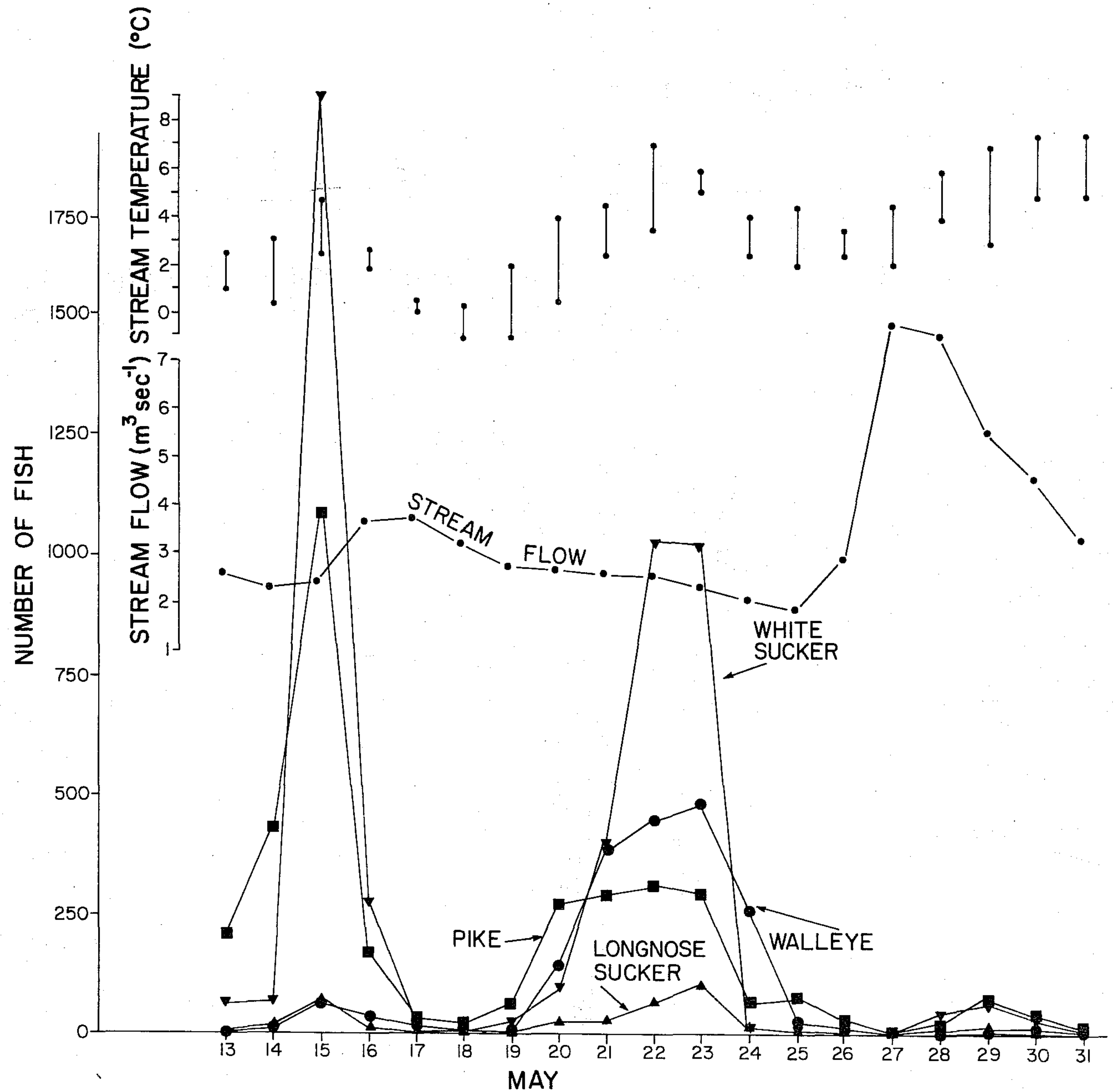

Fig. 5. Numbers of walleye, northern pike, longnose sucker and white sucker moving upstream per day plotted with associated stream conditions, Sandhill stream, May 1978.

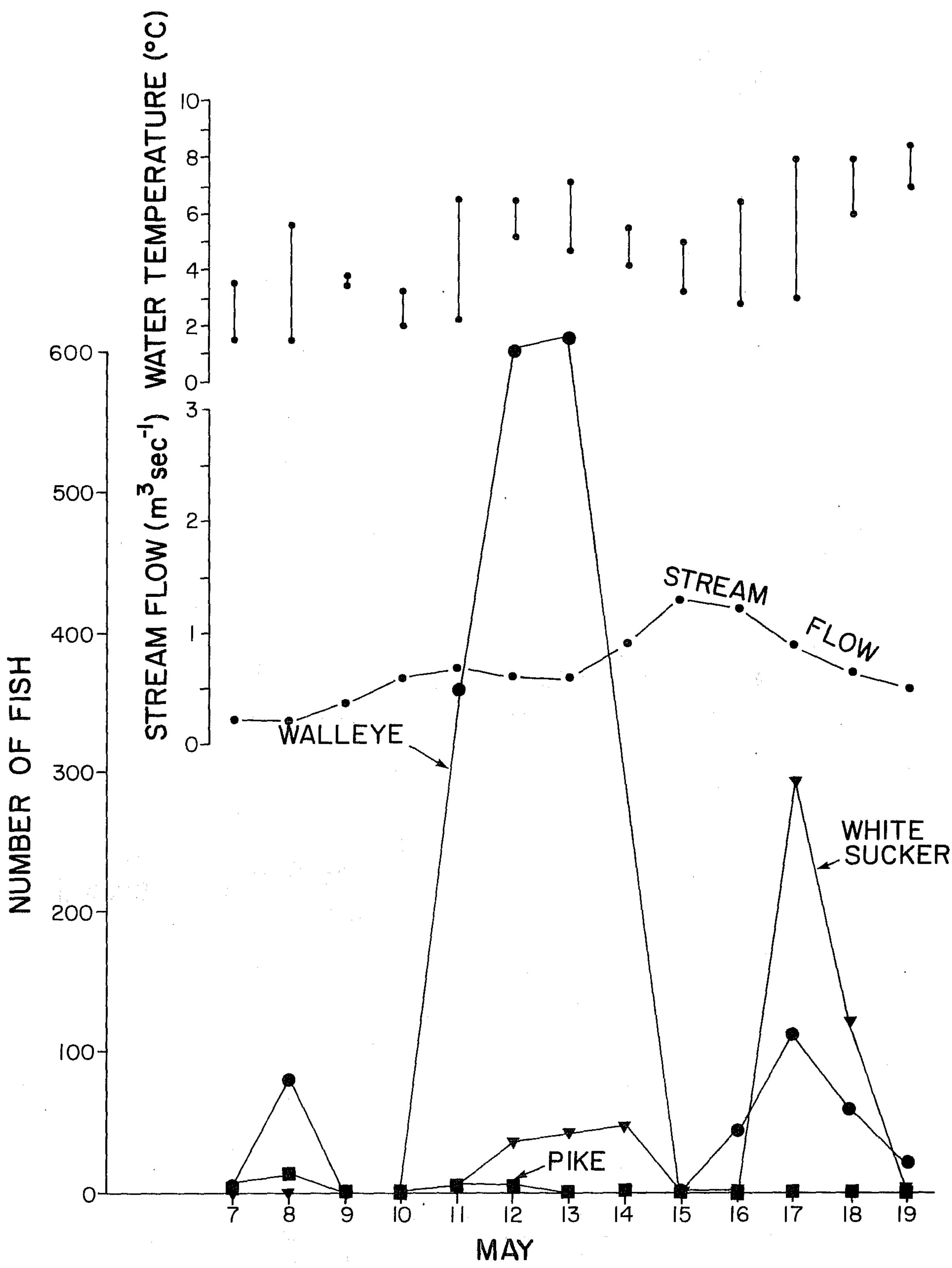

Fig. 6. Numbers of walleye, northern pike and white sucker moving upstream per day plotted with associated stream conditions, Poplar stream, May 1976.

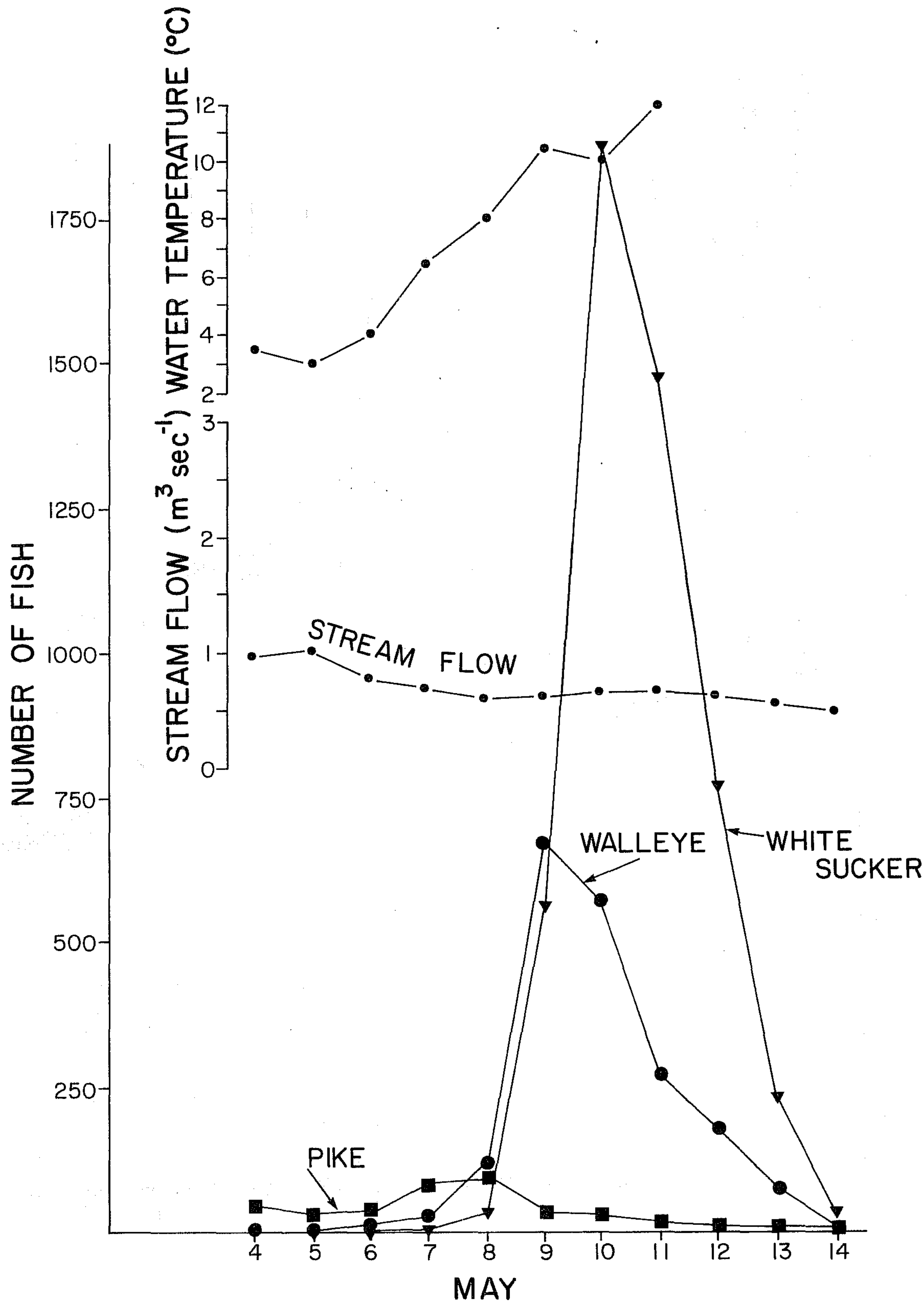

Fig. 7. Numbers of walleye, northern pike and white sucker moving upstream per day plotted with associated stream conditions, Poplar stream, May 1977.

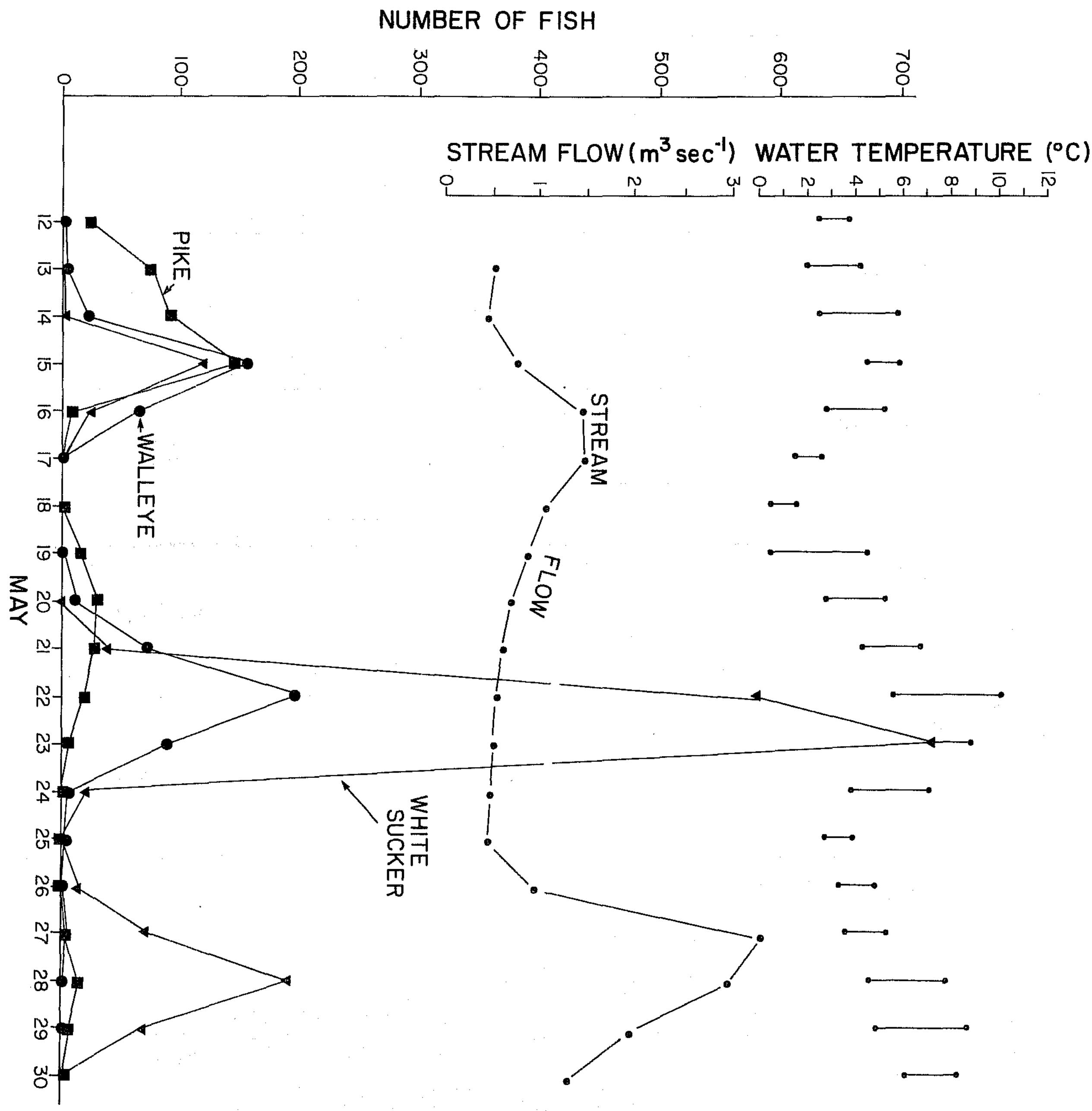

Fig. 8. Numbers of walleye, northern pike and white sucker moving upstream per day plotted with associated stream conditions, Poplar stream, May 1979.

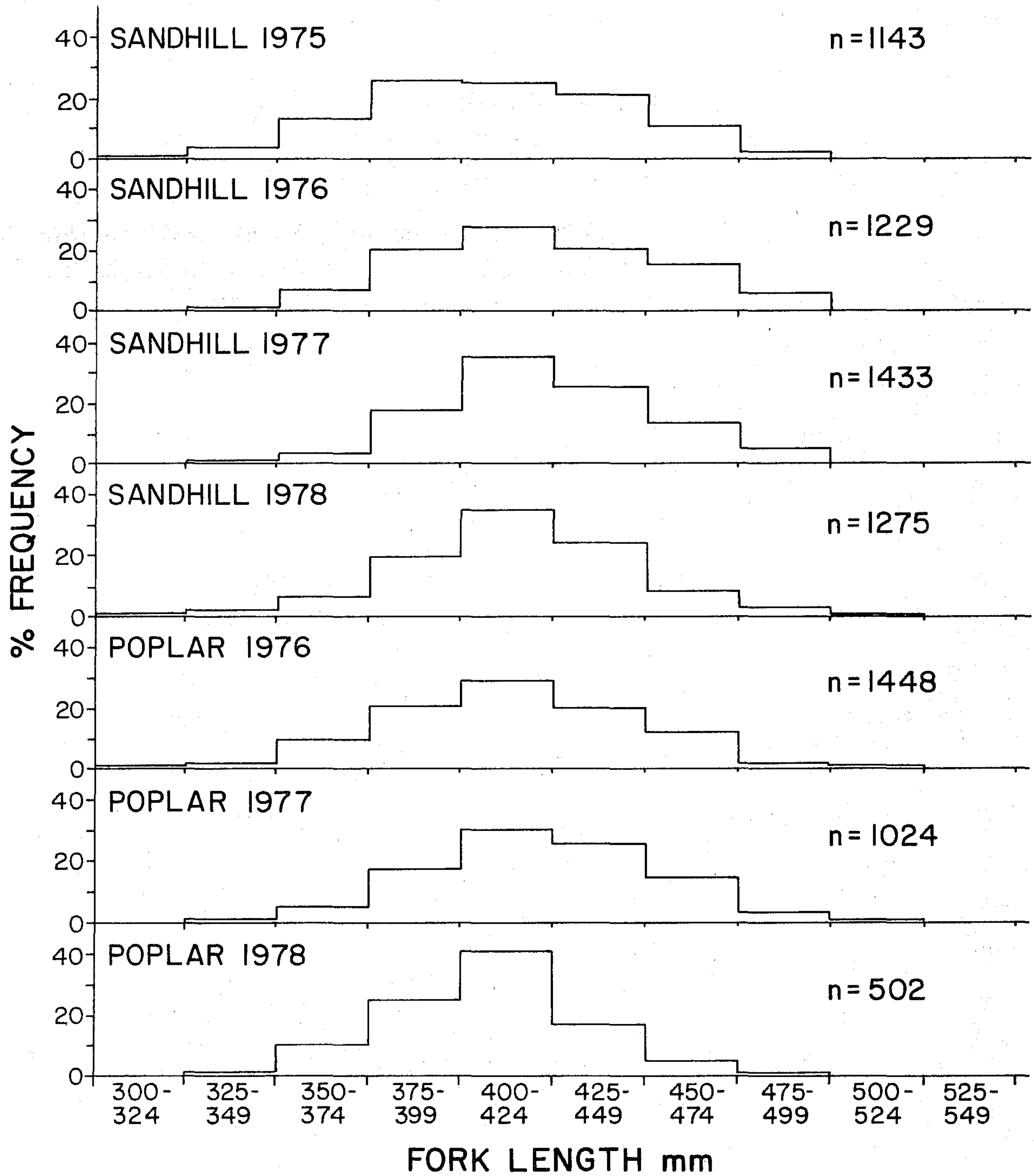

Fig. 9. Length frequency distributions for male walleyes caught in spring spawning runs.

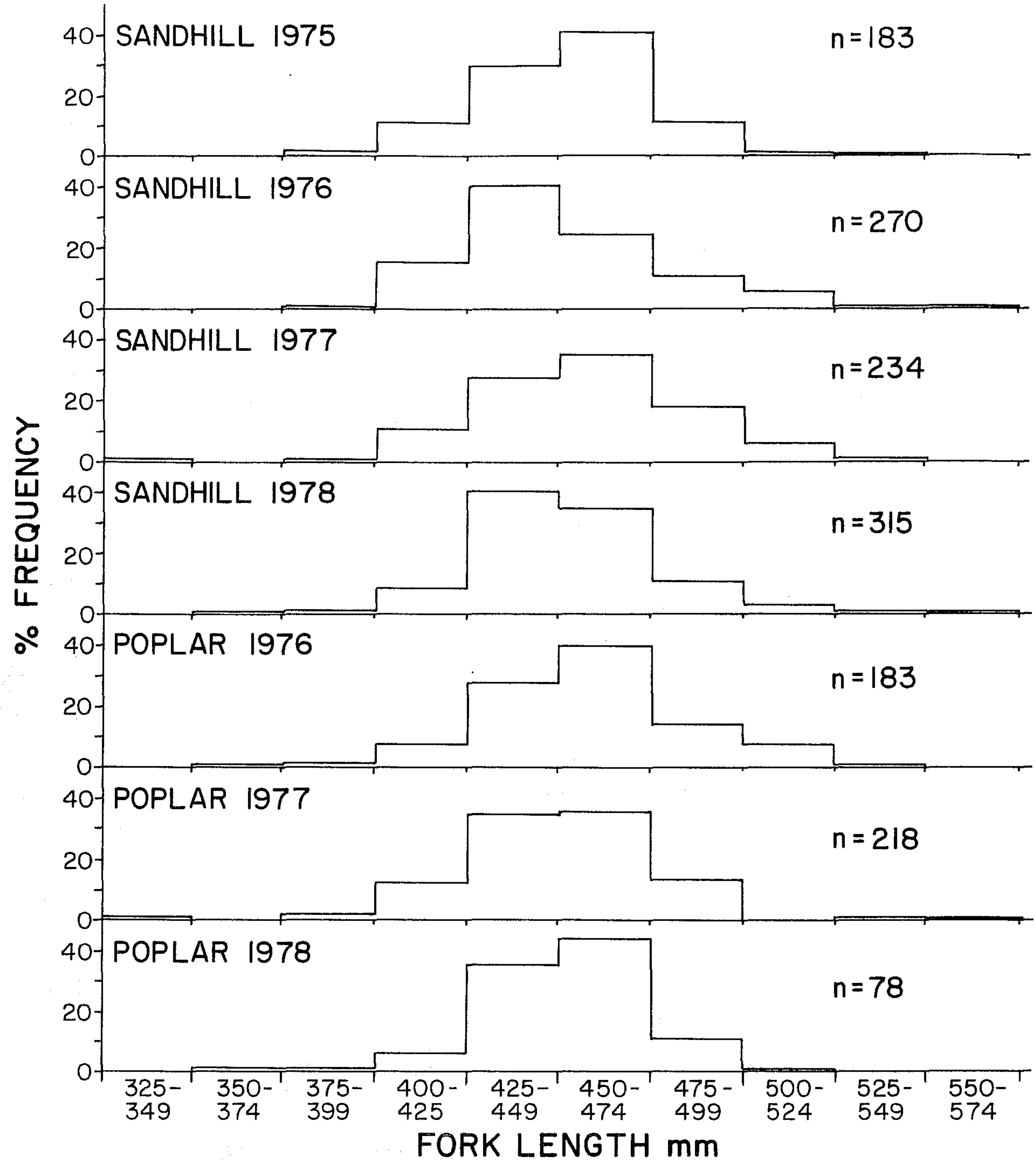

Fig. 10. Length frequency distributions for female walleyes caught in spring spawning runs.

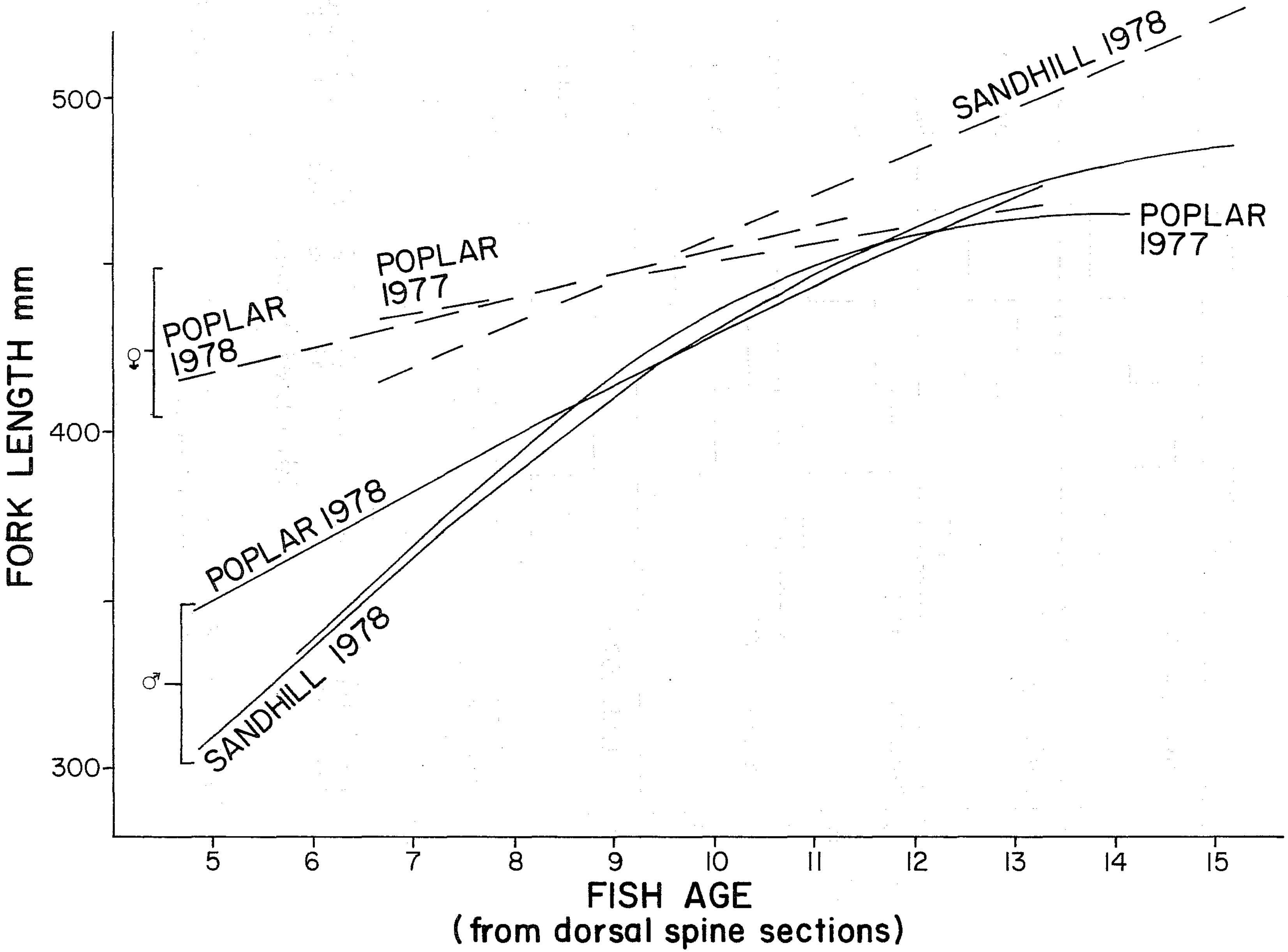

Fig. 11. Regressions of fork length on dorsal spine age for male and female walleye, Sandhill 1978 and Poplar 1977 and 1978.

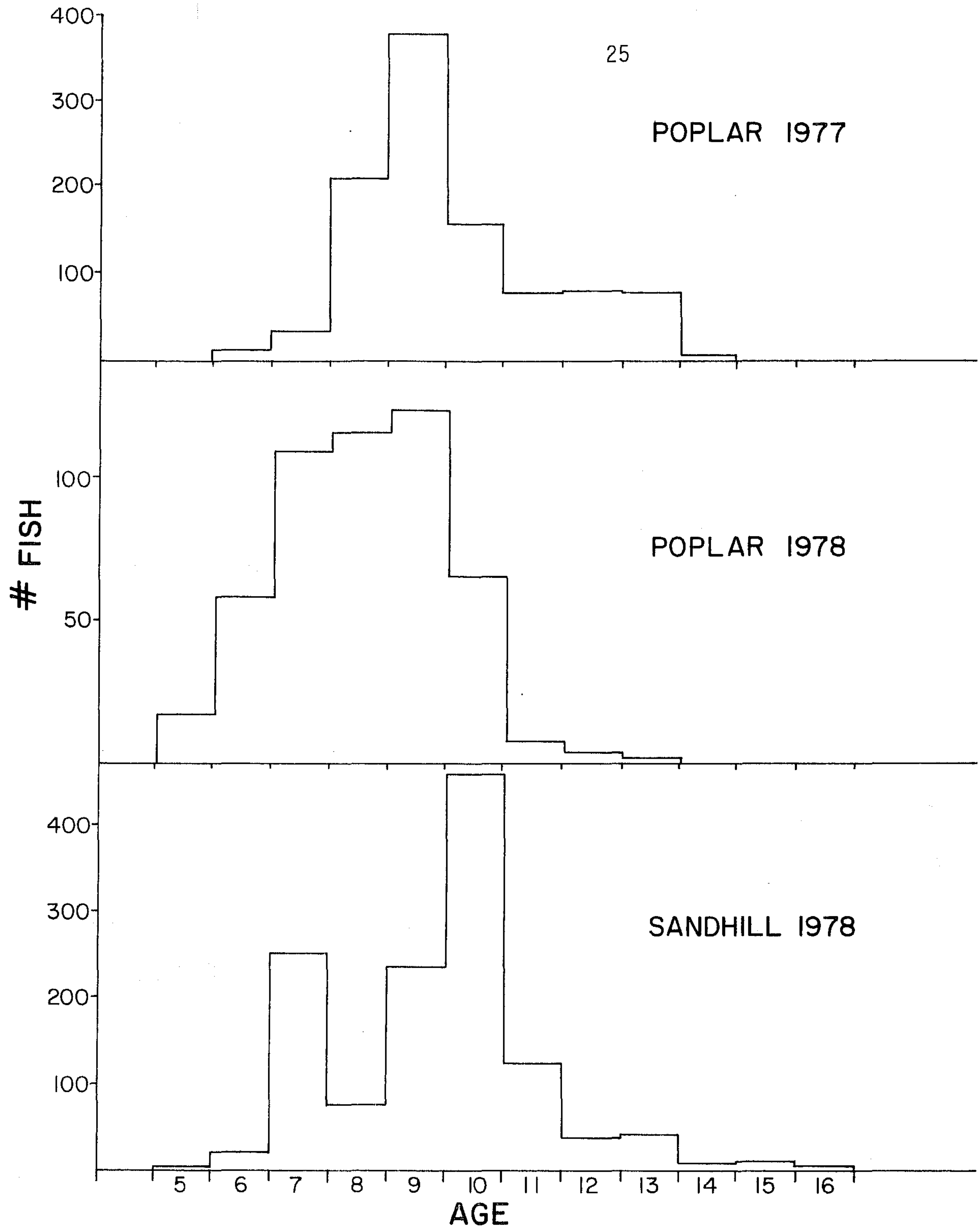

Fig. 12. Age frequency distributions for male walleye captured in spring spawning runs.

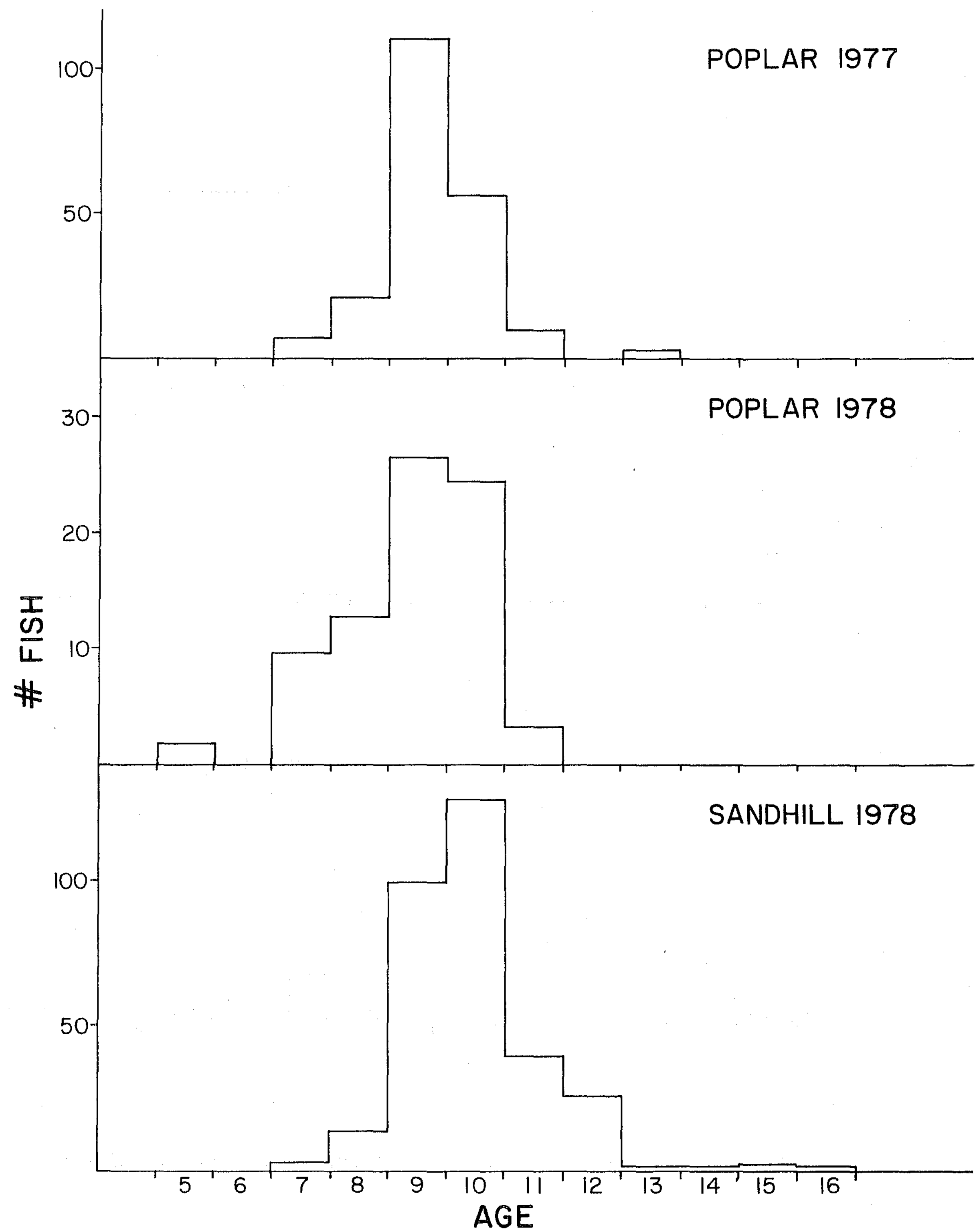

Fig. 13. Age frequency distributions for female walleye captured in spring spawning runs.

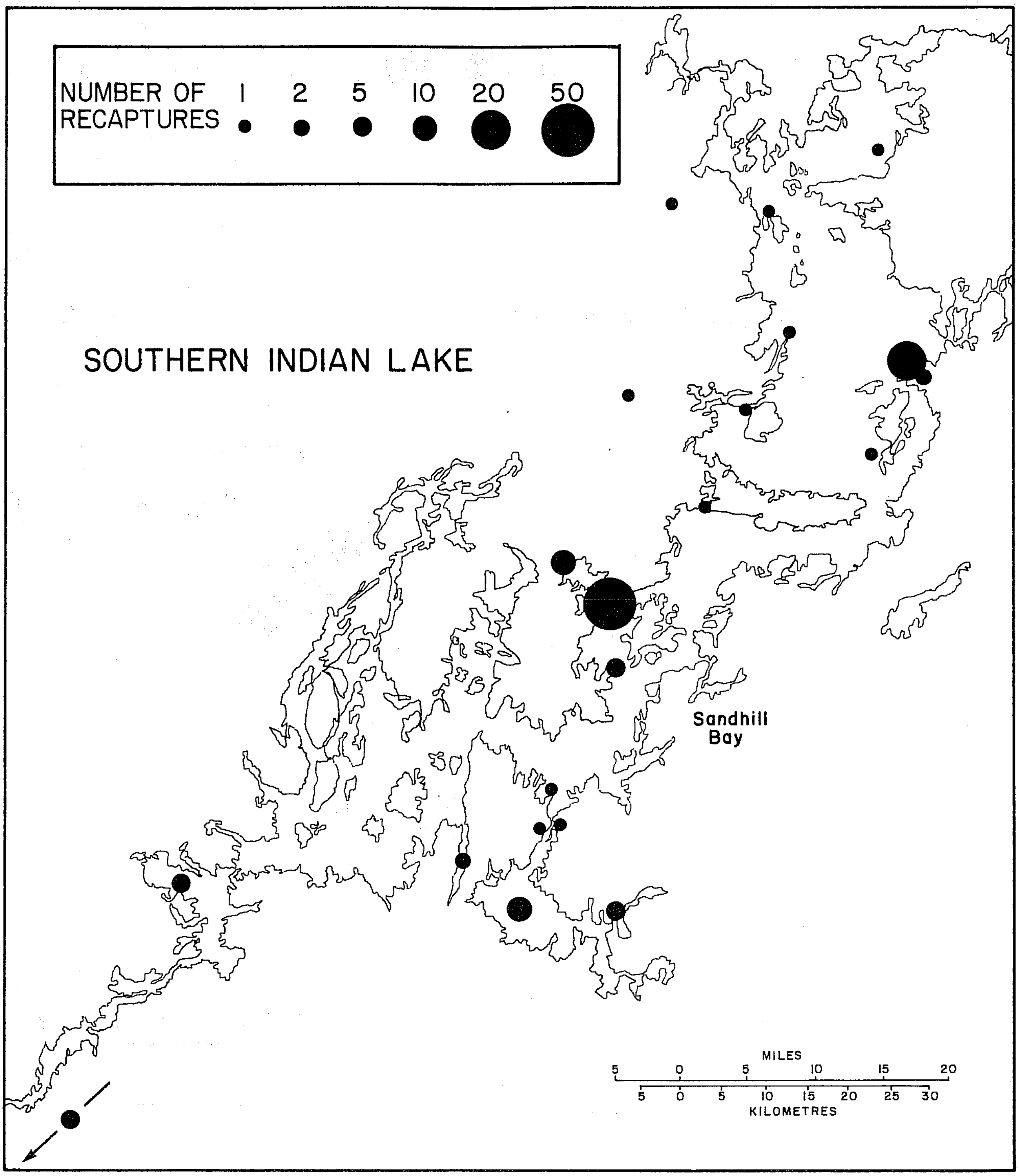

Fig. 14. Dispersal of walleye tagged at Sandhill stream over the months June, July and August, 1975-1978.

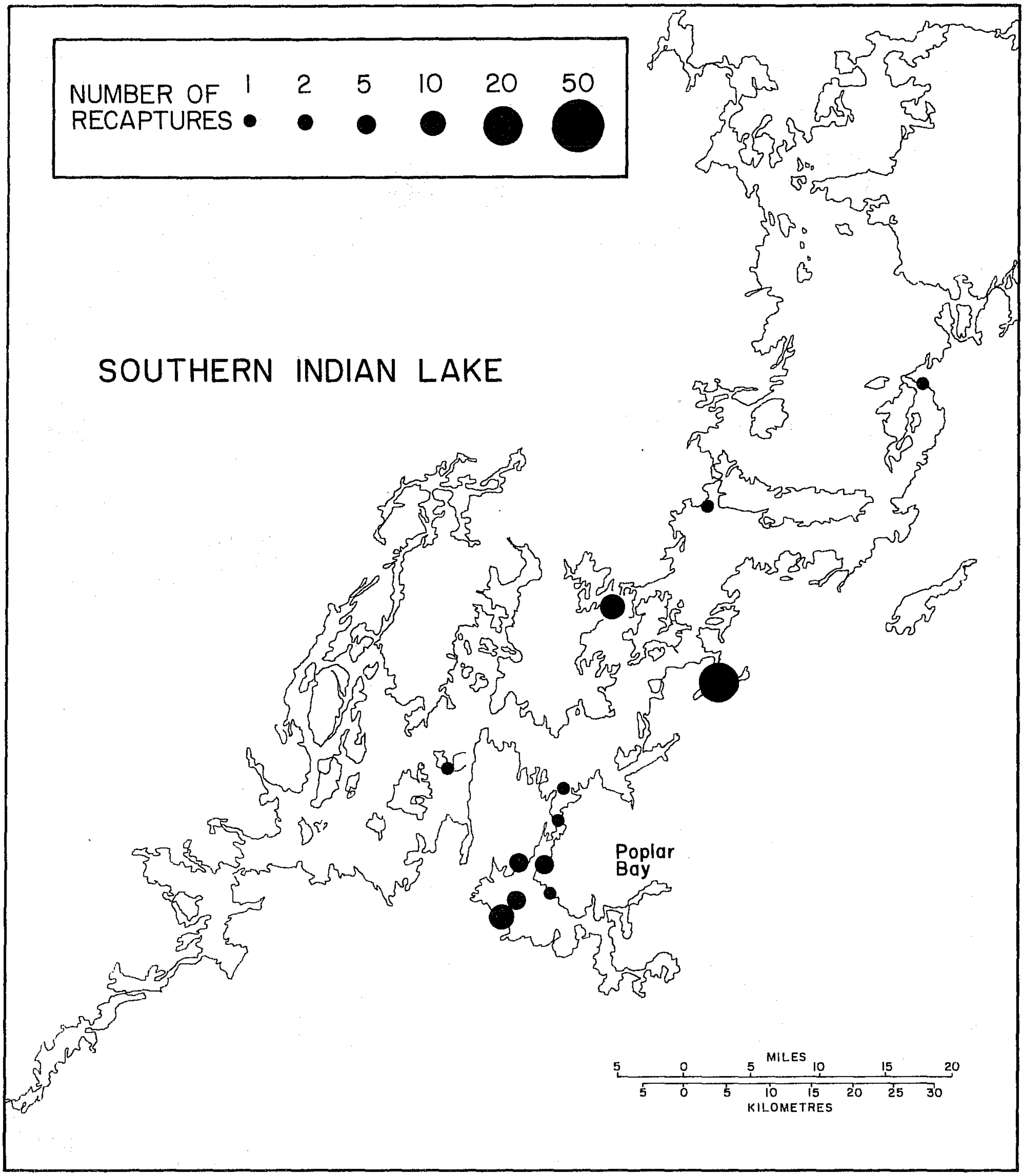

Fig. 15. Dispersal of walleye tagged at Poplar stream over the months June, July and August, 1975-1978.

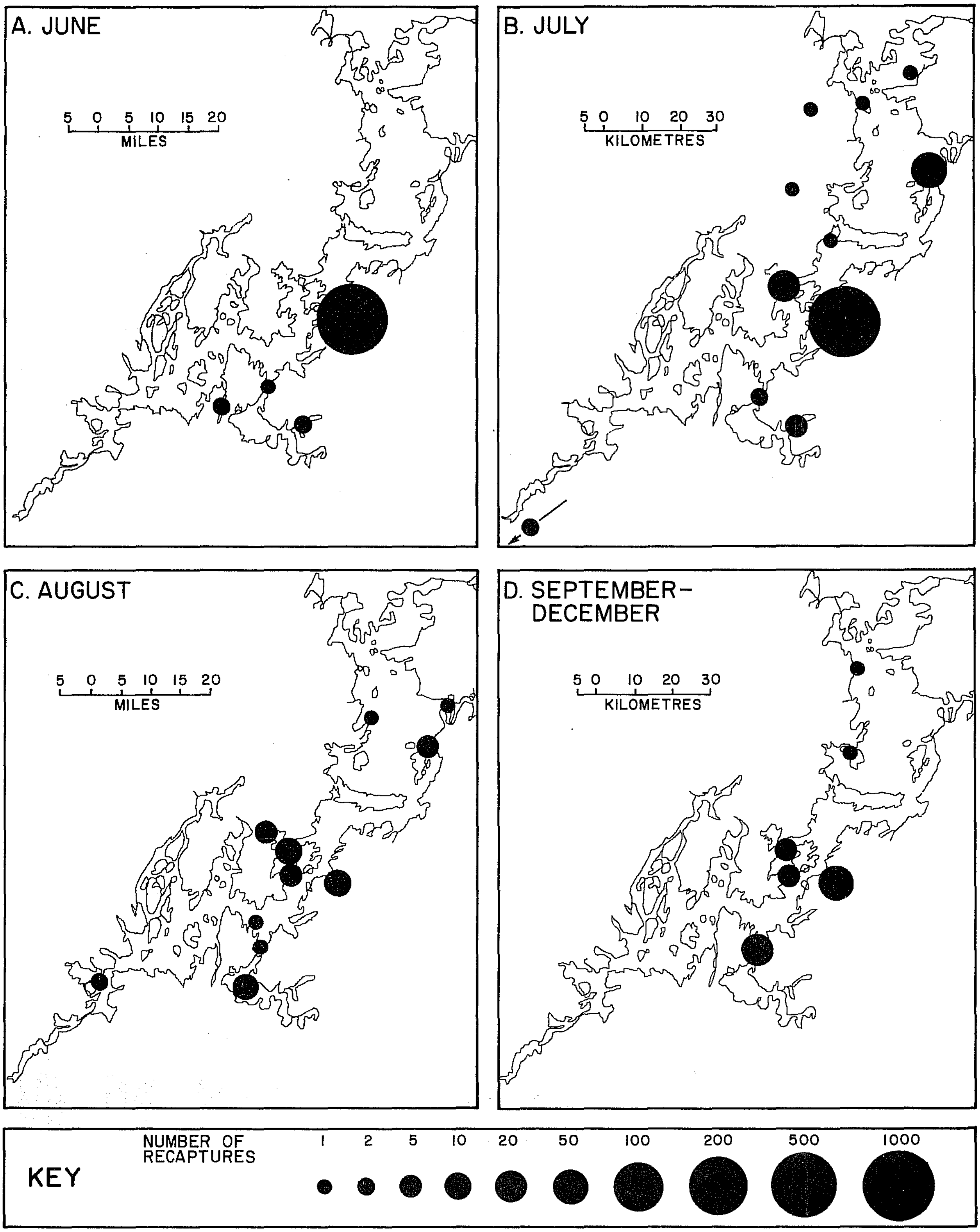

Fig. 16. Recapture locations for walleye tagged at Sandhill stream, 1975-1978.

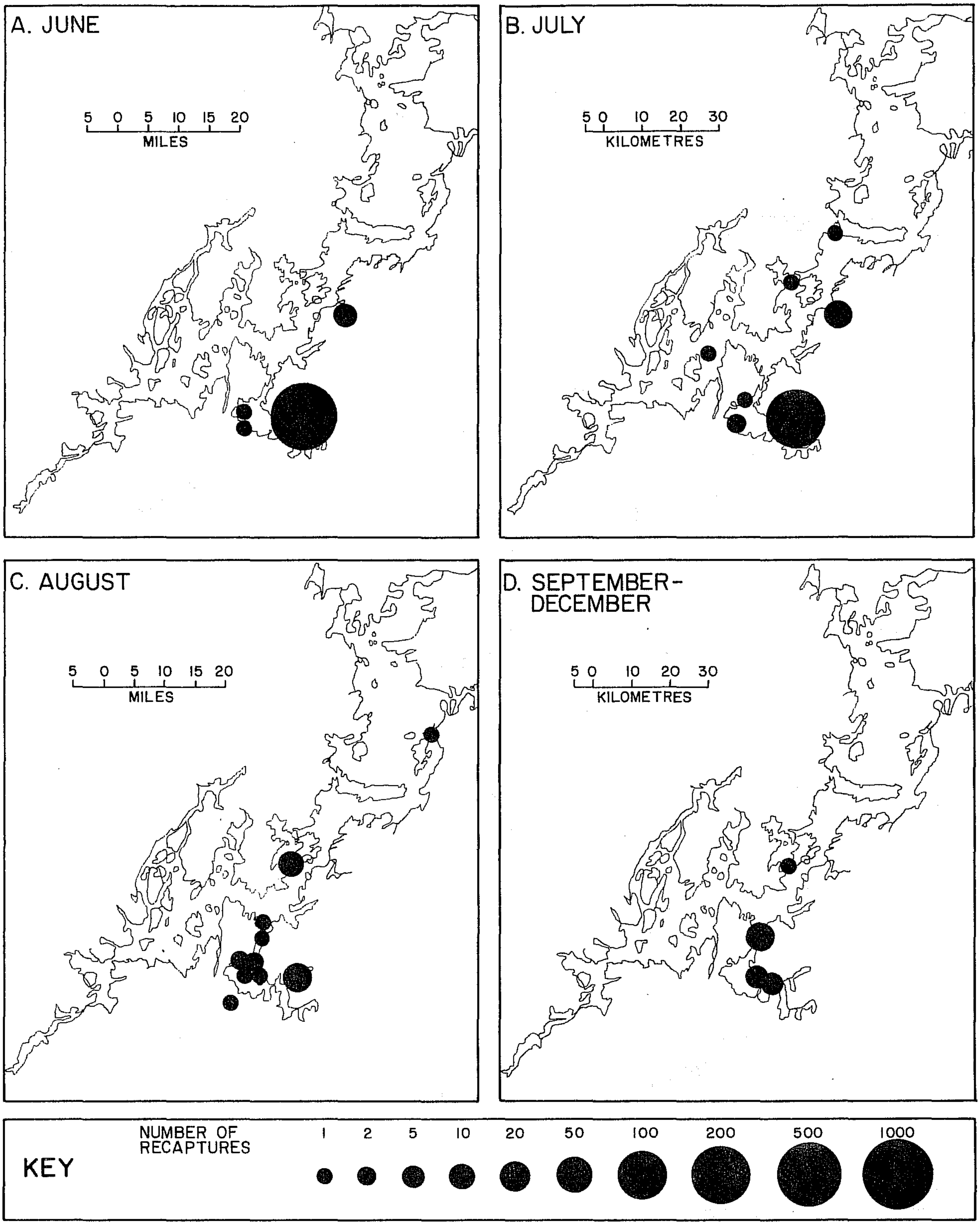

Fig. 17. Recapture locations for walleye tagged at Poplar stream, 1975-1978.