Reprint from The Canadian Fish Culturist, No. 32 May, 1964, published by the Department of Fisheries of Canada, Ottawa.

The Survival, Growth and Movement of *Esox masquinongy* Transplanted from Nogies Creek Sanctuary to Public Fishing Waters

by

Barry S. Muir[1] and John G. Sweet

University of Toronto, Toronto 5, Ontario

Introduction

Conservationists in Ontario have been concerned for many years with the apparent decline in numbers of the maskinonge, or lunge *(Esox masquinongy).* A great deal of effort has been expended in artificial propagation with the aim of augmenting natural reproduction, and large numbers of fry and fingerlings have been planted throughout southern Ontario each year. In 1960, for example, approximately four million fry and fifty thousand fingerlings were reared at the provincial hatchery at Deer Lake and planted throughout the province. In view of the many natural enemies of juveniles, and since maskinonge do not normally reach maturity until the fifth or sixth year, there would appear to be merit in raising the fish to a larger size before planting. Elson (1940), experimenting with the planting of fry in a nursery area, obtained a minimum survival of 0.08% for the first year. The experiments were not, however, pursued.

In 1952 the transplanting of juvenile and adult maskinonge from Nogies Creek Sanctuary was begun, to determine their value in restocking public lakes. Although hatchery fingerlings were planted into the sanctuary from 1952 on (Muir, 1960), the bulk of the harvested fish were the result of natural reproduction by the resident population. It is noteworthy however, that the planted hatchery fingerlings displayed a survival rate (to age III) ranging from about three per cent to about ten per cent (unpublished). The present report deals with the survival, growth and movement, until time of recapture, of the fish transplanted from the sanctuary.

Methods

Each fall since 1952, maskinonge have been netted and transplanted from Nogies Creek to the nearby public fishing waters of Pigeon and Sturgeon lakes. Some of the fish netted had already been tagged in previous spring periods, and the remainder were tagged prior to transplanting. The tag used was a numbered yellow plastic disc tag attached to the preopercular bone with nylon monofilament.

---

[1] Present address, Department of Zoology, University of Hawaii, Honolulu 14, Hawaii.

The catches, held in twelve-foot retainer nets until transport, were normally transplanted the same day. Occasionally, on days when nets were moved or when the catch was small, the fish were held over in the retainers and transplanted the following day. The fish were transported in tanks approximately three feet in each dimension freshly filled with water to a depth of about two feet (approximately 115 imperial gallons). The number of fish per tank varied with the size and number of fish to be moved, and the distance travelled. In most cases, the trip was made in late afternoon and seldom exceeded thirty minutes so that no icing or aeration was required.

Since the operation seldom started before the first week of October, the newly transplanted fish were subjected to little angling before the close of the season on the 15th of that month. Thus angling pressure was not encountered until the following summer. Anglers were advised of the study and requested to return the tags (even from the sublegal fish) with pertinent information. A lucky draw, held at the close of each season, created interest among the anglers and publicized the study. Although an occasional report was received regarding tags not returned, it is believed that angler co-operation was good and that a high percentage of tags encountered was returned.

In two years, 1956 and 1959, maskinonge were not transplanted but were returned to the sanctuary for further study. Plantings subsequent to that time (not included in this report) have been followed by an intensive creel census to estimate the portion of tagged fish in the anglers' catch (Dursley and Fry, ms 1961).

Habitat

Nogies Creek Sanctuary, as a maskinonge habitat, has been previously described (Crossman, 1956; Muir, 1960, 1963). Essentially, it is a five-mile stretch of river ending in an artificial lake of about 100 acres. The river portion is from 20 to 30 yards wide and from 4 to 12 feet deep. Crossman estimated the flow of water to be about 90 cubic feet per second in July. Although the speed of the current varies with the meandering of the river, it is always detectable. Standing and fallen dead trees are abundant on the drowned land portion and the entire area, except the actual river channel, supports dense growths of aquatic vegetation. A concrete dam at the lower end controls the water level and prevents immigration. Since only three tags have been recovered from fish that apparently escaped over the dam, it is believed that emigration is not significant. The ruins of a stone dam prevents emigration at the upper end.

Pigeon and Sturgeon lakes, separated by locks and control dam (Fig. 1), are part of the chain of lakes that form the Trent Canal System. Both lakes are fairly eutrophic and both contain large, shallow, weedy areas. Although no figures are available, Pigeon Lake appears to support larger populations of all the local game species. Residents report that both lakes have lost many of their weed beds during the last two decades but that Sturgeon Lake has changed more than Pigeon Lake. At present, Sturgeon Lake appears to be "less suitable", in the writer's opinion, for maskinonge than does Pigeon Lake. Such opinion is admittedly biased, however, by the results recorded in this paper and by other observations, and is not founded on any objective evidence. The general flow of water approximately follows the long axis of both lakes. The volume of water passing through Bobcaygeon is estimated to be about 1200-1500 cubic feet per second during July and August and about 4500 cubic feet per second during the spring flooding. These estimates are derived from the 1960 to 1962 records of the Department of Transport for the major rivers entering Sturgeon Lake.

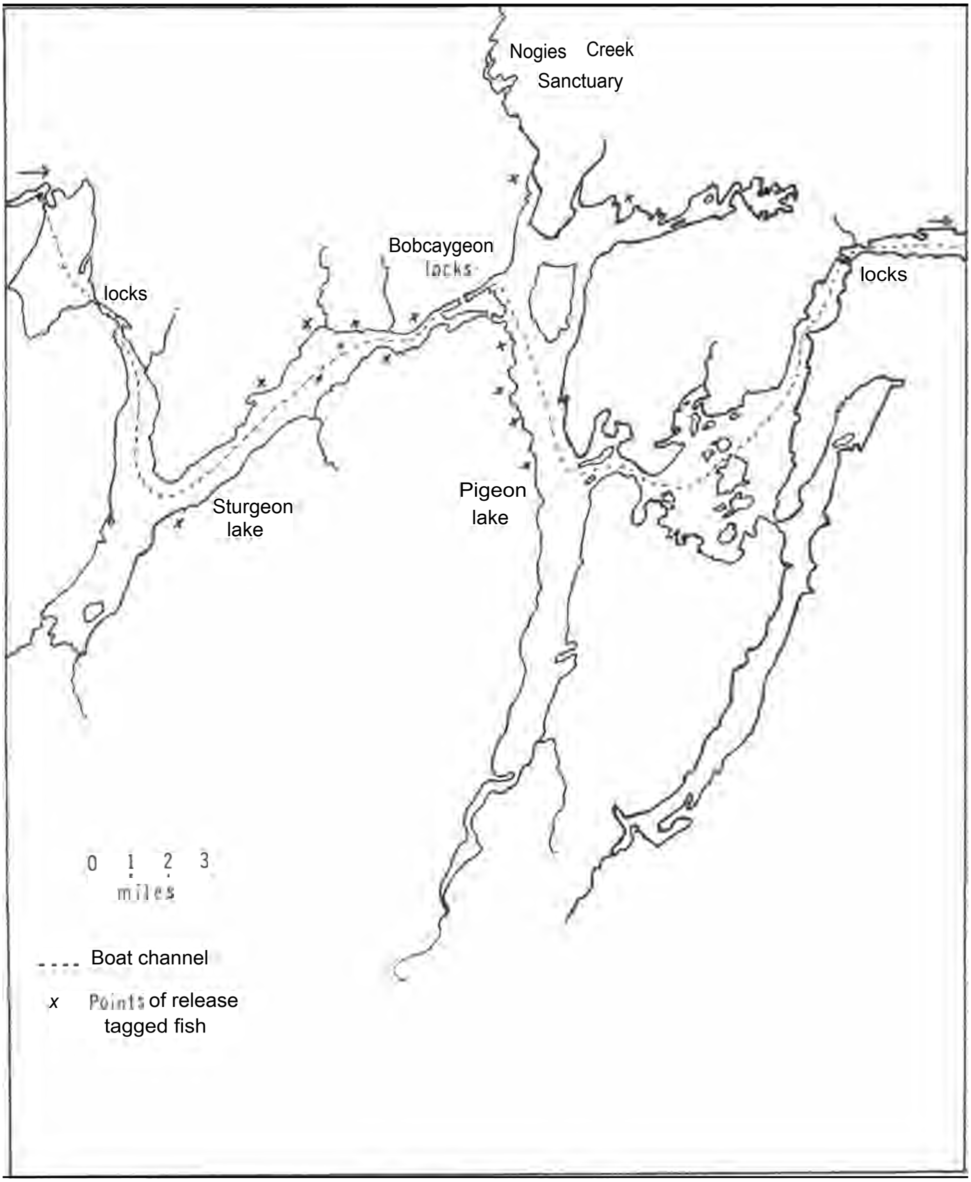

FIGURE 1. *Map of Pigeon and Sturgeon Lakes.*

Transplanting and Tag Returns

During the month of October in the years 1952 to 1958 (excluding 1956) 1533 tagged and 520 untagged maskinonge were transplanted from Nogies Creek to Pigeon and Sturgeon lakes *(see* Table 1). A total of 227 of the tagged fish were reported caught by anglers by the close of the 1960 season, providing recapture rates of 14.7 per cent and 14.9 per cent of the fish planted into Pigeon and Sturgeon lakes respectively. However, of the 103 recaptures from fish planted in Sturgeon Lake, 32 (31.1%) had passed down into Pigeon Lake, either through the canal locks or over the dam. Since the apparent survival of fish planted into the two lakes is essentially the same, it is convenient to treat the two lakes as one system in so far as the recapture data are concerned.

The numbers of fish transplanted each year and the returns in subsequent years are shown in Table II. In all plantings, the largest number of tag returns was from the first year after planting (n +1) and no tags were returned after the fourth year (n+4). The data are rearranged in Table III to show the numbers of each age-group planted and subsequently recaptured. The percentage returned, by year of planting, ranges from 11.0 per cent for 1952 to 23.3 per cent for 1953, and by age, from 5.4 per cent for age-group II to 33.3 per cent for age-group IX. The progressive increase in recapture with age appears to be discontinuous, however, between ages IV and V *(see* Fig. 2) with a sharp increase from about 10 per cent to 20 per cent. The final column of Table III shows the percentage return, from the planting of each year, of fish age V and older at the time of planting. These figures range from 15.5 per cent to 31.6 per cent. The average length of fish from age-group V is approximately legal length (Muir, 1960) and these fish would presumably all be legal size during the angling season the following year.

The data are finally rearranged, in Table IV by age and by year of recapture. Of the 227 recaptures, 196 were caught in year n+1 (first season after planting) whereas only 29 were caught in subsequent years. The bottom row of Table IV shows the totals for fish age V and older. Of 757 releases, 142 were recaptured in n+1 and 17 in n+2. Consideration of the recapture of fish age IV and younger as seen in Table IV and Fig. 2, suggests that, unless a high rate of tag loss is affecting the recorded recapture rates, very few of these fish survive to contribute to the legal fishery. The following consideration of mortality will be confined to fish age V and older.

TABLE I

Numbers of tagged maskinonge transplanted to Pigeon and Sturgeon lakes (1952-1958) and the resulting recaptures (1953-1960).

Lake	Number transplanted	Number recaptured	Percentage recaptured
Pigeon	841	124	14.7
Sturgeon	692	103	14.9

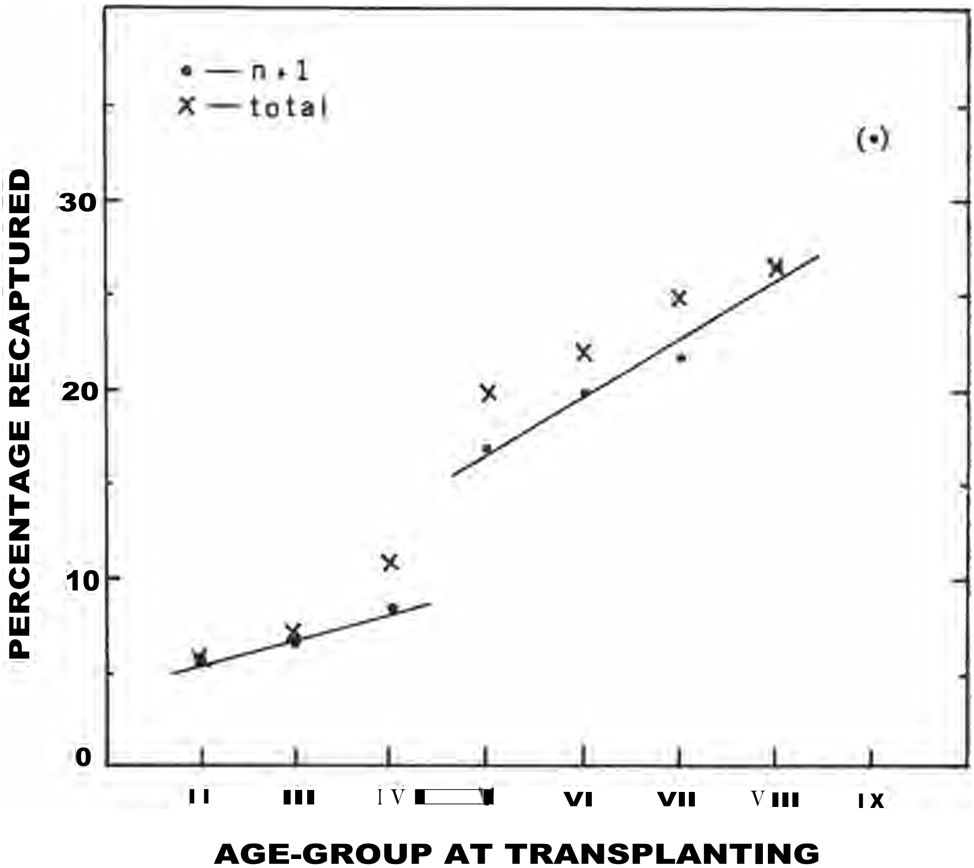

FIGURE 2. The percentage of tags recaptured for each age-group at time of transplanting. Values are shown for the year following transplanting and for total recaptures. Plantings of 1952-1958.

TABLE II

The numbers of fish transplanted each year and the returns by year of recapture.

Year of plant	Number planted	Total return	Year of return							
			1953	1954	1955	1956	1957	1958	1959	1960
1952	155	17	16	0	1					
1953	133	31		26	4	1				
1954	131	20			15	3	1	1		
1955	298	53				41	10	1	1	
1956	—	—								
1957*	323	43					1	39	3	
1958	493	63						1	59	3
Total	1533	227	16	26	20	45	12	42	63	3

* 520 untagged fish were also transplanted in 1957.

TABLE III

The number of maskinonge of each age-group transplanted from Nogies Creek in the years 1952 to 1958 and the subsequent recaptures. None transplanted in 1956.

Year of plant	Data	Age at tra isplaneng													Percent	
		II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIV	Total	II+	V+
1952	plaited	3	17	60	39	27	9							155		
	captured		2	2	5	8								17	11.0	17.3
1953	planted	1	13	44	56	18	1							133		
	captured		1	10	17	3								31	23.3	26.7
1954	planted	2	16	49	32	24	4	2	0	1	1			131		
	captured			9	6	4	1							20	15.3	17.2
1955	planted	5	43	82	94	48	16	5	1	1	2	1		298		
	captured		2	6	20	15	8	2						53	17.8	26.8
1957	planted	36	1	45	109	77	58	27	2	3	0	0	1	323		
	captured				10	13	12	7					1	43	13.3	15.5
	untagged	36	117	192	111	47	15	1	1					(520)		
1958	planted	156	150	89	57	26	9	4	3					493		
	captured	9	11	12	19	5	4	1	2					63	12.8	31.6
Planted (tagged)		167	240	369	387	219	97	38	6	5	3	1	1	1533		
Recaptured		9	16	39	77	48	25	10	2	0	0	0	1	227		
Percentage		5.4	6.7	10.6	19.9	21.9	25.8	26.3	33.3							

TABLE IV

Number of maskinonge planted at each age and the recaptures by year. Plantings of 1952-1958.

Age at plant	Number planted	Year of recapture					Percentage	
			n+1	n+2	n+3	n+4	n+1	total
II	167		9				5.4	5.4
III	240		15		1		6.3	6.7
IV	369		30	6	2	1	8.1	10.6
V	387	1	65	11			16.8	19.6
VI	219	1	43	3	1	1	19.6	21.9
VII	97		21	3			21.6	24.7
VIII	38		10				26.3	26.3
IX	6		2				33.3	33.3
X	5		0					
XI	3		0					
XII	1		0					
XIV	1		0					
Total	1533	2	196	23	4	2		
Total V+	757	2	142	17		1		

The first estimate of the average rate of exploitation of fish age V and older is 142/757 = 0.188, which means that 19 per cent of the fish transplanted were caught in year n+1. This in itself is minimum since a portion of the fish may have died as a result of the transplanting and others may have lost tags. However even if these portions were known, the estimate would be the exploitation of fish eight months after transplanting during which time "ordinary" natural mortality would have taken its toll.

It is of more interest to know the rate of exploitation of tagged fish, during the actual fishing season, which are present at the beginning of that season. For this, we need an estimate of the loss of tags or tagged fish during the eight months between planting and the start of the fishing season. The fishing season extends from July 1st to October 15th, a period of 3½ months. However, since the greatest amount of fishing occurs during July and August and relatively little after mid-September, we shall consider the season to be of only 2½ months' duration.

An estimate of the loss during the first eight months may be approached by first estimating the rate of natural mortality for the interval beginning with the start of fishing in n+1 (July 1st) and ending at the same point in n+2. This mortality rate could be applied to the period from transplanting to the start of fishing provided the following assumptions are reasonably met.

1. That natural mortality occurs at a uniform rate throughout the entire year and is similar for the various age-groups involved.
2. That whatever tag loss or mortality due to the tag exists, occurs at a uniform rate throughout the period of study.
3. That the catchability of the tagged fish is uniform, so that the catches in n+1 and n+2 are approximations of relative abundance.

Taking the catches of 142 and 17 to represent abundance of tagged fish, near the middle of the fishing season in n+1 and n +2, we may use the "catch curve method" (Ricker, 1958, pg. 44) to estimate total mortality during the interval. During this one-year period the total disappearance of tags (i.e. apparent total mortality, a) is 0.88. The second of the above assumptions, that of tag loss, is probably the most important in this particular study (Muir, 1963). Within the sanctuary, the rate of tag loss increases with time in violation of the assumption. Since this would tend to increase the apparent mortality, the estimate of $a = 0.88$ is probably a maximum. Since the heaviest loss due to mortality caused by tagging and handling would occur well in advance of the start of the first fishing season, it does not likely influence this estimate.

A conditional disappearance of 0.88 corresponds to an instantaneous rate of disappearance (i') of 2.12 which can be fractionated

$$= p + q' = 2.12 \qquad (1)$$

where p is the instantaneous rate of fishing mortality and q' designates the instantaneous rate of loss due to natural mortality (q) plus tag loss and the additional mortality imposed by the tag. The basic notation i, p, and q, is that of Ricker (1958) and the symbols correspond to Z, F, and M of the "International Notation" (Holt *et al*, 1959).

The problem of separating i' into its components may be approached by considering the period of 8 months between the period of release and the start of the fishing season and then the period of $2\frac{1}{2}$ months for the fishing season itself. We must assume, however, that the estimate for disappearance of 0.88 which was derived from the 12-month period between the start of fishing in n+1 and in n +2, also applies to the 12-month period immediately following the transplanting in year n. Thus after 8 months the survivors of a unit number of tagged fish are:

$$e^{-8q'/12} \qquad (2)$$

During the fishing season the fraction caught, of those present at its start (i.e. of those represented by expression (2)) is shown by the expression (which is analogous to pa/i):

$$\frac{p\left(1-e^{-(p+2.5q'/12)}\right)}{p+2.5q'/12} \qquad (3)$$

The product of (2) times (3) is the fraction of the number tagged and released that are caught in the first fishing season and corresponds to $142/757 = 0.188$ from above.

Thus,

$$\frac{p\left(1-e^{-(p+.208q')}\right)}{p+.208q'}\, e^{-.667q'} \qquad (4)$$

is solved by taking trial values of p, obtaining the corresponding q' from (1) and comparing the computed product with 0.188. The final values, obtained in this manner, are $p = 0.75$ and $q' = 1.37$ (which sum to 2.12 of (1)). These coefficients correspond to conditional mortality rates of 0.53 for fishing and 0.75 for the other causes, the total disappearance still remaining 0.88. The estimate of fishing mortality is probably low since some of the fish which had lost tags would survive to be caught although not recognized.

The estimate of exploitation during the fishing season is given by expression (3). For a p value of 0.75, the rate of exploitation (u) is 0.47, which is the fraction of the tagged fish estimated to be present at the beginning of the fishing season which were actually caught during the season. Of 757 transplanted fish, only 303 remained with tags when the season opened in $_{n+1}$ and 142 (47%) of these were caught.

Although these estimates are close to the best that can be made from the data, they must be considered with great caution. The first estimate of exploitation (0.19) is certainly too low since many fish must have died or lost tags during the 8 months between transplanting and the fishing season. The second estimate (0.47) is probably high for several reasons. The basic estimate, 0.88 for total mortality between n +1 and n+2, was considered to be maximum and the extrapolation from this period to the one following the transplanting could involve very serious errors. In view of the high mortality during the season following tagging, observed within the sanctuary (Muir, 1963) it is probable that the true exploitation falls at least mid-way between these two—of the order of 0.35 or greater.

Growth of Transplanted Fish

Anglers were requested to report the length of tagged fish at the time of recapture. From the transplantings of 1953, 1955, 1957 and 1958, 121 lengths were reported in year n+1 and 19 in n+2 for fish in age-group IV to VIII at the time of planting. Most measurements reported appeared credible, but a few indicated exceptional growth and a few were less than the length recorded at the time of transplanting. Under such circumstances, it is probably more advisable to use all measurements reported than to subjectively eliminate those that appear to be out of line.

Recaptures were made during the period from July 1st to October 15th. The measurements were therefore taken throughout the major part of the growth season, and the average increments, calculated from the measurements returned by anglers, will be something less than the true increments for the entire growing season. How much less, however, can not be determined from the available data.

The average growth increments for fish recaptured in year n+1 are shown in Table V for age-group V to IX (in year $_{n+1}$). These increments are plotted in Fig. 3 together with the increments determined for tagged and untagged fish in the sanctuary during the growing season of 1957 (Muir, 1960). From the figure it is apparent that the partial growth increment for tagged fish transplanted to the larger lakes was greater than the increment during 1957 for tagged fish returned to the sanctuary, but still less than that for untagged fish in the sanctuary.

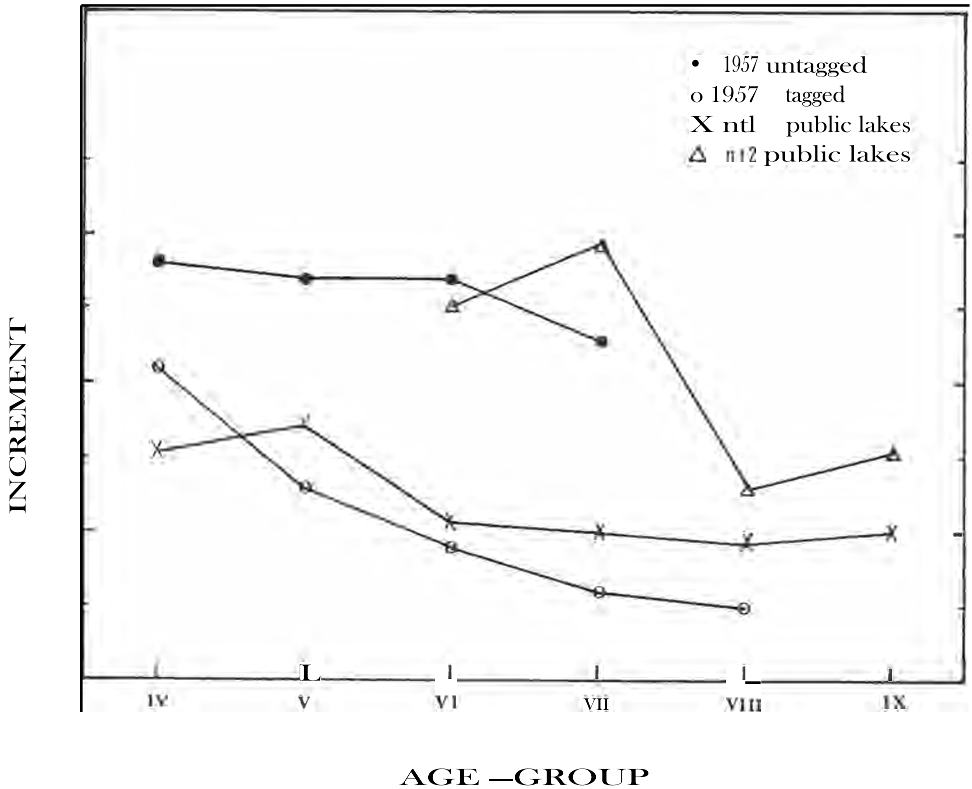

FIGURE 3. Annual growth increments. Values for the 1957 tagged and untagged increments in Nogies Creek are taken from Muir (1960), and for the public lakes, derived from data returned by anglers. The increment for n+2 was obtained by subtracting the appropriate n+ 1 increment from the 2-year increment observed in n+2.

TABLE V

Growth increments (inches) for each age, estimated from lengths reported by anglers. Measurements were taken during the growing season so that the increments represent less than a full year. One-year increments for n+2 obtained by subtracting the increment in n+1 for the appropriate age-group.

	Age-group in year of recapture					
	IV	V	VI	VII	VIII	IX
Year *n+1*						
Number	11	18	52	27	17	7
Increment	1.5	1.7	1.1	1.0	0.9	1.0
Year n+2						
Number			5	9	3	2
Increment (2 yr)			4.2	4.0	2.3	2.5
(n+2) — (n+1)			2.5	2.9	1.3	1.6

The growth increments for the second year after tagging (n+2) for 19 fish are also shown in Table V and Fig. 3. The increment for the second season was determined by subtracting the increment observed in n+1 from the two year increment observed in n+2, adjusting for increased age. The plotted data suggest that growth during the second year was greater and more nearly normal than during the first year after tagging.

This appears to be contrary to an earlier statement (Muir, 1960) that "the few measurements available after the second season (within the sanctuary) indicate that normal growth was not resumed". In both cases however, the data for the second year are certainly too few to give a reliable picture.

If the average increments determined from the anglers' measurements are reliable, which their consistency (Fig. 3) seems to suggest, then it would appear that the tagged fish, at least, attain a greater length in the larger lakes than in Nogies Creek. It remains to obtain a tag which does not interfere with the growth, to determine whether the slower growing Nogies Creek fish will attain lengths comparable to those native to the larger lakes.

Movement

Of the reports returned by anglers, 144 (from year n+1) included points of recapture that could be located on the map. The distance between the points of release and recapture represents the minimum distance travelled during the interval. From the examination of the direction and distances moved, four categories were established, as follows:

Less than one half mile—fish recaptured at or near the point of release.

Across—fish recaptured at some point greater than one half mile from release, but in a direction that could not be considered to be in the next two categories.

Downstream—movement greater than one half mile, considered to be in the same general direction as the flow of water through the system.

Upstream—movement greater than one half mile, considered to be opposite to the general flow or into the mouth of one of the many streams and rivers entering the system.

Reference to Fig. 1 indicates that many directions of movement are possible for which such categorization is almost arbitrary. The definitions were followed as closely as possible however, and the number of fish in each category and each age-group are shown in Table VI. None of the categories used indicates a trend in the direction moved. Of the 144, 55 (39%) moved less than one half mile or in the across direction, 44 moved in a general downstream direction and 45 moved upstream. Of the 44 that moved downstream however, 26 (59%) passed through the locks or over the dam from Sturgeon to Pigeon Lake and most of these were caught in the river below the dam. Had they been able to re-enter Sturgeon Lake, their observed net movement could well have been upstream. A total of 98, of the 144 fish, were recaptured in rivers or at river mouths, indicating a strong preference for moving water. Such preference may be related to the river condition of the sanctuary, since in localities such as the Bobcaygeon River, between Pigeon and Sturgeon lakes, tagged maskinonge are apparently caught out of proportion with untagged fish.

The average distances travelled for fish of each age group are shown in the final row of Table VI. The values in parentheses, for age-groups IV and VII, are exclusive of two fish that travelled extraordinary distances (23 miles downstream each). With the exclusion of these two fish, the average distance travelled increases with age from 1.8 miles for age-group III to 2.7 miles for age-group VII. A similar increase in the distance travelled with age was observed for maskinonge within the sanctuary (Muir, 1963).

The distance between point of release and point of recapture gives little indication, however, of the nature of the movement since the time out involved was nearly one year. Reports are quite common of particularly large fish apparently being seen in the same location for several days or even weeks, and many anglers believe that "lunge" tend to remain in "home territories". The significance of the recapture of so many tags in Pigeon Lake, that were planted into Sturgeon Lake, is not clear. It is questionable that it represents selection on the part of the fish. If movement in the reverse direction were not so difficult, the significance might be more apparent. Two reports were received of Pigeon Lake tags being caught in the upper lake but in both cases the information was not complete enough to include in the above table. Fish are occasionally observed in the locks at Bobcaygeon, providing the only natural explanation for the upward movement, and probably accounting for part or all of the downward movement.

TABLE VI

Direction, average distance moved and number of each age-group determined at point of recapture in year n+1. Figures in parentheses exclude two fish that moved extraordinary distances. Read table, for example, five fish from age-group III moved across an average of 1.8 miles. See text for explanation of categories of movement.

Movement	Age-group at p anting						
	III	IV	V	VI	VII	Number	Average
Less than ¼ mile	2	4	7	12	5	30	—
Across	1.8/5	1.8/4	2.4/11	2.3/3	3.2/2	25	2.2
Downstream	2.0/1	4.9/10*	2.3/18	3.8/9	8.5/6*	44	3.9(2.9)
Upstream	2.8/4	3.6/5	3.3/20	4.4/13	4.6/3	45	3.7
Total number	12	23	56	37	16	144	
Average distance	1.8	3.2(2.3)	2.4	2.7	3.9(2.7)		

* Two fish, age IV and VII, moved 23 miles downstream each and are excluded from the values in parentheses.

Discussion

A reasonable objection to any transplanting program is the indeterminable danger of upsetting the natural balance in the new lake. In certain situations however, where the production of fish is limited by adverse conditions during a particular stage of the life history, there may be justification for planting fish of a size greater than that of the critical stage.

In the present study, it was hoped to learn whether transplanted juvenile and adult maskinonge would survive to significantly contribute to the existing fishery. The movement study provides little information on the behaviour of the transplanted fish since no comparable data are available for the native fish. The distances moved however, do not appear unduly great as might be expected if the fish could not find suitable habitat. Furthermore, the growth of tagged fish suggests that the public lakes provided conditions that were at least better for growth than Nogies Creek.

Tagged fish were watched for during the 1959 spawning observations in Pigeon Lake. No tags were seen at the time but one lone fish evidently cruised through the field of the underwater camera and was later recognized when the film was viewed. Although active spawning was taking place in the immediate vicinity, it is unknown whether this tagged fish actually spawned. It is quite probable however, that the transplanted fish do contribute to the spawning stock.

The low percentage return of fish younger than age-group V suggests that, unless an extremely large number of tags are lost during the second year, these sub-adult fish do not survive in sufficient numbers to warrant transplanting. Of the adult-sized fish (age-group V and older), 21.5 per cent of the tags were subsequently reported by anglers. Allowing for tags not reported and for tags lost, this figure might be placed as high as 30 per cent for an average utilization of adult fish. This could still be low however, since tagging undoubtedly causes additional mortality that would not be present if untagged fish were transplanted on a management basis. Such utilization of the harvested crop of adult fish from Nogies Creek Sanctuary is inefficient compared to allowing the anglers direct access to the sanctuary.

In defense of such inefficient practices, it should be pointed out that Nogies Creek is a small area with a high catch-per-unit-of-effort (experimental angling), whereas the nearby public lakes are large with a high angling pressure and a low catch-per-unit-of-effort. If the sanctuary were opened, it would be quickly exploited by a few anglers and much damage would be done to the concentrated juveniles. Transplanting, although it decreases the utilization, spreads the additional catch over the entire angling population.

The final phase of the study, presently being conducted, will provide estimates of the rate of tag loss and mortality of the tagged fish and of the portion of the total catch contributed by the transplanted fish.

Acknowledgments

This study was carried on as part of a joint project with financial assistance and direction from the University of Toronto, the Ontario Department of Lands and Forests, and the Toronto Anglers' and Hunters' Association. Appreciation is expressed for the guidance of Dr. F. E. J. Fry, chairman of the project committee, and for the assistance of several undergraduate students and employees of the Ontario Department of Lands and Forests. Dr. W. E. Ricker provided helpful suggestions concerning the section on mortalities.

Literature Cited

CROSSMAN, E. J. 1956. Growth, mortality and movements of a sanctuary population of maskinonge (Esox masquinongy Mitchill). J. Fish. Res. Bd. Canada, 13(5): 599-612.

DURSLEY, R. S. and F. E. J. FRY. 1961. A creel census study of the maskinonge, Pigeon and Sturgeon Lakes. Great Lakes Institute, University of Toronto. Preliminary Report Series No. 1. Mimeo. 15 pp.

ELSON, P. F. 1940. Rearing maskinonge in a protected area. Trans. Am. Fish. Soc., 70: 421-429.

HOLT, S. J., J. A. GULLAND, C. TAYLOR, and S. KURITA, 1959. A standard terminology and notation for fishery dynamics. J. Conseil Expl. Mer, 24(2): 239-242.

MUIR, B. S. 1960. Comparison of growth rates for native and hatchery-stocked populations of Esox masquinongy in Nogies Creek, Ontario. J. Fish. Res. Bd. Canada, 17(6): 919-927.

MUIR, B. S. 1963. Vital statistics of Esox masquinongy in Nogies Creek, Ontario I. Tag loss, mortality due to tagging, and the estimate of exploitation. J. Fish. Res. Bd. Canada, 20(5).

MUIR, B. S. 1964. Vital statistics of Esox masquinongy in Nogies Creek, Ontario II. Population size, natural mortality and the effect of fishing. J. Fish. Res. Bd. Canada, 21(4) (in press).

RICKER, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. No. 119, 300 pp.