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Population Estimates of the Southwestern Newfoundland  
Stock of Herring from Tag Recaptures

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Introduction

The seasonal exodus of herring from the southern Gulf of St. Lawrence in late autumn to over-winter along southwest Newfoundland and their subsequent return to the southern Gulf in the spring were earlier inferred from observations on the seasonal pattern of the fishery and from a comparison of biological characteristics (Hodder, 1969, 1970; Hodder and Parsons, 1971; Iles and Tibbo, MS, 1970). Tagging experiments have subsequently confirmed this migration pattern (Winters, MS, 1971). In addition to determining migration routes of fish, tagging experiments also provide information susceptible to analyses for estimation of certain population parameters (Ricker, 1958). This reports deals quantitatively with the recaptures from taggings of herring carried out along southwest Newfoundland in March 1970 and January 1971 and provides estimates of the population size of the over-wintering stock for 1969-70 and 1970-71.

Theory

The estimation of stock strength from recaptures of tagged fish is based on the assumption that the tagged and untagged fish are caught in the same proportion. This may be expressed mathematically in the following way:

$$\frac{R}{M} = \frac{C}{N}$$

where

- R = number of recaptured tags,
- M = number of fish tagged,
- C = catch or sample taken for census,
- N = population size at time of marking.

Bailey (1951) and Chapman (1951) have shown that the above relationship tends to over-estimate the true population size and propose instead the following relationship:

$$\frac{R+1}{M} = \frac{C+1}{N}$$

from which the population size can be estimated as follows:

$$\hat{N} = \frac{M(C+1)}{R+1}$$

An unbiased maximum likelihood estimate of the rate of exploitation of the population is given by

$$\hat{u} = \frac{R}{M}$$

Confidence limits for  $\hat{u}$  can be obtained in the usual statistical manner. Confidence limits for estimates of population size can be obtained by multiplying the limits of  $\hat{u}$  by R and then substituting these limits in the above population size equation. Confidence limits for  $\hat{N}$  can also be derived by treating R as a binomial or Poisson variable, obtaining limits for it directly from Clopper and Pearson's (1934) chart and substituting these in the population size equation (Ricker, 1958).

#### Population Estimates for 1969-70 Season

From 3 to 13 March three liberations of tagged herring totalling 25,000 fish were released in Lapoile and Roti bays of southwest Newfoundland (Winters, MS, 1971). Although it is likely that some of the herring tagged did not survive the shock of handling and tagging, it is impossible to determine the extent of these losses directly. However, some estimates of tagging mortality can be made. All the fish of each liberation were tagged from the same batch of herring which were held in the holding pounds for two or three days and it was noted that the longer these fish were kept in the holding pounds the greater their scale loss and the poorer their physical condition. Consequently it is reasonable to assume that any differences between returns from the first days' tagging of each liberation and subsequent returns are due to the effects of tagging and will reduce the effective number of fish tagged. Table 1 lists tag recaptures by day of tagging for each liberation of tagged fish in the March 1970 releases. For each liberation the percentage returns decreased after the first days' releases and this may be attributed to tagging mortality. On the basis of these returns the following estimates of the effective number of fish tagged for each liberation can be made:

Liberation (see Table 1)	I	II	III
% returns from best day (A)	3.09	2.24	4.75
Total tags recaptured (B)	212	103	331
Effective number of fish tagged (B/A x 100)	6900	4600	7000

Consequently the maximum effective number of fish tagged for the March 1970 releases is considered to be 18,500 which represents a minimum tagging mortality of 26%.

The stock strength of the southwest Newfoundland population of herring at the time of the 1970 tagging has been estimated from tags recaptured during the remainder of the winter fishery in that area (mid-March to mid-April). The reduction plant at Isle aux Morts, Nfld., was responsible for the bulk of the herring landings during this period and consequently population estimates have been made from tag recaptures reported from that plant. To test the recovery efficiency (e) of the magnetic separators installed in the meal line of the plant a known number of tagged fish (300) was introduced into the plant and the subsequent recoveries were recorded. From these recoveries the efficiency of the magnets was estimated to be 30%. This factor is then applied to the number of tags reported (r) from the Isle aux Morts plant to give an estimate of the actual number of tags recaptured. For the 1970 returns from the Isle aux Morts plant we have the following information:

Landings 13 March-15 April 1970 (C)	10,400 m. tons
Maximum number of fish effectively tagged (M)	18,500
Number of tags reported 13 March-15 April 1970 (r)	222
Effective number of tag recaptures (R) = r/e	740

The population size of the southwest Newfoundland stock of herring at the time of the March 1970 tagging is therefore estimated as

$$\begin{aligned}\hat{N} &= \frac{M(C+1)}{R+1} \\ &= \frac{18,500 \times 10,400}{741} \\ &= 260,000 \text{ m. tons}\end{aligned}$$

The rate of exploitation from landing and tag recapture data at the Isle aux Morts reduction plant during 13 March-15 April 1970, is estimated as

$$\begin{aligned}\hat{u} &= \frac{R}{M} = \frac{740}{18,500} \\ &= 4.00\% \text{ for about one month.}\end{aligned}$$

The 95% confidence limits for  $\hat{u}$  are 3.72-4.28% and for the effective number of recaptures (R) are 688-792 tags. By substituting these latter values for R+1 in the population size equation, the 95% confidence limits for  $\hat{N}$  are estimated as 243,000-280,000 metric tons.

The total landings from the winter fishery along southwest Newfoundland prior to 13 March 1970 were 127,000 m. tons. Thus the stock strength at the start of the 1969-70 fishing season (November) along southwest Newfoundland is estimated to be in the range of 370,000-410,000 m. tons, excluding adjustment for natural mortality.

#### Population Estimates for 1970-71 Season

The stock size of herring supporting the 1970-71 fall and winter fishery is estimated from recaptures resulting from the liberation of 10,000 herring tagged in Bay de Loup, Nfld., during 25-26 January 1971 (Table 2). The reduction plants at Isle aux Morts and Burgeo, Nfld., accounted for the bulk of the landings from the period of tagging to the end of March 1971 and consequently population parameters are estimated from the combined recapture data accruing from these two plants. As was the case for the spring 1970 recapture data, the difference between returns accruing from the first and second days' tagging is considered due to the effects of holding and tagging.

The maximum effective number of tagged herring is estimated as follows:

$$\begin{aligned} \% \text{ returns from best day (A)} &= 6.76 \text{ (see Table 2)} \\ \text{Total number of returns (B)} &= 350 \\ \text{Effective number of tagged fish } \left( \frac{B}{A} \times 100 \right) &= 5200 \end{aligned}$$

Tag recovery efficiency tests were conducted at each plant resulting in tag recovery efficiency of 78% at Burgeo and 48% at Isle aux Morts. Also a special tag detection apparatus was in operation at the Isle aux Morts plant and seeding experiments on this system indicated an efficiency of 90%. The effective number of tag recaptures at each plant was estimated on the basis of these efficiencies and combined to provide an overall effective number of tag recaptures. For the 1970 tagging experiment we have the following information:

$$\begin{aligned} \text{Total landings, 28 January-31 March 1971 (C)} &= 25,000 \text{ m. tons} \\ \text{Number of herring effectively tagged (M)} &= 5,200 \\ \text{Effective number of tag recaptures (R)} &= 590 \end{aligned}$$

An estimate of the population size of the southwest Newfoundland herring stock at the time of the Bay de Loup tagging is

$$\begin{aligned} \hat{N} &= \frac{M(C+1)}{R+1} \\ &= \frac{5200 \times 25,000}{590} \\ &= 220,000 \text{ m. tons} \end{aligned}$$

The rate of exploitation for the period under consideration (28 Jan.-31 Mar. 1971) based on landings at the Isle aux Morts and Burgeo plants is estimated as

$$\begin{aligned} \hat{u} &= \frac{R}{M} = \frac{590}{5200} \\ &= 11.34\% \text{ for about 2 months.} \end{aligned}$$

The 95% limits of confidence for  $\hat{u}$  are 10.50-12.18%. Multiplying these by 5200 the limits of confidence for the effective number of recaptures are 546-633 tags. By substituting these limits for R+1 as above the confidence limits for  $\hat{N}$  are 205,000-238,000 m. tons.

The total landings from the 1970-71 Newfoundland winter fishery prior to 28 January 1971 were 40,000 m. tons. Consequently the population size at the beginning of the 1970-71 fall and winter fishery in Newfoundland, excluding adjustment for natural mortality, is estimated in the range of 245,000-278,000 m. tons.

#### Discussion and Conclusions

The reliability of the above population estimates may be affected by several factors (Ricker, 1958) some of which have already been discussed, i.e. tagging mortality and tag recovery efficiency. The most critical factor affecting the accuracy of population estimates from tag recaptures is the magnitude of the recruitment to the fishable stock during the time the recoveries are being made. If significant recruitment occurs during

that period then obviously the estimates of population size will be too great. Analysis of maturity composition data throughout the Newfoundland winter fishery does not indicate a significant influx of immature herring (Hodder, 1970) and recruitment is considered to occur in the Gulf of St. Lawrence during the post-spawning period.

Another source of error in the above estimates concerns the possibility of tag loss during the period under consideration. Significant tag loss will result in over-estimation of population size. The tagging technique used in the Newfoundland taggings minimized loss of tags through the belly insertion cut which was barely large enough to allow the tag to enter the fish. Using the tip of a scalpel blade the tag was pushed forward into the body cavity and the fish was flexed several times to ensure that the tag was completely inside the belly. Also examination of approximately 150 tagged herring that had become meshed in the seine immediately following liberation failed to reveal a single tag loss.

The representativeness of the tag returns also depends on random mixing of tagged and untagged fish. An indication of random mixing is evident from preliminary analysis of tagged herring recovered by a special tag detection system which has been installed at the Isle aux Morts reduction plant. Herring tagged in the Bay de Loup area 25-26 January 1971 were being recaptured from Bay de Vieux (25 miles east of Bay de Loup) and Garia Bay (60 miles west of Bay de Loup) within the first week after their release and subsequent recaptures have indicated that the tagged herring were spread out along the southwest coast. This shows that rapid mixing occurred following the tagging.

Assuming that natural mortality was the same for the 1969-70 and 1970-71 seasons the estimated population size of the southwest Newfoundland stock of herring at the beginning of the 1970-71 winter fishery was only 60-65% of the stock strength estimated at the beginning of the 1969-70 winter fishery. This decrease in stock strength becomes very significant when one considers that landings from the current (1970-71) winter fishery along southwest Newfoundland are approximately 60% of those for 1970 and attests somewhat to the reliability of the population estimates. Landings from the southwest Newfoundland fishery for the 1969-70 season were 135,000 m. tons which represented a seasonal exploitation rate of approximately 30% based on stock strength estimates. These herring are also fished intensively when they move back to the southern Gulf area in the spring. Herring landings in the southern Gulf for the 1970 fishery (April-November) were 195,000 m. tons. However, it cannot be assumed that all of these landings originated from herring that had moved back from the Newfoundland area in April 1970. Analysis of maturity composition of southern Gulf herring (Messiah, personal communication) has indicated that spring spawners are dominant whereas the southwest Newfoundland herring are predominantly autumn spawners (Hodder, 1970). This disparity would indicate that not all of the southern Gulf of St. Lawrence herring over-winter in the Newfoundland area. Nevertheless the high proportion of recaptures of Newfoundland tagged fish in the southern Gulf during the summer of 1970 (Winters, MS, 1971) suggests that a significant portion of the southern Gulf herring returned to that area in the spring after over-wintering in the southwest Newfoundland area. Consequently the annual rate of exploitation of the Gulf of St. Lawrence-southwest Newfoundland stock complex of herring is probably about 40-50%, a level at which the Atlanto-Scandian stock began to collapse according to the report of the Atlanto-Scandian Herring Working Group.

Landings from the 1971 southwest Newfoundland winter fishery from the time of the Bay de Loup tagging to the end of the fishery in mid-April are projected to be about 30,000 m. tons. Thus the stock strength of the over-wintering body of herring at the end of the Newfoundland fishery is estimated to range from 175,000 to 208,000 m. tons. Unless recruitment to the exploited stock is considerably more than is evident from age composition data (Hodder, personal communication) a further drop in herring landings from the Newfoundland winter fishery would appear imminent for the 1971-72 season.

References

- Bailey, N.J.J. 1951. On estimating the size of mobile populations from recapture data. *Biometrika*, 38: 293-306.
- Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. *Univ. California Publ. Statistics*, 1: 131-160.
- Clopper, C. J., and E. S. Pearson. 1934. The use of confidence or fiducial limits applied to the case of the binomial. *Biometrika*, 26: 404-413.
- Hodder, V. M. 1969. Herring landings and distribution of catches in the Newfoundland area, 1967-68. *Fish. Canada*, 22(4): 3-6.
1970. Recent developments in the Newfoundland herring fishery. *Fish. Res. Bd. Canada, St. John's Biol. Sta. Circ.* 18: 1-19.
- Hodder, V. M., and L. S. Parsons. 1971. Comparison of certain biological characteristics of herring from Magdalen Islands and southwestern Newfoundland. *ICNAF Res. Bull. No. 8* (In press).
- Iles, T. D., and S. N. Tibbo. MS, 1970. Recent events in Canadian Atlantic herring fisheries. *ICNAF Ann. Meet. June 1970, Res. Doc. 70/78, Ser. No. 2426*, 14 p.
- Ricker, W. E. 1958. Handbook of computation for biological statistics of fish populations. *Fish. Res. Bd. Canada, Bull. No. 119*, 300 p.
- Winters, G. H. MS, 1971. Migrations of the southwest Newfoundland stock of herring as indicated by tag recaptures. *ICNAF Ann. Meet. June 1971, Res. Doc. 71/108*.

Table 1. Tag returns from the March 1970 tagging experiment by liberation and day of release.

Liberation	Date tagged	Number tagged	Number of returns	% returns
I	3 March	1,100	34	3.09
	4 "	4,600	132	2.87
	5 "	2,700	46	1.70
Total		8,400	212	2.52
II	7 March	4,500	101	2.24
	8 "	300	2	0.67
Total		4,800	103	2.15
III	11 March	2,000	95	4.75
	12 "	7,000	210	3.00
	13 "	2,800	26	0.93
Total		11,800	331	2.81

Table 2. Tag returns to 31 March 1971 from the January 1971 tagging experiment by day of release.

Date tagged	Number tagged	Number of returns	% returns	
25 Jan. 1971	4,200	284	6.76	
26 Jan. 1971	5,800	66	1.14	
Total		10,000	350	3.50