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Estimation of numbers of herring to be tagged in addressing the herring stock intermixture problem[1]

by

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Herring in the southern area of ICNAF have three major spawning areas - Georges Bank-Nantucket Shoals, Jeffreys Ledge, and Lurcher Shoals. Many smaller spawning areas exist but these are less well known and apparently support limited fisheries. Management to date has been placed separately on fisheries harvesting these three spawning stocks but under an overall regulation regime that would minimize adverse effects on the stocks if, in fact, a significant intermixture occurs. Currently, however, the extremely low level of stocks in ICNAF Subarea 5-Statistical Area 6 and the declining stock size in Subarea 4 raises question about the continued validity of the latter assumption. Knowledge of the stock(s) to which juvenile herring recruit has also become more critical to assessing the status of the adult stocks as the adults stocks have declined. Further, the nature of the fisheries has changed with fisheries previously on autumn spawning populations on the spawning grounds to fisheries throughout the year in several areas. While stocks may segregate to spawn, they may be mixed at other times of the year. There is, thus, the need for obtaining quantitative information on the degree of intermixture so that appropriate management regulations can be developed. Prior work with meristic counts, morphometrics, and biochemical tools have not provided the quantitative separation needed to maintain stock abundance. This is particularly true for the Jeffreys Ledge (ICNAF Div. 5Y), Georges Bank (ICNAF Div. 5Z and Statistical Area 6) areas for which environmental conditions are similar.

Herring tagging has been demonstrated to be technically feasible by Canadian biologists (Stobo *et al.*, 1975, Stobo, 1976). Their tagging has already demonstrated that there are interrelations between herring from southwest Nova Scotia and Chedabucto Bay (Div. 4Wa), the Gulf of Maine (Div. 5Y), and even Georges Bank (Div. 5Z).

What is required is a major coordinated tagging study in several areas. The current ICNAF requirement for reporting catch and effort statistics by 30-minute squares should produce sufficient recaptures so that they can be interpreted quantitatively. Strong efforts should be made to measure initial tagging mortality. Proper design of the tagging procedures and methods of recovery might also allow the data to be analyzed for mortality rates as well as for stock interrelationships.

The major fishing areas in ICNAF Subareas 4, 5, and Statistical Area 6 are:

1. The US Point Judith fishery in Subdiv. 5Zw with some fish being taken in Statistical Area 6. This is a winter fishery, December-March, apparently an overwintering area for adult herring.

2. The Georges Bank fishery in Subdiv. 5Ze from June to November. This fishery harvests adult feeding fish around Georges Bank in June-September and spawning fish in September-October on the northern edge of Georges Bank and on Nantucket Shoals. A particular area of interest is in Groundfish Stratum 24 which is off Cape cod just north of the Great South Channel. If herring migrate seasonally to and from Div. 5Y, this is the most likely area of stock inter-mixture between Div. 5Y and 5Z.

3. The Jeffreys Ledge fishery in Div. 5Y off Gloucester, Massachusetts. This was a fishery on adult spawning herring in the fall of the year in the early 1970's. Recently, this fishery has changed taking herring both in the spring and autumn on Jeffreys Ledge and during the summer on Cape Cod Bay. Generally, adult herring are taken but some age 2 fish have recently been taken.

4. The juvenile fisheries from Portland, Maine, to Saint John, New Brunswick. The fishery harvests feeding juvenile herring of ages 1-3 from June to October. (Small amounts of spawning herring are also fished in the fall in a few areas in Western and Central Maine.

5. The Nova Scotia spawning fishery which occurs generally near Lurcher Shoals and Trinity Ledge off southwest Nova Scotia from August to October. The Grand Manan spawning fishery on the other side of the Bay of Fundy has been lumped with the Nova Scotia fishery due to its proximity, the infrequent fishing there and the ignorance associated with it. Many spawning locations exist from St. Mary's Bay to Seal Island, which are considered in the Nova Scotia adult spawning fishery. On the south side of the Bay of Fundy, juvenile herring are also caught in relatively small amounts - generally near St. Mary's Bay.

6. The Chedabucto Bay fishery in Div. 4Wa in northeastern Nova Scotia near Cape Breton. This is apparently on overwintering area for age 3 and older herring providing a fishery in January-March.

In each area, the number of tags must be of sufficient number to ensure adequate recoveries. It is assumed that 200 recoveries in an area of interest (usually a fishery) will suffice.

If we assume:

$$r_j = T_o \, RP(1-e^{-Z})\frac{F}{Z} e^{-Z(j-1)}$$

or

$$r_1 = T_o \, RP(1-e^{-Z})\frac{F}{Z} \text{ for 1 year} \qquad \text{(equation 1)}$$

where r_1 = recaptures made during the year that are actually reported other than those recovered within 2 weeks of the release date and within 3 miles of the release site,

T_o = number of tagged fish released,

R = fraction of tagged herring that survive tagging routine,

P = fraction of total recaptures that are actually recovered, reported and returned,

then, from the total Canadian tagging data (using all recoveries - see Table 1) for 1973 and 1974, we have:

$$1584 = 48{,}078 \, RP(1-e^{-Z})\frac{F}{Z} \qquad \text{(1584 expected number of recoveries in an approximate year)}$$

or $\frac{1584}{48078} = RP(.24)$ and RP = .137 (.24 assumes an F of .3 and an M of .2).

Assuming a handling mortality of .25.

R = .75, then P = .18.

Of 1,143 recoveries as reported in Res.Doc. 75/38 (Table 1), 328 (28.7%) were recovered within 2 weeks and within 3 miles of the release site. If P = .18, then 328/.18 = 1,822 were actually recaptured within 2 weeks and within 3 miles of the release site. These need to be removed from the number released, i.e., 48,078 - 1,822 = 46,256 = effective number of tags at large.

The expected number of tags <u>returned</u> within a year is then calculated from the recoveries that are assumed to be mixed with the herring population (Table 1). This requires that tag recoveries from tag release numbers 3, 4, and 5 be increased to a 12-month basis. This increases the number of tag returns from 815 (Table 1) to 1,116 which produced a return rate of 1,116/46,256 = 2.4%. It follows then, from equation 1 that if F = .3, M = .2, R = .75, then P = .136. This value of P differs from the previous estimates since this P deals with the effective number of tags at large, i.e., 46,256, thereby excluding the herring caught within 2 weeks of the release date and within 3 miles of the tagging site. It is assumed that these rates will apply in ICNAF Div. 4X and 5Y in 1977-78 and the number of tags to be applied is determined from:

$$200 = T_o \, (.75)(.136)(.24) = T_o \, (.024)$$

where (.75)(.136) = RP and .24 = exploitation rate, with F = .3 and M = .2,

$$T_o = \frac{200}{.024} = 8{,}333 \text{ for a given fishery in Div. 4X and 5Y.}$$

It should be remembered that the tag returns apply only to 1 year.

The situation on Georges Bank is not the same as in Div. 4X and 5Y. The average fishing mortality in the 1970 year-class (the most abundant in the stock) for 1974 and 1975 was nearly the same in Div. 4X and 5Y, but greater in Div. 5Z. With an F of 0.3 in Div. 5Y and 4X in future years, the F on Georges Bank may be assumed to be about 0.5. In terms of exploitation rate (about .24 for Div. 5Y and 4X and .36 for Div. 5Z), this means that the probability that tagged herring from the Georges Bank area will be recaptured is about 1.5 times the probability that a tagged herring will be recaptured from Div. 5Y or 4X.

The rate of recovery after the tag is recaptured on Georges Bank is not known. Herring are caught in large numbers and processed by factory trawlers in many ways. Tags on herring that are processed in bulk without individual handling would probably not be detected. An estimate of tag return after recapture of .25 of that achieved in the inshore fisheries seems reasonable. The rate of return in relation to that in Div. 5Y and Div. 4X is then (1.5) (.25) = .375. In terms of equation (1) then

$$r_1 = T_o\ (.75)\ (.136)\ (.25)\ (.236)\ (1.5) = T_o\ (.0090)$$

where .75 = R; (.136) (.25) = P; (.236) (1.5) = the exploitation rate.

To obtain a return of 200 tags, $\frac{200}{.0090}$ = 22,200 must be tagged in Div. 5Z if the recoveries are made there.

Tags Required for Stock Mixture

1) Point Judith (5Zw) tagging in Jan-March:

assuming tag returns from 2 fisheries - 5Y and 4X
" F = .3 in each fishery, M = .2
" RP = .102 in each fishery, (R = .75, P = .136)
200 recoveries fro the first year in each fishery.

Then from equation 1: $$T_o = \frac{r_1}{RP(1-e^{-z})F/Z} = \frac{400}{(.102)\ (1-e^{-0.8})\ (0.6/0.8)} = \frac{400}{(.102)\ (.413)}$$

$$T_o = 9{,}500$$

This assumes that the complete tagged population is available to both fisheries at the same time. If the tagged fish became available to each fishery in sequence for 6 months each the number of tagged fish would have to be 12,000 to produce 200 tags in the second fishery. This would give 298 tags in the first fishery. If the tagged fish separate with half going to each fishery, 16,600 tags would be required. If the herring went to only one fishery, as before, only 8,300 tags are required. This latter assumption is probably not the case, however.

2) The Georges Bank Fishery:

If some Georges Bank tagged herring migrate into 5Y the number of fish tagged is related to the expected movements. Assuming that 25% of tagged herring on Georges Bank move into 5Y then:

$$T_o\ (.25) = (.25) = \frac{200}{.024} = 8{,}300$$

and T_o = 33,330 to allow a return of 200 tags in 5Y

to produce a tag return of 200 tags in 5Z then:

$$T_o\ (.75) = \frac{200}{.0090} = 22{,}200$$

and T_o = 29,600

The number of tags varies between 8,000-33,000 depending on the assumption about migration and the purpose of the experiment. A level of 25,000 is recommended if tagging is done just after spawning and fish leave the area shortly thereafter. If herring were tagged just before spawning, the fishing mortality from the Georges Bank fishery might produce a large number of tag returns before the fish have a chance to move into other areas and the number of fish tagged would then have to be increased if 200 returns were expected.

3) Jeffreys Ledge (5Y)

This situation is similar to Point Judith i.e. 8,300 to 16,600 tags. Since it is likely that some of this fish migrate to 4X the higher figure is recommended to ensure sufficient recoveries in both fisheries.

4) The juvenile fisheries in the State of Maine and New Brunswick.

In addition to the mortalities involved with adults it may be expected that the handling mortality of juveniles would be at least .8(0.25 for adults). Therefore, the return rate would be .64% (RPU = .2 x .136 x .236). To obtain 200 returned would require 31,200 tagged. If the juveniles moved to 5Z then 82,000 tags need to be released to ensure a return of about 200 on Georges Bank, i.e.

$$r_1 = \text{to PRU} = 82{,}000(.2)(.136)(.36)(.25) = 201$$

If tagged herring are caught by the juvenile fishery immediately upon release and a year passes before the herring are recruited to Georges Bank, then more herring than 82,000 need to be tagged.

With a range of 30,000 to 82,000 tags at least, at least 40,000 is recommended for the Maine juvenile fishery and also for the New Brunswick juvenile fishery.

5) The Southwest Nova Scotia fishery.

Of 23,938 tags released in this area, 40(.17%) were recovered at Cape Breton (ICNAF Div. 4VWa) and 16(.067%) were recovered in 5Y or 5Z during the first 7 months. To obtain 200 recoveries in 5Y and 5Z would require 300,000 tags at this rate and to obtain 200 recoveries in 4VWa would require 118,000 tags. Total recoveries from this area were very low in the first 7 months .62% (Table 1). To obtain a total of 200 returns would mean tagging 32,000 on this basis. The average return rate from the Canadian tagging in the first year was 2.4% which would require 8,333 tags to produce a return of about 200. Since we are interested in returns from other fisheries, as many tags as possible should be released.

A summary of suggested minimum tag releases is as follows:

1. 5ZW - Point Judith adults - 17,000
2. 5Ze - Georges Bank adults - 25,000
3. 5Y - Jeffreys Ledge adults - 17,000
4. 5Y - Maine Juveniles - 40,000
5. 4X - New Brunswick juveniles - 40,000
6. 4X - Nova Scotia adults - 25,000

TOTAL - 164,000

Such a large undertaking would require the assistance and cooperation of several countries (particularly on Georges Bank) in the tagging and all countries in reporting the returns. Although such an operation may be expensive it should provide an insight to the errors in the present management system in so far as stock overlap is concerned. Such tagging studies will help to ensure that fishing effort is not concentrated on any one stock (such as the small Jeffreys Ledge stock in 5Y) and may indicate to which adult spawning population the juvenile herring in Maine and New Brunswick recruit. This in turn might allow management of this complete stock (at age and by area).

References

STOBO, W.T., J.S. SCOTT, and J.J. HUNT. 1975. Movements of herring tagged in the Bay of Fundy. *Ann. Meet. Int. Comm. Northw. Atlant. Fish. 1975*, Res.Doc. 75/38 Serial No. 3517 (mimeographed).

STOBO, W.T., 1976. Movements of herring tagged in the Bay of Fundy - Update. ICNAF Res.Doc. 76/VI/48 Serial No. 3834.

Table 1. Summary of Canadian tagging (from Res.Doc. 75/38 plus other sources).

Tag release No.	Location of tagging	Year	Date	No. tagged	Recoveries						Gear used in collec. fish	No. tags per day	Recovery period
					Total	Total for 12 mos.	Near site	Assumed mixed	Assumed mixed for 12 mos.	% recov.[1]			
1	Grand Manan	1973	21-30 Nov	3,370	110	110	5	105	105	3.12	PS	337	12 mos.
2	" "		3-5 Dec	8,777	167	167	31	137	136	1.59	PS	2,915	12 mos.
3	" "	1974	24-27 Jun	3,860	143	190	30	113	151	3.08	Weir	965	9 mos.
4	Campobello Is.	1974	24-31 Jul	8,133	575	863	262	313	470	4.83	Weir	1,017	8 mos.
5	SW Nova Scotia	1974	20-31 Aug	23,938	148	254	0	148	254	0.62	PS	2,176	7 mos.
TOTAL				48,078	1,143	1,584	328	815	1,116			1,335 (average)	

[1] Number of assumed mixed herring divided by the effective number of tags at large.