Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC
Res. Doc. 81/69

Annual Variation in Standing Stock in a Newfoundland Population of Lobsters, *Homarus americanus*

by

G. P. Ennis
Department of Fisheries and Oceans
Research and Resource Services
P. O. Box 5667
St. John's, Newfoundland
A1C 5X1

ABSTRACT

A time series of Petersen estimates of standing stock is presented for a localized lobster fishing area in Notre Dame Bay on the northeast coast of Newfoundland. Standing stock has increased substantially during the 1970's as a result of increased recruitment. The proportion of recruits in the standing stock ranged as high as 91% and exploitation rates in the fishery as high as 93.5%. It is suggested that in a fishery so heavily dependent on recruitment, dramatic fluctuations in annual landings are inevitable. Greater stability in landings could be achieved with lower levels of exploitation.

RESUME

Nous présentons une série chronologique de Petersen d'estimations du stock actuel d'une zone de pêche du homard limitée de la baie Notre-Dame, sur la côte nord-est de Terre-Neuve. Le stock actuel a augmenté substantiellement dans les années 1970 par suite d'un recrutement accru. La proportion des recrues dans le stock actuel atteint 91 % et les taux de capture, 93,5 %. Dans une pêche aussi étroitement dépendante du recrutement, des fluctuations dramatiques des débarquements annuels sont, à notre avis, inévitables. Une exploitation moins intense conduirait à une plus grande stabilité des débarquements.

INTRODUCTION

Lobster landings in most areas are characterized by sharp annual fluctuations which have a dramatic impact on economic conditions in coastal communities throughout Atlantic Canada. It is clearly important to understand the causes of these fluctuations as a basis for identifying resource management options which might be employed to develop greater stability in the fishery. To this end a study of the lobster fishery and various aspects of lobster population biology has been conducted at Comfort Cove, Notre Dame Bay since 1971. This paper presents the time series of annual estimates of standing stock and related population parameters which are available to date from this study.

MATERIALS AND METHODS

In the autumn of 1971, following the molting period, special fishing was carried out in the area of Comfort Cove, Notre Dame Bay. Commercially legal lobsters were tagged with carapace strap tags (Wilder 1954) and released immediately after being removed from the traps. Field staff maintained frequent contact with fishermen during the following spring fishing season to ensure return of all recaptured tags. This tagging was repeated in 1974 and has been each year since. The number of lobsters tagged has ranged from 220 to 501. In 1976, 1977, 1978 and 1979 highly visible secondary marks (colored lobster claw bands positioned on the carpopodite of each claw) were applied as well. Fishermen were asked to maintain records of untagged lobsters bearing these marks. This informaton was used to obtain an estimate of tag loss over the 6 month period between tagging and the start of the following spring fishing season. Starting in 1974 all lobsters caught during the tagging period were examined for shell condition to determine whether or not each had molted during the preceding summer molting period (Ennis 1977). These observations were used to estimate proportions molting at size as described by Ennis (1978a). Throughout the fishing season several fishermen recorded their daily catch (number of commercially legal lobsters) and effort (traps hauled) in a log-book provided. The weekly catches of these and other fishermen were sampled for carapace length and sex throughout the season. Molt increment data for lobsters in this area were obtained from a "sphyrion" tagging project conducted in 1971 (Ennis et al., in prep.).

RESULTS AND DISCUSSION

ASSUMPTIONS OF THE PETERSEN MODEL

The Petersen method was used to estimate standing stock. These estimates are valid only insofar as the seven basic assumptions of the model are met. A consideration of the extent to which these assumptions are met in the present study follows.

1. <u>N is constant</u>. Tagging studies (unpublished) in the area of Comfort Cove and elsewhere in Newfoundland indicate that lobsters have rather restricted movements and practically all tag recaptures have been within the tagging area. The Comfort Cove lobster grounds include a stretch of shore line of about 10.8 miles (17.4 km) and along this shoreline lobsters are restricted to a narrow band of rocky bottom that generally does not extend more than 150 m

from shore. At the ends of this stretch of shoreline there are no barriers to movement of lobsters into or out of the area. Tagging has been conducted throughout the area but recoveries from outside have been negligible. In this area, molting, spawning and hatching occur during late July to late August. Hence there are no changes to the size of the commercially legal lobster population as a result of these activities between the fall (October) tagging period and the spring (April 20 - July 15) fishing season. Indications are that annual natural mortality at commercial sizes ($\geq$ 81 mm CL) is quite low for lobsters and it is expected that most would be associated with annual molting activity. In conclusion, there appears to be no serious violation of the assumption that population size is constant.

2. No tag loss. Some tags are lost during the 6 month period between tagging in the fall (October) and the commercial fishing season (April 20-July 15) the following spring. Estimates of tag loss are available from the use of highly visible secondary marks during the fall tagging in Comfort Cove for the years 1976-79. Fishermen were canvassed at intervals during each fishing season to obtain data on recaptured lobsters with secondary marks only. The estimate of tag loss ranged from 0.3% to 2.8% (Table 1). The four years' data were pooled to get a mean estimate of 1.7% which was used to determine the number of tagged lobsters left in the population at the beginning of the fishing season.

3. Tagging does not affect catchability. In the present study no attempt has been made to test this assumption. Presumably any such affect (e.g. reduced catchability because of handling etc.) would be short term. Tagging was done well in advance of the fishing season and there is nothing to suggest that catchability of tagged lobsters during the fishing season was affected by the tagging or by the presence of the tag. It is also assumed that there is no mortality associated with tagging.

4. In the second sample tagged animals are randomly distributed throughout the population. An unbiased estimate of population size is possible if there is uniform mixing of tagged and untagged animals in the population. In the present study the tagging operation itself ensured a high degree of mixing. The traps used to catch the lobsters for tagging were distributed throughout the area and each trap was moved repeatedly during the tagging period. In addition, even though lobsters have rather restricted movements particularly during cold water periods of the year, it is quite likely that further mixing would be achieved during the 5-6 month period between tagging in the fall and the beginning of the fishing season the following spring. It is considered that in this study uniform mixing of tagged lobsters has been achieved to the extent that no significant bias is present.

5. All animals have the same probability of being caught in the first sample. A comparison of sex ratios of commercial lobsters ($\geq$ 81 mm CL, non-ovigerous) taken in traps in the fall and during the fishing season the following spring indicates that females are undersampled in the fall. In the fall samples males outnumber females by around 2 to 1 whereas in spring the sexes are usually very close to equally represented (Table 2). This is not readily explained and it is not clear if it is due to increased catchability of males or reduced catchability of females. To test the importance of this, estimates of N were derived for males and females separately and combined. In six out of seven estimates N was lower when males and females were combined. The

difference ranged from 0.3 to 11% of the estimate obtained when males and females were treated separately and added together. In one estimate N was higher by 3.9%. To eliminate any possible bias, the estimate of N and subsequent calculations using N were derived for males and females separately. Size frequency distributions from these same fall and following spring samples were compared to determine if there was any difference in catchability related to size for either sex between fall and spring. While there was no obvious difference in the size frequencies, in five out of six comparisons there were significantly smaller proportions in the recruit size range (i.e. more larger lobsters) in fall than in spring for the males; however, for the females this was true in only one out of six comparisons (Table 3). In the case of males there is a slight tendency for larger animals to be caught in the fall; however, it is considered that any bias in the estimate of N resulting from this would be very slight. Because of the small numbers of larger lobsters tagged, it would be unrealistic to try to remove this bias by estimating the numbers of smaller and larger lobsters separately as was done for males and females. For this reason this possible bias is being ignored in the estimates presented here.

6. All animals in the second sample are correctly classified as tagged or untagged. The carapace strap tag is attached along the mid-dorsal line of the carapace and is very conspicuous. Since the catch per trap haul is generally quite low (mean CPUE is less than 1 commercial lobster per trap haul) and all lobsters caught are handled individually, it is extremely unlikely than any tagged lobsters in the catch would be missed.

7. All tags are reported on recovery. To ensure that all recaptured tags were returned, field staff met with each fisherman in the area periodically throughout the fishing season. Fishermen were not required to mail or bring the tags anywhere. Rewards were paid in cash as the tags were collected or in a lump sum at the end of the season. It is felt that this procedure eliminated non return of tags as a bias.

Conclusion Regarding Assumptions. There appear to be no serious violations of the basic assumptions of the Petersen model. The degree of reliability in the estimates of population size therefore, should be fairly high. However, absolute accuracy is not critical in the present study, the main purpose of which is to measure and explain year to year fluctuations. Any biases that may be present should be consistent from year to year and any substantial differences in the estimates should reflect real changes in population size over time.

ESTIMATES OF STANDING STOCK

The number of commerical lobsters (i.e. $\geq$ 81 mm CL and non-ovigerous) present on the Comfort Cove grounds at the beginning of each fishing season was estimated using Chapman's (1951) modified version of the Petersen method. This is as follows:

$$N = \frac{(M+1)\ (n+1)}{m+1}$$

where

M = number of marked animals from the first sample;
n = number of animals examined for marks in the second sample; and
m = number of marked animals in the second sample.

The data on which the estimates are based are provided in Table 4. As explained above, estimates were derived for males and females separately and then added to obtain the estimate of N. Variance was also estimated for males and females separately, using the formula

$$v = \frac{(M+1)\ (n+1)\ (M-m)\ (n-m)}{(m+1)^2\ (m+2)}$$

and added. A normal distribution is assumed and 95% confidence limits were derived according to

$$N \pm 1.96\ \sqrt{v_m + v_f} \quad \text{(see Seber 1973, p. 59-62)}$$

Confidence limits ranged from ±13 to ±21%. There is some overlap in 95% confidence limits for the series of estimates of N, however, it is clear that there has been a substantial increase in population size over the period for which estimates are available (Fig. 1). The estimates indicate a doubling in population size between 1972 and 1978.

Estimates of the parameters most likely to cause annual fluctuations in the abundance of commercial lobsters were obtained and their variation in relation to the population size estimates examined. Most are derived from N using various sampling data. No attempt has been made to determine confidence limits.

With exploitation rates in the Comfort Cove area as high as 93.5% (Table 4), it is obvious that recruitment has to be the major factor in determining the size of the standing stock in any given year. The upper limit of the recruit size ranges (81-92 for males; 81-90 for females) and the lower limits of the prerecruit size ranges (70-80 for males; 71-80 for females) were determined from the premolt-postmolt relationships (Ennis, et al., in prep). The number of recruits (i.e. the number of lobsters that molted to commercial size ($\geq$ 81 mm CL) since the preceding fishing season) was estimated as described by Ennis (1979) using data from the preceding fall shell condition sampling and from commercial catch sampling during the fishing season. The proportion of recruits in the standing stock (N) varied from 79 to 91% and the variation in the number of recruits coincided with variation in N (Fig. 1A). The cause of increased recruitment during the 1970's cannot be determined with certainty. Better than average environmental conditions for survival of lobster larvae to settlement stage and beyond may have prevailed during the 1960's. Another possibility is improved conditions for growth and survival of prerecruits because of low levels of recruit abundance, as indicated by commercial landings (Ennis et al., in prep.) during the early 1970's.

The number of prerecruits in the population the preceding year was estimated by dividing the number of recruits in the current year by the proportion molting in the prerecruit size range the preceding year times the survival rate (i.e. 90%-annual natural mortality assumed to be 10%). Variation in the abundance of prerecruits in the preceding year also coincided with variation in N (Fig. 1A). The number of commercial lobsters remaining in the population following exploitation in the preceding year (Fig. 1A) which would make up the majority of non-recruit lobsters in N the following year (Fig. 1A) ranged between 1000 and 3000 and had very little, if any, impact on annual variation in N. There was annual variation in proportion molting in both the prerecruit and recruit size ranges (Fig. 1B). Annual variation in proportion molting in the prerecruit size range tended to coincide with variation in N the following year.

From the comparisons it is quite clear that recruitment is the key factor involved in annual variation in the abundance of commercial lobsters and in any given year this is determined by numbers and proportion molting in the prerecruit size range the preceding year. Dramatic fluctuations in landings from year to year are inevitable in a fishery that is heavily dependent on recruitment. Even under an ideal fisheries management regime, natural fluctuations in abundance of lobsters (and hence landings) will occur, however, far greater stability in landings than the present management regime allows can be achieved. The key is a lower level of exploitation which will allow an increase in the abundance of non-recruit lobsters in the standing stock which will provide a buffer against annual fluctuations in recruitment. In addition, reduced exploitation rates will result in increased yield per recruit and increased egg production within the population (Ennis 1978b, 1980). Presumably, increased egg production would result in a higher average level of recruitment, thereby providing for a more rapid increase in abundance and greater stability in landings.

ACKNOWLEDGMENTS

A large number of technical staff and casual employees participated in various aspects of this study at different times. I am particularly indebted to G. Dawe who was responsible for carrying out most of the field work and data compilation and to P. W. Collins who participated in some of the field work and carried out most of the analyses and computations.

REFERENCES

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. Univ. Calif. Public. Stat. 1: 131-160.

Ennis, G. P. 1977. Determination of shell condition in lobsters (*Homarus americanus*) by means of external macroscopic examination. Proc. Nat. Shellfish. Assoc. 67: 67-90.

1978a. Growth curves for Newfoundland lobsters from data on molt increment and proportion molting. CAFSAC Res. Doc. 78/29, 11 p.

1978b. Yield per recruit assessments for Newfoundland lobster stocks. CAFSAC Res. Doc. 78/31, 18 p.

1979. Estimates of abundance and recruitment to the standing stock for a Newfoundland population of the lobster, Homarus americanus, with a method of estimating its natural mortality. Rapp. P-v Réun. Cons. Int. Explor. Mer 175: 225-228.

1980. Further yield per recruit analyses for Newfoundland lobsters. CAFSAC Res. Doc. 80/39, 14 p.

Ennis, G. P., P. W. Collins, and G. Dawe. Fisheries and population biology of lobsters (Homarus americanus) at Comfort Cove, Newfoundland. IN PREPARATION.

Seber, G. A. F. 1973. The estimation of animal abundance and related parameters. Griffin, London. 506 p.

Wilder, D. G. 1954. The lobster fishery of the southern Gulf of St. Lawrence. Fish. Res. Board Can. Atl. Biol. Stn., Circ. 24, 16 p.

Table 1. Estimates of tag loss between tagging in the fall and the fishing season the following spring at Comfort Cove, 1977-80.

Year	No. tagged in preceding fall	No. of fishermen canvassed	No. of tags returned	No. of lobsters observed with secondary marks only	% tags lost
1977	488	24	428	9	2.1
1978	501	18	379	1	0.3
1979	499	13	353	10	2.8
1980	476	15	371	7	1.9
All years	1964	-	1531	27	1.7

Table 2. Comparison of sex ratios in commercial landings at Comfort Cove, 1975-80 and in commercial lobsters taken in sampling the preceding fall.

	Commercial landings				Preceding fall sampling			
Year	No. males	No. females	M:F	P	No. males	No. females	M:F	P
1975	1017	760	1:0.75	<.005	573	283	1:0.49	<.005
1976	1365	1146	1:0.84	<.005	502	258	1:0.51	<.005
1977	1319	1260	1:0.96	>.10	614	295	1:0.48	<.005
1978	1469	1389	1:0.95	>.10	617	340	1:0.55	<.005
1979	1422	1541	1:1.08	>.025	583	382	1:0.66	<.005
1980	1726	1962	1:1.14	<.005	568	271	1:0.48	<.005

Table 3. χ^2_c values (2 x 2 contingency table) from comparisons of proportions in recruit size range in fall tagging sample and commercial catch sample the following spring.

	Males					Females				
	Fall		Spring			Fall		Spring		
Fall/ Spring	Total	Proportion in recruit size range	Total	Proportion in recruit size range	χ^2_c	Total	Proportion in recruit size range	Total	Proportion in recruit size range	χ^2_c
1974/1975	380	.839	1017	.920	18.94	91	.912	760	.922	0.02
1975/1976	381	.885	1365	.925	5.68	138	.928	1146	.905	0.51
1976/1977	442	.855	1319	.923	17.35	122	.893	1260	.930	1.70
1977/1978	492	.884	1469	.914	3.59	161	.938	1389	.911	0.97
1978/1979	454	.881	1422	.928	9.11	239	.833	1541	.897	8.15
1979/1980	439	.875	1726	.933	15.44	125	.864	1962	.885	0.33

Critical value of chi-square with 1 d.f. at P = 0.05 = 3.84
Critical value of chi-square with 1 d.f. at P = 0.01 = 6.63

Table 4. Tag-recapture data, etc. from which estimates of population size were obtained.

Year	Number lobsters tagged preceding fall		Number tagged lobsters in population at beginning of fishing season		Number tagged lobsters returned during fishing season	Exploitation rate (%)	Number tagged lobsters returned by fishermen who provided catch data		Number lobsters caught by fishermen who provided catch data	
	M	F	M	F	M/F combined	M/F combined	M	F	M	F
1972	357	127	351	125	371	77.9	82	36	1469	1465
1975	265	88	261	86	291	83.9	64	13	1918	1433
1976	160	60	157	59	202	93.5	41	12	2464	2068
1977	376	112	370	110	439	91.5	136	40	3890	3717
1978	368	133	362	131	450	91.3	119	35	3478	3289
1979	298	201	293	198	417	84.9	102	63	3136	3398
1980	363	113	357	111	417	89.1	114	32	3251	3696

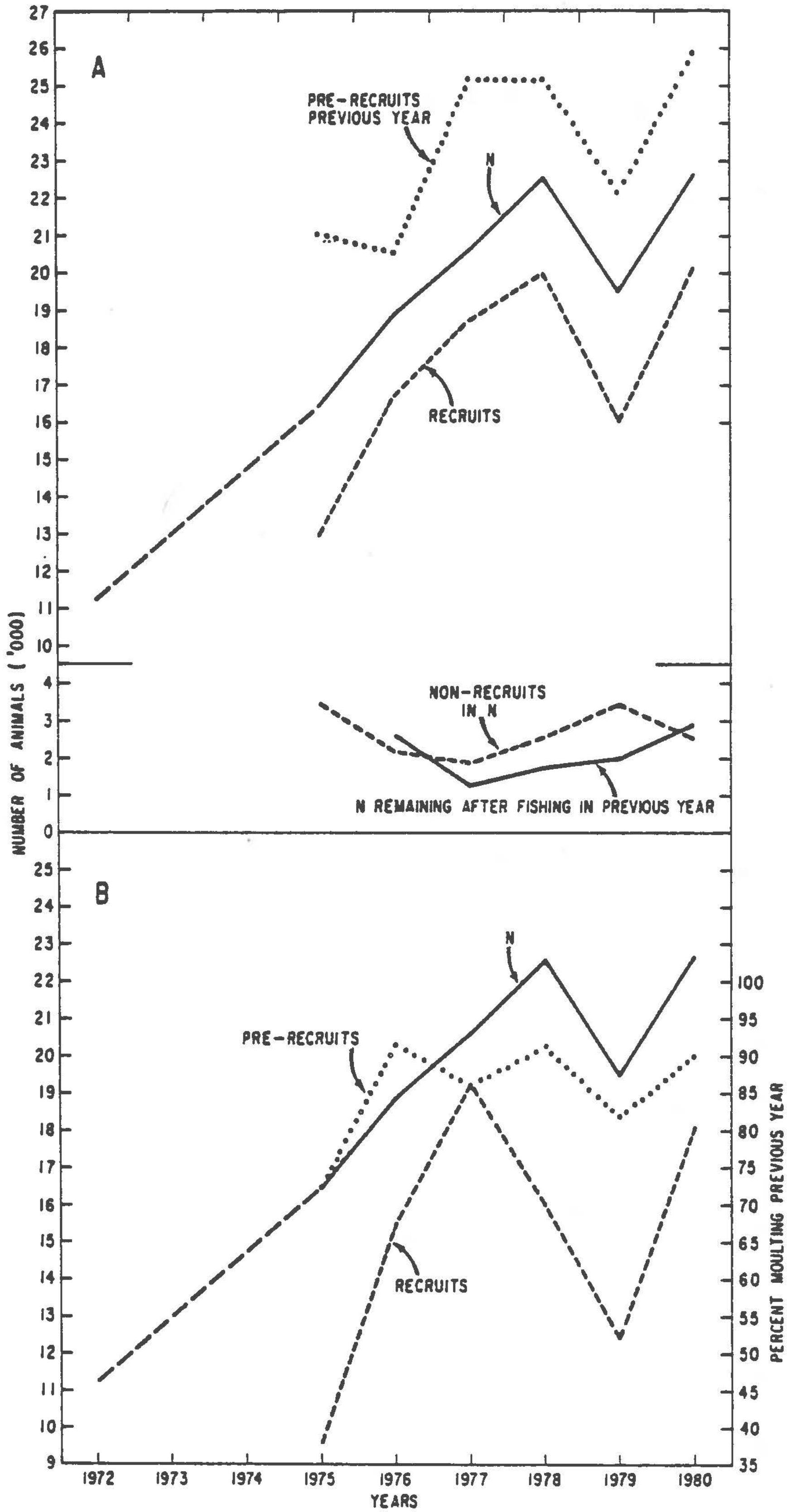

Fig. 1. Estimates of the standing stock of lobsters at Comfort Cove for 1972 and 1975-80. A-in relation to estimates of the components of the standing stock and prerecruit abundance the preceding year; and B-in relation to estimates of proportions molting in the prerecruit and recruit size ranges the preceding year.