# Fecundity of Atlantic Cod (*Gadus morhua*) in the Southwestern Gulf of St. Lawrence

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# FECUNDITY OF ATLANTIC COD (*GADUS MORHUA*) IN THE SOUTHWESTERN GULF OF ST. LAWRENCE

by

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## ABSTRACT

Buzeta, M.-I., and K. G. Waiwood. 1982. Fecundity of Atlantic cod (Gadus morhua) in the southwestern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 1110: iii + 6 p.

Fecundity estimates were made on 30 Atlantic cod (Gadus morhua) specimens collected from the southwestern Gulf of St. Lawrence in 1980. Maturing ovaries were placed in Gilson's fluid to free ripening oocytes from their follicles. Absolute fecundity was estimated by measuring the collective volume of eggs larger than 250 µ, counting the number of eggs in 0.5-mL subsamples and adjusting by the appropriate multiplication factor. Fecundity-size relationships were evaluated, using regression analysis, and subsequently compared with those derived from previous studies for this and other cod populations. The fecundity-size relationship giving best fit was of the form $F = aW^b$, and the average relative fecundity was found to be 379 eggs/g of body weight.

A method to reduce clumping of eggs and to increase efficiency of sample preparation is described. The contribution of non-follicular tissue to relative ovary weight was estimated.

Key words: cod, Gadus morhua, Gulf of St. Lawrence, fecundity methods

## RÉSUMÉ

Buzeta M.-I., and K. G. Waiwood. 1982. Fecundity of Atlantic cod (Gadus morhua) in the southwestern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 1110: iii + 6 p.

Nous avons estimé la fécondité de la morue franche (Gadus morhua) sur un échantillon de 30 individus recueillis dans le sud-ouest du golfe du Saint-Laurent. Les ovaires en voie de maturation furent placés dans le liquide de Gilson afin de séparer les ovocytes mûrissant de leurs follicules. La fécondité absolue a été estimée en mesurant le volume collectif des oeufs plus gros que 250 µ, en comptant ensuite le nombre d'oeufs dans des sous-échantillons de 0,5 mL et, enfin, en multipliant par un facteur approprié. Une analyse de régression a servi à calculer les relations fécondité-taille que nous avons ensuite comparées avec celles découlant d'études antérieures sur celle-ci et d'autres populations de morues. La relation de forme $F = aW^b$ est celle qui donne la meilleure adéquation. La fécondité relative moyenne a été calculée à 379 oeufs/g de poids corporel.

Nous décrivons une méthode pour empêcher les oeufs de se grouper en masse compacte et pour permettre de préparer les échantillons plus efficacement. Nous estimons enfin la contribution du tissu non folliculaire au poids relatif de l'ovaire.

## INTRODUCTION

Relatively little is known about the reproductive biology of cod in the southwestern Gulf of St. Lawrence (Fig. 1). Tagging studies (McCracken 1959; Martin and Jean 1964; Kohler 1975) have shown that the stock migrates annually from the Sydney Bight area in early spring to the Magdalen Shallows where it remains during the summer months. Migration back to the overwintering area occurs in late fall. The exact timing and geographic distribution of spawning have not been documented for this stock. However, Powles (1957) showed that spawning occurred during May to September in the Bay of Chaleur area, with peak reproductive activity in late June. In that study, southern Gulf of St. Lawrence cod attained sexual maturity at about 42 cm (male) and 46 cm (female). The lengths at which 50% of the population matured were 50 and 52 cm, respectively, for males and females. However, Lett's analysis (1980) indicated a decrease of 13 cm (58-45 cm) in the length at which 50% of the females matured during the period 1959-74.

The only fecundity estimates for this stock are those of Powles (1957) in a study conducted in the summers of 1955-56. At this time, the cod population showed accelerated growth rates, probably due to increased predation on herring, a result of an epizootic outbreak (Ichthyosporidium hoferi) which decimated pelagic stocks (Kohler 1964). Hence, Powles' fecundity estimates may not represent the "normal" or at least the current situation, as growth rates achieved during the summer previous to spawning may influence population fecundity by altering the number of developing eggs in mature fish (Woodhead and Woodhead 1965).

In the following study, fecundity was determined in cod sampled from the southwestern Gulf of St. Lawrence in May-June 1980. This was part of a larger study which considered food and tissue composition in Div. 4T cod (Waiwood and Majkowski, in preparation; Waiwood and Lanteigne, in preparation). During the course of the study,

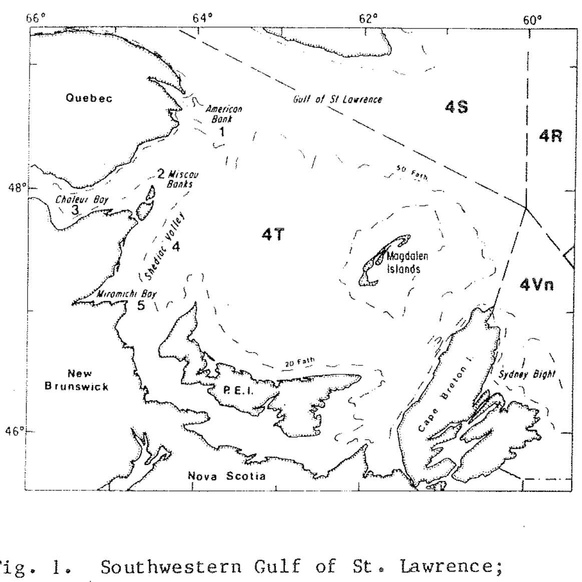


Fig. 1. Southwestern Gulf of St. Lawrence; collection sites for the 30 cod sampled are shown.

several significant modifications were made to the technique for estimating fecundity as described by Kändler and Pirwitz (1957, in Bagenal 1968). A method to evaluate the relative contribution of ovarian connective tissue and a procedure for reducing clumping of eggs are also described.

## MATERIALS AND METHODS

Ovaries from 32 cod were collected in May-June, 1980 in the following areas of the southwestern Gulf of St. Lawrence: Miramichi Bay, Miscou Banks, Shediac Valley, Chaleur Bay, and American Banks (Fig. 1). Cod length ranged from 47.8-102.7 cm. Several methods were used to obtain fish for this study, including gillnet, otter trawl, jigger, and Danish seine. Measurements were taken of fork length, total weight, gutted weight, and gonad weight. Two fish were not used in the analysis because they were thought to have commenced spawning. Frozen ovaries were returned to St. Andrews, N.B., and subsequently weighed (discrepancies between field and laboratory ovary weights were resolved by using the more accurate weight obtained in the laboratory). One ovary or a longitudinal slice of an ovary was weighed to the nearest 0.10 g, cut into small pieces and placed in a jar containing modified Gilson's fluid (Simpson 1951). The jars were shaken periodically and fluid was changed 1-3 times to accelerate breakdown of the ovarian connective tissue.

Samples were deemed ready for further treatment when a large number of eggs were free from their follicles and a milky layer of debris had settled above the eggs. To overcome persistent clumping of eggs, a 10-speed cycling Osterizer blender with a 336-mL mini-container was used in preparing the samples. Preliminary tests were conducted to determine the efficiency of breaking down the various sized egg clumps, and when damage occurred to the eggs themselves. Each sample containing egg clumps was placed in the blending vessel with approximately 280 mL of water. The blender was set on the lowest blending speed (stir) and "intermittent" cycling. Each cycle lasted 2 s during which approximately 160 revolutions of the blade occurred. During each cycle, the speed varied from 3000-6500 rpm (as measured with a hand-held tachometer). After each series of cycles, counts were obtained of the number of eggs, clumps (2-4 and 5-10 eggs), and ruptured eggs. A histogram of the above counts versus the number of blending cycles demonstrated an optimum blending regime of 15 cycles was required to achieve the breakdown of the majority of clumps without significant loss of eggs (Fig. 2). Ovary samples could then be sieved through 1000- and 250-μ meshes. The larger mesh size retained egg clumps and ovarian connective tissue. The lower sized sieve was chosen to conform with Sivertsen's (1935) description that ripe cod ovaries contain eggs larger than 250 u, and with Powles' (1957) use of a 212-μ mesh sieve to separate mature and immature eggs. To estimate connective tissue contribution to total ovary wet weight, tissue was removed, squeezed free of water, and weighed.

Once the majority of clumps had been broken down in the blender for 15-18 cycles, the sample was poured into an Inhoff cone, allowed to settle, and measured for total volume. The sample was then poured into a 1000-mL beaker and placed on a magnetic stirrer. Three 0.5-mL subsamples of packed

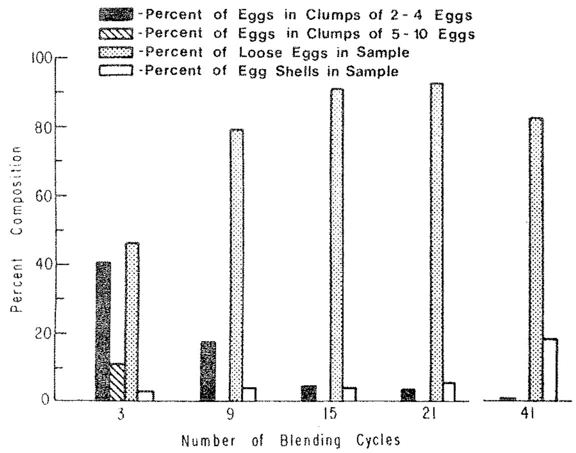


Fig. 2. Effect of blending on egg clumps; the percent occurrence of free eggs, egg shells, and eggs in clumps of different sizes for five blending regimes is shown. Each blending cycle consisted of a 2-sec burst of approximately 160 revolutions (see text for details).

eggs were taken with a suction pipet, each being placed in a 0.1-mL calibrated, conical, centrifuge tube. The subsample was then poured into a petri dish and a magnifying glass was used to count each subsample. If necessary, individual eggs in any remaining clumps were counted with the aid of a Zeiss stereoscope. The counting error was estimated by recounting the same subsample three times. Subsampling variability (coefficient of variation) was calculated from triplicate counts. The total number of maturing eggs in each female (absolute fecundity) was calculated by the following formula:

$$N = \left(\frac{Ac}{0.5\ \text{mL}} \times V\right) \times \frac{Wt}{Ws}$$

where: Ac = the average number of eggs of diameter greater than 250 $\mu$ (i.e. maturing oocytes) in a subsample,
V = sample volume of the eggs processed in Gilson's fluid (mL, measured in Inhoff cone),
Wt = total weight of both ovaries (g),
Ws = sample weight of ovary processed in Gilson's fluid (g).

## RESULTS AND DISCUSSION

The method used here to estimate fecundity was relatively simple and its reliability was easily tested. Possible errors originated from either the subsampling (eggs not settled properly in conical tube) or the sampler's counting error. Both of these procedures could be checked by calculating the coefficient of variation and, if necessary, repeated. The coefficient of variation for the three egg subsamples ranged from 0-11% with an average of 4.3 $\pm$ 2.4% (sd) (Table 1). This variation compares favorably with the corresponding values reported by May (1967) for the whirling vessel method (6.0%) and the weight method (3.1%), and by Pitt (1964) for the whirling vessel method (9.5%). Similarly, the counting reproducibility was estimated to be within 1%, which compares with the values of 0.2-2.0% and 0.02-0.92% reported, respectively, for wet and dry electronic counting methods used by Oosthuizen and Daan (1974).

The blender modification solved the problem of egg clumping and greatly decreased the time required to prepare the samples for counting. It was necessary, however, to make sure that eggs were well hardened by the Gilson's fluid, and that the proper speed and number of cycles were used. Clumps consisting of 5-10 eggs accounted for 10% of the eggs in the sample after 3 blending cycles and were not observed after 9 blending cycles. Likewise, the percentage of eggs in clumps of 2-4 eggs fell from 40.5 - 0.5 after 3-41 blending cycles. The number of egg shells remained relatively constant (3-5%) for up to 21 blending cycles but accounted for 18.0% of the sample after 41 blending cycles (Fig. 2). To avoid the breakdown of eggs due to blending, egg clumps collected in the top sieve were blended for only 15-18 blending cycles.

Mesenteries and other ovarian tissue contributed an average of 1.99% ($\pm$0.64 SD) to the total gonad weight (Table 1). Figure 3 shows a strong relationship ($r^2$ = 0.87) between total ovary and non-egg ovarian tissue weights. This, however, is still an underestimate, as much of the ovarian wall and follicular membranes may have dissolved while in Gilson's fluid. Nevertheless, it represents a possible error of up to 4% in fecundity estimates based on egg/ovary weight (or volume) relationships.

The length, weight, and fecundity for each cod sampled are shown in Table 1. Absolute fecundity was defined by Bagenal (1978) as "the number of ripening eggs found in a female just prior to spawning." In this study, a ripening egg was defined as any oocyte that did not pass through a 250-$\mu$ mesh sieve. This conformed to the size criterion outlined by Sorokin (1961) who found that Barents Sea cod in ripening condition (stage II or R1) had oocytes larger than 280 $\mu$. May (1967) found that eggs smaller than 200 $\mu$ represented second generation eggs and were not to be included in fecundity estimates.

Absolute fecundity ranged from 231,271 to 8,635,180 eggs, with an average relative fecundity (Bagenal 1978) of 379 eggs/g (Table 1). Equations relating fecundity to size are shown in Table 2 and Fig. 3 and 4. The fecundity-size relationship showing best fit (highest $r^2$) was of the form $F = aw^b$ (Table 2, eq. 2). The $r^2$ for this power curve was much higher (0.86) than for the linear form F = bW + a (0.77). The relation between fecundity and length (Table 2 and Fig. 4, eq. 1) was also highly significant ($r^2$ = 0.81). To compare these results with those of Powles (1957, 1958), it was necessary to re-analyze (regression analysis was used) his original data. Although his original presentation included only 34 points (Powles 1957, Fig. 8), only 3 of the 46 fecundity measurements included in Table 6 of the Appendix (Powles 1957) were discarded as being "outliers." No justification was found for eliminating other data.

Multiple regression analyses, using a dummy variable (where DV = 0 for Powles' study and DV = 1

Table 1. Length, weight, and fecundity estimates of cod sampled in the southwestern Gulf of St. Lawrence in 1981.

| Fish length (cm) | Fish weight (g) | Total ovary weight (g) | Ovary weight (%) | Ovary section weight (g) | Total mesentary weight (g) | Section mesentary weight (g) | Ovary weight due to mesentaries (%) | Relative fecundity (eggs/g) | Absolute fecundity (no. eggs) | Coefficient of variation in egg counts (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 101.7 | 11 252 | 1625.4 | 14.45 | 463.1 | 45.45 | 12.95 | 2.80 | 767.44 | 8 635 180 | 4 |
| 102.0 | 10 598 | 966.3 | 9.12 | 453.6 | 14.08 | 6.61 | 1.46 | 352.09 | 3 731 418 | 5 |
| 97.9 | 10 475 | 1381.4 | 13.19 | 309.2 | 34.00 | 7.61 | 2.46 | 547.11 | 5 731 005 | 4 |
| 52.2 | 1 257 | 120.6 | 9.59 | 57.8 | 1.92 | 0.92 | 1.59 | 366.15 | 460 250 | 0 |
| 86.1 | 5 443 | 683.9 | 12.56 | 321.6 | 10.72 | 5.04 | 1.57 | 339.64 | 1 848 636 | 9 |
| 102.7 | 9 536 | 376.1 | 3.94 | 178.6 | 8.23 | 3.91 | 2.19 | 360.23 | 3 435 108 | 2 |
| 96.2 | 8 167 | 1244.5 | 15.24 | 324.1 | b | b | b | 304.41 | 2 486 102 | 6 |
| 81.0 | 5 965 | 582.6 | 9.77 | 318.7 | 12.67 | 6.93 | 2.17 | 455.77 | 2 718 642 | 5 |
| 80.3 | 4 798 | 550.8 | 11.48 | 267.2 | 8.68 | 4.21 | 1.58 | 283.24 | 1 358 997 | 3 |
| 79.5 | 5 881 | 1121.7 | 19.07 | 268.4 | 31.59 | 7.56 | 2.82 | 584.59 | 3 437 985 | 3 |
| 76.7 | 3 265 | 441.2 | 13.51 | 224.8 | 10.38 | 5.29 | 2.35 | 271.02 | 884 865 | 3 |
| 77.2 | 4 413 | 328.2 | 7.44 | 187.7 | 5.28 | 3.02 | 1.61 | 419.87 | 1 852 893 | 6 |
| 47.8 | 1 222 | 91.8 | 7.51 | 43.4 | 2.62 | 1.24 | 2.85 | 315.57 | 385 631 | 8 |
| 53.0 | 1 321 | 120.5 | 9.12 | 71.2 | 2.83 | 1.67 | 2.35 | 362.02 | 478 223 | 6 |
| 69.0 | 3 321 | 400.2 | 12.05 | 239.7 | 5.66 | 3.39 | 1.41 | 379.78 | 1 261 246 | 4 |
| 65.2 | 3 395 | 478.1 | 14.08 | 221.4 | 17.28 | 8.00 | 3.61 | 373.25 | 1 267 172 | 3 |
| 52.0 | 1 349 | 124.8 | 9.25 | 51.4 | 1.31 | 0.54 | 1.05 | 398.37 | 537 401 | 3 |
| 80.2 | 6 073 | 532.3 | 8.77 | 221.9 | 10.75 | 4.48 | 2.02 | 266.87 | 1 620 713 | 3 |
| 83.2 | 4 288 | 775.6 | 18.09 | 335.2 | 7.94 | 3.43 | 1.02 | 393.48 | 1 687 242 | 4 |
| 56.0 | 2 028 | 272.8 | 13.45 | 140.4 | 2.72 | 1.40 | 1.00 | 658.38 | 1 335 192 | 4 |
| 51.0 | 1 404 | 114.0 | 8.12 | 44.5 | 3.18 | 1.24 | 2.79 | 164.72 | 231 271 | 2 |
| 83.5 | 5 805 | 535.8 | 9.23 | 228.9 | 13.83 | 5.91 | 2.58 | 331.03 | 1 921 627 | 3 |
| 64.4 | 2 418 | 233.4 | 9.65 | 99.6 | 5.09 | 2.17 | 2.18 | 519.36 | 1 255 801 | 2 |
| 49.2 | 1 365 | 126.5 | 9.27 | 57.5 | 1.72 | 0.78 | 1.36 | 204.52 | 279 171 | 5 |
| 66.0 | 2 721 | 470.5 | 17.29 | 224.8 | 8.25 | 3.94 | 1.75 | 282.53 | 768 776 | 5 |
| 63.6 | 2 241 | 254.0 | 11.33 | 108.0 | b | b | b | 444.89 | 996 997 | 1 |
| 69.4 | 3 672 | 700.3 | 19.07 | 300.1 | 13.18 | 5.65 | 1.88 | 270.88 | 994 655 | 11 |
| 66.2 | 4 079 | 484.8 | 11.89 | 243.3 | 9.43 | 4.73 | 1.95 | 412.00 | 1 680 530 | 1 |
| 65.3 | 3 432 | 459.1 | 13.38 | 224.6 | 7.97 | 3.90 | 1.74 | 253.10 | 868 646 | 7 |
| 85.3 | 5 818 | 652.2 | 11.21 | 385.9 | 10.97 | 6.49 | 1.68 | 282.31 | 1 642 476 | 5 |
| 79.5[a] | 4 668 | 379.5 | 8.13 | 204.5 | 11.38 | 6.13 | 3.00 | 42.53 | 198 510 | 4 |
| 56.2[a] | 1 364 | 87.9 | 6.44 | 43.0 | 1.96 | 0.96 | 2.23 | 124.06 | 169 218 | 6 |

[a]Not included
[b]Not available

for the present study) were used to determine if the fecundity length relationships in the two studies were significantly different (Draper and Smith 1966, p. 134). No variability in fecundity could be significantly attributed to the dummy variable ($P > 0.10$). The fecundity-length relationship for the combined data sets is given in Table 2 (eq. 7).

A direct comparison of fecundity-weight relationships between this and the previous study was not possible as weights were not available from Powles' data. Further, no satisfactory length-weight relationship for the period and area of collection could be found. However, if the length-weight relationship ($W = 0.0155\ L^{2.9106}$) for 1959 research data (Maguire, pers. comm.) is used to estimate weights of cod from Powles's study, a fecundity-weight relationship can be approximated by equation 5 in Table 2 and Fig. 5. It is felt that this length-weight conversion is more realistic than that used by Oosthuizen and Daan (1974), who applied a length-weight relationship established for North Sea cod. An equation representing the combined weight/fecundity data from this and Powles' study (with the above-mentioned length-weight conversion) is presented in Table 2 (equation 8).

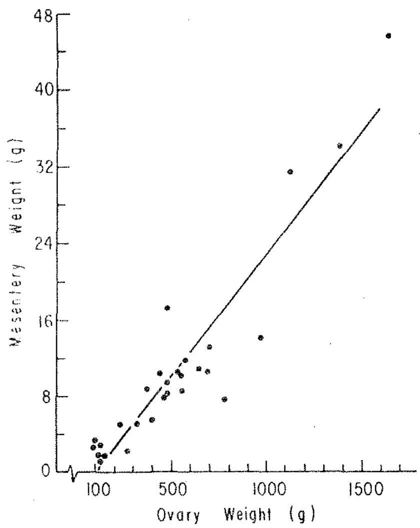


Fig. 3. Relationship between ovary and mesentary weight (n = 28); $Y = 0.03X - 2.37$, $r^2 = 0.87$.

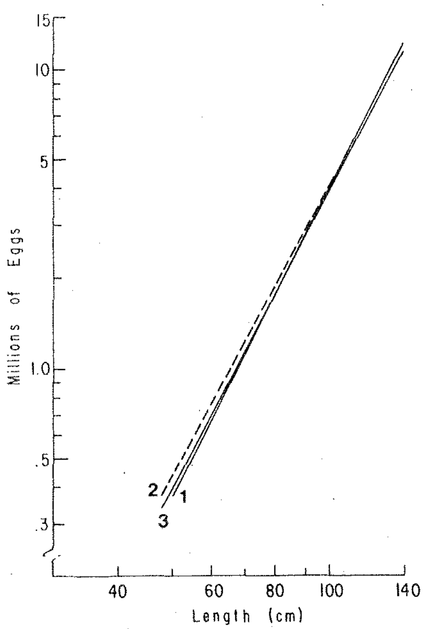


Fig. 4. Relationship between fecundity and length.

1. $F = 0.38\ L^{3.50}$ (Powles 1957)
2. $F = 1.10\ L^{3.28}$ (Buzeta and Waiwood, this study)
3. $F = 0.68\ L^{3.28}$ (combined data from both studies)

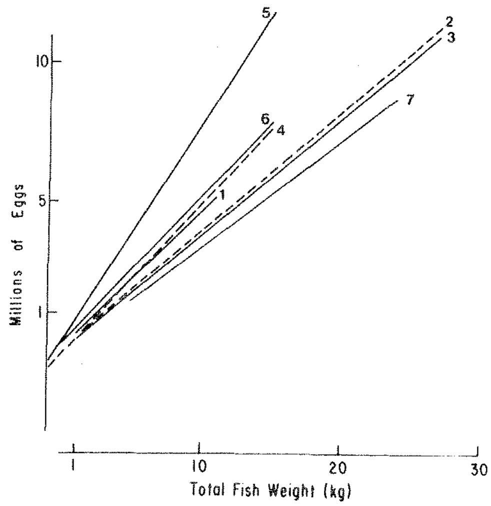


Fig. 5. Relationship between fecundity and weight for data from this study (1982), Powles (1957), and combined data from both studies. Other equations were obtained from Oosthuizen and Daan (1974).

1. $F = 520\ W - 516888$ Buzeta and Waiwood (this study)
2. $F = 425\ W - 245579$ combined data
3. $F = 415\ W - 289333$ Powles (1957)
4. $F = 569\ W - 807000$ Oosthuizen and Dann (1974)
5. $F = 790\ W - 41600$ Botros (1962) cited in May (1967)
6. $F = 519\ W$ Joakimsson (1969)
7. $F = 0.5\left(\frac{W}{0.0105}\right)^{1.14}$ May 1967

Table 2. Equations of size-fecundity relationships based on data from this study and from Powles (1957). Weights used in equations 5, 6 were derived from length-weight data from a 1959 research vessel cruise ($W = 0.0155\ L^{2.9106}$)

| Source | Equation | a | b | SE of B | SE of est. | R | N |
|---|---|---|---|---|---|---|---|
| 1. Buzeta and Waiwood (this study) | $F = aL^b$ | 1.10 | 3.28 | 0.30 | 0.16 | 0.81 | 30 |
| 2. " " " | $F = aW^b$ | 109.65 | 1.14 | 0.09 | 0.14 | 0.86 | " |
| 3. " " " | $F = bW + a$ | -516888 | 520 | 54.51 | 868194 | 0.77 | " |
| 4. Powles (1957) | $F = aL^b$ | 0.38 | 3.50 | 0.24 | 0.17 | 0.83 | 43 |
| 5. " " | $F = aW^b$ | 56.62 | 1.20 | 0.08 | 0.17 | 0.83 | " |
| 6. " " | $F = bW + a$ | -289333 | 415 | 22.49 | 812803 | 0.89 | " |
| 7. 1957, (this study) | $F = aL^b$ | 0.68 | 3.38 | 0.19 | 0.17 | 0.82 | 73 |
| 8. " " " | $F = bW + a$ | -245579 | 425 | 21.13 | 0.02 | 0.85 | " |

Oosthuizen and Daan (1974) calculated fecundity of cod from Norway, Iceland, Labrador, and the North Sea, based on the data of Botros (1962, sited in May 1967), Joakimsson (1969), May (1967), and Oosthuizen and Daan (1974), respectively. From this study and that of Powles (1957), Gulf of St. Lawrence cod appear to have lower fecundity than all other areas except Labrador (Fig. 5; all lines based on equations given in Oosthuizen and Daan 1974).

Interstock variability in fecundity has not been adequately explained and, without a critical evaluation of the various methods used, comparisons between studies should be made with caution. Notwithstanding this, it has been suggested that fecundity is influenced by environmental factors, such as water temperature, which may indirectly alter the development of oocytes (Hodder 1965). Scott (1962) demonstrated that restricted ration and starvation in rainbow trout, Salmo gairdneri, resulted in a lowered maturation rate and follicular atresia. Though follicular atresia has not been demonstrated in cod, Woodhead and Woodhead (1965) suggested a mechanism whereby food availability in the summer, prior to spawning, could affect fecundity the following spring. If this mechanism operated, fishing effort could affect fecundity indirectly by changing population density and hence intraspecific competition for food. The remarkable similarity in the fecundity-length relationships between this and Powles' (1957) study suggests that either growth rates and/or environmental factors were not greatly different in the two periods, or the effect of growth on fecundity is relatively small when compared to genetically determined factors. However, further studies over several years must be undertaken in order to evaluate year-to-year variation in fecundity.

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## REFERENCES

Bagenal, T. B. 1968. Fecundity, p. 161-169. In W. E. Ricker (Ed.) Methods for assessment of fish production in fresh waters. IBP Handbook No. 3, Ch. 7(1) Blackwell Scientific Publications.

1978. Aspects of fish fecundity, p. 75-101. In S. D. Gerking (Ed.) Ecology of Freshwater Fish Production. John Wiley and Sons, Inc.

Draper, N. R., and H. Smith. 1966. Applied Regression Analysis. John Wiley and Sons Inc., N.Y.

Hodder, V. M. 1965. The possible effects of temperature on the fecundity of Grand Bank haddock. Int. Comm. Northw. Atl. Fish. Spec. Publ. 6: 515-522.

Joakimsson, G. 1969. Fruchtbarkeitsbestimmungen an Kabeljau, Schellfisch und Hering in islandischen Gewässern. Kiel. Meeresforsch. 25: 172-189.

Kohler, A. C. 1964. Variations in the growth of Atlantic cod (Gadus morhua L.). J. Fish. Res. Board Can. 21: 57-100.

1975. Recoveries from 1969 cod tagging in ICNAF division 4Vn. Int. Comm. Northw. Atl. Fish. Res. Doc. 75/91, 2 p.

Lett, P. 1980. A comparative study of the recruitment mechanisms of cod and mackerel, their interaction, and its implication for dual stock assessment. Can. Tech. Rep. Fish. Aquat. Sci. 988, 45 p.

Martin, W. R., and Y. Jean. 1964. Winter cod taggings off Cape Breton and offshore Nova Scotia banks 1959-62. J. Fish. Res. Board Can. 21: 215-238.

May, A. W. 1967. Fecundity of Atlantic cod. J. Fish. Res. Board Can. 24: 1531-1551.

McCracken, F. D. 1959. Cod tagging off northern New Brunswick in 1955 and 1956. Fish. Res. Board Can. Prog. Rep. Atl. Coast. Sta. 72: 8-19.

Oosthuizen, E., and N. Daan. 1974. Egg fecundity and maturity of North Sea cod, Gadus morhua. Neth. J. Sea Res. 8: 378-397.

Pitt, T. K. 1964. Fecundity of American plaice, Hippoglossoides platessoides (Fabr.) from Grand Bank and Newfoundland areas. J. Fish. Res. Board Can. 21: 597-612.

Powles, P. M. 1957. Studies of feeding and reproduction of cod (Gadus callarias L.) in the southwestern Gulf of St. Lawrence. M.Sc. Thesis. University of Western Ontario, London, Ont., 66 p.

1958. Studies of reproduction and feeding of Atlantic cod (Gadus callarias L.) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Board Can. 15: 1383-1402.

Scott, D. P. 1962. Effect of food quantity on fecundity of rainbow trout Salmo gairdneri. J. Fish. Res. Board Can. 19: 715-736.

Simpson, A. C. 1951. The fecundity of the plaice. Min. Agric. Fish. Invest. Ser. 11, 17(5): 1-27.

Sivertsen, E. 1935. Torskens gytning Med sxrling hendblikk Pa den arbige cyplus i generas jonsorganenes tilstand. Fiskeridir Skr. Ser. Havunders. IV, 29 p.

Sorokin, V. P. 1961. The oogenesis and reproduction cycle of the cod (Gadus morhua Linn.). Trudy Pinro 10: 125-144.

Woodhead, A. D., and P. M. J. Woodhead. 1965. Seasonal changes in the physiology of the Barents Sea cod, Gadus morhua L., in relation to its environment. Int. Comm. Northw. Atl. Fish. Spec. Publ. 6: 691-715.