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Fecundity of cod in the Northwest Atlantic

Fécondité de la morue dans l'Atlantique Nord-Ouest

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ABSTRACT

This document presents the time series of fecundity data that have been collected in the Newfoundland region for a variety of Atlantic cod (*Gadus morhua*) stocks. Ovaries were collected from 1266 Northwest Atlantic cod (Table 1) during spring bottom trawl surveys conducted by Fisheries and Oceans Canada research vessels. Samples were collected from Div. 2J3KL, 3M, 3NO, and Subdiv. 3Ps and 3Pn. The years of sampling varied from area to area but overall ranged from 1978 to 2004. Equations relating fecundity to fork length for all areas and years for which the regression was significant and for which 15 or more fish were sampled are presented. For 3NO and 3Ps time series of fecundity at length (in this case 55 cm) and relative fecundity are given. It is clear that there is substantial spatial and temporal variation in fecundity of cod in the Newfoundland region. Continued collection of fecundity data would allow the construction of longer time series of egg production and would allow further exploration of the causes of the large variation in fecundity.

RÉSUMÉ

Ce document présente la série chronologique des données sur la fécondité recueillies dans la région de Terre-Neuve relativement aux stocks d'une espèce de morue de l'Atlantique (*Gadus morhua*). Les ovaires ont été prélevés sur 1 266 morues de l'Atlantique Nord-Ouest (tableau 1) durant les relevés au chalut de fond réalisés au printemps par les navires de recherche de Pêches et Océans Canada. Des échantillons ont été prélevés dans les divisions 2J3KL, 3M, 3NO, et dans les sous-divisions 3Ps et 3Pn. Les années d'échantillonnage variaient selon la région mais la plupart s'étendaient de 1978 à 2004. On présente les équations reliant la fécondité à la longueur à la fourche pour toutes les régions et les années pour lesquelles une régression a été importante et pour lesquelles 15 poissons ou plus ont été échantillonnés. Pour la division 3NO et la sous-division 3Ps, on présente la série chronologique des données sur la fécondité en fonction de la longueur (55 cm dans ce cas-ci) et de la fécondité relative. Une variation spatiale et temporelle importante est évidente relativement à la fécondité de la morue dans la région de Terre-Neuve. La poursuite de la collecte de données sur la fécondité permettrait l'élaboration d'une série chronologique plus longue sur la production des œufs et, par conséquent, une étude plus approfondie des causes de la variation importante de la fécondité.

INTRODUCTION

To estimate total egg production in a population data on population number, proportion mature, sex ratio, length or weight and fecundity are necessary. Fecundity data is not as readily available as the other information needed to estimate population egg production (Tomkiewicz et al. 2003). Both spatial and temporal variability in individual fecundity have been reported for many species, including cod (Bagenal 1973; Rijnsdorp 1994; Kjesbu et al. 1998; Yoneda and Wright 2004; Rideout and Morgan 2007; Stares et al. 2007). Although factors such as ration level or nutritional condition have been positively linked with individual egg production (Kjesbu et al. 1991; Millner et al. 1991; Rijnsdorp 1991; Rijnsdorp et al. 1991; Kjesbu et al. 1998; Ma et al. 1998; Lambert and Dutil 2000) strong proxies for fecundity do not exist for most stocks. In the absence of predictive relationships between fecundity and other variables such as fish condition (Marshall et al. 1998) or prey availability (Kraus et al. 2002), an up to date time series of fecundity data is required to obtain accurate estimates of population egg production.

Here we present the time series of fecundity data that have been collected in the Newfoundland region for a variety of Atlantic cod (*Gadus morhua*) stocks.

MATERIALS AND METHODS

Ovaries were collected from 1266 Northwest Atlantic cod (Table 1) during spring bottom trawl surveys conducted by Fisheries and Oceans Canada research vessels. Samples were collected from Div. 2J3KL, 3M, 3NO, and Subdiv. 3Ps and 3Pn. The years of sampling varied from area to area but overall ranged from 1978 to 2004.

Females were designated as ripening for the upcoming spawning season based on macroscopic inspection of the ovaries. Only ovaries containing opaque oocytes but no clear oocytes were included, since the presence of clear oocytes would indicate that spawning has already started (and therefore egg counts may not be accurate). Fork length was recorded for all fish. Whole weight was also recorded for most fish from 3NO, 3Ps and 3Pn but for less than 20% of fish from 2J3KL. Whole weight was not recorded for fish collected in 3M. Generally those fish without whole weights were sampled prior to the availability of electronic balances at sea.

Ovaries were sliced longitudinally and placed in Gilson's fluid for 4-6 weeks (up to several months for large ovaries) to facilitate the breakdown of ovarian connective tissue. Prior to the late 1970s the Gilson's fluid was based on the formulation of Simpson (1951), which contained mercuric chloride. However, mercuric chloride has since been replaced by zinc chloride in order to reduce the toxicity of this fixative (Barszcz 1976). First generation oocytes (i.e. >200 µm, those that would have been spawned in the current year) were separated from second generation (i.e. immature) oocytes and connective tissue by rinsing through a series of sieves. The cleaned oocytes were stored in ethanol until counted.

Oocytes were fractionated down to a countable number using a modified whirling vessel (Wiborg 1951). Each spinning of the whirling vessel resulted in one tenth of the number of oocytes placed in the vessel. The one tenth sub-sample could then be placed back into the vessel to obtain a one hundredth sub-sample of oocytes. The process was continued until the sub-sample was considered large enough to give an accurate count but small enough to make manual counting practical, typically 800-2000 oocytes. Counting was done manually using a stereomicroscope. Four sub-samples were collected from each pair of ovaries but the last two were only counted if the difference between the first two counts was greater than 5%. The mean oocyte count was scaled up based on the sub-sampling fraction (i.e. the proportion of the whole sample that was counted) to obtain the overall individual potential fecundity estimate (from here on referred to simply as fecundity).

The relationship between fecundity and fish length, fish weight and fish age was explored using linear regression based on log-log transformed data. For those fish that had weight data, relative fecundity was calculated as the number of eggs produced per gram of total body weight. Some comparisons across time and among stocks are presented.

RESULTS

Table 1 gives the equations relating fecundity to fork length for all areas and years for which the regression was significant and for which 15 or more fish were sampled. The estimated relationships between fecundity and length, weight and age are shown for 2J3KL, 3NO and 3Ps in Fig. 1 along with the observed data for all years sampled. The relationship between fecundity and weight was linear while those between fecundity and length or age were exponential. Although the relationships are all significant it can be seen that there is a large amount of variation around the fitted curves. This variation is both within and between years.

Fecundity at length shows variation among stocks with fecundity being lowest in 3M and highest in 2J3KL, 3NO and 3Pn (Fig. 2). Interpretation is confounded by the fact that the years sampled and length range varies from stock to stock.

Relative fecundity (number of eggs per gram of body weight) was highest in 3Ps (Fig. 3). This area also showed the lowest temporal variation in this parameter.

For 3NO and 3Ps there are enough years to present a time series of fecundity at length (in this case 55 cm) and relative fecundity (Fig. 4). Fecundity at 55 cm was highly variable for 3NO. In 3Ps there is an increase in fecundity at length from 1993 to 1998 followed by lower values from 1999 to 2001 and a return to the levels of 1998 from 2002 to 2004. Relative fecundity over the time period was somewhat higher in 3Ps than in 3NO, averaging 428 and 387 eggs per gram respectively (Fig. 4). Relative fecundity in 3NO increased from 1990 to 1995 and was below average in most years from 1998 to 2004. In 3Ps, relative fecundity did not vary much from the long term average except in 2001 when it was below average and in 2003 when it was above average.

DISCUSSION

This document summarizes data collected during a long-term cod fecundity project that was initiated by the Newfoundland region of Fisheries and Oceans Canada in 1978 and continued until 2004. Sampling intensity varied greatly across space and time but the available data clearly demonstrate substantial spatial and temporal variation in fecundity for cod stocks in this region, a conclusion supported by more formal analyses of the data for 2J3KL, 3NO and 3Ps (Stares et al. 2007). The sources of this variability are not fully understood. Although variability in fecundity for other cod populations has been linked to differences in fish nutritional condition, we have been unable to find clear evidence of such a relationship for Newfoundland cod stocks. Without effective proxies for fecundity, the continued collection of fecundity data will be necessary to allow the construction of longer time series of egg production and would allow further exploration of the causes of the large variation in fecundity. Newer and much more time efficient methods for collecting samples and estimating cod fecundity have been developed and will be used to continue the cod fecundity project (Thorsen and Kjesbu 2001).

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Table 1. Information on fecundity sampling for Northwest Atlantic cod, including regression analyses for the effect of fork length on fecundity. Regression equations and fecundity estimates (millions of eggs) at three fork lengths are given for areas and years with sample size ≥15. Estimates in parentheses are for fish sizes outside the observed length range.

Area	Year(s)	Month(s)	n	Length (cm)	r^2	p	Equation	50 cm	70 cm	90 cm
2J3KL	1988[a]	2,5	89	41-109	0.875	<0.0001	$F = 0.183\ L^{3.659}$	0.301	1.032	2.588
	1989[a]	2,5	64	44-111	0.858	<0.0001	$F = 0.349\ L^{3.502}$	0.311	1.010	2.435
	1990[a]	5,6	33	45-105	0.873	<0.0001	$F = 0.144\ L^{3.752}$	0.341	1.206	3.095
	1993	2,6	38	40-62	0.700	<0.0001	$F = 0.033\ L^{4.055}$	0.256	(1.001)	(2.773)
	1994	6	5	39-56	0.985	0.0008				
	1998	6	12	50-71	0.404	0.0241				
	1999	6	4	60-69	0.253	0.4973				
	2001	6	6	44-58	0.036	0.7193				
	2003	6	7	48-73	0.712	0.0169				
	2004	6	1	63						
	1988-2004	2,5,6	259	39-111	0.808	<0.0001	$F = 0.279\ L^{3.573}$	0.328	1.092	2.680
3M	1979[b]	2	21	44-76	0.797	<0.0001	$F = 0.297\ L^{3.533}$	0.299	0.981	(2.383)
	1982[b]	2	5	58-86	0.761	0.0537				
	1983[b]	2	31	57-101	0.680	<0.0001	$F = 0.010\ L^{4.219}$	(0.147)	0.609	1.758
	1984[b]	2	18	63-91	0.758	<0.0001	$F = 0.004\ L^{4.422}$	(0.130)	0.577	1.753
	1985	2	13	50-91	0.827	<0.0001				
	1979-1985	2	88	44-101	0.746	<0.0001	$F = 0.930\ L^{3.194}$	0.248	0.727	1.623
3NO	1988	4,5	48	54-136	0.871	<0.0001	$F = 0.449\ L^{3.477}$	(0.363)	1.169	2.800
	1989	4,5	45	50-132	0.929	<0.0001	$F = 0.254\ L^{3.580}$	0.307	1.024	2.518
	1990	4,5	76	56-131	0.879	<0.0001	$F = 0.048\ L^{3.973}$	(0.270)	1.028	2.789
	1993[a]	4,5	63	40-120	0.902	<0.0001	$F = 0.387\ L^{3.529}$	0.383	1.256	3.050
	1994[a]	5	15	47-124	0.790	<0.0001	$F = 0.103\ L^{3.805}$	0.300	1.080	2.810
	1995[a]	5	10	52-89	0.000	0.9996				
	1996	5	15	51-75	0.443	0.0094	$F = 1.417\ L^{3.185}$	(0.365)	1.067	(2.375)
	1998	5,6	20	30-89	0.772	<0.0001	$F = 125.693\ L^{2.080}$	0.430	0.865	(1.459)
	1999	5	17	51-99	0.672	<0.0001	$F = 8.312\ L^{2.796}$	(0.468)	1.198	2.419
	2000	5	12	75-131	0.579	0.0041				
	2001	5	16	78-108	0.256	0.0456	$F = 2.584\ L^{3.058}$	(0.405)	(1.134)	2.445
	2002[a]	4,5	23	29-109	0.311	0.0057	$F = 301.176\ L^{1.792}$	0.334	0.610	0.957
	2003[a]	5,6	20	50-108	0.799	<0.0001	$F = 15.795\ L^{2.588}$	0.394	0.941	1.803
	2004[a]	5	10	57-89	0.210	0.1835				
	1988-2004	4,5,6	390	29-136	0.816	<0.0001	$F = 0.492\ L^{3.440}$	0.344	1.094	2.598
3Ps	1993[a]	2,4	67	43-89	0.729	<0.0001	$F = 0.274\ L^{3.618}$	0.384	1.298	(3.223)
	1994[a]	4	43	39-98	0.650	<0.0001	$F = 0.124\ L^{3.824}$	0.389	1.410	3.685
	1995[a]	4	40	45-109	0.581	<0.0001	$F = 11.281\ L^{2.716}$	0.464	1.158	2.291
	1998	4	70	38-99	0.406	<0.0001	$F = 250.219\ L^{1.963}$	0.541	1.048	1.716
	1999	4,5	46	42-107	0.741	<0.0001	$F = 0.141\ L^{3.724}$	0.299	1.048	2.672
	2000	4,5	86	41-110	0.676	<0.0001	$F = 2.250\ L^{3.084}$	0.391	1.103	2.394
	2001	4	60	48-112	0.632	<0.0001	$F = 0.736\ L^{3.304}$	0.302	0.919	2.107

Table 1 (Cont'd.)

	2002[a]	4	40	47-103	0.603	<0.0001	F = 12.084 $L^{2.706}$	0.478	1.189	2.346
	2003[a]	4	35	42-106	0.801	<0.0001	F = 9.950 $L^{2.782}$	0.530	1.352	2.720
	2004[a]	4,5	18	43-113	0.864	<0.0001	F = 2.073 $L^{3.121}$	0.416	1.189	2.605
	1993-2004	2,4,5	505	38-113	0.674	<0.0001	F = 3.602 $L^{2.974}$	0.407	1.106	2.336
3Pn	1999	4	13	40-91	0.819	<0.0001				
	2000	4	4	50-72	0.939	0.0308				
	2001	4	1	45						
	2003	4	6	45-73	0.344	0.2213				
	1999-2003	4	24	40-91	0.732	<0.0001	F = 0.522 $L^{3.439}$	0.363	1.156	2.744

Note: [a]Data from Stares et al. (2007). [b]Wells (1986) presented partial data (sample sizes in his study were 15 (1979), 5 (1982), 5 (1983), 11 (1984)).

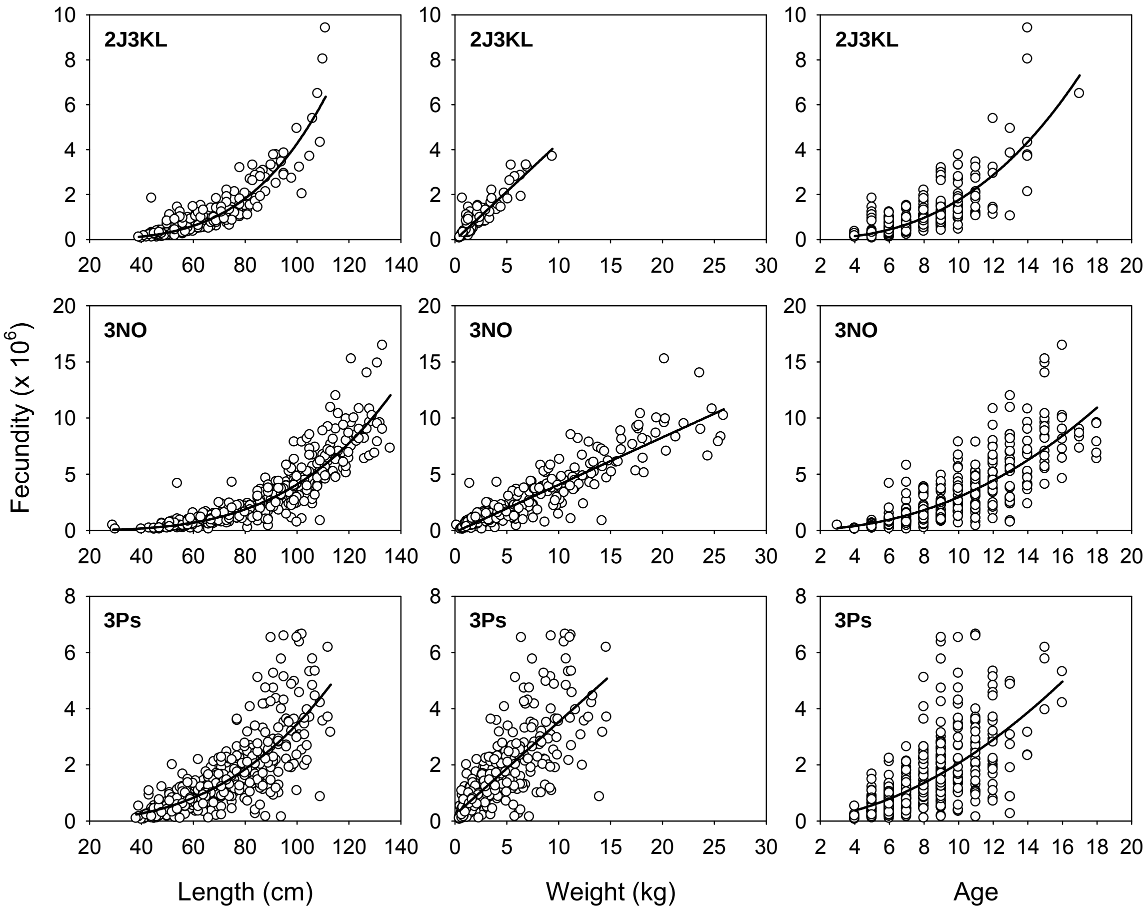

Figure 1. Relationships between potential fecundity and fish length, weight and age for Northwest Atlantic cod. Data pooled across years.

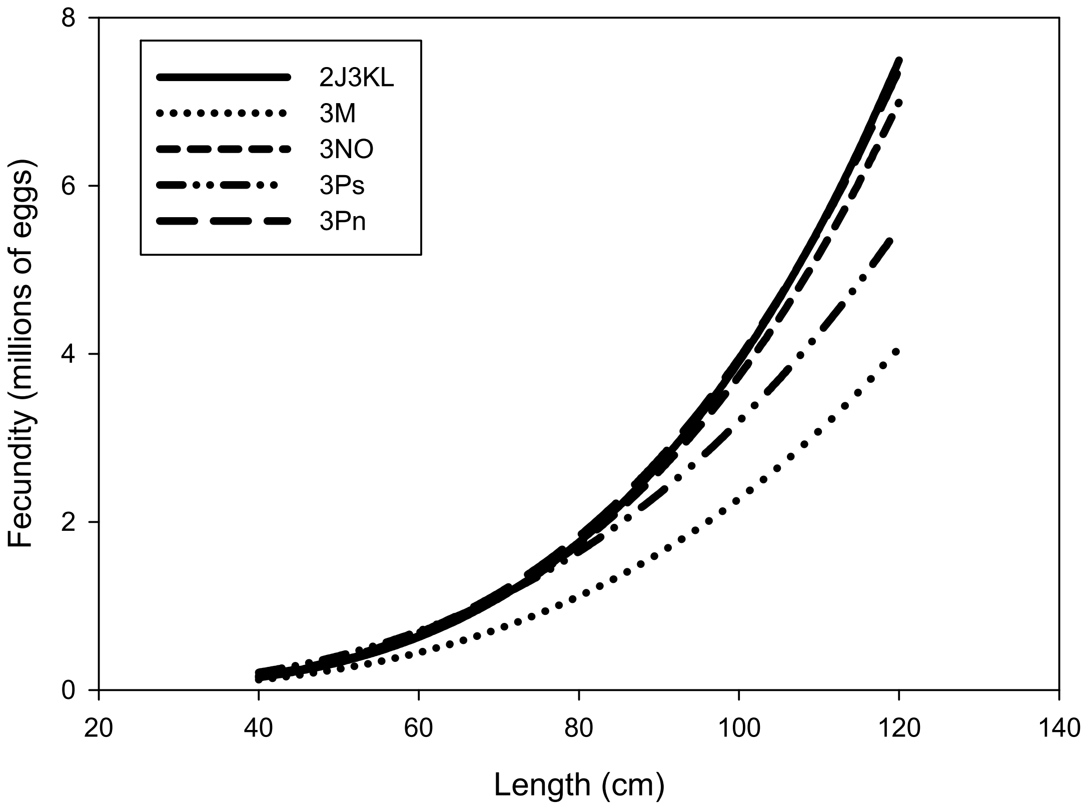

Figure 2. Estimated fecundity at length by stock area, all years combined.

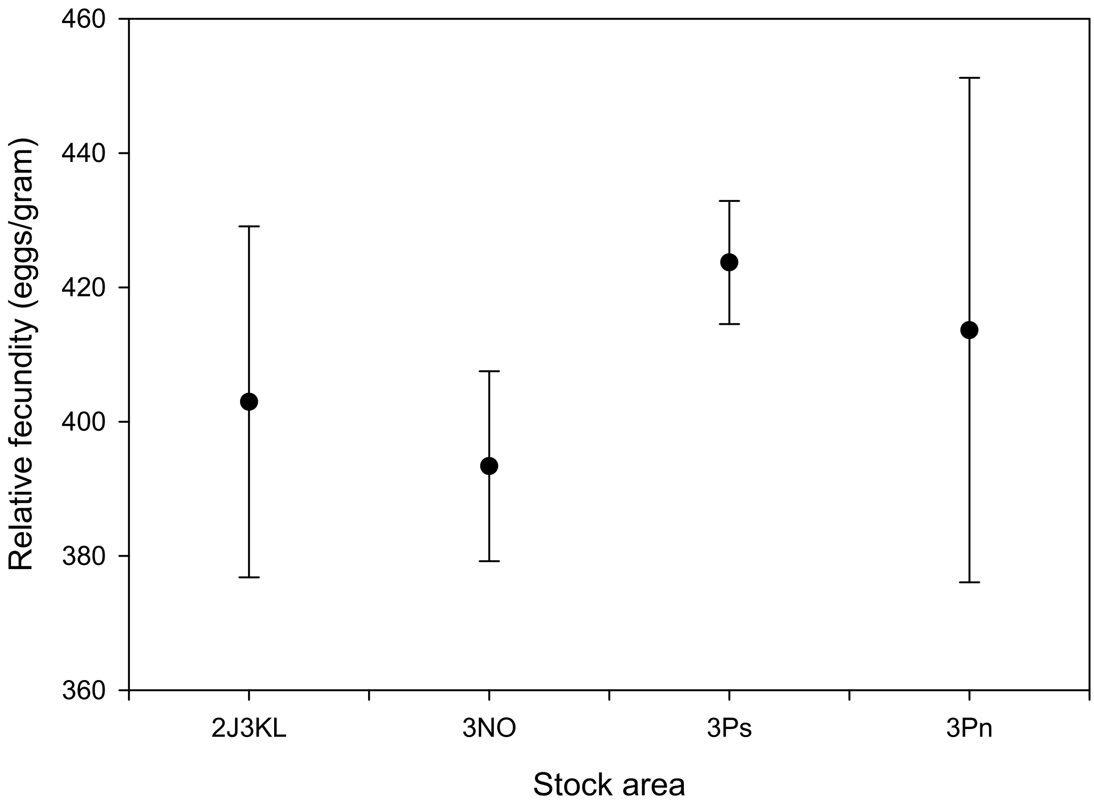

Figure 3. Mean (±1 standard error) relative fecundity by stock area, all years combined.

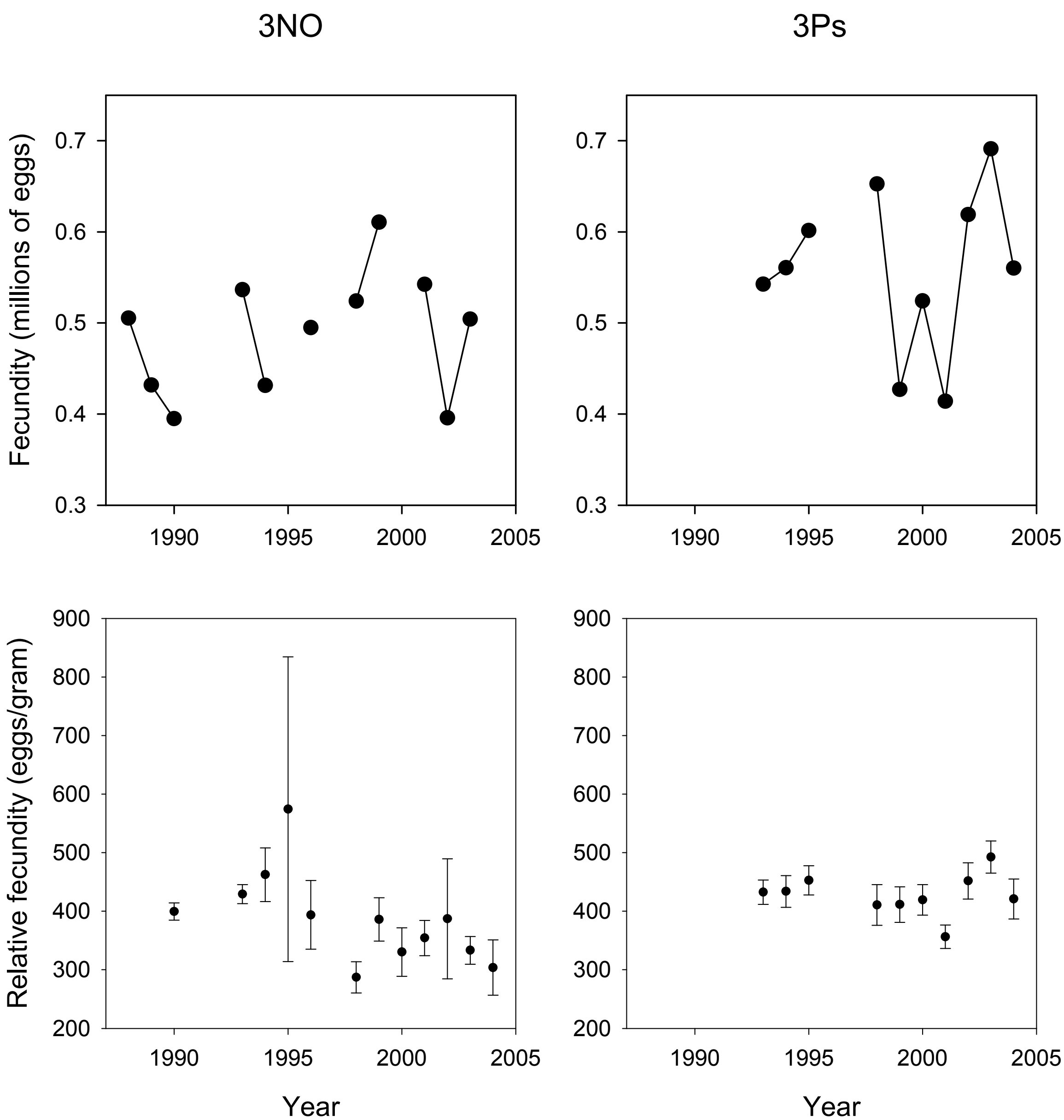

Figure 4. Time series of fecundity (millions of eggs) at 55 cm and relative fecundity (eggs per gram of body weight) for 3NO and 3Ps cod.