Temporal trends in age and length at maturity of Atlantic cod (Gadus morhua) from NAFO
Subdivision 3Ps

by

J. Brattey and M. J. Morgan
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland
A1C 5X1

Abstract

This study presents a time series of observed and estimated proportions mature at age and length for female and male cod from NAFO Subdivision 3Ps from 1972 to 1996. The proportion of fish maturing at an early age or shorter length has been increasing among cod in this management unit from the late 1980's until the early to mid 1990's; however, estimates for the last few years suggest that the declining trend has reversed or at least halted. The estimated age at 50% maturity for females declined from a high of 7.2 yr during 1988 to a low of 5.0 during 1994, with the most recent (1996) value at 5.54. Among males the corresponding values were a high of 5.89 during 1987, a low of 4.55 during 1992, with the most recent value at 4.87. Median length at maturity shows a similar trend with females declining from a high of 63.18 cm during 1988 to a low of 46.72 during 1994 with the current value at 47.81. Males declined from a median length at maturity of 57.38 during 1979 to a low of 42.35 during 1994 with the current value at 43.41. We found no evidence for differences in age at maturity between cod sampled during bottom trawl surveys in 3Ps during 1995/96 and cod sampled inshore during the 1995 Sentinel Survey in 3Ps during the spring and fall 1995.

Résumé

Est présentée une série temporelle de pourcentages observés et estimés de morue femelle et mâle à maturité selon l'âge et la longueur dans la sous-division 3Ps de l'OPANO pour la période 1972- 1996. Le pourcentage d'individus atteignant maturité à un bas âge ou à une faible longueur a augmenté dans cette unité de gestion de la fin des années 80 jusqu'au milieu des années 90. Toutefois, des estimations portant sur les dernières années portent à croire que cette tendance à la baisse s'est renversée ou du moins s'est arrêtée. L'âge estimé de maturité de 50 % des femelles a chuté d'un pic de 7,2 ans en 1988 à un creux de 5,0 ans en 1994, la plus récente valeur obtenue en 1996 se situant à 5,54 ans. Chez les mâles, la valeur correspondante se situent à 5,89 ans en 1987, 4,55 ans en 1992 et 4,87 ans en 1996. La longueur médiane à maturité montre une tendance semblable, les femelles passant d'un pic de 63,18 cm en 1988 à un creux de 46,72 cm en 1994, la valeur en 1996 se situant à 47,81 cm, tandis que les mâles ont passé de 57,38 cm en 1979 à 42,35 cm en 1984, pour atteindre une longueur de 43,41 cm en 1996. Nous n'avons trouvé aucune explication de la différence de l'âge à maturité entre la morue échantillonnée en 1995-1996 dans le cadre de relevés au chalut de fond dans 3Ps et la morue échantillonnée au cours du printemps et de l'automne 1995 dans le cadre de la pêche de contrôle dans les eaux côtières de 3Ps.

Introduction

Estimates of spawning stock biomass are important for stock assessment purposes and can be obtained by combining information on average weights at age and age at maturity. In recent years there has been an increase in the proportion of mature fish at younger ages in cod stocks off eastern Canada (Rollet et al. MS 1995; Morgan and Shelton, MS 1995; Morgan et al. 1994; Xu et al. MS 1991). Traditionally estimates of spawning stock biomass have assumed that all fish beyond a specific age were mature; however, these so-called knife-edge estimates of age at maturity do not take temporal trends into account. Small changes in age at maturity can have a significant impact on the estimation of spawning stock biomass, particularly when a large proportion of the biomass is within the age range where maturity occurs. Clearly, the best estimates of proportion mature at age should be used to estimate spawning stock biomass. Changes in age at maturity can also indicate stress in a population so that an examination of the trends themselves may be important (Trippel, 1995). Accurate estimates of length at maturity are also useful, particularly for comparative purposes where age data may be lacking. Estimates of length at maturity may also be useful from a conservation/harvesting perspective for establishing small fish protocols.

This study provides a time series of observed and estimated proportion mature at age and length for female and male cod from NAFO Subdivision 3Ps from 1972 to 1996 based on samples collected during research vessel (RV) surveys. We also calculated observed proportions mature at age for samples collected inshore during the 1995 Sentinel Survey and compared these with estimates from the offshore RV surveys.

Methods

Maturity data from surveys in Div. 3Ps from 1972 to 1996 were used in the analyses. The timing of the surveys has varied somewhat throughout the time series, with a switch from January-February prior to 1994 to April in more recent years (see Murphy et al., MS 1996). The methodology used here was essentially as described by Morgan and Hoenig, (MS 1993), Morgan and Shelton, (MS 1995) and Morgan and Brattey (MS 1996). Fish were assigned to the category 'mature' or 'immature' based on the criteria described by Templeman et al. (1978). The first stage in this scheme is classed as immature and all other stages show some evidence of maturing to spawn or of having spawned in the current year and are classed as mature. The 'other' or 'unknown' category was excluded from analyses. Because of the length stratified collection of otoliths, the calculation of proportion mature at age included a weighting by the female population number at length (Morgan and Hoenig, MS 1993). Estimates of proportion mature at age and length as well as age and length at 50% maturity (A_{50}) were produced for each year using Probit analyses with a logit link function (SAS Institute Inc. 1989).

Samples of cod from the Sentinel Survey were transported to the laboratory, frozen for storage, and thawed before being examined for maturity. Fish were assigned to mature and immature categories as above. These data were collected in a length stratified manner so the proportions were weighted by the length frequency. Data from the sentinel samples was divided into two geographic areas and time periods (west of the Burin Peninsula sampled during spring, and Placentia Bay-east of the Burin Peninsula sampled during fall, using Lord's Cove at the tip of the Burin Peninsula as the dividing line and excluding data from that community. Burin-west included all samples collected from that area during January-May 1995 and Placentia Bay-east included samples collected from that area during August-December. These data were then compared with estimates of proportion mature at age from research vessel surveys conducted during 1995 (vs. Burin-west) and 1996 (vs. Placentia Bay-east). The effect of area on proportion mature at age was examined using a generalized linear model

4

with a binomial error distribution and a logit link function, to determine if the addition of an area term significantly decreased the deviance of the model (McCullagh and Nelder, 1983; SAS Institute Inc.,1993). One year was added to the ages of fish from the fall Sentinel Survey samples to make them comparable to the 1996 survey.

Results and Discussion

The annual observed proportion mature at each age for female and male cod collected during the bottom trawl surveys from 1972 to 1996 is shown in Tables 1 and 2. Throughout the time series the youngest observed age at maturity was 4 yr for females and 3 yr for males, but mature fish were rare among these age groups. Overall, male and female cod in 3Ps show an increase in the proportion mature at younger ages, particularly among ages 5 and 6 among females and ages 4 and 5 among males. In the early portion of the time series, generally less than 30% and often less than 10% of the females at age 5 were mature. In most recent years, 35 to 51% of age 5 females have been mature. Six year old females show a similar trend, with the proportion mature increasing from 20 to 70% in the first years of the time series to 74 to 96% in recent years. The increase in the proportion mature at age 5 and 6 among females has been particularly evident since 1992. A similar pattern is evident among the data for males although maturation generally occurs at about a year younger for males.

Estimated age at 50% maturity (A_{50}) among females was generally around 6 yr from 1972 to the mid 1980's and appears to have varied by about 0.5 yr (Fig. 1). However, since the mid 1980's the A_{50} has declined from a high of 7.2 yr during 1988 to a low of 5.0 during 1994, with the most recent (1996) value at 5.54. Among males the corresponding values were a high of 5.89 during 1987, a low of 4.55 during 1992, with the most recent value at 4.87 (Fig. 1). A notable feature of the trend is that the decline seen in recent years appears to have reversed or at least halted.

The annual observed proportion mature at length (3 cm groups) for female and male cod from 1972 to 1996 is shown in Tables 3 and 4. Throughout the time series the youngest observed length at maturity was 34 cm for females and 31 cm for males, but mature fish were rare among these length groups. Overall, male and female cod in 3Ps show an increase in the proportion mature at shorter lengths, particularly among 43-67 cm fish for females and 37-61 cm fish among males. The increase in the proportion mature at smaller lengths and has been particularly evident since 1991 for females and 1992 for males.

Median length at maturity (Fig. 2) shows a similar trend as age with females declining from a high of 63.18 during 1988 to a low of 46.72 during 1994 with the current value at 47.81. Males declined from a median length at maturity of 57.38 during 1979 to a low of 42.35 during 1994 with the current value at 43.41. Similar to the age data, a notable feature of the trend is that the decline appears to have reversed or at least halted in recent years.

Plots of estimated proportion mature over time for selected length categories (Fig. 3) show that the overall trend towards increasing proportions mature at smaller lengths is evident over a fairly broad range of lengths.

The observed proportion mature at age of males and females from the Sentinel Survey samples and the bottom trawl survey of 3Ps are shown in Table 5. Proportions mature at age appeared to be very similar in each data set, except among female cod from Placentia Bay where there is an unusually rapid increase in proportion mature at age , with all fish 6 yr or older being classified as mature. The analyses indicate that the addition of an area term to the model did not significantly decrease the deviance over a model including the effect of age alone for three of the four comparisons; in the fourth

comparison (female fish from Placentia Bay vs. the 1996 survey) the area term was significant (Table 6). However, we suspect that the anomalous results for the female cod from Placentia Bay may at least partly due to errors in classifying. During fall gonads of a small proportion of older females (≥ 6 yr) may have been erroneously classified as spent; these can be difficult to distinguish at this time of year, particularly after the gonads have been frozen and thawed. Overall, these results suggest that the maturity schedule in the two areas and in the 1995/96 spawning season were similar.

Acknowledgements.

References

McCullagh, P. and J.A. Nelder. 1983. Generalized Linear Models. Monographs on Statistics and Probability. Chapman and Hall, London. 261p.

Morgan, M.J. and J. Brattey. MS 1996. Maturity of female cod in 2J3KL. DFO Atl. Fish. Res. Doc. 96/64, 12p.

Morgan, M.J. and J.M. Hoenig. MS 1993. Maturity at age from length stratified sampling. ICES C.M. Doc., No D:55, 11p.

Morgan, M.J. and P.A. Shelton. MS 1995. Alternative models of maturity at age applied to cod in NAFO Divisions 2J3KL. DFO Atl. Fish. Res. Doc. 95/24, 12p.

Morgan, M.J., C.A. Bishop and J.W. Baird. 1994. Temporal and spatial variation in age and length at maturity in cod in Divisions 2J and 3KL. NAFO Sci. Counc. Studies 21: 83-89.

Murphy, E. F., D. E. Stansbury, P. A. Shelton, J. Brattey, and G. Lilly. MS 1996. The assessment of the cod stock in NAFO Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 96/--.

Rollet, C., J.-C. Brethes, and A. Frechet. MS 1995. Spatial and temporal variation in cod length frequencies and length at 50% maturity in Divisions 3Pn, 4RS and 3Ps. DFO Atl. Fish. Res. Doc. 95/103.

Templeman, W., V.M. Hodder and R. Wells. 1978. Sexual maturity and spawning in haddock, *Melanogrammus aeglefinus*, of the southern Grand Bank. ICNAF Res. Bull. 13:53-65.

Trippel, E.A. 1995. Age at maturity as a stress indicator in fisheries. BioScience 45:759-771.

SAS Institute Inc. 1989. SAS/STAT User's Guide. Cary, NC. SAS Institute Inc.

Xu, X., J. Baird, C. Bishop and J. Hoenig. MS 1991. Temporal variability in cod maturity and spawning biomass in NAFO Divisions 2J + 3KL. NAFO SCR Doc., No. 112, 12p.

Table 1. Observed proportion mature at age of female Atlantic cod (Gadus morhua) in NAFO Subdiv. 3Ps (1972-1996). A50=median age at maturity (years); L95% and U95%=lower and upper 95% confidence intervals. Parameter estimates of the logit model are also shown: Int=intercept, SE=standard error, n=number of fish aged, dot=no fish sampled.

AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	0	.	0	0	0	.	.	.	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0.01	0.01	0	0	0	0	0	0	0.09	0
5	0.10	0.08	0.08	0.20	0.33	0.25	0.11	0.06	0.10	0.10	0.03	0.14	0.41
6	0.43	0.58	0.44	0.54	0.71	0.47	0.33	0.34	0.21	0.49	0.44	0.53	0.59
7	0.64	0.68	1	0.87	0.69	0.96	0.77	0.61	0.87	0.72	0.69	0.91	0.85
8	0.92	0.93	1	1	0.95	0.89	0.93	0.92	1	0.92	0.93	1	0.91
9	1	1	1	0.83	0.80	1	1	0.85	1	1	0.96	1	1
10	1	1	1	1	1	1	1	1	1	1	1	0.94	1
11	.	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	.	1	1	1	1	.	1	1	1	1	1
13	1	1	.	.	.	1	1	.	1	1	.	1	.
A50	6.49	6.41	6.02	5.93	5.81	5.88	6.36	6.62	6.37	6.30	6.51	5.99	5.78
L 95%	6.16	6.14	5.69	5.71	5.54	5.66	6.14	6.40	6.18	6.06	6.26	5.70	5.52
U 95%	6.77	6.66	6.48	6.18	6.17	6.15	6.58	6.88	6.59	6.55	6.75	6.30	6.01
Slope	1.60	1.68	2.92	1.72	1.45	1.80	1.81	1.51	2.37	1.68	1.83	1.47	1.53
SE	0.23	0.20	0.88	0.20	0.18	0.24	0.22	0.17	0.34	0.20	0.21	0.16	0.22
Int	-10.39	-10.77	-17.56	-10.20	-8.43	-10.59	-11.53	-9.99	-15.09	-10.62	-11.91	-8.81	-8.86
SE	1.57	1.32	5.22	1.16	0.95	1.33	1.39	1.10	2.13	1.31	1.41	0.97	1.29
n	223	301	94	305	332	307	322	312	337	328	391	410	285

Table 1. 3Ps female cod by age (cont'd).

AGE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	.	.	.	.	0	.	0	.	.	.	.	0
2	0	0	0	0	0	0	0	0 .		0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0.05	0	0.07	0	0.11	0	0.01
5	0.05	0.03	0.04	0.02	0.08	0.11	0.18	0.35	0.46	0.50	0.51	0.39
6	0.34	0.35	0.25	0.17	0.49	0.62	0.48	0.87	0.93	0.96	0.79	0.74
7	0.80	0.71	0.60	0.40	0.79	0.80	0.84	0.97	0.94	0.94	0.97	0.92
8	1	0.96	0.86	0.85	0.93	0.82	0.88	1	1	1	0.96	1
9	1	1	1	0.9	0.97	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	0.94	1	1	1	1	1	1	1	.
13	1	1	1	1	1	1	1 .		1	1	1	.
A50	6.32	6.41	6.74	7.20	6.24	6.20	6.08	5.25	5.24	5.00	5.17	5.54
L 95%	6.12	6.28	6.57	6.96	6.02	5.91	5.86	5.06	5.08	4.89	4.92	5.32
U 95%	6.52	6.55	6.92	7.45	6.45	6.52	6.32	5.44	5.39	5.12	5.37	5.74
Slope	2.30	2.04	1.74	1.43	1.74	1.36	1.63	2.35	2.70	2.01	1.68	1.98
SE	0.30	0.18	0.16	0.15	0.19	0.15	0.18	0.33	0.26	0.18	0.23	0.21
Int	-14.53	-13.06	-11.73	-10.31	-10.88	-8.40	-9.94	-12.36	-14.12	-10.06	-8.68	-11.00
SE	1.88	1.14	1.07	1.07	1.19	0.90	1.07	1.75	1.40	0.91	1.26	1.20
n	376	643	548	492	432	317	417	289	476	664	288	420

Table 2. Observed proportion mature at age of male Atlantic cod (Gadus morhua) in NAFO Subdiv. 3Ps (1972-1996). A50=median age at maturity (years); L95% and U95% =lower and upper 95% confidence intervals. Parameter estimates of the logit model are also shown; Int=intercept, SE=standard error, n=number of fish aged.

AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	0	0	0	0	0	0	.	0	0	0	0	0	.
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0.06	0	0.01	0	0	0	0	0	0	0	0
4	0.08	0.12	0.11	0.15	0.13	0.13	0	0	0.11	0.10	0.03	0.04	0.03
5	0.31	0.42	0.58	0.59	0.55	0.50	0.21	0.13	0.52	0.37	0.21	0.61	0.55
6	0.64	0.78	0.91	0.98	0.89	0.72	0.75	0.69	0.47	0.82	0.77	0.91	0.87
7	0.99	0.96	1	0.97	0.93	1	0.76	0.87	1	0.96	0.95	0.81	0.96
8	1	1	1	1	1	1	0.88	1	1	1	0.97	0.89	1
9	1	0.98	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	.	1	1	1	1	1	1	1	1	0.93	1
12	1	1	1	.	1	1	1	.	1	1	1	1	1
13	.	.	.	1	1	1	.	.	1	.	1	1	1
A50	5.42	5.23	4.86	4.81	4.97	5.13	5.91	5.84	5.57	5.27	5.62	5.09	5.09
L 95%	5.10	5.00	4.40	4.61	4.76	4.91	5.64	5.65	5.30	5.02	5.36	4.79	4.84
U 95%	5.87	5.46	5.59	5.02	5.22	5.39	6.21	6.04	5.84	5.50	5.89	5.40	5.29
Slope	2.01	1.70	1.92	2.37	1.98	1.80	1.61	2.15	1.32	2.00	1.99	1.16	2.21
SE	0.31	0.21	0.49	0.31	0.24	0.25	0.21	0.27	0.17	0.26	0.24	0.13	0.30
Int	-10.88	-8.87	-9.34	-11.41	-9.84	-9.27	-9.50	-12.58	-7.37	-10.56	-11.17	-5.89	-11.28
SE	1.71	1.09	2.23	1.47	1.14	1.24	1.18	1.53	0.96	1.42	1.34	0.68	1.64
n	204	336	78	304	353	242	253	275	283	264	336	396	296

Table 2. 3Ps male cod by age (cont'd).

AGE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	.	0	0	0	.	0	.	.	.	.	0
2	0	0	0	0	0	0	0	0	.	0	0	0
3	0	0	0	0	0	0	0.05	0	0	0.06	0	0
4	0	0	0.06	0.07	0.05	0.11	0.23	0.28	0.15	0.25	0.31	0.21
5	0.28	0.35	0.18	0.62	0.32	0.45	0.28	0.81	0.66	0.65	0.70	0.60
6	0.64	0.64	0.56	0.70	0.86	0.80	0.73	0.88	0.87	0.95	0.91	0.93
7	0.83	0.81	0.88	0.95	0.93	1	1	0.96	0.98	1	0.94	0.93
8	0.96	0.98	0.91	0.91	0.98	1	1	1	1	1	1	1
9	1	0.98	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	.	1	1	.
A50	5.79	5.67	5.89	5.36	5.44	5.12	5.24	4.55	4.86	4.62	4.60	4.87
L 95%	5.55	5.50	5.71	5.09	5.21	4.89	4.98	4.31	4.69	4.48	4.28	4.66
U 95%	6.04	5.84	6.08	5.61	5.68	5.38	5.52	4.77	5.04	4.76	4.84	5.11
Slope	1.65	1.50	1.59	1.44	1.86	2.06	1.43	1.85	1.95	1.89	1.68	1.76
SE	0.19	0.13	0.16	0.15	0.20	0.27	0.17	0.23	0.20	0.19	0.23	0.17
Int	-9.56	-8.53	-9.38	-7.75	-10.12	-10.32	-7.49	-8.42	-9.49	-8.75	-7.74	-8.58
SE	1.09	0.75	0.96	0.85	1.08	1.37	0.87	1.12	0.96	0.91	1.17	0.83
n	339	588	458	417	406	265	340	265	394	492	307	421

Table 3. Observed proportion mature at length of female Atlantic cod (Gadus morhua) in NAFO Subdiv. 3Ps (1972-1996). L50=median length at 50% maturity. L95% and U95%=lower and upper confidence intervals. Length in 3 cm intervals: e.g., 55 cm=54-56 cm. Parameter estimates of the logit model are also shown Int=intercept; SE=standard error; n=sample size, dot=no fish sampled.

LEN	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
22	0	0	0	0	0	0	0	0	0	0	0	0	.
25	0	0	0	0	0	0	0	.	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0.08	0	0	0.06	0.05	0	0	0	0
46	0	0	0.09	0	0	0	0	0.06	0	0	0.06	0	0.08
49	0	0.07	0	0.11	0.06	0.09	0.14	0.06	0.13	0.06	0	0.18	0.46
52	0.14	0.33	0	0.14	0.05	0	0.14	0.07	0.06	0.29	0	0.27	0.29
55	0.43	0.50	0.62	0.10	0.14	0.21	0.17	0.15	0.29	0.43	0.23	0.43	0.52
58	0.40	0.56	1	0.26	0.17	0.05	0.15	0.25	0.17	0.36	0.29	0.64	0.52
61	0.54	0.61	0	0.58	0.55	0.25	0.69	0.33	0.20	0.64	0.59	0.46	0.64
64	0.71	0.70	1	0.68	0.74	0.77	0.83	0.46	0.20	0.67	0.44	0.75	0.70
67	0.88	0.75	1	0.86	0.71	1	0.62	0.43	0.20	0.62	0.72	1	0.95
70	0.70	0.85	.	0.84	0.67	0.80	0.80	0.65	0.78	0.92	0.86	0.92	0.85
73	1	0.91	1	0.89	1	0.75	0.88	0.64	1	0.88	0.83	0.94	0.94
76	0.92	1	1	1	1	1	1	0.88	1	1	0.92	0.88	0.92
79	0.91	1	.	1	1	1	0.93	0.77	1	1	0.90	1	1
82	1	1	.	1	1	1	1	0.67	1	1	0.92	1	1
85	1	1	1	1	1	.	1	0.93	1	1	1	1	1
88	1	1	.	1	.	1	1	1	1	1	1	1	1
91	1	1	.	.	.	1	1	1	1	1	1	1	1
L50	60.42	58.56	54.51	61.12	61.74	62.84	61.31	66.89	65.04	59.95	63.12	58.04	56.78
L 95%	57.88	56.67	52.19	59.52	60.14	61.28	59.63	64.49	62.71	57.93	61.16	55.96	54.48
U 95%	62.66	60.39	57.28	62.77	63.62	64.57	63.08	69.47	67.74	62.02	65.11	60.13	58.80
Slope	0.21	0.19	0.42	0.25	0.23	0.30	0.21	0.14	0.19	0.20	0.20	0.21	0.17
SE	0.03	0.02	0.12	0.03	0.03	0.05	0.02	0.02	0.03	0.02	0.02	0.03	0.02
Int	-12.56	-11.34	-23.06	-15.40	-14.43	-18.98	-12.88	-9.74	-12.44	-12.07	-12.44	-12.35	-9.69
SE	1.93	1.35	6.34	1.92	1.73	2.90	1.40	1.09	1.63	1.44	1.45	1.50	1.29
n	223	324	94	305	389	307	395	312	337	328	391	410	285

Table 3. 3Ps female cod by length (cont.'d).

LEN	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
22	0	0	0	0	0	0	0	0	.	0	0	0
25	0	0	0	0	0	0	0	0	0	0	.	0
28	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0.07	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0.07	0	0.06	0.04	0.3	0	0.05
43	0	0.03	0.03	0.12	0	0.10	0.08	0.36	0.25	0.42	0.25	0.32
46	0	0.03	0.11	0.11	0.19	0.11	0.35	0.38	0.31	0.54	0.53	0.33
49	0.07	0.17	0.07	0.07	0.15	0.50	0.36	0.46	0.65	0.95	0.31	0.61
52	0.24	0.31	0.20	0.11	0.28	0.42	0.48	0.72	0.88	0.58	0.78	0.81
55	0.53	0.24	0.21	0.07	0.41	0.50	0.80	0.88	0.82	0.77	0.80	0.82
58	0.24	0.43	0.35	0.15	0.46	0.58	0.44	0.83	0.93	0.93	0.82	0.95
61	0.54	0.51	0.52	0.56	0.67	0.57	0.64	1	0.96	0.83	0.95	1
64	0.71	0.83	0.57	0.44	0.87	0.88	1	0.92	1	1	0.82	1
67	0.73	0.67	0.78	0.74	0.87	1	1	1	1	0.75	1	1
70	0.83	0.96	0.81	0.73	0.94	1	1	1	1	1	1	0.95
73	1	1	0.94	0.94	1	1	1	1	1	1	1	1
76	1	1	0.86	0.81	1	1	1	1	1	1	1	1
79	1	1	1	0.90	1	1	1	1	1	1	1	1
82	1	1	1	1	1	1	1	1	1	1	1	1
85	1	1	1	1	1	1	1	1	1	1	1	1
88	1	1	0.93	1	1	1	1	1	1	1	1	1
91	1	1	1	1	1	1	1	1	1	1	1	1
L50	59.6	58.84	61.23	63.18	56.92	53.92	52.94	48.74	48.01	46.72	49.17	47.81
L 95%	57.68	57.56	59.66	61.17	55.44	52.06	51.21	47	46.44	44.9	47.06	46.31
U 95%	61.61	60.17	62.89	65.22	58.53	56	54.75	50.42	49.64	48.41	51.02	49.28
Slope	0.21	0.21	0.18	0.18	0.22	0.21	0.22	0.25	0.31	0.17	0.202	0.28
SE	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.02	0.03	0.03
Int	-12.6	-12.65	-10.86	-11.07	-12.54	-11.14	-11.94	-12.24	-14.92	-8.06	-9.95	-13.36
SE	1.56	1.01	0.97	1.12	1.20	1.34	1.30	1.62	2.16	0.93	1.33	1.55
n	374	643	547	491	534	317	416	289	271	344	287	419

Table 4. Observed proportion mature at length of male Atlantic cod (_Gadus morhua_) in NAFO Subdiv. 3Ps (1972-1996). L50=median length at 50% maturity. L95% and U95%=lower and upper confidence intervals. Length in 3 cm intervals: e.g., 55 cm=54-56 cm. Parameter estimates of the logit model are also shown. Int=intercept; SE=standard error; n=sample size, dot=no fish sampled.

LEN	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
22	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0.12	0	0.07	0	0	0	0	0	0	0	0.14
40	0	0.08	0.12	0.05	0	0	0	0	0	0	0	0	0
43	0.10	0.25	0.12	0	0	0.38	0	0.07	0.09	0	0	0	0
46	0.12	0.28	0.40	0.18	0.14	0	0.21	0.05	0.33	0.22	0.18	0.18	0.15
49	0.50	0.33	0.29	0.33	0.05	0.22	0.33	0.21	0.50	0.36	0.07	0.37	0.57
52	0.50	0.68	0.5	0.55	0.19	0.46	0.47	0.33	0.77	0.62	0.18	0.73	0.79
55	0.50	0.76	1	0.75	0.43	0.33	0.50	0.47	0.17	0.86	0.29	0.71	0.85
58	0.60	0.90	1	0.90	0.79	0.46	0.89	0.60	0.61	0.94	0.64	1	0.74
61	0.67	0.87	1	0.94	0.78	0.86	0.82	0.62	0.61	0.94	0.86	0.88	0.88
64	1	1	1	0.94	0.82	0.71	0.92	0.69	0.79	0.93	0.83	1	0.96
67	0.92	0.96	1	1	0.96	0.82	0.67	0.79	0.91	0.92	1	0.87	1
70	0.9	1	1	1	1	1	0.6	0.89	0.67	1	0.94	1	1
73	1	0.95	1	1	1	1	0.75	1	1	1	1	1	1
76	1	1	1	1	1	1	0.83	1	1	1	1	1	0.9
79	1	1	.	1	1	1	1	1	1	1	1	1	1
82	1	1	.	1	1	1	1	1	1	1	1	1	1
85	1	1	.	1	1	1	1	1	1	1	1	1	1
88	1	1	1	.	1	1	1	1	1	1	1	1	1
91	1	1	.	.	.	1	.	.	1	1	1	1	1
L50	53.87	50.36	49.67	51.53	55.84	56.35	55.87	57.38	54.84	51.06	56.69	51.15	50.10
L 95%	51.06	48.57	46.30	49.94	54.38	54.09	53.75	55.36	52.38	49.30	55.01	49.47	47.79
U 95%	56.58	51.99	55.48	53.05	57.40	58.74	58.22	59.54	57.36	52.79	58.42	52.76	52.01
Slope	0.22	0.23	0.23	0.31	0.27	0.19	0.16	0.20	0.15	0.30	0.29	0.29	0.22
SE	0.03	0.03	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.03
Int	-11.59	-11.48	-11.65	-16.08	-15.14	-10.61	-9.04	-11.23	-8.46	-15.28	-16.44	-14.63	-10.90
SE	1.81	1.36	2.96	2.22	1.76	1.43	0.99	1.40	1.07	2.21	2.30	2.01	1.52
n	204	348	78	304	419	242	325	275	282	264	336	393	296

Table 4. 3Ps male cod by length (cont'd).

LEN	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
22	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	.	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0.09	0	0.1	0	0
34	0	0	0	0	0	0	0	0.14	0	0.06	0.17	0	0
37	0.14	0	0	0	0	0	0.06	0.13	0.23	0.09	0.19	0.18	0.24
40	0	0.08	0.04	0.05	0.26	0.11	0.16	0.21	0.57	0.13	0.50	0.38	0.43
43	0	0	0	0.16	0.42	0.12	0.46	0.36	0.75	0.43	0.62	0.59	0.41
46	0.15	0.11	0.14	0.16	0.47	0.35	0.50	0.20	0.84	0.56	0.68	0.79	0.76
49	0.57	0.31	0.43	0.33	0.65	0.25	0.73	0.67	0.86	0.76	0.62	0.83	0.78
52	0.79	0.39	0.61	0.30	0.78	0.80	0.71	0.62	0.78	0.84	0.85	0.90	0.85
55	0.85	0.65	0.59	0.67	0.75	0.73	0.90	0.75	0.76	0.83	1	0.90	0.88
58	0.74	0.77	0.73	0.77	0.90	0.93	0.90	0.77	0.94	0.91	1	0.94	0.95
61	0.88	0.93	0.86	0.81	0.84	0.96	1	0.94	0.92	0.95	1	1	1
64	0.96	0.54	0.86	0.85	1	0.94	1	1	1	0.94	1	1	1
67	1	1	0.93	0.9	0.92	1	1	1	1	0.92	1	1	1
70	1	1	1	1	1	1	1	1	1	1	1	1	1
73	1	0.91	0.96	1	1	1	1	1	1	1	1	1	1
76	0.90	1	1	0.91	1	1	1	1	1	1	1	1	1
79	1	1	1	1	1	1	1	1	1	1	1	1	1
82	1	1	1	1	1	1	1	1	1	1	1	1	1
85	1	1	1	1	1	1	1	1	1	1	1	1	.
88	1	1	1	1	1	1	1	1	1	.	1	1	1
91	1	1	1	1	1	1	1	1	1	1	1	1	1
L50	50.10	54.07	52.67	53.42	47.67	50.09	46.16	48.21	41.88	46.04	42.35	42.45	43.41
L 95%	47.79	52.20	51.37	51.92	45.70	48.81	44.38	46.12	39.72	44.01	40.49	40.34	41.88
U 95%	52.01	55.99	53.91	54.92	49.62	51.44	48.07	50.34	43.88	47.98	44.15	44.12	44.96
Slope	0.22	0.22	0.22	0.20	0.19	0.27	0.28	0.19	0.19	0.22	0.20	0.25	0.25
SE	0.03	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.02	0.03	0.03	0.03	0.03
Int	-10.90	-12.00	-11.42	-10.72	-8.97	-13.55	-12.69	-9.24	-8.07	-10.04	-8.52	-10.47	-11.05
SE	1.52	1.49	1.05	1.09	1.01	1.37	1.71	1.05	1.07	1.40	1.18	1.56	1.23
n	296	339	588	457	416	502	264	340	265	228	258	307	421

Table 5. Comparison of observed proportions mature at age between cod collected in NAFO subdivision 3Ps during research surveys and cod collected within two inshore areas of 3Ps during the sentinel survey (N=no. fish aged, Prop.=proportion mature).

Females

AGE	Burin/West Jan.-May Prop.	N	3Ps survey 1995 Prop.	N	AGE	Placentia Bay/East Aug.-Dec. Prop.	N	3Ps survey 1996 Prop.	N
1	.	.	.	.	1	.	.	0	15
2	.	.	0	2	2	.	.	0	38
3	0	7	0	10	3	0	2	0	73
4	0	21	0	22	4	0	21	0.01	59
5	0.57	126	0.51	57	5	0.74	16	0.39	23
6	0.83	253	0.79	87	6	1	56	0.74	57
7	0.95	79	0.97	33	7	1	71	0.92	98
8	0.96	67	0.96	31	8	1	30	1	21
9	1	22	1	20	9	1	24	1	19
10	1	8	1	14	10	1	5	1	9
11	1	1	1	7	11	1	3	1	8
12	1	2	1	1	12	.	.	.	.
13	.	.	1	2	13	.	.	.	.

Males

AGE	Prop.	N	Prop.	N	AGE	Prop.	N	Prop.	N
1	.	.	.	.	1	.	.	0	40
2	.	.	0	1	2	.	.	0	41
3	0.25	6	0	21	3	0	1	0	71
4	0.47	21	0.31	20	4	0.31	13	0.21	62
5	0.69	99	0.70	48	5	0.60	17	0.60	20
6	0.87	209	0.91	96	6	0.97	49	0.93	63
7	0.96	51	0.94	24	7	1	47	0.93	86
8	0.97	34	1	42	8	1	36	1	16
9	1	9	1	31	9	1	22	1	14
10	1	3	1	7	10	1	6	1	3
11	.	.	1	5	11	1	1	1	3
12	.	.	1	1	12	1	2	1	2
13	.	.	1	4	13	.	.	.	.

Table 6. Results of analysis of deviance for effect of area on proportion mature at age.

Sentinel samples west of Burin (January-May 1995) vs 1995 RV survey of 3Ps. Male cod.

Source	Deviance	DF	ChiSquare	Pr>Chi
INTERCEPT	210.3870	0	.	.
AGE	11.5471	1	198.8399	0.0001
AREA	11.5258	1	0.0186	0.8915

Sentinel samples west of Burin (January-May 1995) vs 1995 RV survey of 3Ps. Female cod.

Source	Deviance	DF	ChiSquare	Pr>Chi
INTERCEPT	327.5592	0	.	.
AGE	26.4124	1	301.1468	0.0001
AREA	24.7250	1	1.6873	0.1940

Sentinel samples from Placentia Bay (Sept-Dec. 1995) vs 1996 RV survey of 3Ps. Male cod.

Source	Deviance	DF	ChiSquare	Pr>Chi
INTERCEPT	602.7035	0	.	.
AGE	20.7629	1	581.9406	0.0001
AREA	17.0106	1	3.7522	0.0527

Sentinel samples from Placentia Bay (Sept-Dec. 1995) vs 1996 RV survey of 3Ps. Female cod.

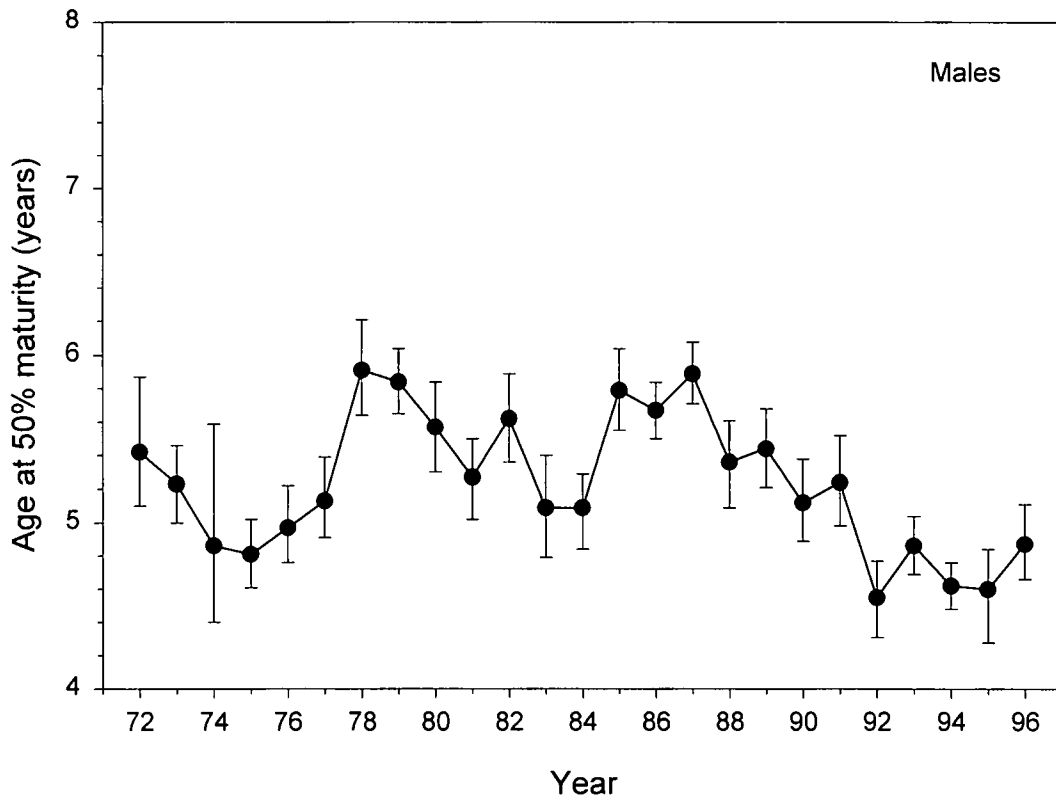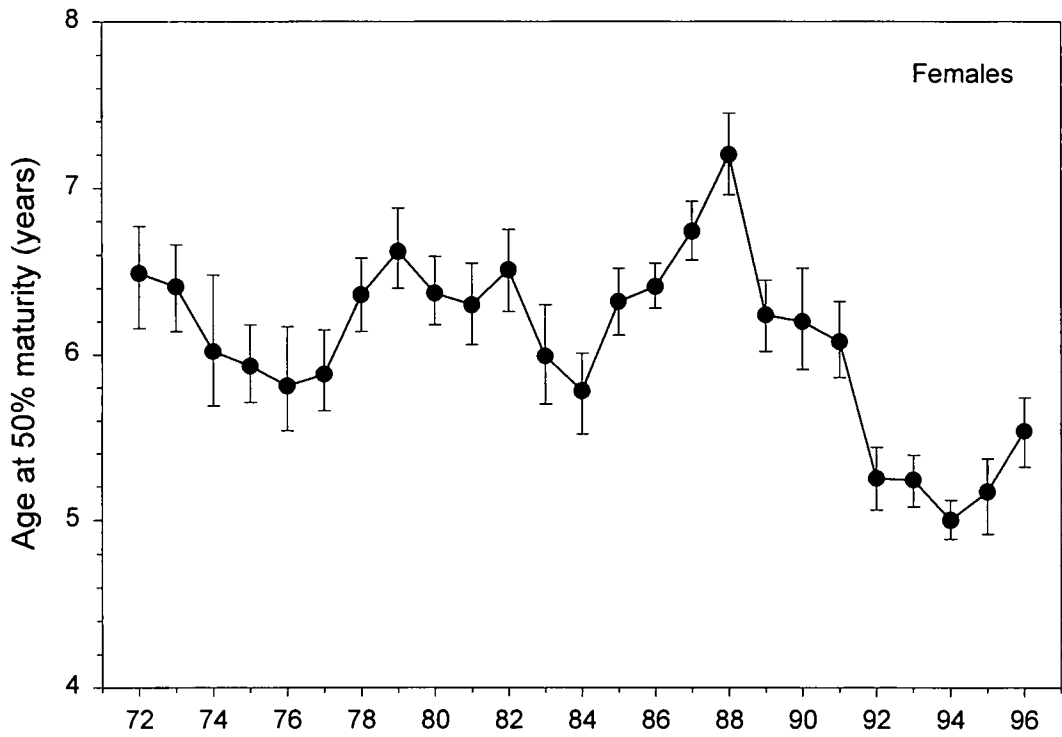| Source	Deviance	DF	ChiSquare	Pr>Chi
INTERCEPT	685.8240	0	.	.
AGE	52.3990	1	633.4250	0.0001
AREA	22.9937	1	29.4053	0.0001

Fig. 1. Age at 50% maturity for cod in NAFO Subdiv. 3Ps from 1972-1996. Error bars are upper and lower 95% confidence intervals.
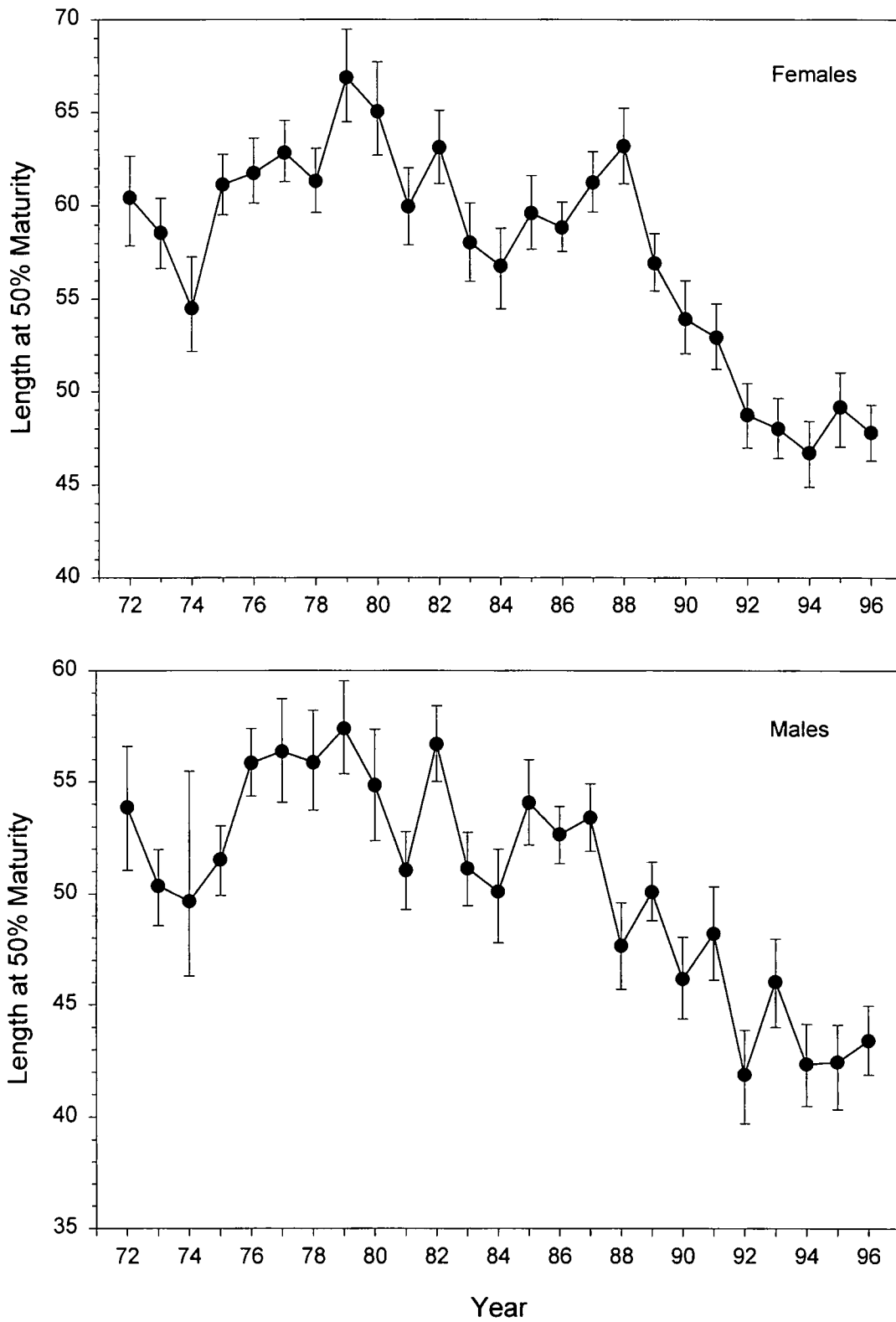
Fig. 2. Length at 50% maturity for cod from NAFO subdiv. 3Ps from 1972-1996. Error bars are upper and lower 95% confidence intervals.
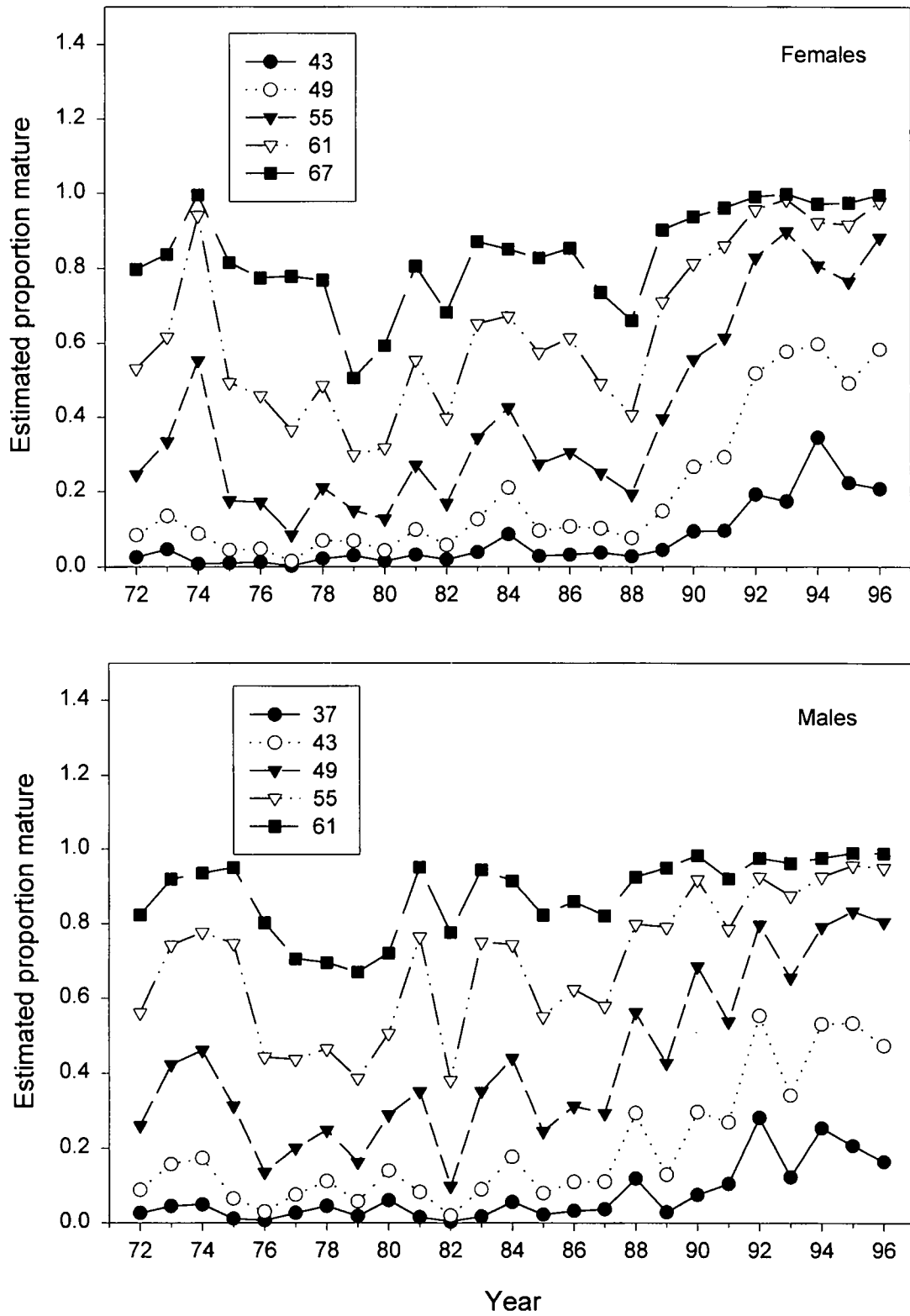
Fig. 3. Estimated proportion mature at selected length categories for male and female cod from NAFO subdiv. 3Ps.