NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N5330 **NAFO SCR Doc. No. 06/80**

SCIENTIFIC COUNCIL MEETING – JUNE 2003

A Year-class Strength Model for Northern Shrimp (*Pandalus borealis*) in NAFO Divisions 3LNO based on Spring and Autumn Canadian Research Survey.

by

D. E. Stansbury.

Department of Fisheries and Oceans, Science Branch
P. O. Box 5667, St. John's, Newfoundland, Canada A1C-5X1

Abstract

Previous assessments of Northern Shrimp (*Pandalus borealis*) in NAFO Divisions 3LNO used numbers of shrimp at age 2 as the index of recruitment. Due to an incomplete 2004 autumn survey there was no autumn estimate of the 2002 year-class. For this reason, to permit use of more information from the surveys' numbers-at-age matrices, it was decided to model the year-class strength from the spring and autumn Canadian survey series. Model results indicated that the 2002 and 2004 year-classes were above average, while the 2003 year-class was below average.

Introduction

Recruitment indices of Northern Shrimp (*Pandalus borealis*) in NAFO Div. 3LNO were based upon modal analysis of length frequencies using Mix 3.1A (Macdonald and Pitcher, 1993). For previous assessments of this stock, numbers at age 2 from the Canadian autumn survey series were used as the recruit index (Orr *et al.*, 2004). This index is plotted in Fig. 1 in the autumn_2 panel. The Canadian autumn 2004 survey was incomplete, due to vessel failure, thus there was no estimate for the 2002 year-class. In 2005, STACFIS examined both the autumn and spring series to estimate a measure of year-class strength (NAFO, 2005). Estimates were obtained by treating each series separately and qualifying each year-class with respect to the mean of the series.

This paper describes a new recruitment index derived from a relative year-class strength model. The model is as described in Healey *et al*. (2002). Several formulations of the model were considered. Sensitivity to the number of ages, and the number of variance parameters used in the model, were examined. The final model was based on ages 1-4 from both spring and autumn Canadian surveys with a single variance parameter.

Input Data

Numbers at age (10^6) for spring and autumn surveys (Orr *et al*. 2006), derived from modal analysis (Macdonald and Pitcher, 1979) of length frequencies, are used to estimate year-class strength. Only ages 1 to 4 are used in the analysis (Table 1). Also, a year-class must be represented by at least three observations to be considered for inclusion in the model. As age 4's may make a significant contribution to the fishery, a comparative analysis to test the sensitivity of including age 4's was performed, and showed no significant change in the relative year-class strengths. Results are not shown here.

Estimates of relative year-class strength from survey data

A multiplicative model was used to estimate the relative year-class strength for this stock based upon survey indices at ages 1 to 4. Similar approaches have been implemented by Healey (2006), Healey *et al*. (2002) for Greenland halibut in Div. 2GHJ+3KLMNO, and by Morgan *et al*. (2002) for American Plaice in Div. 3LNO.

On a log-scale, the model can be written as follows:

$$\log(I_{s,a,y}) = \mu + Y_y + (SA)_{s,a} + \varepsilon_{s,a,y}$$

where: μ = overall mean
s = survey subscript
a = age subscript
y = year class subscript
I = Index (Abundance in 10^6)
Y = year class effect
SA = Survey * Age effect, and
ε = error term.

Model parameter estimates calculated using Proc Mixed in SAS/STAT Version 8

A model was first fitted with 8 survey-age variance parameters (vp) (2 surveys x 4 ages), then a model with a separate variance parameter for each survey (2 vp) was fitted, and finally a model with a single or common variance model was fitted. To test whether a full model is necessary beyond a single variance parameter, a likelihood ratio chi-square test based on differences of the -2 times the log likelihood was performed. Results indicate that a common variance model (general linear model) is not statistically different from the other two models (Table 2). The single variance model output is given in Table 3 and is used to calculate relative year-class strength.

Least square means estimates for year-class strength from 1993-2004 are back-transformed and presented in Fig. 2. The standardized residuals (Figure 3) indicate no model assumption violations. Only one standardized residual lies outside ± 2 reference line and there appears to be no year effect.

Conclusion

Estimates of year class strength indicate that the 2002 and 2004 year-classes are above average, while the 2003 year-class is below average. Year-classes prior to 1997 are considered weak. Further work should be conducted prior to the next assessment to investigate how this index correlates with the fishable biomass in subsequent years.

References

Healey, B. P., N. G. Cadigan, and W. B. Brodie. 2002. Analysis of pre-recruit data from surveys for Greenland halibut in NAFO Subarea 2 and Divisions 3KLMNO. *NAFO SCR. Doc*., No. 21, Serial No. N4625.

Healey, B. P. 2006. Greenland Halibut (*Reinhardtuis hippoglossoides*) in Subarea 2 and Divisions 3KLMNO: Trends in recruitment based upon research vessel survey data *NAFO SCR. Doc*., No. 42, Serial No. N5265.

MacDonald, P. D. M., and T. J. Pitcher. 1979. Age-groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. *J. Fish. Res. Broad. Can*., **36**: 987-1001.

MacDonald, P. D. M., and P. E. J. Green. 1993 Mix 3.1A.An interactive program for fitting mixtures of distributions. Ichthus Data Systems. Hamilton, Ontario.

Morgan, M. J., W. B. Brodie, B. P. Healey, D. Maddock Parsons, K. S. Dwyer, and D. Power. MS 2002. An assessment of American plaice in NAFO Divisions 3LNO. *NAFO SCR Doc*., No. 70, Serial No. N4683.

NAFO. 2005. Scientific Council Reports for 2005.

Orr, D. C., P. J. Veitch, and D. Sullivan. 2004. An Update of Information Pertaining to Northern Shrimp (*Pandalus borealis*, Krøyer) and groundfish in NAFO Divisions 3LNO. *NAFO SCR Doc*., No. 86, Serial No. N5056.

Orr, D. C., P. J. Veitch, and D. Sullivan. 2006. An update of information pertaining to northern Shrimp (*Pandalus borealis*, Krøyer) and groundfish in NAFO Divisions 3LNO. *NAFO SCR Doc*., No. 73, Serial No. N5323.

SAS/Stat, 1993. Version 8.01. Carey, South Carolina. USA.

Table 1. Population estimates (10^6) at age (1-4) for *P. borealis* from autumn and spring Canadian surveys in NAFO Div. 3LNO. Estimates derived from modal analysis (Macdonald and Pitcher, 1993).

	Autumn				Spring			
Year/Age	1	2	3	4	1	2	3	4
1995	899	290	59	6				
1996	449	3971	838	208				
1997	540	3041	3450	623				
1998	3545	3108	5341	1329				
1999	672	5935	2278	1536	132	4268	1832	3485
2000	1944	9230	14891	1745	514	5196	8388	2833
2001	675	9090	13534	22506	99	4648	6369	8102
2002	1401	5802	17913	14640	442	2618	9633	14068
2003	1958	6580	10587	16082	430	4704	8090	20029
2004		Incomplete Survey			177	2073	6244	6546
2005	928	2887	14750	21221	264	2975	8227	5954
2006					151	6615	4596	11274

Table 2. Likelihood ratio chi-square tests based on differences of the -2 times the log likelihood estimate from 3 different models (vp = variance parameter).

Null	**Test Statistic**	**df**	**p-value**
vp for each Survey x Age	14.0	8-1 = 7	0.0512
vp for each survey	1.0	2-1 = 1	0.3173

Table 3. Output from the SAS procedure 'Proc Mixed' using age 1 to 4 and a single variance parameter.

sa = survey*age
y c = year-class
grp = variance parameter grouping

Model Information	
Data Set	WORK.SELECT
Dependent Variable	y
Covariance Structure	Variance Components
Group Effect	grp
Estimation Method	REML
Residual Variance Method	None
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Between-Within

Class Level Information		
Class	**Levels**	**Values**
yc	12	1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
sa	8	autumn_1 autumn_2 autumn_3 autumn_4 spring_1 spring_2 spring_3 spring_4
SURVEY	2	autumn spring
grp	1	1

Dimensions	
Covariance Parameters	1
Columns in X	21
Columns in Z	0
Subjects	68
Max Obs Per Subject	1
Observations Used	68
Observations Not Used	0
Total Observations	68

Table 3 cont'd. Output from the SAS procedure 'Proc Mixed' using age 1 to 4 and a single variance parameter.

Iteration History			
Iteration	**Evaluations**	**-2 Res Log Like**	**Criterion**
0	1	90.35252213	
1	1	90.35252213	0.00000000

Convergence criteria met.

Covariance Parameter Estimates					
Cov Parm	**Group**	**Estimate**	**Alpha**	**Lower**	**Upper**
Residual	grp 1	0.1904	0.05	0.1329	0.2957

Fit Statistics	
-2 Res Log Likelihood	90.4
AIC (smaller is better)	92.4
AICC (smaller is better)	92.4
BIC (smaller is better)	94.6

PARMS Model Likelihood Ratio Test		
DF	**Chi-Square**	**Pr > ChiSq**
1	0.00	1.0000

Table 3 cont'd. Output from the SAS procedure 'Proc Mixed' using age 1 to 4 and a single variance parameter.

Solution for Fixed Effects							
Effect	**sa**	**yc**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Intercept			9.2104	0.3122	49	29.50	<.0001
sa	autumn_1		-1.9033	0.2102	49	-9.06	<.0001
sa	autumn_2		-0.2737	0.2127	49	-1.29	0.2042
sa	autumn_3		0.2808	0.2169	49	1.29	0.2014
sa	autumn_4		0.001649	0.2252	49	0.01	0.9942
sa	spring_1		-3.6159	0.2358	49	-15.33	<.0001
sa	spring_2		-0.9059	0.2258	49	-4.01	0.0002
sa	spring_3		-0.2939	0.2216	49	-1.33	0.1909
sa	spring_4		0				.
yc		1993	-2.9348	0.3819	49	-7.69	<.0001
yc		1994	-1.1302	0.3519	49	-3.21	0.0023
yc		1995	-1.1908	0.3371	49	-3.53	0.0009
yc		1996	-1.3471	0.3265	49	-4.13	0.0001
yc		1997	0.2153	0.3146	49	0.68	0.4970
yc		1998	-0.05982	0.3050	49	-0.20	0.8453
yc		1999	0.3697	0.3050	49	1.21	0.2313
yc		2000	-0.4375	0.3093	49	-1.41	0.1636
yc		2001	0.07094	0.3095	49	0.23	0.8197
yc		2002	0.06675	0.3155	49	0.21	0.8333
yc		2003	-0.5443	0.3415	49	-1.59	0.1174
yc		2004	0				.

Table 3 cont'd. Output from the SAS procedure 'Proc Mixed' using age 1 to 4 and a single variance parameter.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
sa	7	49	60.66	<.0001
yc	11	49	17.52	<.0001

Least Squares Means						
Effect	**yc**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
yc	1993	5.4368	0.2631	49	20.66	<.0001
yc	1994	7.2414	0.2261	49	32.03	<.0001
yc	1995	7.1808	0.2008	49	35.77	<.0001
yc	1996	7.0245	0.1816	49	38.67	<.0001
yc	1997	8.5869	0.1665	49	51.56	<.0001
yc	1998	8.3118	0.1543	49	53.87	<.0001
yc	1999	8.7413	0.1543	49	56.66	<.0001
yc	2000	7.9341	0.1664	49	47.69	<.0001
yc	2001	8.4425	0.1662	49	50.80	<.0001
yc	2002	8.4384	0.1811	49	46.59	<.0001
yc	2003	7.8273	0.2257	49	34.68	<.0001
yc	2004	8.3716	0.2631	49	31.82	<.0001

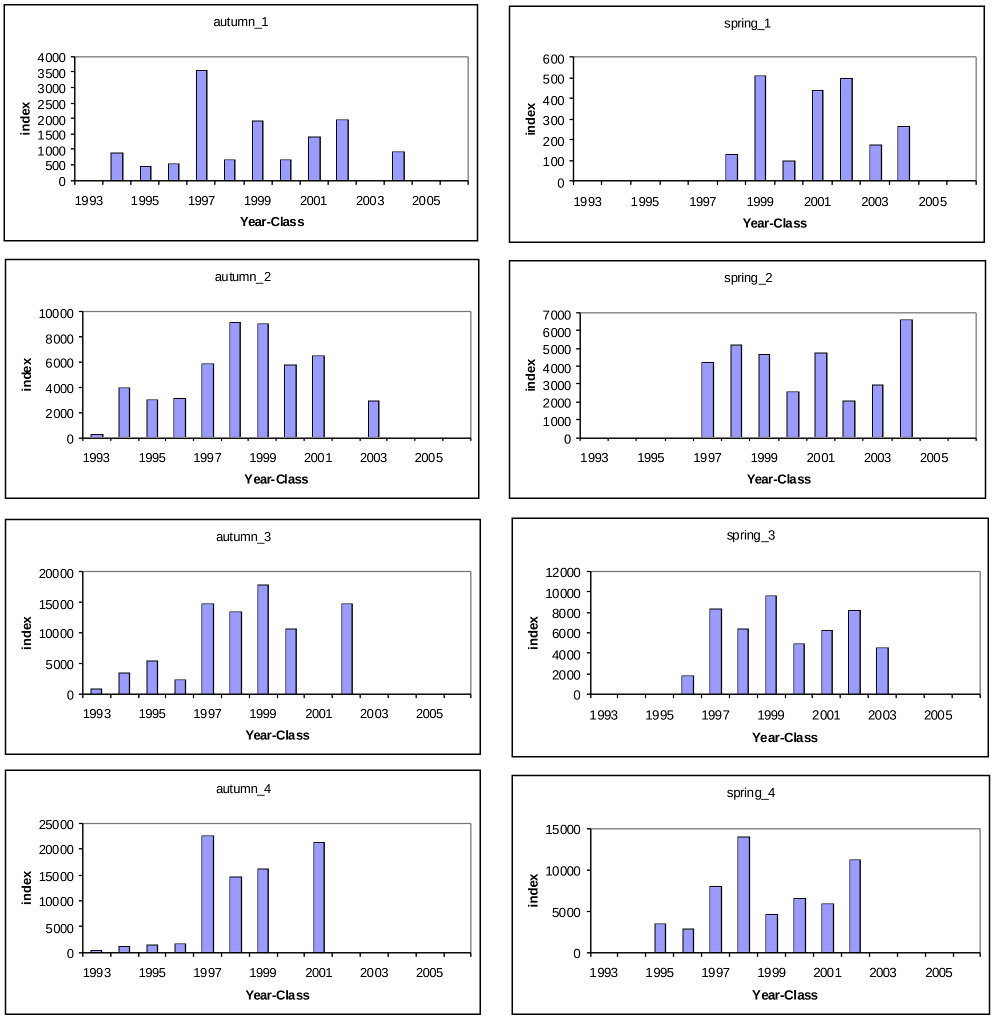

Fig. 1. Year-class index 10^6 by survey age as derived using Mix 3.1A.

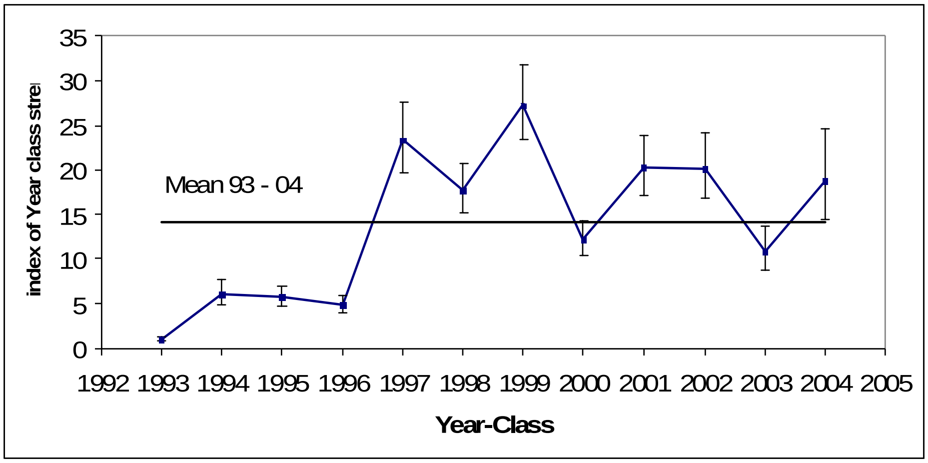

Fig. 2. Index of relative year-class strengths (±1 SE) as determined from Canadian autumn (1995-2005) and spring multi-species surveys (1999-2006).

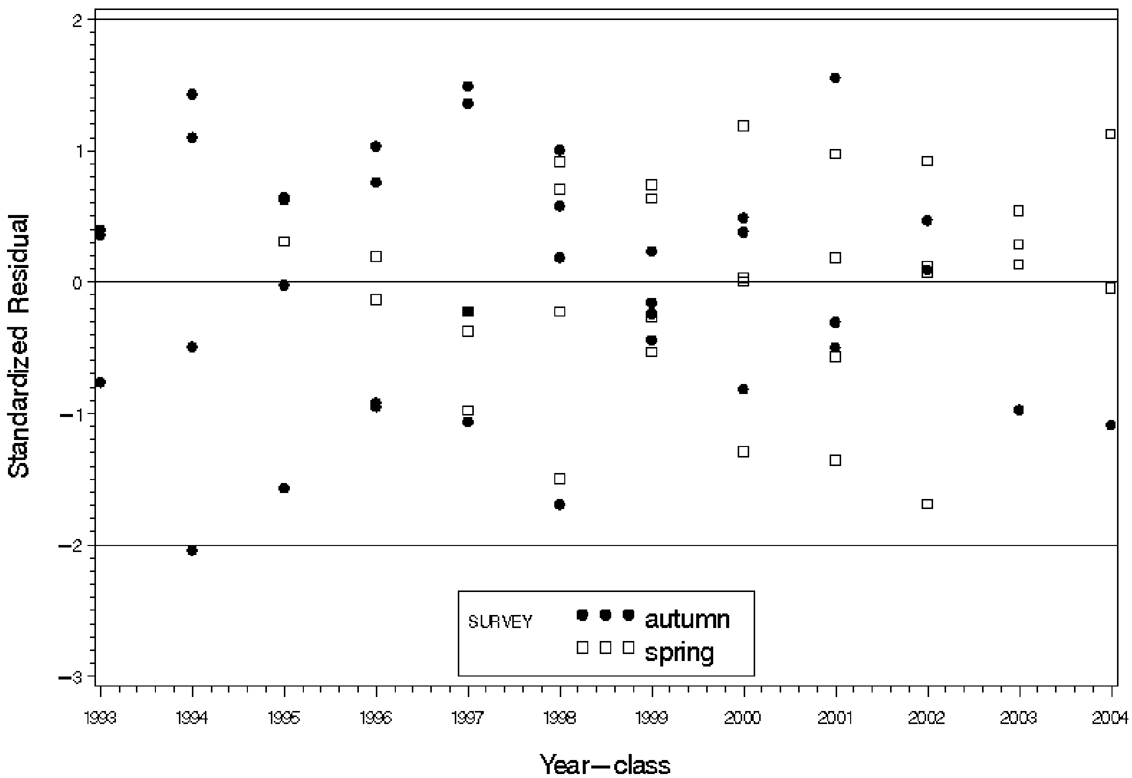

Fig. 3. Standardized residuals from the model using ages 1 to 4 and a single variance parameter..