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Investigating Parameter Estimates of Fishing Mortality and Biological Reference Points Using Research Survey Data: Yellowtail Flounder in NAFO Divisions 3LNO, a Case Study.

by

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Introduction

Yellowtail flounder fishery in NAFO Div. 3LNO has been under quota management since 1973. Due to recent sharp declines in biomass, after large catches in 1985 and 1986, the fishery has been under moratorium since 1995. Since the validity of a SPA was dismissed in 1984 due to unexplained high Z's in older ages, the health of this resource and subsequent scientific advice has been based on a variety of annual bottom trawl survey indices.

At the March 1998 Precautionary Fishery Workshop, several models were used to estimate reference points using survey data: 1) ASPIC non-equilibrium production model with covariates, 2) Thompson-Bell yield per recruit model, 3) Evans' recruitment model, 4) Sissenwine and Shepherd age structure model of stock productivity, 5) Cook's age structured separable fishing mortality model and 6) Caddy's stock traffic-light model. The survey results cover the time period 1975-1995 based upon the Engel 145 bottom trawl results.

Results and Discussions

ASPIC (Prager 1994)*:* Several data sets were entered into this model under various combinations and included: Canadian fishery CPUE 1965-93, exploitation rate (catch/survey biomass) for 1975-95, Canadian spring biomass survey indices for 1975-95, 1984 VPA biomass for 1968-1983 estimates, Russian biomass survey indices for 1972-91, Canadian spring abundance indices for 1972-95, Canadian fall biomass survey indices for 1990-94 and

Canadian juvenile biomass survey indices from 1986-94 (see Figs. 1-2). An example of an output is shown in Table 1 which shows bootstrap estimates of various parameters from using Canadian spring abundance surveys with nominal catch and Russian biomass survey indices. Noteworthy, is that r (0.39) is very low which is suggestive of a long lived, low productivity stock and $F_{0.1}$ is 0.18. These estimates are contradictory to our perception that this is stock is relatively fast growing and has been subjected to high fishing mortalities in recent years. Most runs indicated an *r* of about 0.1 to 0.3 and constraining the *r* does not improve the model outputs. Most indices had strong trends in the residuals. More explorations of this model will continue.

Thompson-Bell yield per recruit model: Tables 2-3 and Fig 3 show input parameters for this model and Fig. 4 shows the output. The y/r curve is flat topped for this stock. Both $F_{0.1}$ and F_{max} are very high, as expected, however, these estimates are sensitive to choice of M. Thus, the interpretation of these estimates may be confounded by the fact that Z on older ages is quite high for this species.

Semi-parametric description of recruitment as a function of spawning biomass. As was done for the American plaice case study, an extension of the approach used by Evans and Rice (1988) to describe recruitment as a function of spawning biomass was applied to yellowtail flounder in 3LNO. However, as "absolute" estimates of spawning biomass and recruitment were not available for this stock, the technique had to be applied to an index of spawning biomass and an index of recruitment coming directly from the research survey. The method provided an evaluation of the probability that a given level of recruitment index would be exceeded as a function of the spawning biomass index (Fig. 5). It was also used to describe the probability that a given level of the recruitment index will be exceeded as a function of spawners index (Fig. 6).

Age-structured analysis of stock productivity. While applying the Evans and Rice (1988) method directly to indices may provide insight on the underlying S-R relationship (Fig. 7), it also limits its applicability in the analysis of production of the type suggested by Sissenwine and Shepherd. The range of possible scalar values that would be needed to translate the underlying yield in terms that could be compared to past fishery yields was investigated through simulations. However, as this was carried only to gain insight into the processes involved, the resulting models are provided for illustrative purposes only (Fig. 8). It was concluded that we need to extend the time series of observations to cover a larger portion of the stock dynamics and to obtain additional insight into the magnitude of the scalar terms needed. For instance, it was felt that a VPA using all available data and exploration of changes in natural mortality as a function of age would be useful for that purpose.

Cook's age structured separable fishing mortality model: Annual bottom trawl survey data from the 1975-95 spring surveys of yellowtail flounder are analyzed using a model which assumes that fishing mortality, F, can be separated into an age effect and a year effect. The model also assumes that the selection pattern is constant over time but is rescaled each year by measure of overall fishing. A full description of the method is given in Cook (1995).

The research vessel data analyzed are given in Table 4 with estimates of mean weight at age, maturity and natural mortality. Estimates of the research vessel survey catchability are also given. These have been chosen to give positive values of selectivity and need to be verified with reference to real data as they are simply guesstimates in this analysis.

Results from the analysis are given in Tables 5-10, which give the age related fishing mortalities, imputed catch at age and fitted survey values. Table 10 shows the stock summary statistics of SSB, recruitment, yield and mean fishing mortality rate for ages 4-8. With the exception of fishing mortality, these summary statistics are on a relative scale.

Figure 9 shows the stock summary statistics plotted as a time series. This suggests that fishing mortality increased substantially in recent years and that SSB has declined continuously.

Caddy (John) stock traffic-light model: This qualitative model summarizes life history and fishery characteristics of yellowtail flounder stock. It has some potential as an aid in deciding absolute and relative importance of different management control options.(Table x). For example, if there are 5 redlights then management's response may be to closed the fishery

Conclusions

Catch base analysis such as ASPIC non-equilibrium logistic growth model is heavily dependent on the assumption that catch is measured without error. Nominal catches of yellowtail flounder from the fishery does not include estimates of discards and unreported landings. Since absolute estimates of stock biomass from VPA are not valid because of high Z's in older fish then estimates of stock size, SSB and recruitment are only available from fishery-independent survey indices, i.e. relative estimates. This makes it difficult to estimate biological and fishery related reference points and developing a conceptual framework for implementation of the Precautionary

Approach. Precise estimation of M as a function of age and more accurate estimates of commercial catch and effort data are critical to the success of using these analytical models.

Survey data has been analyzed to gain insight into the analytical models processes and the resulting models are provided for illustrative purposes only. However, the age structured separable fishing mortality model (Cook 1997) on first glance offers good potential in deriving estimates of SSB, recruitment and fishing mortality on individual ages. Perhaps it will provide some insight on estimating an age dependent M.

Nevertheless, this preliminary investigation has been fruitful in confirming some of the basic tenets of Scientific Council's perception of this stock and in challenging some of our views of life history parameters.

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TABLE 1. An example of one of the ASPIC non-equilibrium production model outputs for 3LNO yellowtail flounder.

3LNO yellowtail flounder -- ASPIC 3.65

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.454E+00	2.301E+00	-6.22%	2.076E+00	2.802E+00	2.240E+00	2.632E+00	3.921E-01	0.160
K	1.383E+02	1.488E+02	7.62%	1.083E+02	1.996E+02	1.213E+02	1.640E+02	4.273E+01	0.309
r	3.933E-01	3.679E-01	-6.46%	2.386E-01	5.551E-01	3.169E-01	4.778E-01	1.608E-01	0.409
q(1)	1.168E+00	1.126E+00	-3.60%	7.842E-01	1.621E+00	9.573E-01	1.385E+00	4.278E-01	0.366
q(2)	3.078E+00	2.988E+00	-2.91%	2.110E+00	4.108E+00	2.562E+00	3.598E+00	1.036E+00	0.337
MSY	1.362E+01	1.369E+01	0.49%	1.126E+01	1.498E+01	1.243E+01	1.438E+01	1.941E+00	0.143
Ye(1997)	1.360E+01	1.315E+01	-3.35%	1.015E+01	1.511E+01	1.211E+01	1.448E+01	2.368E+00	0.174
Bmsy	6.914E+01	7.441E+01	7.62%	5.414E+01	9.981E+01	6.064E+01	8.200E+01	2.136E+01	0.309
Fmsy	1.966E-01	1.839E-01	-6.46%	1.193E-01	2.775E-01	1.585E-01	2.389E-01	8.041E-02	0.409
fmsy(1)	1.724E-01	1.634E-01	-5.23%	1.413E-01	2.014E-01	1.560E-01	1.883E-01	3.225E-02	0.187
fmsy(2)	6.442E-02	6.156E-02	-4.44%	5.522E-02	7.238E-02	6.006E-02	6.835E-02	8.289E-03	0.129
F(0.1)	1.770E-01	1.656E-01	-5.81%	1.074E-01	2.498E-01	1.426E-01	2.150E-01	7.237E-02	0.409
Y(0.1)	1.348E+01	1.355E+01	0.48%	1.115E+01	1.483E+01	1.231E+01	1.423E+01	1.922E+00	0.143
B-ratio	8.558E-01	8.017E-01	-6.33%	6.245E-01	1.066E+00	7.361E-01	9.812E-01	2.451E-01	0.286
F-ratio	2.672E-02	2.892E-02	8.24%	2.021E-02	4.004E-02	2.253E-02	3.204E-02	9.502E-03	0.356
Y-ratio	9.855E-01	9.607E-01	-2.53%	8.629E-01	9.998E-01	9.325E-01	9.979E-01	6.537E-02	0.066
f0.1(1)	1.551E-01	1.470E-01	-4.71%	1.271E-01	1.812E-01	1.404E-01	1.695E-01	2.902E-02	0.187
f0.1(2)	5.797E-02	5.540E-02	-3.99%	4.970E-02	6.515E-02	5.406E-02	6.152E-02	7.460E-03	0.129
q2/q1	2.665E+00	2.654E+00	-0.44%	2.304E+00	3.086E+00	2.472E+00	2.881E+00	4.098E-01	0.154

NOTES ON BOOTSTRAPPED ESTIMATES:

- The bootstrapped results shown were computed from 1000 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence:	0
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	33
Residual-adjustment factor:	1.0654

<u>Input indices</u>

[1] Annual Canadian spring survey indices of abundance from 1971-95 with nominal catch.
[2] Annual Russian spring survey biomass indices from 1972-91.

TABLE 2. Input parameters for stock production models

Age	Partial Recruitment	Percent Maturity	Weight-at-age	M
3	0.000	0.0007305	0.040	0.3
4	0.100	0.005104	0.098	0.3
5	0.090	0.037268	0.180	0.3
6	0.290	0.278826	0.312	0.3
7	0.780	0.802140	0.483	0.3
8	1.000	0.971876	0.755	0.3
9	1.000	0.996744	1.157	0.3
10	1.000	0.999556	1.157	0.3

TABLE 3. Results of Thompson-Bell yield-per-recruit model. M assumed to be 0.3.

F0.1	0.481
Yield(kg)/R	0.113
SSB/R	0.1303
Fmax	0.819
Yield(kg)/R	0.1204
SSB/R	0.0869

ANALYSIS BY RCSEP OF Yellowtail flounder

TABLE 4. Source data

Age	M	Prop.mat.	cat.wt	stk.wt	survey catchability
3	.30	.00	.0400	.0400	.001
4	.30	.01	.0980	.0980	.01
5	.30	.04	.1800	.1800	.05
6	.30	.28	.3120	.3120	.2
7	.30	1.00	.4830	.4830	.8
8	.30	.97	.7550	.7550	1
9	.30	1.00	1.1570	1.1570	1

TABLE 5. Abundance index data.

Age	1975	1976	1977	1978	1979	1980
3	.8	3.9	.2	2.9	.9	5.0
4	12.7	16.5	3.1	9.9	6.0	11.1
5	63.8	73.8	18.6	38.2	12.6	37.9
6	92.1	100.7	45.5	70.4	50.3	97.7
7	106.8	92.5	121.7	73.1	129.2	140.0
8	26.0	18.7	99.5	38.2	61.8	45.4
9	3.1	.5	32.2	4.1	8.1	3.2

Age	1981	1982	1983	1984	1985	1986
3	1.1	5.5	.3	.7	.1	.1
4	2.0	18.8	3.5	2.5	1.8	.5
5	8.8	38.6	26.4	12.9	11.8	6.4
6	37.9	56.1	94.0	52.8	30.3	20.2
7	97.3	87.4	131.0	90.9	93.7	56.5
8	101.8	56.7	56.5	42.1	45.7	76.3
9	24.9	16.2	4.5	3.6	7.1	8.2

Age	1987	1988	1989	1990	1991	1992
3	.1	2.4	.8	.4	1.0	.5
4	1.2	23.8	7.9	5.6	5.2	7.6
5	1.6	25.9	22.1	27.0	11.0	18.4
6	9.5	27.3	29.3	39.3	26.3	39.2
7	31.8	33.5	45.6	39.3	26.1	41.7
8	45.8	17.2	38.6	19.6	12.0	15.0
9	9.5	1.8	5.3	2.8	2.7	1.5

Age	1993	1994
3	.3	.1
4	2.0	2.8
5	9.2	3.3
6	24.0	32.4
7	30.5	38.8
8	14.1	19.1
9	1.0	.1

TABLE 6. Parameter estimates.

	Parameter	s.d.
year effects		
	1.4336	.2703
	1.1532	.2141
	1.1674	.2101
	.8897	.2096
	.7553	.2092
	.7090	.2094
	.7424	.2085
	.8300	.2089
	1.0543	.2092
	.9097	.2096
	.8135	.2093
	.7808	.2084
	.5033	.2074
	.4889	.2079
	1.0555	.2095
	1.4175	.2111
	1.3899	.2110
	1.4373	.2120
age effects		
	.0142	.3623
	.2583	.2680
	.3085	.1159
	.7056	.1151
	.5710	.1162
	2.0451	.2525
y/c effects		
	1.0591	1.2098
	3.1968	.3737
	4.5973	.2923
	6.3540	.2802
	6.8648	.2476
	7.2426	.4297
	7.2454	.4463
	7.4153	.3785
	6.9180	.3827
	6.9628	.3214
	6.7903	.2958
	7.2713	.2888
	7.1927	.2968
	6.6066	.3185
	5.9686	.3567
	5.7442	.3256
	5.5256	.3068
	6.2295	.3062
	6.5172	.2580
	6.7823	.2932
	6.7792	.3734
	6.7481	.4470
	6.5561	.4578
	5.3105	.5155
	5.8297	.8989
	4.6052	1.2143

TABLE 7. F-at-age.

Age	1975	1976	1977	1978	1979	1980
3	.0203	.0163	.0165	.0126	.0107	.0100
4	.3703	.2979	.3016	.2298	.1951	.1831
5	.4422	.3557	.3601	.2744	.2330	.2187
6	1.0116	.8137	.8238	.6278	.5330	.5003
7	.8186	.6584	.6666	.5080	.4313	.4094
8	2.9319	2.3583	2.3876	1.8196	1.5448	1.4501
9	2.9319	2.3583	2.3876	1.8196	1.5448	1.4501

Age	1981	1982	1983	1984	1985	1986
3	.0105	.0118	.0149	.0129	.0115	.0111
4	.1918	.2144	.2723	.2350	.2101	.2017
5	.2290	.2560	.3252	.2806	.2509	.2408
6	.5239	.5857	.7440	.6419	.5740	.5510
7	.4239	.4739	.6020	.5194	.4645	.4458
8	1.5183	1.6974	2.1562	1.8604	1.6636	1.5968
9	1.5183	1.6974	2.1562	1.8604	1.6636	1.5968

Age	1987	1988	1989	1990	1991	1992
3	.0071	.0069	.0150	.0201	.0197	.0204
4	.1300	.1263	.2726	.3662	.3590	.3713
5	.1552	.1508	.3256	.4372	.4287	.4433
6	.3552	.3450	.7448	1.0003	.9808	1.0143
7	.2874	.2792	.6027	.8094	.7936	.8207
8	1.0293	.9999	2.1568	2.8991	2.8426	2.9395
9	1.0293	.9999	2.1586	2.8991	2.8426	2.9395

Age	1993
3	.0208
4	.3793
5	.4530
6	1.0363
7	.8386
8	3.0035
9	3.0035

TABLE 8. Fitted index.

Age	1975	1976	1977	1978	1979	1980
3	1401.6	1661.2	1010.3	1056.6	889.2	1438.4
4	1397.7	1017.4	1210.7	736.2	772.9	651.7
5	958.0	715.0	559.6	663.4	433.4	471.1
6	574.8	456.1	371.2	289.2	373.5	254.3
7	99.2	154.8	149.7	120.6	114.3	162.4
8	24.5	32.4	59.4	57.0	53.8	55.0
9	2.9	1.1	2.3	4.2	7.3	9.7

Age	1981	1982	1983	1984	1985	1986
3	1329.7	740.0	391.0	312.4	251.0	507.5
4	1055.0	974.8	541.8	285.3	228.4	183.8
5	402.0	645.1	582.8	305.7	167.1	137.2
6	280.4	236.9	370.0	311.9	171.1	96.3
7	114.2	123.0	97.7	130.3	121.6	71.4
8	80.2	55.4	56.7	39.6	57.4	56.6
9	11.2	14.8	9.5	5.7	5.2	8.8

Age	1987	1988	1989	1990	1991	1992
3	676.7	882.1	879.4	852.4	703.5	202.5
4	371.8	497.7	648.9	641.8	618.9	511.0
5	111.3	241.9	325.0	366.0	329.7	320.2
6	79.9	70.6	154.1	173.8	175.1	159.1
7	41.1	41.5	37.0	54.2	47.4	48.7
8	33.9	22.9	23.2	15.0	17.9	15.9
9	9.8	11.6	9.4	2.8	.7	.8

Age	1993	1994
3	340.3	100.0
4	147.0	246.9
5	261.2	74.5
6	152.3	123.0
7	42.7	40.0
8	15.9	13.7
9	.7	.6

TABLE 9.Fitted catch-at-age.

Age	1975	1976	1977	1978	1979	1980	1981	1982
3	24.4	23.3	14.3	11.4	8.2	12.4	12.0	7.5
4	377.2	228.1	274.4	131.3	118.9	94.7	159.8	163.4
5	299.0	186.5	147.5	138.5	78.3	80.4	71.5	126.7
6	323.9	223.8	183.6	118.3	135.1	87.6	100.1	92.0
7	48.9	65.6	64.0	42.0	35.0	47.2	34.5	40.6
8	21.3	26.7	49.2	43.0	37.9	37.7	56.1	40.7
9	2.5	.9	1.9	3.2	5.2	6.6	7.9	10.9

Age	1983	1984	1985	1986	1987	1988	1989	1990
3	5.0	3.5	2.5	4.8	4.2	5.3	11.3	14.6
4	112.3	51.9	37.6	29.2	39.3	51.2	134.7	171.6
5	140.9	65.1	32.2	25.5	13.9	29.4	78.7	113.2
6	170.8	129.7	65.5	35.7	20.8	18.0	71.2	97.3
7	38.7	46.2	39.5	22.4	8.9	8.8	14.7	26.5
8	45.5	30.2	41.8	40.5	19.3	12.8	18.7	13.1
9	7.6	4.3	3.8	6.3	5.6	6.5	7.5	2.4

Age	1991	1992	1993
3	11.9	3.5	6.1
4	162.7	138.2	40.5
5	100.4	100.2	83.1
6	96.8	89.8	87.1
7	22.9	24.0	21.4
8	15.513.8	13.9	
9	.6	.7	.6

TABLE 10. Summary statistics.

Year,	TSB,	SSB,	Yield,	Fbar,	RECS
1975,	1.841,,	1.181,,	2.113,,	1.115,,	1.715,
1976,	1.611,,	1.354,,	1.612,,	.897,,	2.033,
1977,	1.484,,	1.451,,	1.629,,	.908,,	1.236,
1978,	1.289,,	1.261,,	1.181,,	.692,,	1.293,
1979,	1.229,,	1.299,,	1.074,,	.587,,	1.088,
1980,	1.248,,	1.454,,	.991,,	.551,,	1.760,
1981,	1.334,,	1.446,,	1.152,,	.577,,	1.627,
1982,	1.299,,	1.333,,	1.173,,	.645,,	.906,
1983,	1.169,,	1.273,,	1.362,,	.820,,	.478,
1984,	.875,,	1.195,,	.965,,	.707,,	.382,
1985,	.671,,	1.149,,	.763,,	.633,,	.307,
1986,	.541,,	.893,,	.606,,	.607,,	.621,
1987,	.495,,	.597,,	.344,,	.391,,	.828,
1988,	.600,,	.544,,	.336,,	.380,,	1.079,
1989,	.754,,	.577,,	.717,,	.821,,	1.076,
1990,	.772,,	.545,,	.840,,	1.102,,	1.043,
1991,	.719,,	.510,,	.791,,	1.081,,	.861,
1992,	.605,,	.489,,	.741,,	1.118,,	.248,
1993,	.467,,	.450,,	.609,,	1.142,,	.416,
1994,	.331,,	.387,,	.000,,	.000,,	.122,

TABLE 11. Application of a precautionary checklist to yellowtail flounder in NAFO Div. 3LNO Preliminary analysis (Caddy's Stock Traffic-light Model).

	Criteria	Green	Orange	Red	Comments
Characteristics of the environment and ecosystem					
	Environment				
1	Latitudinal Range			*1*	Recruitment is irregular
2	Life history vulnerability		1		Adult distribution overlaps offshore nursery habitat
3	Unfishable areas exist			*1*	All stock areas fishable
	Predators and prey				
4	Predator abundance	1			Low
5	Prey abundance	1			Diverse polychaetes and amphipods
6	Vulnerability to fishery		1		Juveniles vulnerable in offshore nursery area
	Characteristics of the stock				
	Stock composition and Recruitment				
7	Stock definition	1			One stock
8	Spawning biomass		1		SSB in 1994&95 less than 50% of long term average (1975-91)
9	Recruitment regularity		1		Regular but highly variable
10	S-R relationship		1		Unknown
11	Survey indices	1			Annual spring surveys from 1975 onward
	Vulnerability to recruitment overfishing				
12	Fecundity				**Unknown**
13	Age/size at maturity			*1*	Within last decade high juvenile exploitation
14	Spawning aggregations	1			none suspected
15	Nursery areas		1		Juveniles restricted to area of Southeast Shoal
	Mortality(Z)				
10	Z<Z(MBP)				**Unknown**
11	F				Unknown, but suspected high
12	M				Assumed =0.3 but suspected very high in older ages
Characteristics of the Fishery					
13	Allocation of rights		1		Tranboundary stock
14	Management Structure		1		Political > Management
15	Management Plan		1		No long term objectives
16	Fishing strategy		1		Multi-species fishery
17	Formal assessment	1			Fishery moratorium 1994-97
18	Discard damage		1		Little discard data
19	Bycatch	1			Other overlapping fisheries closed
20	Unit value of species		1		Both directed and bycatch fishery
21	Catch trends			*1*	Fishery Moratorium
22	Fleet trends			*1*	Mixture of regulated and unregulated mesh size
TOTALS		7	12	*5*	

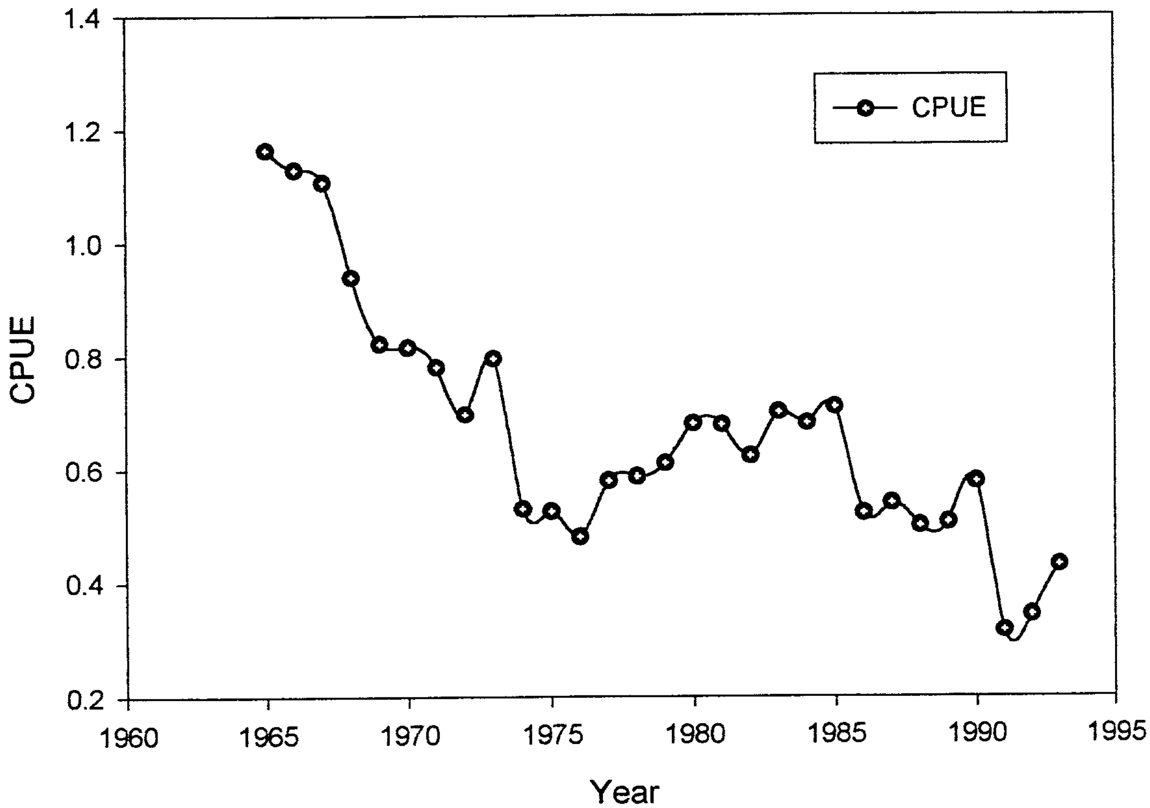


Fig. 1. Canadian series of CPUE estimates from yellowtail flounder fishery in NAFO Div. 3LNO.

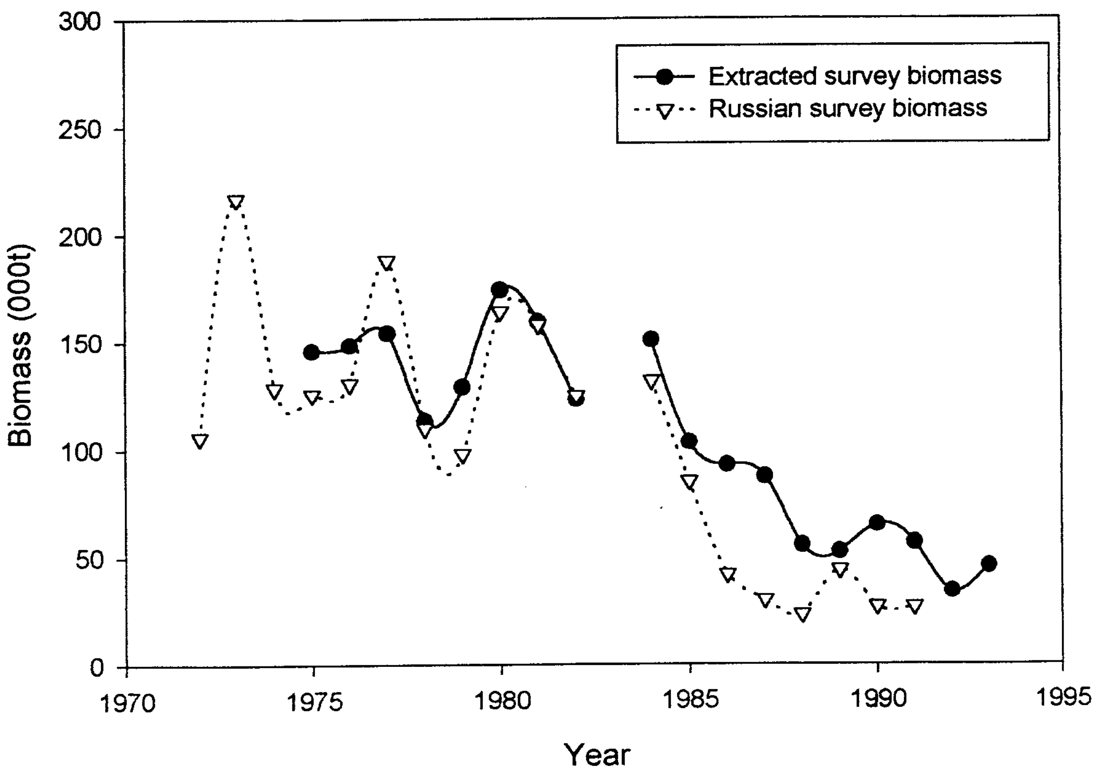
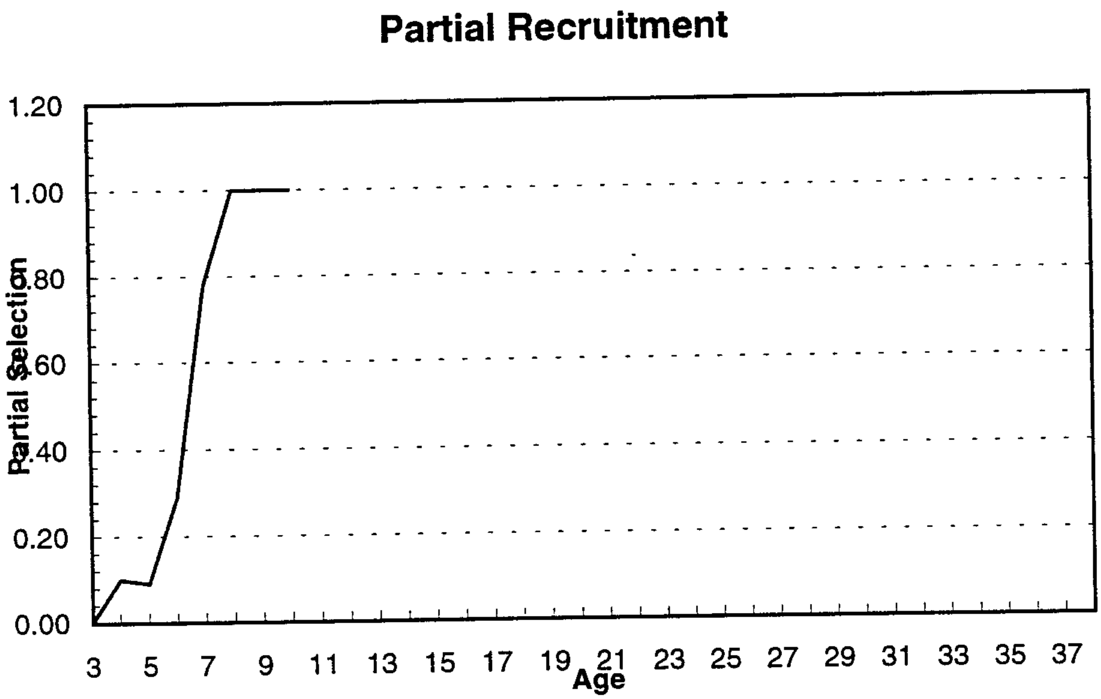


Fig. 2. Comparison of Canadian (extracted) survey biomass and Russian biomass survey for yellowtail flounder, NAFO Div. 3LNO.



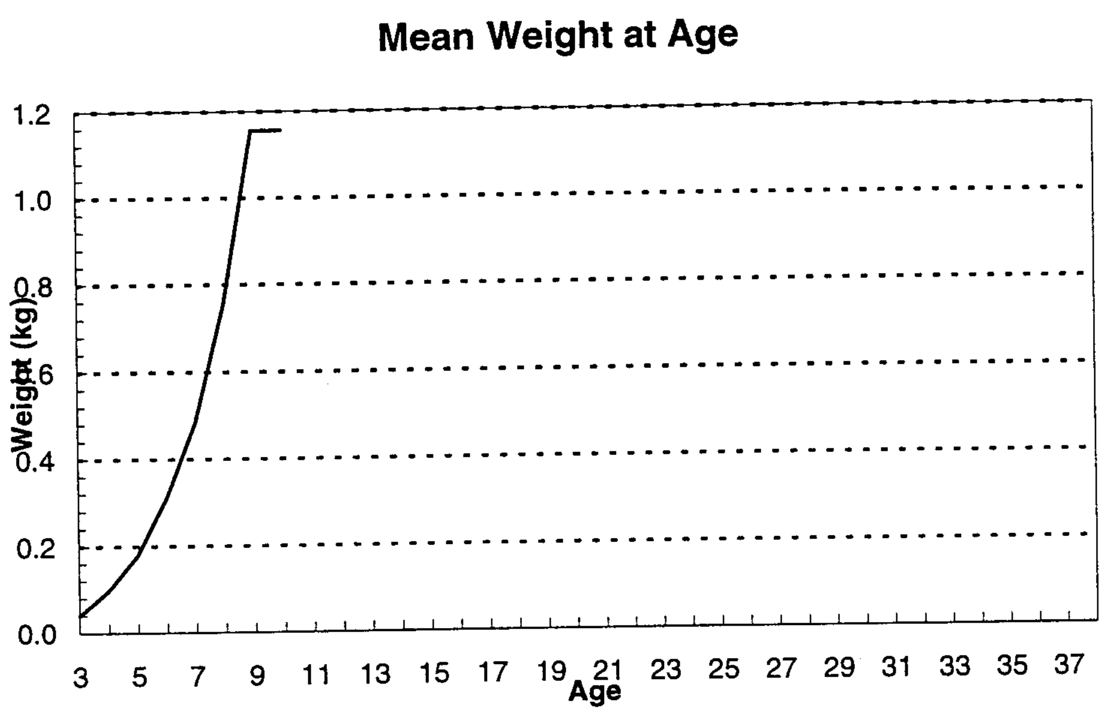


Fig. 3. PR and mean weight-at-age patterns in Div. 3LNO yellowtail flounder fishery.

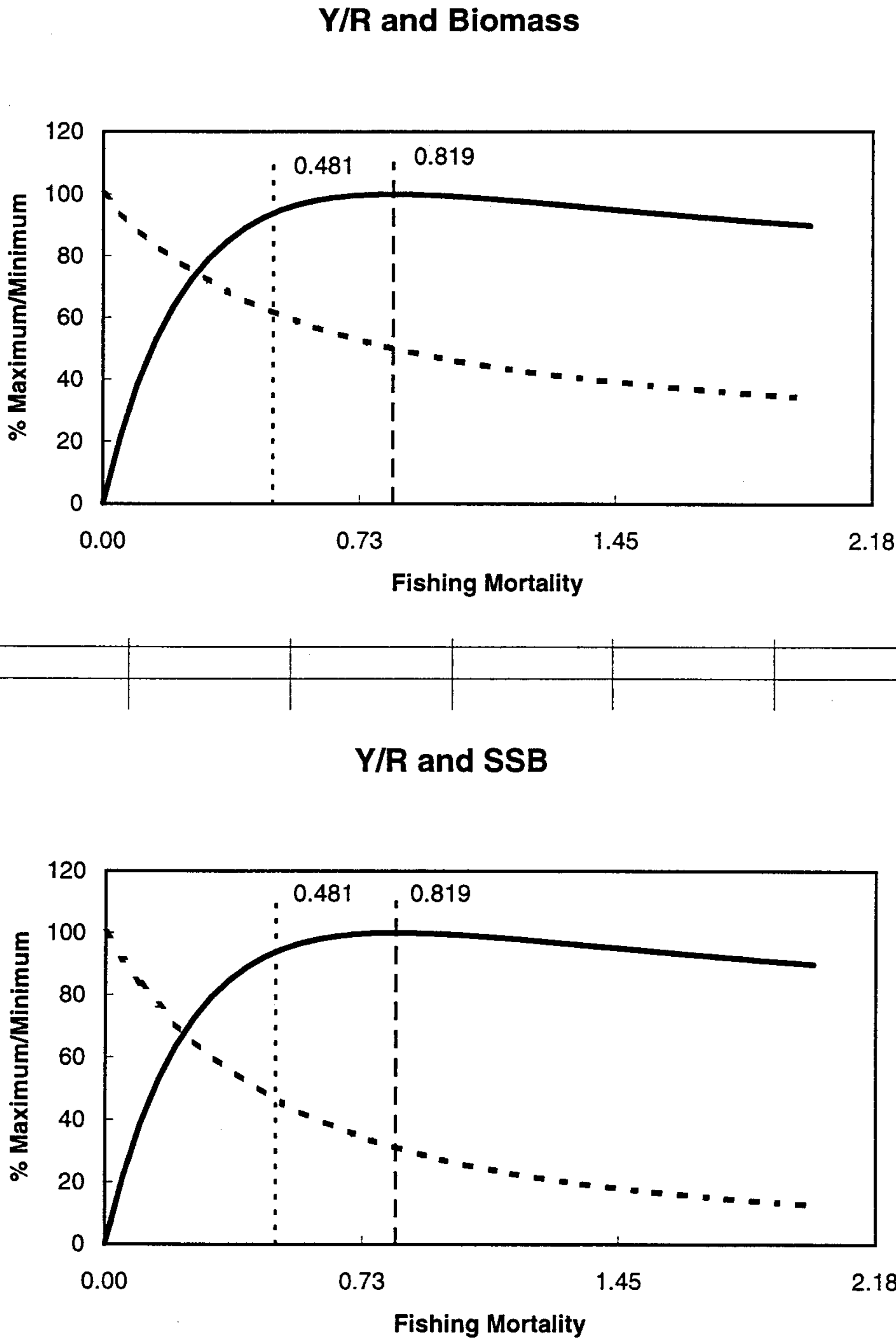
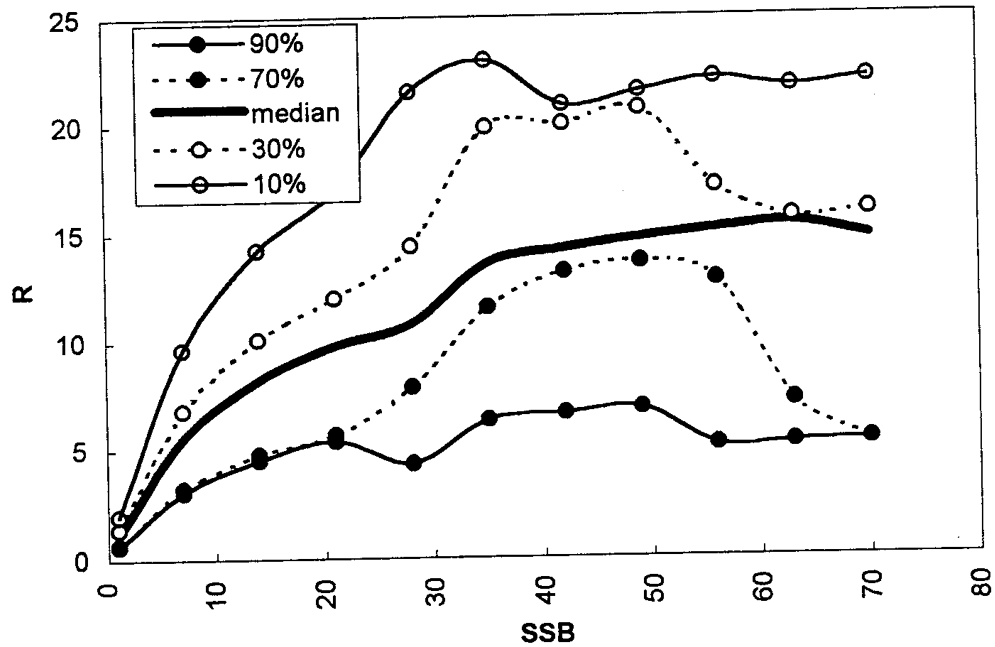


Fig. 4. Yield-per-recruit and biomass and yield-per-recruit and SSB expressed as a function of fishing mortality as estimates by a Thompson and Bell yield-per-recruit model.

Yellowtail Flounder in Div. 3LNO – Low smoothing
1975 to 1991



Probability that a given recruitment level will be exceeded, as a function of SSB (heavy line is median of recruitment series).

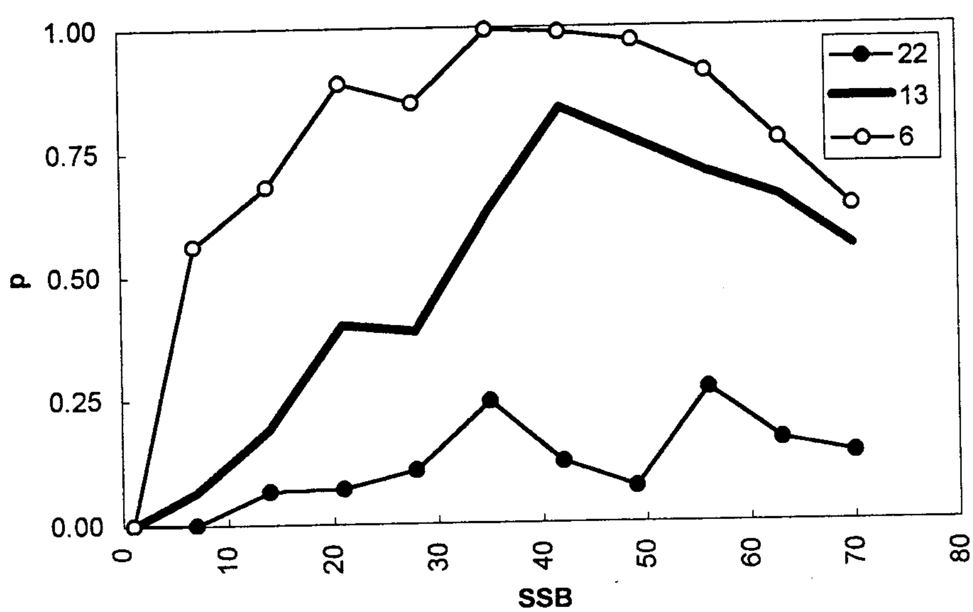


Fig. 5. Recruitment that would be exceeded 10%, 30%, 50% (median), 70% and 90% of the time as a function of SSB.

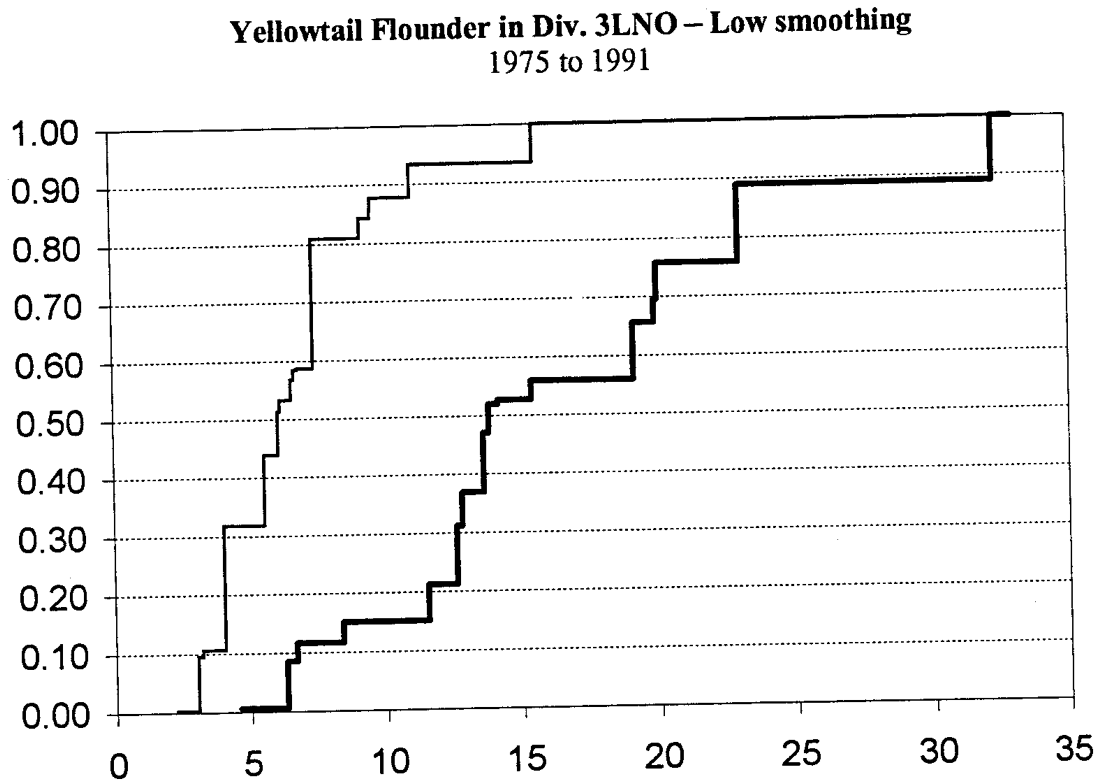


Fig. 6. Cumulative probability of recruitment if SSB is **35** (heavy line)
7 (thin line)

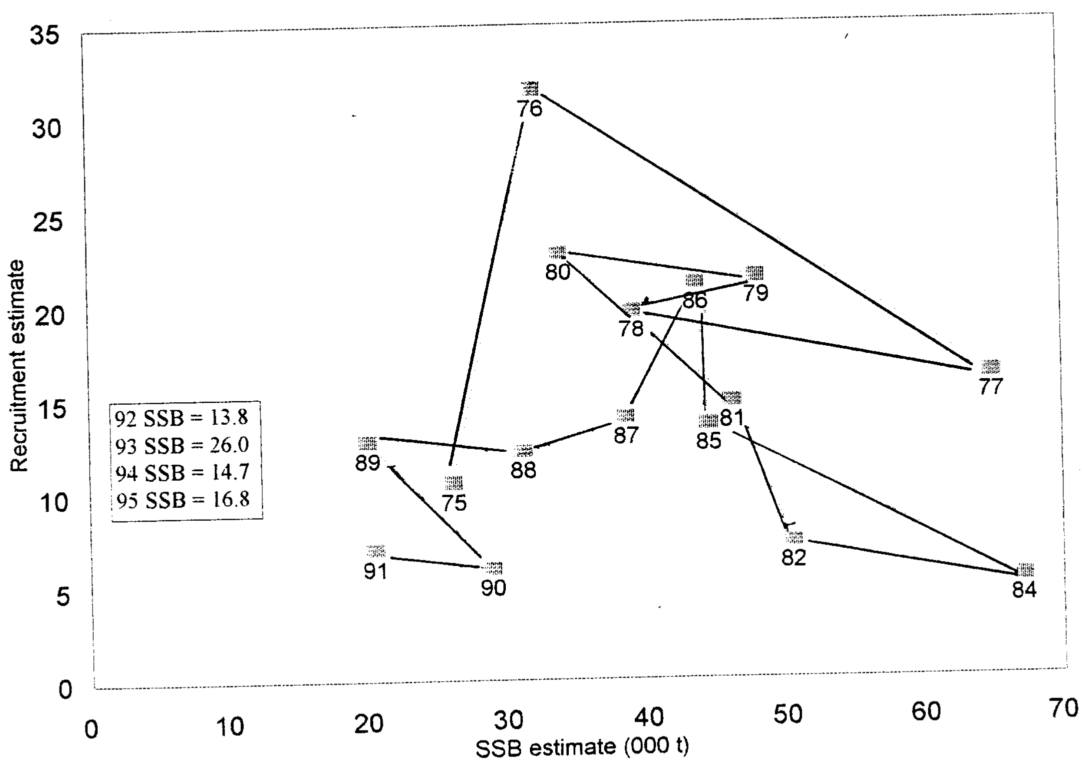


Fig. 7.Stock recruitment plot for yellowtail flounder in Div. 3LNO derived from survey estimates, 1975-95. Recruits are estimated from a multiplicative analysis of ages 2-5 years using a biased corrected cohort strength model.

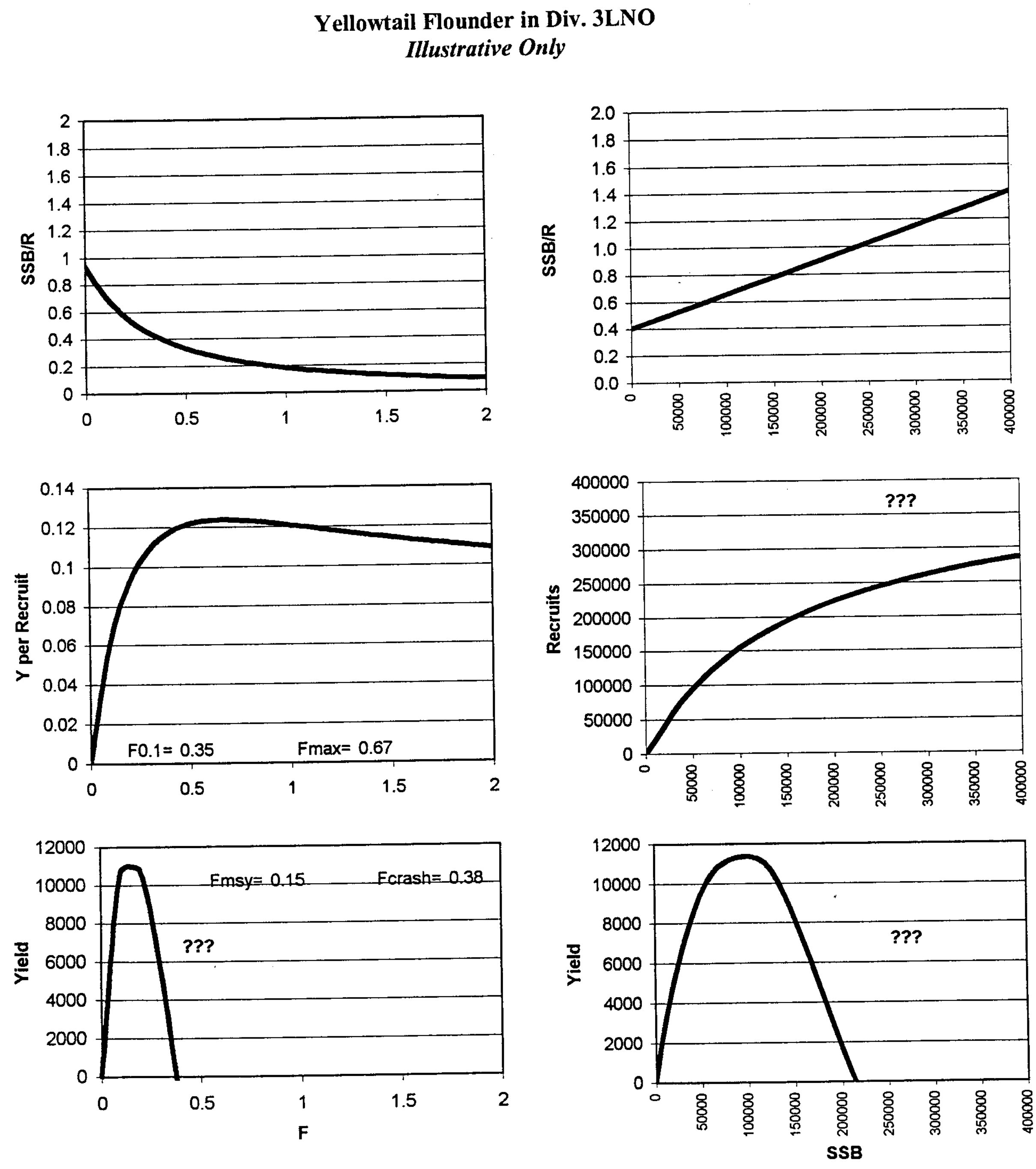


Fig. 8. Simulation of stock productivity in yellowtail flounder using Sissenwine-Shepherd model.