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Fishery Effects on Spawner Escapement in the Northwest Atlantic *Illex illecebrosus* Stock

by

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Abstract

Trends in relative fishing mortality rates in relation to spawner biomass levels, during 1983-1997, show that spawner biomass is low, generally below average, when relative fishing mortality rates for the stock are high. This indicates that fishing mortality rates from all Subareas (SA 2-6) have an effect on the spawner escapement biomass of this stock. A prolonged decline in the mean weights of *Illex* squid caught in the SA 5+6 and the SA 4 surveys is evident from annual data. Mean weights of squid from both surveys declined in 1982, following the period of high landings which occurred in SA 3+4 during 1976-1981, and have remained low since this time

Regardless of the autumn spawning migration route, an adequate level of spawner escapement from all fishery areas is required to maintain recruitment to the stock during the subsequent year. During the past ten years, management of the *Illex argentinus* fishery in the Falkland Islands has been based on maintaining a target of 40% proportional escapement which, under average recruitment, implies absolute escapement above a threshold minimum spawning stock biomass

During the high productivity period, 1976-1981, the SA 4 July survey biomass index averaged 12.6 kg/tow and abundance averaged 74.8 squid per tow. The low productivity period which occurred prior to this time (1970-1975) was also a period of low relative fishing mortality in Subareas 3+4, so survey indices from this period could be used as a basis for comparison with the high productivity regime. During 1970-1975, the average biomass index was 2.0 kg/tow and the average abundance index was 18.3 squid per tow. This represents an 84% difference in mean weight per tow and 75% difference in mean number per tow. Mean weights of squid caught in this survey during the current low productivity period (75 g) are 50% lower than those during the high productivity period (150 g). Given these data, a change to a high productivity regime could be defined as an 80 % increase, during one year, of the SA 4 July survey biomass and abundance indices with indices at the same value or higher during the subsequent year. In addition, there should be a 50% increase in survey mean weights during the same two-year period.

Introduction

Based on a review of the biology and population dynamics of northern shortfin squid (*Illex illecebrosus*) in the northwest Atlantic Ocean, this species is now considered to constitute a unit stock throughout its range in NAFO Subareas 2-6 (Dawe and Hendrickson 1998; NAFO 1998). As such, fishing mortality rates in SA 3+4 must be considered in relation to those in SA 5+6 with respect to ensuring that the annual level of spawner escapement is sufficient to provide a high probability of successful recruitment during the subsequent year. Sufficient spawner escapement is particularly important for an annual species such as *Illex illecebrosus* in that recruitment is highly variable and overfishing during a year of poor recruitment could lead to stock collapse. During the past ten years, the management of another ommastrephid squid fishery, the *Illex argentinus* fishery in the Falkland Islands, has been based on maintaining a target of 40% proportional escapement, which under average recruitment, implies absolute escapement above a threshold minimum spawning stock biomass (Beddington et. al. 1990; Rosenberg et. al. 1990; Basson et. al. 1998).

Material s and Methods

Subarea 5+6 autumn bottom trawl survey indices of *Illex* squid relative biomass (standardized, stratified mean kg per tow) can be considered an indication of relative spawner escapement levels. This survey occurs around the timing of the offshore spawning migration of this species and near the end of the fishing season (Hendrickson et. al. 1996). Relative biomass indices of *Illex* squid from the Scotian Shelf bottom trawl survey can be considered as pre-fishery biomass indices in that this survey occurs during July, which is at the start of the fishing season in Subareas 3+4. In order to standardize these indices, a General Linear Model (GLM) was run with log-transformed relative biomass indices from both surveys, weighted by the area covered by each survey, for 1970-1997 (Table 1). Table 2 shows the GLM output ($r^2 = 0.679$; CV = 6.59% and MSE = 0.74). Total stock landings (SA 3-6) (Table 3) were divided by the year coefficients from the GLM to produce a time series of relative fishing mortality rates. However, relative F values are inaccurate prior to 1979 due to under-reporting of *Illex* squid landings in the U.S. EEZ by distant water fleets and the lack of reporting domestic landings of squid by species. In addition, 1982 data from SA 4 were excluded from the GLM analysis because a different vessel and gear were employed during that year.

Results and Conclusions

The stock has been defined to be at a low productivity level since 1982 (Rivard et. al. 1998). Trends in stock relative F values in relation to spawner biomass levels, during 1983-1997, are shown in Figure 1 for this low productivity time period. This Figure indicates that spawner biomass is low, generally below average, when relative fishing mortality rates for the stock are high. This indicates that fishing mortality rates from all Subareas (SA 2-6) have an effect on the spawner escapement biomass of this stock. Negative biological effects, such as truncation of age groups or reduction in mean weights, may be difficult to detect in this annual species without the benefit of biological data collected during time scales shorter than its life span. However, a prolonged decline in the mean weights of *Illex* squid caught in the SA 5+6 and the SA 4 surveys is evident from annual data. Mean weights of squid from both surveys declined in 1982, following the period of high landings which occurred in SA 3+4 during 1976-1981, and have remained low since this time (Figure 2).

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Table 1. Stratified mean weight (kg) per tow of *Illex illecebrosus* caught during SA 5+6 (autumn) and SA 4 (July) research bottom trawl surveys and standardized relative biomass indices calculated from a GLM.

Year	SA 4 Biomass Index (kg/tow)	SA 5+6 Biomass Index (kg/tow)	Standardized Survey Biomass Index
1970	0.4	0.268	0.26
1971	2.8	0.337	0.78
1972	0.7	0.292	0.37
1973	1.5	0.353	0.59
1974	1.8	0.392	0.68
1975	5.0	1.417	2.15
1976	42.7	7.018	13.98
1977	9.5	3.740	4.81
1978	2.3	4.529	2.61
1979	14.2	6.053	7.48
1980	2.2	3.285	2.17
1981	4.9	9.340	5.46
1982	2.1	0.602	*
1983	2.1	0.233	0.56
1984	1.5	0.519	0.71
1985	2.7	0.355	0.79
1986	0.4	0.257	0.26
1987	0.4	1.527	0.63
1988	2.7	2.997	2.30
1989	2.7	3.307	2.41
1990	4.8	2.401	2.74
1991	1.8	0.691	0.90
1992	7.3	0.804	1.96
1993	5.4	1.595	2.37
1994	4.2	0.860	1.53
1995	2.4	0.700	1.05
1996	0.9	0.926	0.74
1997	4.8	0.521	1.00

* No value calculated due to vessel change

Table 2.

GLM ILLEX LOG(catwt)

FACTORS ARE YEAR, SA

ILLEX Bottom Trawl Research Survey Indices, 1970-83

General Linear Models Procedure

Dependent Variable: LNACATWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	13	40.68618600	3.12970662	6.46	0.0014
Error	12	5.81470007	0.48455834		
Corrected Total	25	46.50088608			

R-Square	C.V.	Root MSE	LNACATWT Mean
0.874955	5.976602	0.69610225	11.64712387

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	12	37.94196377	3.16183031	6.53	0.0014
SA	1	2.74422223	2.74422223	5.66	0.0348

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	12	37.94196377	3.16183031	6.53	0.0014
SA	1	2.74422223	2.74422223	5.66	0.0348

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		10.26287203 B	20.09	0.0001	0.51079940
YEAR	1970	-0.75913804 B	-1.09	0.2969	0.69610225
	1971	0.32836526 B	0.47	0.6456	0.69610225
	1972	-0.43644861 B	-0.63	0.5424	0.69610225
	1973	0.03948036 B	0.06	0.9557	0.69610225
	1974	0.18303652 B	0.26	0.7971	0.69610225
	1975	1.33638061 B	1.92	0.0790	0.69610225
	1976	3.20872935 B	4.61	0.0006	0.69610225
	1977	2.14257952 B	3.08	0.0096	0.69610225
	1978	1.52909592 B	2.20	0.0484	0.69610225
	1979	2.58428880 B	3.71	0.0030	0.69610225
	1980	1.34630279 B	1.93	0.0770	0.69610225
	1981	2.26916152 B	3.26	0.0068	0.69610225
	9999	0.00000000 B	.	.	.
SA	4	0.64975998 B	2.38	0.0348	0.27303377
	99	0.00000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Table 2.

GLM ILLEX LOG(catwt)
FACTORS ARE YEAR, SA
ILLEX Bottom Trawl Research Survey Indices, 1983-97

General Linear Models Procedure

Dependent Variable: LNACATWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	16.40653271	1.09376885	1.36	0.1044
Error	14	7.72400867	0.55171490		
Corrected Total	29	24.13054138			
	R-Square	C.V.	Root MSE		LNACATWT Mean
	0.679907	6.593030	0.74277514		11.26606722

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	14	12.78130985	0.91295070	1.65	0.1786
SA	1	3.62522286	3.62522286	6.57	0.0225
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
YEAR	14	12.78130985	0.91295070	1.65	0.1786
SA	1	3.62522286	3.62522286	6.57	0.0225

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		10.24013044 B	18.86	0.0001	0.54344626
YEAR	1984	0.23219714 B	0.31	0.7592	0.74277514
	1985	0.33619825 B	0.45	0.6578	0.74277514
	1986	-0.78009416 B	-1.05	0.3114	0.74277514
	1987	0.11089798 B	0.15	0.8834	0.74277514
	1988	1.40202261 B	1.89	0.0798	0.74277514
	1989	1.45203726 B	1.95	0.0709	0.74277514
	1990	1.57964137 B	2.13	0.0517	0.74277514
	1991	0.46647596 B	0.63	0.5401	0.74277514
	1992	1.24224967 B	1.67	0.1166	0.74277514
	1993	1.43402729 B	1.93	0.0740	0.74277514
	1994	0.99952141 B	1.35	0.1998	0.74277514
	1995	0.61678767 B	0.83	0.4203	0.74277514
	1996	0.26627015 B	0.36	0.7253	0.74277514
	1997	0.81569641 B	1.10	0.2907	0.74277514
	9999	0.00000000 B	.	.	.
SA	4	0.69524316 B	2.56	0.0225	0.27122313
	99	0.00000000 B	.	.	.

Table 3. *Illex* landings (mt) in NAFO Subareas 5+6 (U.S. EEZ) and Subareas 3+4 during 1963-1998 1,2,3,4,5 and TACs.

	Cape Hatteras to the Gulf of Maine (Subareas 5+6)			Subareas (3+4)	All Subareas (3-6)	TAC (mt)	
Year	Domestic (mt)	Foreign (mt)	**Total** (mt)	Total (mt)	**Total** (mt)	3+4	5+6
1963	810		**810**	2,222	**3,032**		
1964	358	2	**360**	10,777	**11,137**		
1965	444	78	**522**	8,264	**8,786**		
1966	452	118	**570**	5,218	**5,788**		
1967	707	288	**995**	7,033	**8,028**		
1968	678	2593	**3,271**	56	**3,327**		
1969	562	975	**1,537**	86	**1,623**		
1970	408	2418	**2,826**	1,385	**4,211**		
1971	455	6159	**6,614**	8,906	**15,520**		
1972	472	17169	**17,641**	1,868	**19,509**		
1973	530	18625	**19,155**	9,877	**29,032**		
1974	148	20480	**20,628**	437	**21,065**		71,000
1975	107	17819	**17,926**	17,696	**35,622**	25,000	71,000
1976	229	24707	**24,936**	41,767	**66,703**	25,000	30,000
1977	1,024	23771	**24,795**	83,480	**108,275**	25,000	35,000
1978	385	17207	**17,592**	94,064	**111,656**	100,000	30,000
1979	1,493	15748	**17,241**	162,092	**179,333**	120,000	30,000
1980	299	17529	**17,828**	69,606	**87,434**	150,000	30,000
1981	615	14956	**15,571**	32,862	**48,433**	150,000	30,000
1982	5,871	12762	**18,633**	12,908	**31,541**	150,000	30,000
1983	9,775	1809	**11,584**	426	**12,010**	150,000	30,000
1984	9,343	576	**9,919**	715	**10,634**	150,000	30,000
1985	5,033	1082	**6,115**	673	**6,788**	150,000	30,000
1986	6,493	977	**7,470**	111	**7,581**	150,000	30,000
1987	10,102	0	**10,102**	566	**10,668**	150,000	30,000
1988	1,958	0	**1,958**	800	**2,758**	150,000	30,000
1989	6,801	0	**6,801**	7,000	**13,801**	150,000	30,000
1990	11,670	0	**11,670**	11,000	**22,670**	150,000	30,000
1991	11,908	0	**11,908**	3,996	**15,904**	150,000	30,000
1992	17,827	0	**17,827**	2,000	**19,827**	150,000	30,000
1993	18,012	0	**18,012**	2,668	**20,680**	150,000	30,000
1994	18,350	0	**18,350**	5,970	**24,320**	150,000	30,000
1995	14,058	0	**14,058**	1,032	**15,090**	150,000	30,000
1996	16,969	0	**16,969**	8,731	**25,700**	150,000	21,000
1997	13,629	0	**13,629**	14,521	**28,150**	150,000	19,000
1998	22,705	0	**22,705**	1,918	**24,623**	150,000	19,000
AVERAGES							
1976-1981	674	18,986	19,661	80,645	100,306		
1982-1987	7,770	2,868	10,637	2,567	13,204		
1988-1993	11,363	0	11,363	4,577	15,940		
1994-1998	17,142	0	17,142	6,434	23,577		

[1] Landings during 1963-1978 were not reported by species, but are proration-based estimates by Lange and Sissenwine (1980)

[2] Landings during 1979-1997 are from the NEFSC Weighout Database and the Joint Venture Database

[3] Domestic landings during 1982-1991 include Joint-Venture landings

[4] Includes landings from Subarea 2

[5] Landings during 1998 are preliminary for all Subareas

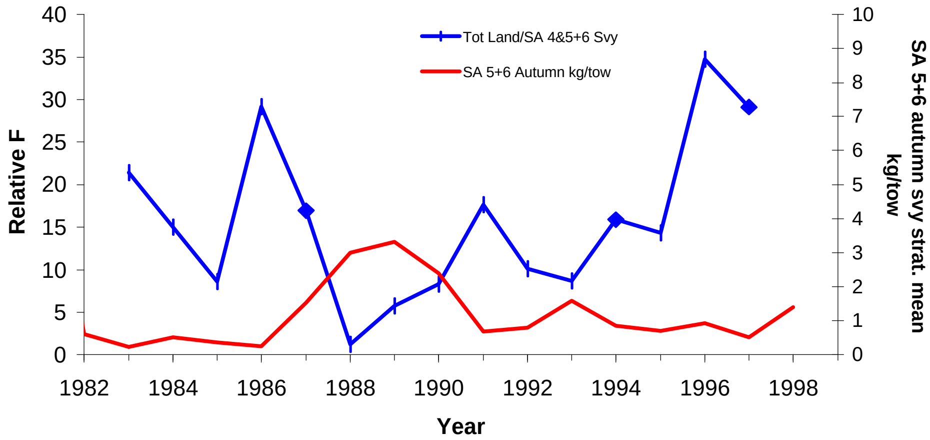

Figure 1. Trends in relative fishing mortality rates for the *Illex illecebrosus* stock (SA 3-6 landings/SA 4 July survey biomass index), during 1983-1997, and SA 5+6 autumn survey stratified mean biomass (kg/tow) index during 1982-1998.

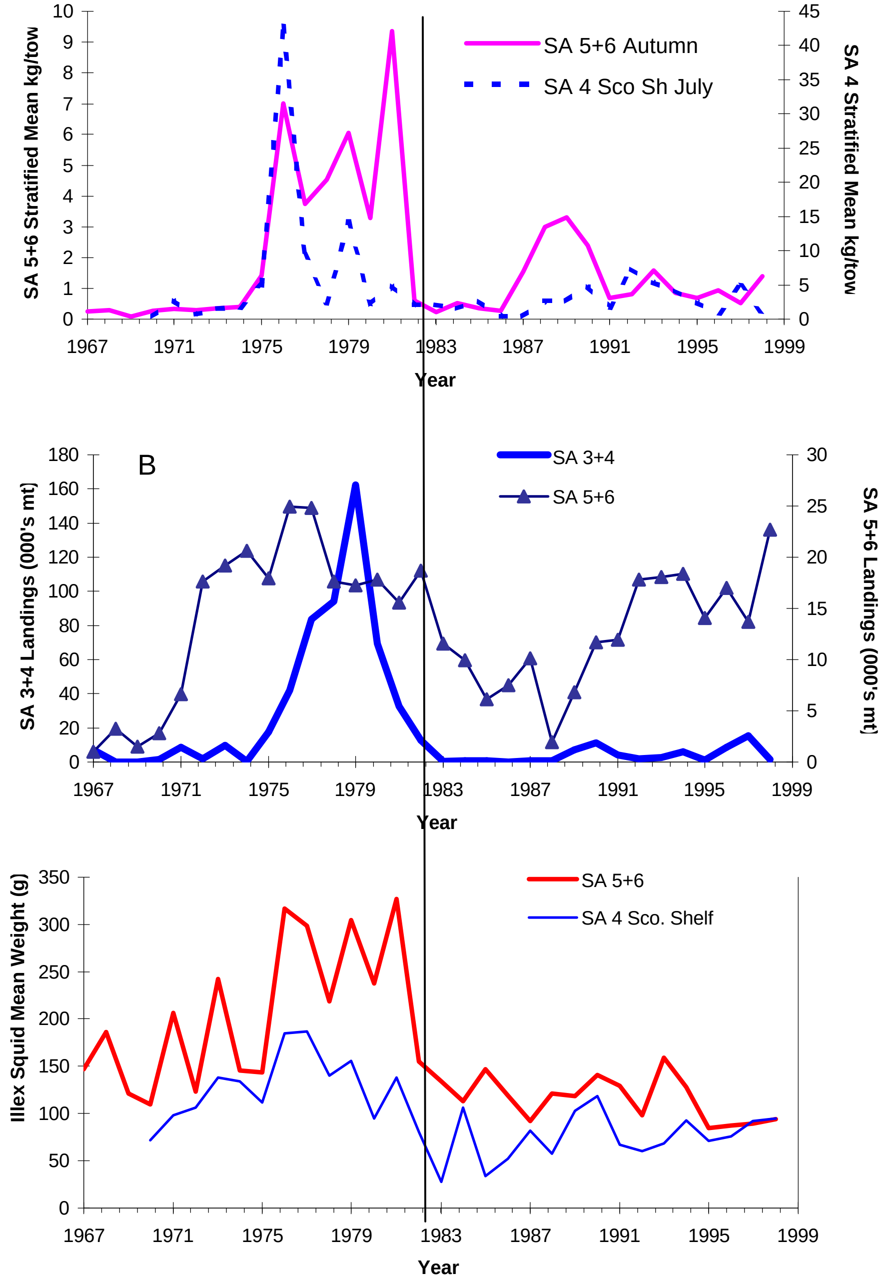

Figure 2. Trends in A.) stratified mean weight (kg) per tow indices of *Illex illecebrosus* captured in SA 5+6 autumn surveys (1967-1998) and SA 4 Scotian Shelf July survey indices (1970-1! B.) trends in landings for Subareas 5+6 and Subareas 3+4 (1967-1998); and C.) trends in *Illex* squid mean weights of Illex squid captured in SA 5+6 and SA 4 Scotian Shelf surveys