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An Evaluation of 0-Group Abundance Indices of Barents Sea Fish Stocks

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Abstract: The International 0-group fish survey in the Barents Sea (1965-2002) aimed to give initial indication of the recruiting year class strengths. Since 2003 the 0-group survey has been a part of a Joint Norwegian-Russian ecosystem survey of the Barents Sea, conducted by IMR (Norway) and PINRO (Russian Federation). The electronic 0-group databases were missing some data and contained errors, therefore the databases have been quality checked and corrected for the period 1980-2006. Two separate sets of 0- group indices were re-estimated, both with and without correction for capture efficiency, using a stratified sample mean approach, and 0-group indices were correlated with other appropriate abundance indices. The exclusion of errors from the database has improved our confidence in the indices and analysis. In general, the 0-group indices seem to be reliable predictors of year class strengths and are adequate to use as input in stock assessment-models and recruitment studies.

Key Words: 0-group fish, abundance, Barents Sea, recruitment.

INTRODUCTION

The knowledge of the size of the recruiting year classes is an important contribution for a successful assessment. The main goal with the Joint International 0-group fish survey has been to give an initial indication of year class strength of the commercially important fish stocks in the Barents Sea. The survey has been conducted since 1965 by the Institute of Marine Research, (IMR), Norway, the Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia, and the United Kingdom (up until 1976). Since 2003 the 0-group survey has been a part of a Joint Norwegian-Russian ecosystem survey of the Barents Sea [1].

The 0-group survey has been carried out annually during August-September. In 1980 a standard trawling procedure was recommended by ICES [2, 3] and has since been used on Norwegian and Russian vessels. The standard procedure consists of predetermined tows at three or more depths, each of 0.5 nautical mile, with the head-line at 0, 20 m, 40 m and so on.

Developing methods for estimating year class strength/ abundance has been an urgent task during the whole investigation period 1965-2006. The possibility of estimating abundance of 0-group fish, using echo-sounder was presented by Dragesund and Olsen [4]. Nakken and Raknes [5], improved the "area index" method [6], and this method is still in use. The "logarithmic index" method, developed by Randa [7], was used until 2004. Dingsør [3] applied the "stratified sample mean" method and calculated the 0-group indices, this procedure was further developed [8] and is now the standard method for establishing the 0-group indices in the Barents Sea. In 2005 two separate sets of indices were estimated, both with and without correction for capture efficiency (called as old indices here).

The biological data collected during the survey is the basis for estimation of fish abundances. Thus, the quality of the collected data will influence the results and conclusions. After the survey, the collected data were exchanged between the Institutes. Before computer techniques were common, hand-written data were exchanged. In later years, data have been exchanged in electronic form. IMR and PINRO were responsible for punching of the historical hand-written data, from which two databases were established. The first aim for this work is to recalculate the 0-group abundance indices using a scrutinized and corrected database.

Several studies have compared the 0-group abundance indices with other abundance indices of early and later life stages. Gundersen and Gjøsæter [9] found significant correlation between 0-group and 1-group indices of capelin, but no correlation between larval indices and 0-group nor 1-group indices. The suggested explanation to this was a high mortality during the first months of capelins life. Helle *et al.* [10] found significant correlation between 0-group indices of cod and spawning-stock biomass (SSB) and acoustic survey abundance indices (WA). The second aim of this work is to compare the new indices with other year class estimates of the most important commercial species.

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MATERIALS AND METHODS

Recalculation of 0-Group Indices

Information in the databases was compared with the hand-written data and between the databases. The database was updated and errors were corrected. The corrected datasets (1980-2006) were used to re-estimate the 0-group indices of Barents Sea capelin *Mallotus villosus*, Norwegian spring spawning herring *Clupea harengus*, Northeast Arctic cod *Gadus morhua*, Northeast Arctic haddock *Melanogrammus aeglefinus*, Northeast Arctic saithe *Pollachius virens*, redfish *Sebastes* spp., Greenland halibut *Reinhardtius hippoglossoides*, long rough dab *Hippoglossoides platessoides*, and two populations (western and eastern) of polar cod *Boreogadus saida*. These indices, which are given both with and without correction for capture efficiency, are calculated by the method of stratified sample mean.

The number of fish per square nautical mile, $\rho_{s,l}$, of length, l (in 1cm groups), at each station, s, are estimated by the following equation

$$\rho_{s,l} = \frac{f_{s,l} \cdot Keff}{a_s} \quad (1)$$

where $f_{s,l}$ is the observed number of fish in lengthgroup l at station s, $Keff$ is the correction functions defined below ($Keff=1$ when not correcting for capture efficiency), and a_s is the swept area found by

$$a_s = \frac{d_s \cdot ws}{1852} \quad (2)$$

where ws/1852 is the wingspread of the trawl converted into nautical mile and d_s is the effective trawl distance found by total distance trawled divided by the number of depth layers [11].

The stratified swept area estimate, is given by

$$\bar{y}_{st} = \sum_{i=1}^{N} A_i \bar{y}_i \quad (3)$$

where N is the number of area-strata, A_i is the covered area in the i-th stratum, and $\bar{y}_i$ is the average density in stratum i given by

$$\bar{y}_i = \sum_s \sum_l \rho_{s,l} / n_i \quad (4)$$

where n_i is the number of stations in stratum i. The full description of the stratified sample mean method was published in volume 2 of the 2004 survey report [8].

Capture efficiency of pelagic trawl is highly selective for 0-group fish [12, 13], and the selectivity depends on species and fish length. Length correction functions, *Keff*, for trawl capture efficiency have been estimated by regressions between fish densities from simultaneous trawl and acoustic estimates of relatively "pure" concentrations [14]. By "pure" concentrations, we mean that only one species dominates the catches. Correction functions for three species types are:

$$Keff_{gadoids} = 17.065*\exp(-0.1932*l) \quad (5)$$

$$Keff_{capelin} = 7.2075*\exp(-0.1688*l) \quad (6)$$

$$Keff_{herring} = 357.23*\exp(-0.6007*l) \quad (7)$$

where l is the observed length in cm. Unfortunately, because of the requirement of "pure" concentrations, there are no correction functions available for other species.

Comparing 0-Group Indices

A comparison of abundance estimates of Barents Sea fish at larval, 0-group, 1-group stages and recruitment for the year classes 1980-2005 will give an indication of abundance variation through the different life stages. The indices included in the analysis and general information about the surveys and the periods in which they were conducted are given in Table **1**.

Pearson's correlation was estimated to determine if the relative abundance of 0-group fish is proportional to its relative abundance at an earlier or later life stage. Pearson's r reflects the degree of linear relationship between two variables. It ranges from +1 to -1, a correlation of +1 means that there is a perfect positive linear relationship between variables. However, it is important to keep in mind that biases in the surveys will influence the results [3, 12], i.e. variable biases will weaken the correlations. 0-group indices (0grI) were correlated with the "area index" (AI), capelin larval index (LI), 1-year old abundance indices or estimate (1grE), bottom trawl index (WBT), acoustic index (WA), age-3 recruits (3R), maturing biomass (MB) and spawning stock biomass (SSB) (Table **1**). In addition a regression analysis was performed to describe ability of 0-group indices to predict 1 and 3 years old fish abundance. The correlations between 0-group indices of capelin, herring, cod, haddock, and saithe were also analyzed.

RESULTS

Recalculation of 0-Group Indices

The Norwegian and Russian 0-group databases containing twenty-six years of survey-data were quality checked. The main reason for a mismatch between the databases was punching errors and lack of specific test-programs to detect errors before the data are entered into the database.

New indices with and without length correction of 0-group capelin, herring, cod, haddock, saithe, polar cod, redfish, Greenland halibut and long rough dab were calculated for the period 1980- 2006 (Table **2**).

The recalculated 0-group indices showed some differences (Table **3**) from the old indices [1], and these differences varied between species. 0-group indices of capelin, herring, redfishes and Greenland halibut had the largest changes, and four year classes (1980, 1982, 1995 and 2001) of the eastern population of polar cod were missing in the old indices.

Comparison of 0-group Indices

The Fig. (**1**) shows time series of 0-group abundance (0grI and 0grIK) and abundance of older fish for capelin, herring, cod, haddock, and saithe.

Table 1. Summary of the Datasets Included in the Study

Index	Species	Abbre-viation	Age, Month	Time Series	Survey	Covered Area/Time	Sampling GEAR	Ref.
Capelin larval Index	Capelin	LI	0-1	1981-2005	Capelin larval survey up to 2002, later the Barents Sea Ecosystem Survey (spring)	Norwegian coast and up to 74°N-June	GULF-III	[15]
0-group area index	Capelin, cod and haddock. Herring	AI	5-6	1980-2005 1993-2005	0-group fish survey	Barents Sea -August-September	Midwater trawl	[5, 15]
New 0-group fish indices	All analyzed species	0grI and 0grIK	5-6	1980-2005	0-group fish survey up to 2003, later the Barents Sea Ecosystem Survey (autumn)	Barents Sea -August -September	Midwater trawl	
Age-1 abun-dance index	Capelin	1grI	16	1980-2005	Autumn capelin survey up to 2003, later the Barents Sea Ecosystem Survey (autumn)	Barents Sea -August -September	Midwater, bottom trawls, acoustic	[17]
Age-1 abun-dance estimate	Herring	1grE	12	1980-2004		Barents Sea		[15, 16]
Age-3 abun-dance, VPA	Cod, had-dock and saithe	3R	36	1980-2003		Barents Sea		[17]
Winter bottom trawl indices	Cod and haddock	WBT	10	1980-2005	The Barents Sea demersal fish survey	Barents Sea -February	Shrimp trawl (bot-tom trawl)	[17, 18]
Winter acoustic indices	Cod and haddock	WA	10	1980-2005	The Barents Sea demersal fish survey	Barents Sea -February	Shrimp trawl (bot-tom trawl)	[17, 18]
Spawning stock biomass (VPA)	Cod and saithe Her-ring	SSB		1980-2005 1980-2004		Barents Sea Norwegian Sea		[15, 17]
Maturing bio-mass, in 1.October	Capelin	MB		1980-2005	Autumn capelin survey up to 2003, later the Barents Sea Ecosystem Survey (autumn)	Barents Sea -August -September	Midwater trawl	[15]

Indices of 0-group capelin, herring, cod, haddock, and saithe without length correction (0grI) were compared with length corrected indices (0grIK), using Pearson's correlation. There were significant linear correlations between 0grI and 0grIK, with high values of Pearson's r; 0.91 (herring), 0.95 (saithe), 0.98 (cod) and 0.99 (haddock and capelin).

Table **4** contains the estimated Pearson's correlation between 0-group indices and other available indices (Table **1**). Highly significant correlations were found between the new 0-group indices (0grI and 0grIK) and the area index (AI) for all species, with Pearson's r between 0.80 and 0.89.

Capelin The new capelin 0-group indices varied some from the old indices [1], and shows that the old indices underestimated the 1987, 1992, 1995, and 2001 year classes, while the 1988, 1994, and 2003 year classes were overestimated (Table **3**).

We found a significant linear correlation between capelin 0-group and 1-group indices, but weaker correlation with the larval index and the maturing biomass (Table **4**). The relationship between 0-group and 1 group (1grI) of capelin can be described by regressions

$$1grI = 40.697 + 0.0027*0grI \quad (R^2=0.668,\ p<0.01)$$

$$1grI = 47.523 + 0.0008*0grIK \quad (R^2=0.652,\ p<0.01)$$

Herring The new herring 0-group indices (0grI) varied some from the old indices [1]. The 1982, 1984, and 1990 year classes were underestimated, while 1980, 1986, 1994, and 1995 were slightly overestimated (Table **3**). The largest changes (in percentage) were observed in the years with low herring abundance. 0-group index without length correction (0grI) had stronger correlation with 1-group indices than 0grIK had. However, both 0grI and 0grIK had a significant linear correlation with 1grE and SSB (Fig. **1** and Table **4**).

The relationship between 0-group and 1 group (1grE) of herring can be described by regressions

$$1grE = 15.543 + 0.0015*0grI \quad (R^2=0.560,\ p<0.01)$$

$$1grE_I = 29.959 + 0.0002*0grIK \quad (R^2=0.277,\ p=0.01)$$

Table 2. Abundance Indices (in Millions) of 0-Group Fish in the Barents Sea, without (0grI) and with (0grIK) Correction for Catching Efficiency

Species Year	Capelin		Cod		Haddock		Herring		Redfish	Saithe		Gr. Halibut	LRD	Polar Cod (East)		Polar Cod (Eest)	
	0grI	0grIK	0grI	0grIK	0grI	0grIK	0grI	0grIK	0grI	0grI	0grIK	0grI	0grI	0grI	0grIK	0grI	0grIK
1980	197278	740289	72	276	59	265	4	77	277873	3	21	111	1273	28958	203226	9650	82871
1981	123870	477260	48	289	15	75	3	37	153279	0	0	74	556	595	4882	5150	46155
1982	168128	599596	651	3480	649	2927	202	2519	106140	143	296	39	1013	1435	1443	1187	10565
1983	100042	340200	3924	19299	1356	6217	40557	195446	172392	239	562	41	420	1246	1246	9693	87272
1984	68051	275233	5284	24326	1295	5512	6313	27354	83182	1339	2577	31	60	127	871	3182	26316
1985	21267	63771	15484	66630	695	2457	7237	20081	412777	12	30	48	265	19220	143257	809	6670
1986	11409	41814	2054	10509	592	2579	7	93	91621	1	4	112	6846	12938	102869	2130	18644
1987	1209	4032	167	1035	126	708	2	49	23747	1	4	35	804	7694	64171	74	631
1988	19624	65127	507	2570	387	1661	8686	60782	107027	17	32	8	205	383	2588	4634	41133
1989	251485	862394	717	2775	173	650	4196	17956	16092	1	10	1	180	199	1391	18056	164058
1990	36475	115636	6612	23593	1148	3122	9508	15172	94790	11	29	1	55	399	2862	31939	246819
1991	57390	169455	10874	40631	3857	13713	81175	267644	41499	4	9	1	90	88292	823828	38709	281434
1992	970	2337	44583	166276	1617	4739	37183	83909	13782	159	326	9	121	7539	49757	9978	80747
1993	330	952	38015	133046	1502	3785	61508	291468	5458	366	1033	4	56	41207	297397	8254	70019
1994	5386	13898	21677	70761	1695	4470	14884	103891	52258	2	7	39	1696	267997	2139223	5455	49237
1995	862	2869	74930	233885	472	1203	1308	11018	11816	148	415	15	229	1	6	25	195
1996	44268	136674	66047	280916	1049	2632	57169	549608	28	131	430	6	41	70134	588020	4902	46671
1997	54802	189372	67061	294607	600	1983	45808	463243	132	78	341	5	97	33580	297828	7593	62084
1998	33841	113390	7050	24951	5964	14116	79492	476065	755	86	182	8	27	11223	96874	10311	95609
1999	85306	287760	1289	4150	1137	2740	15931	35932	46	136	275	14	105	129980	1154149	2848	24015
2000	39813	140837	26177	108093	2907	10906	49614	469626	7530	206	851	43	233	116121	916625	22740	190661
2001	33646	90181	908	4150	1706	4649	844	10008	6	20	47	51	162	3697	29087	13490	119023
2002	19426	67130	19157	76146	1843	4381	23354	151514	130	553	2112	51	731	96954	829216	27753	215572
2003	94902	340877	17304	81977	7910	30792	28579	177676	216	65	286	13	78	11211	82315	1627	12998
2004	16701	53950	19157	65969	19144	39303	133350	773891	849	1395	4779	70	36	37156	290686	367	2892
2005	41808	148466	21532	72137	33283	91606	26332	125927	12332	55	176	9	200	6540	44663	3216	25970
2006	166400	515770	7860	25061	11421	28505	66819	294649	20864	142	280	11	710	26016	182713	2078	15965
Mean	62766	217010	17746	68057	3800	10581	29632	171320	63208	197	560	31	603	37809	309303	9106	74971
Median	38144	126155	9367	32846	1326	4083	19642	93900	14937	82	277	14	190	11217	89595	5026	46413

Cod The differences between new and old 0-group abundance indices were larger in 1982, 1986, 1993, 1994, and 2004 than in other years (Table **3**).

Cod 0-group indices were highly correlated with all analyzed indices, except age-3 recruits, and the variation in 0-group abundance was retained through the other indices (Fig. **1** and Table **4**). The regression analyses show no significant relationship between of 0-group and 3 years old cod (3R).

Haddock The old 0-group haddock indices was underestimated in 1982, 1986, and 1993 and overestimated in 1980, 1994, and 2001, but differences between old and new indices were small (Table **3**). Haddock 0-group indices were significantly correlated with all analyzed indices (Fig. **1** and Table **4**).

Table 3. Differences (%) Between Old and New Abundance Indices of 0-Group Fish, without (0grI) and with (0grIK) Correction for Catching Efficiency. If New Indices are 100% Correct, Differences (Diff) Between Old (x) and New (y) can be Describes as Diff=100-((x*100)/y). Negative that the Old Index was Overestimated While Positive Numbers Means that Old Index was Underestimated

Species Year	Capelin		Cod		Haddock		Herring		Redfish	Saithe		Gr. HALIBUT	LRD	Polar Cod (East)		Polar Cod (West)		Mean Year
	0grI	0grIK	0grI	0grIK	0grI	0grIK	0grI	0grIK	0grI	0grI	0grIK	0grI	0grI	0grI	0grIK	0grI	0grIK	
1980	-9	-9	8	-15	-12	-16	-12	-21	-2	10	2	48	7	100	100	-35	-53	5
1981	11	10	-1	4	3	6	3	-1	-2	0	0	7	7	49	49	-5	-5	8
1982	-7	-2	23	26	17	22	17	68	-37	4	10	-2	15	100	100	74	74	30
1983	-1	2	-1	18	0	28	0	38	69	-2	25	5	-3	-11	-13	36	36	13
1984	-7	39	-11	16	1	32	1	33	48	43	61	0	25	3	86	-2	-2	22
1985	-12	-15	2	5	0	0	0	-50	23	-13	-14	6	-6	-6	41	-4	-4	-3
1986	-16	-35	9	8	20	20	20	-20	-17	-10	-9	-2	-5	34	38	1	1	2
1987	50	43	0	0	-2	-6	-2	-1	-4	-1	-1	-6	-4	-1	-1	-4	-3	3
1988	-32	-41	-4	-4	-1	-2	-1	-3	36	4	3	2	3	-5	-5	-2	-2	-3
1989	-3	-2	0	0	-1	-2	-1	2	0	1	0	-20	3	-13	-15	4	4	-3
1990	1	0	0	0	1	1	1	48	2	4	4	-64	2	4	3	-1	-1	0
1991	3	3	-2	-2	-3	-4	-3	-1	7	4	2	-66	7	29	30	-4	-4	0
1992	88	85	-2	-2	-4	-3	-4	-6	0	-2	-2	-1	-7	5	5	-1	-1	9
1993	22	19	29	28	19	18	19	-13	-5	-2	-2	-3	9	68	67	-2	-2	16
1994	-42	-51	-19	-23	-13	-16	-13	-26	-2	3	8	0	-6	29	43	-1	-1	-8
1995	29	28	-16	-19	-13	-14	-13	-30	-28	-14	-14	-22	-12	100	100	-10	-12	2
1996	-6	-5	-7	1	-2	1	-2	-3	1	-10	-10	0	-5	-6	-4	0	0	-3
1997	-5	-4	-1	-1	-4	-4	-4	-1	-10	-3	-3	-1	0	3	3	-2	-2	-2
1998	-6	22	4	4	0	0	0	0	1	9	10	1	-1	-10	82	0	0	7
1999	-4	-3	-5	-6	-1	-2	-1	-3	13	1	1	-14	-1	-1	-1	-9	-11	-3
2000	1	1	0	-1	-1	-1	-1	0	0	-1	-1	9	7	3	3	-7	-8	0
2001	85	78	-8	-10	-15	-17	-15	-2	-7	-2	-2	-1	52	100	100	-18	-22	17
2002	-6	67	0	55	0	0	0	38	-1	42	76	-17	-3	0	88	-8	-9	19
2003	-27	-35	-9	-10	-8	-7	-8	-8	11	-81	-100	-11	-36	3	0	-41	-12	-22
2004	-19	-28	-15	-18	-5	-6	-5	-3	-17	-2	-2	-14	-4	10	11	14	16	-5
2005	-12	-4	0	0	-1	-1	-1	0	0	1	2	4	6	11	11	-4	-6	0
2006	-11	-10	-2	-3	-1	-3	-1	-4	-20	-1	-1	-41	-12	8	7	-19	-23	-8

The regression analyses shows that relationship between 0-group and abundance of 3 years old haddock (3R) can be described by

$3R=1.1134+ 0.5548*\ln(0grI)$ ($R^2=0.552$, $p<0.01$)

$3R_I=47.523+ 0.0008*\ln(0grIK)$ ($R^2=0.511$, $p<0.01$)

Saithe 0-group index without length correction (0grI) had weaker correlation with age-3 recruits (3R) and SSB than 0grIK had. However, the correlations were poor with 3R and SSB for both 0grI and 0grIK (Fig. **1** and Table **4**).

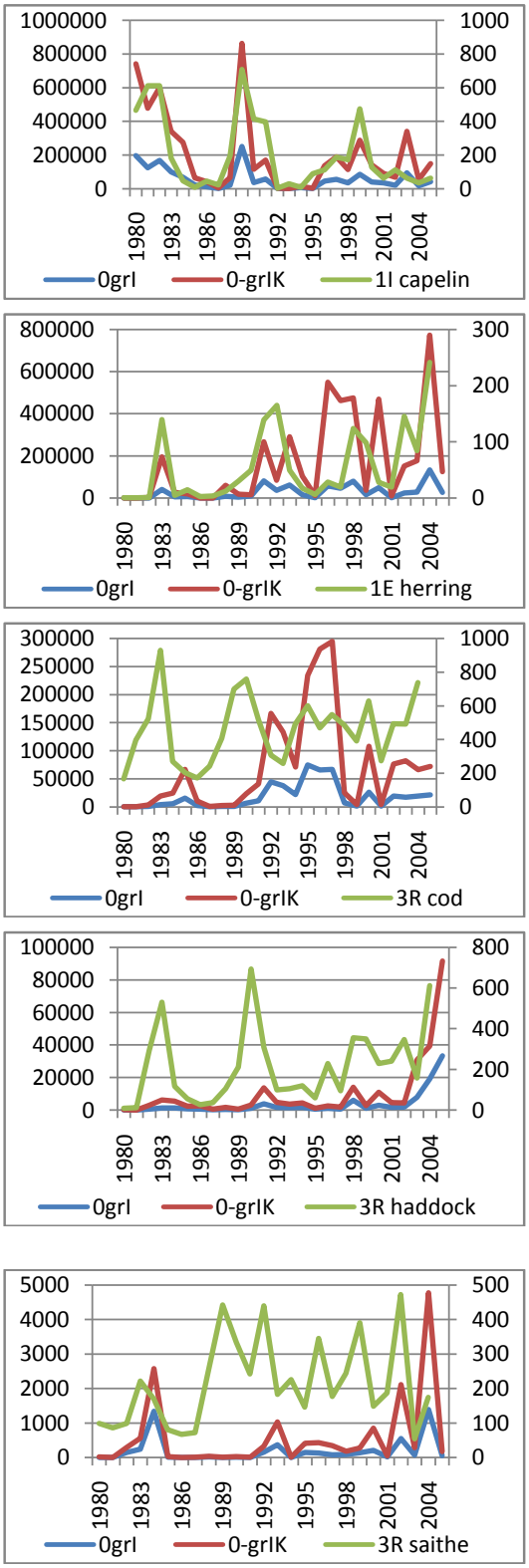

Fig. (1). Time series of 0-group (0grI in blue and 0grIK in red) and abundance for capelin (1grI), herring (1grE), cod (3R), haddock (3R) and saithe (3R). Abundance of older fish shows as a green line.

The regression analyses show no significant relationship between of 0-group and abundance of 3 years old saithe (3R).

Table 4. Pearson's Correlation Between Other Recruitment Indices and the New 0-Group Indices (0grI and 0grIK). N is Number of Years in the Analysis and Index is Abbreviations of Analyzed Abundance Andices. Correlations Significantly Different from Zero (p≤0.05) are Shown in Bold

	Index	N	r_{0grI}	r_{0grIK}
Capelin	LI	26	0.23	0.23
	AI	26	**0.83**	**0.80**
	1grI	26	**0.82**	**0.81**
	MB	26	0.15	0.16
Herring	AI	13	**0.87**	**0.84**
	1grE	26	**0.60**	**0.69**
	SSB	25	**0.75**	**0.53**
Cod	AI	26	**0.81**	**0.80**
	3R	25	0.02	0.01
	WBT	26	**0.70**	**0.66**
	WA	26	**0.81**	**0.80**
	SSB	26	**0.64**	**0.61**
Haddock	AI	26	**0.89**	**0.88**
	3R	25	**0.49**	**0.43**
	WBT	26	**0.70**	**0.66**
	WA	26	**0.64**	**0.59**
	SSB	26	**0.63**	**0.61**
Saithe	3R	24	0.04	0.07
	SSB	26	0.28	**0.43**

Interaction Between 0-group Fishes

Correlations between 0-group indices of capelin, herring, cod, haddock and saithe are shown in Table **5**.

Capelin was negatively correlated with cod, haddock, herring, and saithe. However, only the correlation with cod was significant. Herring was positively correlated with cod, haddock, and saithe. Saithe was positively, but not significantly correlated with haddock.

Table 5. Pearson's Correlation Between Indices (0grI and 0grIK) of 0-Group Capelin (A), Herring (B), Cod (C) and Haddock (D). Correlations Significantly Different from Zero (p≤0.05) are Shown in Bold

	0grI				0grIK			
r	A	B	C	D	A	B	C	D
Herring	-0.18				-0.22			
Cod	**-0.39**	0.25			-0.36	**0.46**		
Haddock	-0.06	**0.43**	0.01		-0.05	0.28	-0.02	
Saithe	-0.15	**0.42**	0.03	0.24	-0.18	**0.52**	0.08	0.21

DISCUSSION

Recalculation of 0-Group Indices

The quality of the database is fundamental for the estimated results. The joint Norwegian-Russian database was corrected and updated for the period 1980-2006. The increased quality of the database makes us more confident in the indices and hence in analyses based on these data. Indices were estimated both with and without correction for capture efficiency.

The 0-group indices estimated in this work showed some differences from the old indices and the differences vary between years. The differences are mainly due to errors in punching of historical data. Therefore, to avoid these faults in later recording of historical data or during later surveys, collected biological data must be tested by specific test-programs, which detect errors before the data are entered into the database.

The corrections to the indices due to errors in the database are severe in some years. E.g. the years 1987-88, 1992-95, 2001 and 2003 for capelin, 1986 for herring, 1982, 1993-94 for cod, and 1986 for haddock. During this work we also found mistakes in punching of fish lengths, which influence the length corrected indices (0grIK). 0-group survey data was also used to study fish growth, errors may have influenced results if studies were based on data from years 1984-88, 1992-95, 2001-04 for capelin, 1982-86, 1994-95 and 2002 for herring, 1982-83 and 1993-94 for cod, and 1982-84 for haddock. Although we call attention to changes, the general trends have not changed much, and we do not know how the errors have influenced the results of earlier recruitment and fish growth studies.

Comparison of 0-group Indices

Capelin Our results showed that capelin 0grI and 0grIK had no significant correlation with the maturing capelin biomass (MB). Capelin is the main prey species for larger predatory fish such as cod, as well as for marine mammals [20, 21]. Estimated MB, based on the autumn survey, will therefore differ from the spawners' abundance in following winter-spring due to predation and harvesting. In addition, variable survival of larvae and post-larvae will weaken the correlation between MB and 0-group of capelin.

Gundersen and Gjøsæter [9] found no correlation between larval index and 0-group index nor between larval index and 1-group index. Our results showed that capelin 0grI and 0grIK had a no significant correlation between the larval index (Table **4**), while strong correlation with 1grI. Egg and larvae are the most vulnerable stages of the fish life cycle due to suitable food availability and predation pressure in areas they are transported through. Therefore, variable survival of capelin during its first months of life, as demonstrated for other species in the area [19], may cause the weak correlation between larvae and 0-group.

The 0grI and 0grIK were proportional to the estimates 1-group and the 0-group "area index", and more than 60% of 1-group abundance variation was explained (Table **4**) by the variation in 0-group abundance. Therefore new indices of 0-group abundance appear to be a better predictor of year class strength than the estimates of maturing biomass or the larval index. Hence, it is adequate and recommended to use the 0-group index in management and recruitment analyses as an early predictor of capelin recruitment.

Herring Our results showed that 0-group herring abundance indices (0grI and 0grIK) were significant correlated with the age-1 estimate (Table **4**). Regression analyses showed that 0grI explained a large part (56%) of the variation in age-1, while 0grIK explain only (28%). Weaker correlation between 0grIK and age-1 estimate may be influenced by uncertainties in length correction function for herring. Our results showed that the variation in 0-group herring abundance in the Barents Sea is strongly correlated with SSB (Table **4**). SSB have commonly been used in herring assessment and management as a predictor of recruitment [15]. Therefore, we can recommend using the 0-group index as input in SeaStar (herring assessment model) [15] and as predictor of year class strength in herring recruitment studies and analyses.

Cod The 0-group indices were significantly correlated with all analyzed indices, except age-3 recruits. The variation in 0-group abundance can be explained by the variation in SSB (Table **4**), and higher SSB level will in most years give a higher level of 0-group abundance. The 0-group abundance of cod is highly correlated with abundance at age-1. It seems that age-1 estimate from the acoustic winter survey (WA) is better correlated with 0grI than age-1 estimates from the bottom trawl winter survey (WBT). This may be caused by a better detection, by the acoustic gear, of age-1 cod distributed in the pelagic. Our results showed that 0-group indices (0grI and 0grIK) were not significantly correlated with recruitment at age-3, this may be related to a high variability in survival at age-1 and age-2. Nevertheless, 0-group indices for cod appear to be reliable predictors of year class strengths; this is useful to study cannibalism and survival, and thus can be applied in to assessment models.

Haddock 0-group indices of haddock were significantly correlated with all analyzed indices, and level of 0-group indices explained most of age-1 estimate from the bottom trawl winter survey (WBT), and the variation in age-3 abundance (Table **4**). Haddock 0-group is also highly correlated to SSB. Higher number of spawners increases the abundance of 0-group, and only 0-group indices, without environmental condition and predation pressure, can explain about 50% of variation of abundance at age-3.

In conclusion, the 0-group abundance of haddock is highly correlated with abundance at older ages and the 0-group indices appear to be reliable predictors of year class strengths and can be useful as input in to assessment model.

Saithe Correlations and regression analyses showed that saithe 0-group indices were poorly correlated with both age-3 abundance and SSB (Table **4**). During the first years of life, a large proportion of this saithe stock is distributed in the fjords along the Norwegian coast [22], and is therefore not available to be covered by the 0-group survey. Consequently, saithe 0-group indices are underestimates and representative only for the surveyed area. Thus, the saithe 0-group indices can not be recommended as year class

strengths indicators. However, 0-group data is useful in spatial and temporal multispecies analyses.

Interaction Between 0-group Fishes

The transport of egg and larvae along the Norwegian and Murman coast and into the Barents Sea is largely determined by currents. Inter-annual variation in currents and climate will therefore influence the distribution and survival of 0-group fish [23, 24]. Distribution varied between years and between species. In the western, central and southern parts of the Barents Sea more or less all of the analyzed species have been observed, while in the northern part mostly capelin, polar cod, and cod have been observed. Therefore, the positive correlation between cod, herring, haddock, and saithe (Table **5**) indicate a possible spatial overlap during the first summer and a homogenous response to the environment. We found negative correlations between 0-group capelin and 0-group of cod, herring, and saithe (Table **5**), species that overlap both spatially and temporally. Capelin and cod, herring and saithe presents different biogeographic groups, with different responses to temperature and environmental conditions. In addition, our results are in agreement with an earlier study [25] showing that 0-group of cod, herring, and saithe are potential predators of capelin. Therefore, variation in 0-group fish abundance indices depends on oceanographic conditions as well as interactions between 0-group fishes and their spatial and temporal overlap during the first crucial months of their life.

CONCLUSIONS

The goal with this work has been to improve the joint Norwegian and Russian 0-group database and estimate new sets of abundance indices of Barents Sea capelin, Norwegian spring spawning herring, Northeast Arctic cod, Northeast Arctic haddock, Northeast Arctic saithe, redfish, Greenland halibut, long rough dab and two populations of polar cod. 0-group indices have been used in recruitment studies and in stock assessment, therefore it was necessary to correct both database and indices. The updated database has improved the abundance estimates and we have larger confidence in the new indices. We call attention to the errors that have been present in the database and old indices. The general abundance trends have not changed much, and we do not know how the errors have influenced the results of earlier studies of fish growth and recruitment. In general, the 0-group indices seem to be reliable predictors of year class strengths. Capelin, herring and haddock 0-group indices are able to predict numbers of older fish and may be used in stock assessment. While cod and saithe 0-group indices seem to be incapable to predict recruitment at age-3. Nevertheless, indices for cod appear to be reliable predictors of year class strengths, and can be useful as input in to assessment models. 0-group saithe data is useful in spatial and temporal multispecies analyses.

ABBREVIATIONS

LI = capelin larval Index

AI = 0-group area index

0grI = new 0-group fish indices without correction for catching efficiency

0grIK = new 0-group fish indices with correction for catching efficiency

1grI = age-1 abundance index

1grE = age-1 abundance estimate

VPA = Virtual Population Analyse

3R = age-3 abundance, VPA

WBT = winter bottom trawl indices

WA = winter acoustic indices

SSB = spawning stock biomass (VPA)

MB = Maturing biomass, in 1.October

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