FISKEN OG HAVET

no. 1-2018

ISSN 0071-5638

Estimation of acoustic indices with CVs for Northeast Arctic saithe in the Norwegian coastal survey 2003–2017 applying the Sea2Data StoX software

Sigbjørn Mehl, Espen Johnsen, Åsmund Skålevik and Asgeir Aglen

HAVFORSKNINGSINSTITUTTET

Project Report

Report: FISKEN OG HAVET
No. – Year: 1-2018
Date: 23.01.2018

Title:
Estimation of acoustic indices with CVs for Northeast Arctic saithe in the Norwegian coastal survey 2003–2017 applying the Sea2Data StoX software

Authors:
Sigbjørn Mehl, Espen Johnsen, Åsmund Skålevik and Asgeir Aglen

Distribution: Open

Project no.:
82354

Assignor(s):
Ministry of Trade, Industry and Fisheries

Program:
Coastal ecosystems

Research group:
Demersal fish

Number of pages in total:
19

Summary (Norwegian):
Sea2Data programmet StoX er brukt til å estimere akustiske indekser med CV og lengde og vekt ved alder for nordøstarktisk sei fra det norske kysttoktet Varanger – Stad i 2013 til 2017. Indeksene er sammenlignet med indekser tidligere estimert med programmet BEAM, og forskjeller er i hovedsak forklart ved forskjeller i strata-areal.

Summary (English):
The Sea2Data software StoX was applied to estimate acoustic indices with CVs and length and weight at age for Northeast Arctic saithe from the Norwegian coastal survey Varanger - Stad in 2013 to 2017. The indices are compared to indices previously estimated by the BEAM software, and differences are mainly explained by different strata areas.

Emneord (norsk):
1. **Nordøstarktisk sei**
2. **Akustiske indekser**
3. **Norskekysten Varanger-Stad**
4. **StoX programvare**

Subject heading (English):
1. **Northeast Arctic saithe**
2. **Acoustic indices**
3. **Norwegian coast Varanger-Stad**
4. **StoX software**

Content

1 Background

The Institute of Marine Research (IMR), Bergen, has performed an acoustic survey annually in October-November since 1985 to obtain indices of abundance and estimates of length and weight at age of saithe north of 62ºN. The indices are the only fishery-independent data in the assessment of Northeast Arctic saithe in ICES. In autumn 2003 the saithe- and coastal cod surveys were combined. A new survey was designed, with new stratification and smaller strata based on depth and fish distribution in recent years, and with new and more regular transects (Figure 2.2). However, only the part of the new combined survey representing the traditional saithe survey area have so far been included in the estimation of acoustic abundance indices for saithe in order to maintain a uniform time series for tuning of the assessment model.

The new Sea2Data software StoX was applied to estimate acoustic indices with CVs for saithe for the period 2003 to 2017. The main difference between the SAS based BEAM Program (Totland and Godø 2001) used for saithe until 2016 and StoX acoustic abundance estimation is that in BEAM the survey area is divided into rectangles, and for each rectangle an average acoustic density (sA) is calculated, while in StoX transects are defined within each stratum as primary sampling units (PSUs) and used to calculate acoustic density (Jolly and Hampton 1990).

StoX does not use age-length keys (ALK) in the traditional sense with ALKs estimated for large areas. Missing age information is imputed from known age-length data within station. If age information is still missing StoX searches within strata, or lastly within all strata. If no age is available for a length group, the abundance estimate is presented as unknown age. StoX does also allow for uncertainty estimation by bootstrapping the transects and assigned trawl stations.

2 Material and Methods

2.1 Survey operation and data sampled

Table 2.1 presents the vessels participating in the survey in 2003-2017 with some basic trawl information.

Table 2.1. Sea2Data cruise number, start and end data, serial numbers, number of trawl stations for vessel participating in the Norwegian acoustic coastal survey in 2003-2017.

Year	Vessel	Cruice number	Start	End	Serial number		No. trawl stations
					From	To	
2003	Johan Hjort Jan Mayen	2003211 2003705	1010 1020	1108 1114	81601 81801	81686 81942	228
2004	Johan Hjort Jan Mayen	2004212 2004704	1011 1015	1111 1109	55001 55201	55090 55320	210
2005	Johan Hjort Jan Mayen	2005212 2005704	1011 1013	1107 1111	55001 55201	55061 55303	164
2006	Johan Hjort Jan Mayen	2006213 2006705	1024 1021	1119 1118	55001 55201	55074 55376	250
2007	Johan Hjort Jan Mayen	2007212 2007703	1015 1023	1110 1119	55001 55201	55079 55350	229
2008	Johan Hjort Jan Mayen Håkon Mosby	2008210 2008705 2008623	1028 1118 1125	1207 1120 1216	55001 00001 55558	55133 00011 55650	237
2009	Johan Hjort Jan Mayen Jan Mayen Håkon Mosby	2009209 2009703 2009704 2009623	1005 0928 1108 1201	1029 1018 1112 1206	55001 55201 55281 55401	55081 55280 55291 55426	198
2010	Johan Hjort Jan Mayen	2010211 2010704	0927 1108	1109 1111	55001 55201	55165 55212	177
2011	Johan Hjort Helmer Hansen Helmer Hansen	2011214 2011722 2011723	1006 1016 1114	1028 1112 1115	55001 55301 55399	55050 55398 55410	160
2012	Johan Hjort Håkon Mosby	2012210 2012620	1002 1015	1029 1113	55001 55301	55083 55377	160
2013	Johan Hjort Håkon Mosby Helmer Hansen	2013210 2013623 2013851	1003 1013 1101	1026 1113 1108	55001 55201 55301	55066 55281 55315	162
2014	Johan Hjort Håkon Mosby Helmer Hansen	2014213 2014621 2014011	1002 0926 1031	1031 1023 1101	55001 55201 55551	55096 55296 55563	205
2015	Johan Hjort Håkon Mosby Helmer Hansen	2015211 2015621 2015843	1007 1002 1103	1105 1028 1106	55001 55201 55301	55092 55289 55314	195
2016	Johan Hjort Håkon Mosby Helmer Hansen	2016210 2016620 2016883	1001 1005 1027	1030 1031 1103	55001 55201 55101	55098 55303 55115	216
2017	Johan Hjort Kristine Bonnevie	2017210 2017620	1005 1001	1115 1107	55001 55201	55118 55326	244

Table 2.2 gives an account of the age material for demersal species sampled from all trawl hauls and Table 2.3 gives the area used in the saithe acoustic abundance estimates with BEAM and the corresponding default area in the StoX kysttokt_strata.txt used for saithe, by Main Areas. The StoX area used for saithe was on average 90% of the area used in BEAM.

Table 2.2. Number of demersal fish measured for age in the Norwegian acoustic coastal survey 2003-2017.

Year	Saithe	Haddock	Cod	Beaked redfish	Golden redfish	Hake	Halibut	Anglerfish
2003	1589	3135	3390					
2004	1415	3784	2539					
2005	1052	1828	1669					
2006	1241	1963	1583					
2007	1184	2066	1183					
2008	1153	1850	1785	13	262		31	31
2009	883	1402	2341	56	138		35	33
2010	1116	1632	2466	9	93		43	28
2011	1009	1325	2056	14	93		93	6
2012	1078	1500	2196	63	226	170	39	17
2013	905	1408	2432	106	255	44	49	7
2014	1139	1710	2632	129	188	122	39	8
2015	1627	1711	2424	179	544	156	39	12
2016	1448	1895	2931	209	577	114	69	23
2017	1612	2314	2653	212	918	192	95	30

Table 2.3. Area (NM^2) used in the saithe acoustic abundance estimation with BEAM in 2003-2016 and corresponding default area in the StoX kysttokt_strata.txt used for saithe, by Main Areas

Year	A 6930-7130	B 6700-6930	C 6330-6700	D 6200-6330	Total
2003	8117.6	8893.0	2149.8	3243.8	22404.2
2004	8552.0	8354.3	2546.4	5171.8	24624.4
2005	9224.8	9041.1	3342.5	4115.6	25723.9
2006	8601.8	8938.8	2546.4	4327.6	24414.7
2007	8601.8	9041.1	2745.3	4327.6	24715.8
2008	9224.8	8219.0	3740.4	4327.6	25511.9
2009	8601.8	6876.8	2944.3	4327.6	22750.6
2010	9224.8	7633.5	2944.3	4327.6	24130.3
2011	8414.9	7161.5	3094.3	4327.6	22998.4
2012	8414.9	7735.5	1750.3	4327.6	22228.3
2013	8626.8	6088.5	2944.3	4327.6	21987.3
2014	9254.8	7625.0	3194.3	4327.6	24401.8
2015	8322.8	7335.0	2746.3	4327.6	22731.8
2016	9254.8	7745.0	2746.3	3986.5	23732.6
StoX saithe	8882.7	6979.2	1783.4	4324.7	21970.0

2.2 Acoustic measurements

The method is explained by Dalen and Nakken (1983), MacLennan and Simmonds (1991) and Nedreaas (1997). The acoustic equipment has been continuously improved. Since the early 1990s Simrad EK500 echo sounder and Bergen Echo Integrator (BEI, Knudsen 1990) were used. The Simrad EK60 echo sounder and the Large Scale Survey System (LSSS, Korneliussen *et al*. 2016) replaced the EK500 and BEI; on R/V "Johan Hjort" since the 2005 survey and on R/V "Helmer Hanssen" since the 2008 survey. Since the 2017 survey both R/V "Johan Hjort" and R/V "Kristine Bonnevie" have used the new Simrad EK80 echo sounder.

In the mid-1990s the echo sounder transducers were moved from the hull to a retractable centreboard, on R/V "Johan Hjort" since the 1994 survey and on R/V "Helmer Hanssen" since the 2008 survey. This latter change has largely reduced the signal loss due to air bubbles in the close to surface layer.

The acoustic backscattering values (s_A) are stored at high resolution in LSSS. After scrutinizing and allocating the values to species or species groups, the values are stored with 10 m vertical resolution and 1 nautical mile (NM) horizontal resolution. The procedure for allocation by species is based on:

- composition in trawl catches (pelagic and demersal hauls)
- the appearance of the echo recordings
- inspection of target strength distributions
- inspection of target frequency responses

For each trawl catch the relative s_A-contribution from each species is calculated (Korsbrekke 1996) and used as a guideline for the allocation. If the trawl catch gives the true composition of the species contributing to the observed s_A value, those catch-based s_A - proportions could be used directly for the allocation. In the scrutinizing process, the scientists should evaluate to what extent these catch-based s_A - proportions are reasonable, or if they should be modified based on knowledge about the fish behaviour and the catching performance of the gear.

The survey area is divided into four Main Areas (A, B, C and D, Fig 2.1). Each area is divided into a number of strata, which is defined from polygons where also a "donut variant" exists, i.e. a stratum completely encloses another stratum. Within each stratum, the acoustic course tracks are divided into transects (Fig. 2.2). For the time series 2003-2016 this was done by first running a R-script tagging all the transects as defined in the Excel spreadsheets applied for acoustic abundance estimation of haddock in the coastal survey (Mehl et al. 2016) and then the transects are inspected and in some cases edited manually in StoX.

The conversion of mean nautical area scattering coefficient (NASC) (m^2 nmi^{-2}) to density of fish followed a standard procedure where at least 3 trawl stations (with a catch of more than 2 individuals of saithe) were assigned to each PSU. As a rule, all stations within a stratum was assigned to the PSUs in the same stratum, however, if less than 3 trawl stations had been carried out in a stratum, stations in neighboring strata were assigned to the PSUs such that at least 3 stations were assigned to each PSU.

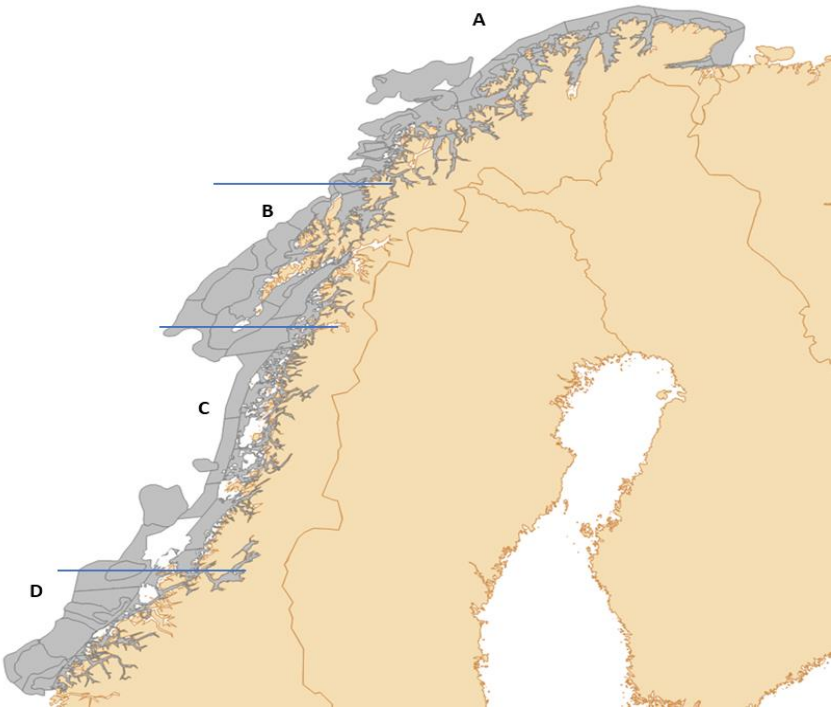

Figure 2.1. Strata and Main Areas (A,B,C and D) used for acoustic estimations with StoX. The Main Areas were also used for acoustic estimations with BEAM.

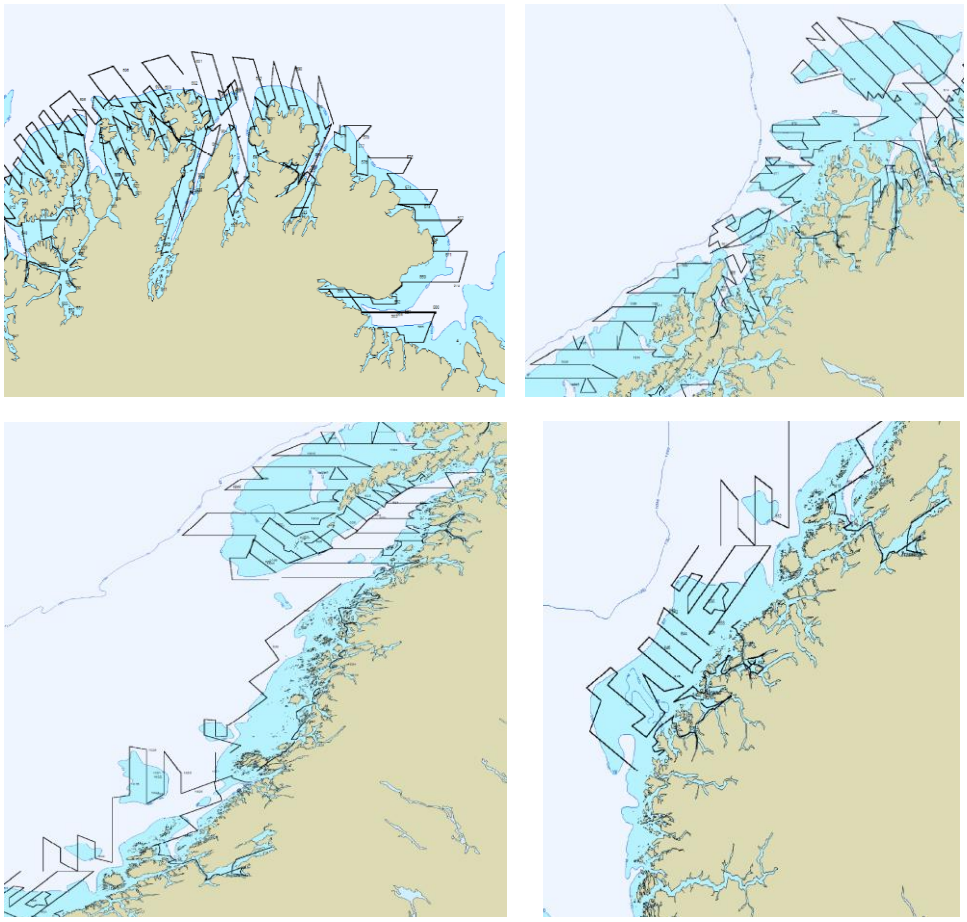

Figure 2.2. Standard transects in the new combined saithe and coastal survey.

The combined length distribution (d) was calculated for each transect (PSU (j)) as:

$$d_{l,j} = \sum_{s=1}^{s} d_{l,s,j}$$

where $d_{l,s,j}$ is density (number by 1 n.mi. tow distance) by 1 cm length group (l) for the stations (s) assigned to PSU (j).

The areal density of fish (ρ) (n per nmi^2) by length group l by transect j was calculated as

$$\rho_{j,l} = \frac{\mathrm{NASC}_{j,l}}{\sigma_l}$$

where $\mathrm{NASC}_{j,l}$ is the mean nautical area scattering coefficient by transect (j) and length group (l) and σ_l is the acoustic backscattering cross-section for a fish of length l.

$\mathrm{NASC}_{j,l}$ is calculated as:

$$\mathrm{NASC}_{j,l} = \mathrm{NASC}_j \frac{\sigma_{l,p}}{\sum_l \sigma_{l,p}}$$

where $\sigma_{l,p}$ is the acoustic backscattering cross-section for a fish of length l multiplied with the proportion (p) of a fish of length l in the total length distribution and NASC_j is the mean nautical area scattering coefficient in transect.

The acoustic backscattering cross-section (m^2) for a fish of length l is calculated as

$$\sigma_l = 4\pi 10^{(\frac{TS_l}{10})}$$

where the target strength, TS, for a fish of length l (cm) is calculated as

$$TS_l = m \log_{10}(l) + a$$

Where m and a are constants. We applied

$$TS = 20 \log(l) - 68$$ (Foote, 1987),

The abundance (N) of saithe by length group (l) for stratum k is:

$$N_{k,l} = \rho_{k,l} A_k ,$$

where A is stratum area and the mean density of saithe of length group l and stratum k is:

$$\rho_{k,l} = \frac{1}{n_k} \cdot \sum_{k=1}^{n_k} w_{kj} \rho_{kj,l}$$

where $w_{kj} = L_{kj} / \overline{L}_k$ (j= 1,2, n_k) are the lengths of the n_k sample transects.

Estimates by length are converted to estimates by age using available age-length data from all selected (filtered) stations for the stratum, weighted by station density. The total biomass is estimated by multiplying the numbers at age by weight at age. The abundance by stratum is then summed for defined main areas (Figure 2.1).

2.3 Sampling of catch and use of age-length data

Sorting, weighing, measuring and sampling of the catch are done according to instructions given in Mjanger *et al*. (2017). Since 1999 all data except age are recorded electronically by Scantrol Fishmeter measuring board, connected to stabilized scales. The whole catch or a representative sub sample of most species was length measured on each station. At each trawl station age (otoliths) were sampled from 5 saithe per 5 cm length-group.

2.4 Estimation of variance

The acoustic survey indices of saithe made with StoX are presented together with an estimate of uncertainty (coefficient of variation; CV). These estimates were made using StoX with a stratified bootstrap routine treating each transect as the primary sampling unit. In addition, a bootstrap routine for all trawl stations by strata is carried out by run.

The estimated CV (Standard Deviation · 100/mean) is estimated from 500 iterations and is strongly dependent on the choice of estimator for the indices.

2.5 StoX input, settings and filters

StoX version 2.5 and Rstox 1.7 was used for estimation of acoustic indices and CVs (http://www.imr.no/forskning/prosjekter/stox/en). R for Windows version 3.4.3 was used in the R calls (https://www.r-project.org/).

Biotic and acoustic XML-files were with a few exceptions downloaded from: http://tomcat7.imr.no:8080/DatasetExplorer/v1/html/main.html.

In **FilterAcoustic, FreqExpr** was set to **frequency=38000**. In **NASCExpr, acocat** was 22 for saithe.

In **NASC and LayerType** was set to **WaterColumn**.

Under **FilterBiotic** and **FishStationExpr**, the following filter were applied: **fs.getLengthSampleCount('SEI') > 2** filtering out stations with less than three specimen (see Johnsen et al. 2016 for more info about filters).

Under **StationLengthDist** and **LengthDistType**, **NormLengthDist** was used, and under **RegroupLengthDis**t and **LengthInterval**, **1.0** is applied.

In **DefineStrata**, **kysttokt_strata.txt**. In **StratumArea** and **AreaMethod**, **Accurate** was applied.

Under **BioStationAssignment** and **AssignmentMethod**, **UseProcessData** was used, i.e. assignments from the KT-program with adjustments for 2003-2016. **EstLayers** was set to **1~PELBOT**.

Under **BioStationWeighting** and **WeightingMethod, SumWeightedCount** was used.

In Acustic**Density**, **m** was set to **20** and a to **-68**.

Under **SuperIndAbundance** and **AbundWeightMethod**, **StationDensity** was used, with **LengthDist** set to **RegroupLengthDist**.

3 Results

3.1 Total echo abundance of saithe

Table 3.1 presents the time series of total echo abundance (echo density multiplied by area) of saithe in the investigated areas for StoX and BEAM estimates, and ratio between StoX and BEAM echo abundance estimates.

Table 3.1. Total echo abundance of saithe in Norwegian acoustic coastal survey 2003-2017 (m^2 reflecting surface $\cdot 10^{-3}$) estimated by StoX and BEAM (until 2016), and ratio StoX/BEAM.

Year	StoX	BEAM	Ratio
2003	1625	1231	1.32
2004	1873	2102	0.89
2005	1179	1348	0.87
2006	1160	1270	0.91
2007	1000	1140	0.88
2008	604	832	0.73
2009	950	1098	0.87
2010	765	973	0.79
2011	533	667	0.80
2012	801	899	0.89
2013	606	736	0.82
2014	719	906	0.79
2015	853	941	0.91
2016	975	1091	0.89
2017	839		

The highest and lowest total echo abundance ratio StoX/BEAM was 1.32 and 0.73, while the average ratio over all years was 0.88. The differences are explained by the differences in areas used, in StoX the areas were on average 90% of the areas used in BEAM (Table 2.3). In 2003 the areas used for the southernmost Area D was 1.33 times higher in the StoX estimates than what was originally used in BEAM. The BEAM areas for Area D was adjusted in 2004. In 2008, the year with the lowest ratio, the BEAM areas in area C was about twice the size of the areas used in StoX. There was a better coverage of Area C in 2008, beyond the saithe standard areas, and this was used in the BEAM estimates in 2008 but not in the present StoX estimates.

3.2 Saithe abundance indices, ratio StoX/BEAM and CVs

Table 3.2.1 presents acoustic abundance indices for saithe age groups 1-15+, where 15+ is the sum of indices for age group 15 and older, in 2003 to 2017. Table 3.2.2 gives the ratio between StoX and BEAM indices by age groups 1-10+, total index and total biomass in 2003 to 2016. The highest and lowest single index ratio for age 2-10+ was 2.59 and 0.25, while the highest and lowest average ratio over all age groups in one year was 1.59 and 0.75, and the highest and lowest average ratio for one age group over all years was 1.17 and 0.83. The overall average index ratio was 0.95, the average total index ratio was 0.91 and the average total biomass ratio was 0.91. Except for 2003 and 2008, the StoX indices are in general about 10% lower than the indices estimated by BEAM. As for the total echo abundance, this is explained by the differences in areas used. In StoX the areas were on average 90% of the areas used in BEAM (Table 2.3). In 2003 the area used for Area D was 1.33 times higher in the StoX estimates than what was originally used in BEAM, while in 2008 the BEAM areas in area C was about twice the size of the areas used in StoX.

Table 3.2.3 presents estimates of coefficients of variation (%) for age groups 1-14. Estimates are based on a stratified bootstrap approach with 500 replicates (with transects being primary sampling unit). A CV of 20 % or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. CVs for age groups 2-5 are at an acceptable level in most years, for age groups 6-7 in less than half of the years while for age group 1 and age groups older than 8 years CVs are above what could be considered as acceptable in all years.

Table 3.2.1. SAITHE. Abundance indices (numbers in millions) from the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates < 0.005.

	Age group																
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
2003	19.8	51.6	128.7	172.1	47.0	8.18	8.03	1.71	1.63	1.17	0.71	0.29	0.16	0.05	0.07	441.3	357.8
2004	0.01	139.8	196.0	114.7	48.2	16.9	4.32	2.23	2.32	0.61	0.90	0.40	0.18	0.06	0.03	526.6	425.4
2005	4.38	18.1	211.5	49.8	16.1	11.9	7.17	1.84	1.11	0.43	0.25	0.25	0	0	0	322.7	262.3
2006	3.46	88.6	42.2	132.1	13.6	4.40	8.91	5.60	2.11	1.07	0.88	0.30	0.26	0.03	0.04	303.5	258.8
2007	2.02	40.3	90.1	25.8	58.3	6.79	4.06	3.83	3.88	0.34	0.67	0.10	0	0	0	236.3	224.2
2008	0.01	50.9	58.2	16.9	8.24	9.85	2.98	0.90	1.37	0.99	0.16	0.25	0	0.03	0	150.8	125.6
2009	0	50.4	97.4	61.5	7.09	4.05	6.11	1.94	1.90	1.38	0.47	0.80	0.19	0	0	233.1	210.0
2010	0.02	7.60	143.0	22.5	17.1	3.95	1.68	3.58	0.43	0.25	0.18	0.30	0.01	0.20	0	200.8	167.1
2011	0	15.2	42.7	59.6	4.61	4.23	1.07	0.81	0.78	0.19	0.03	0.06	0	0	0	129.4	117.7
2012	0.08	68.5	69.0	29.7	18.8	3.48	2.83	0.32	0.58	0.56	0.08	0.05	0	0	0	193.9	148.6
2013	5.02	12.3	77.1	16.5	13.3	11.6	2.19	1.21	0.61	0.39	0.02	+	0.10	0.14	0	140.5	139.1
2014	2.95	28.4	40.1	70.8	8.73	5.62	5.44	1.61	0.55	0.18	0.43	0.10	0	0	0.02	165.0	166.0
2015	0.06	93.5	72.4	22.7	30.1	6.08	4.22	1.85	0.20	0.14	0.07	0.05	0	0	0	231.4	177.6
2016	0.76	72.6	145.7	32.0	10.5	11.2	4.15	2.04	1.46	0.15	0.22	0.12	0.02	0.05	0	281.1	196.0
2017	35.4	23.6	91.1	63.9	13.3	2.76	5.35	2.21	0.62	0.46	0.01	0.02	0.04	0	0.05	238.8	177.2

Table 3.2.2. SAITHE. Ratio new/old acoustic abundance indices and total biomass from the Norwegian coastal acoustic surveys 2003-2016.

	Age group										Total	Biomass
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**		
2003	1.31	1.66	1.47	1.13	1.80	1.32	1.25	1.43	2.33	1.88	1.41	1.41
2004	-	0.92	0.92	0.97	0.98	0.88	0.92	0.75	0.76	0.70	0.93	0.96
2005	4.02	0.81	0.93	0.74	0.79	0.72	0.93	0.84	0.66	1.00	0.88	0.88
2006	0.79	0.90	0.99	0.92	0.70	0.96	1.05	1.00	1.02	0.74	0.93	0.96
2007	0.40	0.89	0.81	0.95	0.95	0.86	0.70	0.93	0.89	1.05	0.88	0.93
2008	0.41	0.92	0.60	0.58	0.60	0.83	0.74	0.84	1.31	0.88	0.70	0.75
2009	-	0.95	0.79	0.79	0.97	0.78	0.91	2.28	2.59	1.69	0.84	0.93
2010	0.08	0.97	0.77	0.73	0.77	0.99	0.88	1.08	1.62	0.65	0.78	0.83
2011	-	1.19	0.91	0.77	0.89	0.74	1.11	0.25	0.39	2.39	0.84	0.80
2012	1.98	0.94	0.69	0.84	0.80	0.92	0.90	1.04	0.79	1.41	0.81	0.86
2013	1.81	0.96	0.68	0.83	1.22	1.04	0.77	0.89	0.80	0.93	0.81	0.86
2014	0.87	1.13	1.00	0.81	0.59	0.65	0.63	0.63	0.50	0.78	0.87	0.81
2015	0.54	1.18	1.00	0.78	0.88	0.81	0.73	0.58	0.59	0.65	1.00	0.92
2016	0.63	1.35	1.08	0.75	0.68	0.70	0.55	0.66	0.70	0.62	1.02	0.88

Table 3.2.3. SAITHE. Estimates of coefficients of variation (%) for acoustic abundance indices from Norwegian coastal acoustic surveys 2003-2017.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2003	0.40	0.23	0.19	0.16	0.15	0.33	0.31	0.23	0.33	0.37	0.50	0.46	0.43	0.97
2004	1.67	0.21	0.19	0.25	0.28	0.28	0.48	0.65	0.32	0.37	0.46	0.47	0.56	0.88
2005	0.54	0.33	0.14	0.21	0.14	0.26	0.28	0.37	0.54	0.80	0.80	0.80	-	-
2006	0.65	0.19	0.33	0.27	0.22	0.31	0.30	0.45	0.40	0.40	0.36	0.58	0.54	0.71
2007	0.35	0.27	0.22	0.19	0.20	0.22	0.36	0.31	0.31	0.37	0.60	0.75	-	-
2008	1.31	0.20	0.20	0.25	0.30	0.17	0.18	0.31	0.33	0.43	0.51	0.41	-	1.08
2009	-	0.39	0.21	0.12	0.28	0.27	0.25	0.39	0.43	0.40	0.55	0.65	0.43	-
2010	1.68	0.32	0.19	0.19	0.20	0.22	0.20	0.27	0.60	0.35	0.75	0.84	1.20	0.76
2011	-	0.23	0.18	0.16	0.24	0.38	0.40	0.48	0.33	1.11	1.04	1.00	-	-
2012	0.68	0.16	0.15	0.18	0.24	0.21	0.34	0.68	0.33	0.60	0.79	1.29	-	-
2013	0.56	0.17	0.12	0.13	0.31	0.19	0.34	0.41	0.42	0.62	1.09	3.11	0.93	0.82
2014	0.73	0.21	0.22	0.24	0.18	0.21	0.18	0.31	0.43	0.56	0.44	0.83	-	-
2015	1.60	0.17	0.16	0.20	0.22	0.26	0.25	0.31	0.30	0.72	0.49	0.58	-	-
2016	2.23	0.17	0.10	0.14	0.17	0.19	0.22	0.30	0.23	0.81	0.84	0.60	0.65	0.58
2017	0.34	0.61	0.13	0.17	0.20	0.34	0.48	0.45	0.39	0.26	0.73	0.94	0.92	-

3.3 Saithe length and weight at age

Tables 3.3.1 and 3.3.2 present the time series of mean length and mean weight at age for age groups 1-14 in the standard saithe area. Age groups with few observations are marked with " + ", while no observations are marked with " - ". Since StoX does not use age-length keys (ALKs) in the traditional sense with an ALK estimated for large areas as done by the BEAM Program, there are differences in length and weight at age for some age groups in some years. However, the overall average ratio StoX/BEAM 2003-2016 was 1.01 for age 1-8 lengths and for age 1-7 weights it was also 1.01.

Table 3.3.1. SAITHE. Length at age in the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates few samples.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2003	26.1	34.0	39.7	44.1	49.0	59.2	63.6	65.9	69.8	75.2	81.8	+	+	+
2004	28.0	32.3	39.9	46.1	53.5	58.2	70.1	76.1	73.4	77.9	76.6	+	+	+
2005	28.0	36.4	39.5	45.6	51.3	59.1	63.0	68.0	70.9	70.4	+	+	-	-
2006	26.2	35.1	40.7	43.4	51.4	57.7	63.9	67.1	70.2	72.4	75.5	+	+	+
2007	27.0	36.2	40.8	46.7	51.0	57.9	65.7	67.8	68.6	72.7	80.9	+	-	-
2008	26.0	36.8	41.6	48.0	52.1	58.4	61.0	67.5	72.3	76.6	+	+	-	+
2009	-	33.8	41.6	47.6	57.9	62.4	66.5	64.7	68.4	74.9	73.0	77.8	+	-
2010	24.2	34.5	38.4	47.1	57.4	61.0	65.0	66.9	68.9	75.8	+	+	+	+
2011	-	36.8	41.7	44.7	56.7	62.8	69.5	65.7	76.0	+	+	+	-	-
2012	29.0	36.4	42.3	47.3	51.6	60.5	66.5	71.8	66.9	79.5	82.9	87.0	-	-
2013	26.0	36.7	41.1	48.7	55.2	60.0	68.8	74.5	75.3	75.4	78.8	+	+	+
2014	24.3	35.8	44.0	46.7	54.8	60.6	61.4	72.3	76.6	80.2	79.3	85.8	-	-
2015	29.3	34.7	41.1	48.8	53.6	60.0	65.8	71.5	+	+	+	+	-	-
2016	28.5	33.2	38.8	47.1	54.1	60.0	67.0	70.5	72.5	81.8	+	+	+	+
2017	25.1	32.6	39.9	45.7	53.5	63.7	69.6	69.6	69.8	73.1	+	+	+	-

Table 3.3.2. SAITHE. Weight at age in the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates few samples.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2003	169	391	569	828	1144	2104	2482	2923	3543	4348	6017	+	+	+
2004	230	338	622	920	1495	1951	3510	4462	4276	4715	4588	+	+	+
2005	233	500	626	898	1290	2044	2459	2951	3595	3202	+	+	-	-
2006	178	433	682	794	1357	1882	2600	2926	3464	3948	4413	+	+	+
2007	188	471	649	927	1235	1783	2592	2911	2935	3633	4761	+	-	-
2008	193	459	636	986	1274	1846	2140	2817	3633	4243	+	+	-	+
2009	-	376	690	1010	1828	2374	2879	2636	2973	4050	3344	3771	+	-
2010	146	409	556	1016	1814	2227	2624	2851	3116	4363	+	+	+	+
2011	-	503	735	853	1744	2267	3302	2598	4524	+	+	+	-	-
2012	240	456	682	954	1212	1907	2481	3088	2448	4573	4783	4870	-	-
2013	171	481	690	1097	1551	2050	3170	3799	4020	3840	5044	+	+	+
2014	135	445	826	1006	1538	2096	2201	3428	4269	4679	4762	5647	-	-
2015	237	380	624	1042	1361	1955	2674	3390	+	+	+	+	-	-
2016	227	338	518	944	1422	2009	2730	3411	3690	5757	+	+	+	+
2017	142	335	576	882	1477	2511	3165	3277	3246	3576	+	+	+	-

4 Conclusions

The StoX acoustic estimates deviates somewhat from those obtained by the BEAM Program, mainly due to the use of different strata areas (10%) in the two methods.

It is recommended that the present time series of acoustic abundance indices for the period 2003-2017 obtained by StoX become the “official” time series that are used for stock assessment and other purposes. It is further recommended that StoX is used to estimate acoustic indices with CVs from future coastal surveys. At present indices for age groups 3-7 are used in the assessment model. The CV estimates indicates that indices of saithe older than 7 years should not be used for assessment purposes, and it should be investigated how the CVs of age groups 6-7 could be reduce through a better survey design. However, cohort plots show that the survey tracks a year class reasonably well beyond age 7 (Figure 4.1), and the next benchmark assessment for Northeast Arctic saithe should investigate this further.

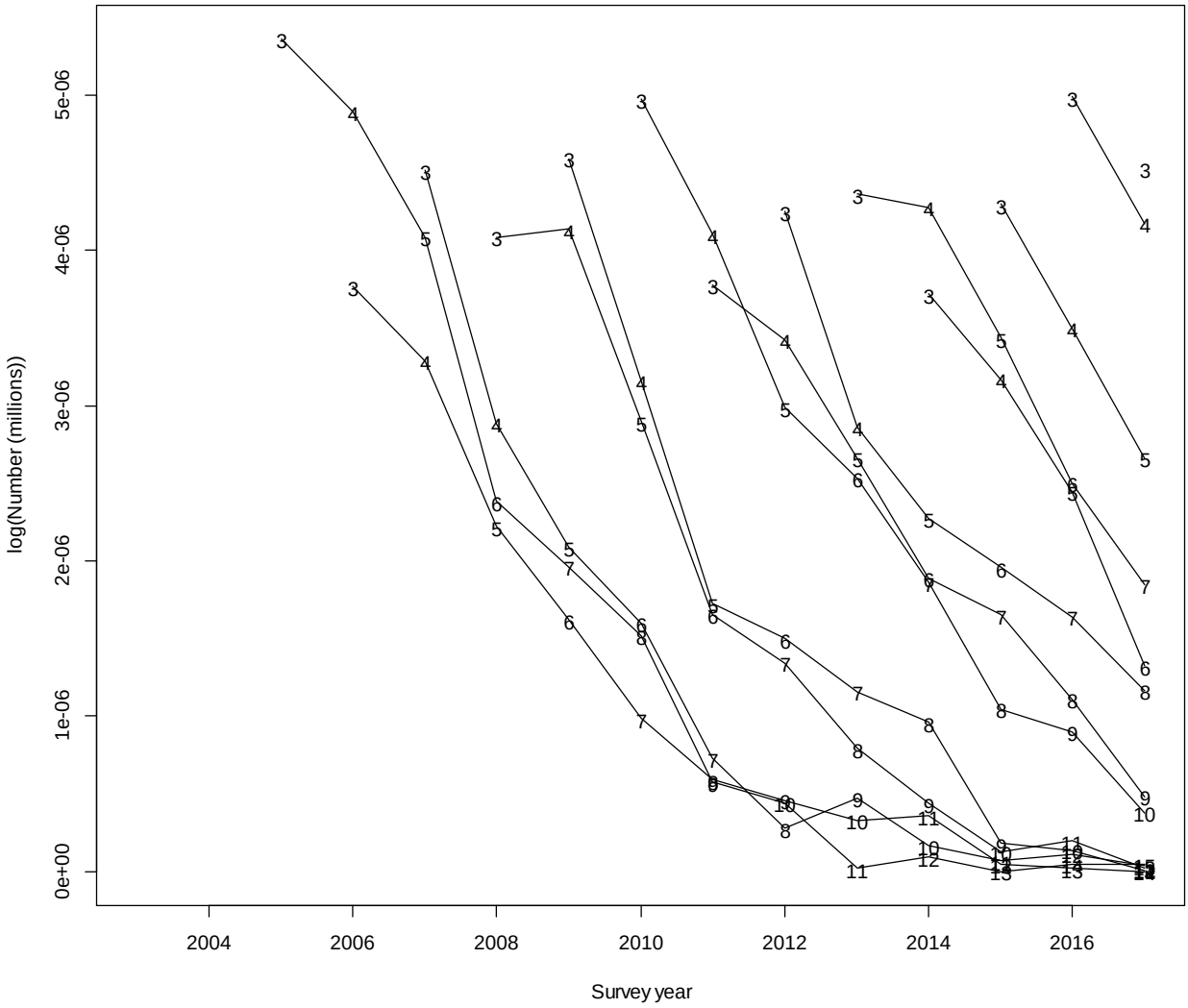

Figure 4.1. Log abundance curves for each cohort of Northeast Arctic saithe age 3–14 from the Coastal Surveys in 2005-2017.

5 References

Dalen, J. and Nakken, O. 1983. On the application of the echo integration method. ICES CM 1983/B: 19, 30 pp.

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. Journal of the Acoustical Society of America, 82: 981-987.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A. J. and Dingsør, G. 2016. StoX Reference Guide. Version 20161003. Havforskningsinstituttet, Institute of Marine Research. 167 p. (http://www.imr.no/forskning/prosjekter/stox/documentation/en).

Jolly, G. M., & Hampton, I. (1990). A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences*, *47*(7), 1282-1291.

Knudsen, H.P. 1990. The Bergen Echo Integrator: an introduction. - Journal du Conseil International pour l'Exploration de la Mer, 47: 167-174.

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., & Eliassen, I. K. (2016). Acoustic identification of marine species using a feature library. *Methods in Oceanography*, *17*, 187-205.

Korsbrekke, K. 1996. Brukerveiledning for TOKT312 versjon 6.3. Intern program dokumentasjon., Havforskningsinstituttet, september 1996. 20s. (upubl.).

MacLennan, D.N. and Simmonds, E.J. 1991. Fisheries Acoustics. Chapman Hall, London, England. 336pp.

Mehl, S, Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2016. Akustisk mengdemåling av sei, kyst-torsk og hyse Finnmark – Møre hausten 2016. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2016. Toktrapport/Havforsknings-instituttet/ISSN 1503-6294, Nr. 15 – 2016. 38s.

Mjanger, H., Svendsen, B.V., Fotland, Å., Mehl, S., Salthaug, A. 2017. Håndbok for prøvetaking av fisk og krepsdyr. Versjon 4.0. Januar 2017. (In Norwegian).

Nedreaas, K.H. 1997. Evaluation of the North-East Arctic saithe (Pollachius virens) acoustic survey. ICES CM 1997/Y:20.

Totland, A. and Godø, OR. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. In T. Nishida, P.R. Kailola and C.E. Hollingworth (Eds): Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science. Fishery GIS Research Group. Saitama, Japan.

6 Appendix 1. Annual survey reports 2003-2016

Berg, E., Korsbrekke, K. og Mehl, S. 2003. Akustisk mengdemåling av sei, kysttorsk og ungsild Finnmark – Møre, hausten 2003. Acoustic abundance of saithe, coastal cod and juvenile herring Finnmark – Møre Autumn 2003. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294/Nr. 23 – 2003. 23s.

Berg, E., Korsbrekke, K., Mehl, S. og Nybakk, A. 2004. Akustisk mengdemåling av sei, kysttorsk og ungsild Finnmark – Møre, miljøundersøkingar i fjordar, hausten 2004. Acoustic abundance of saithe, coastal cod and juvenile herring Finnmark – Møre Autumn 2004. Toktrapport/Havforskningsinstituttet/ ISSN 1503-6294/Nr. 22 – 2004. 25s.

Aglen, A., Berg, E., Mehl, S. og Sunnanå, K. 2005. Akustisk mengdemåling av sei, kysttorsk og ungsild Finnmark – Møre hausten 2005. Acoustic abundance of saithe, coastal cod and juvenile herring Finnmark – Møre Autumn 2005. Toktrapport, Havforskningsinstituttet, ISSN 1503-6294, Nr. 23 – 2005. 20s

Aglen, A., Berg, E., Mehl, S. og Sunnanå, K. 2007. Akustisk mengdemåling av sei, kysttorsk og ungsild Finnmark – Møre hausten 2006. Acoustic abundance of saithe, coastal cod and juvenile herring Finnmark – Møre Autumn 2006. Toktrapport, Havforskningsinstituttet, ISSN 1503-6294, Nr. 1 – 2007. 23s

Aglen, A., Berg, E., Mehl, S. og Sunnanå, K. 2008. Akustisk mengdemåling av sei, kysttorsk og ungsild Finnmark – Møre hausten 2007. Acoustic abundance of saithe, coastal cod and juvenile herring Finnmark – Møre Autumn 2007. Toktrapport, Havforskningsinstituttet, ISSN 1503-6294, Nr. 1 – 2008. 24s.

Aglen, A., Berg, E., Mehl, S. og Sunnanå, K. 2009. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2008. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2008. Toktrapport, Havforskningsinstituttet. ISSN 1503-6294/Nr. 5 -2009. 29s.

Mehl, S, Berg, E. og Aglen, A. 2009. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2009. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2009. Toktrapport, Havforskningsinstituttet, ISSN 1503-6294, Nr. 11 – 2009. 29s.

Mehl, S, Aglen, A og Berg, E. 2010. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2010. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2010. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 9 – 2010. 29s.

Mehl, S, Aglen, A, Berg, E. og Korsbrekke 2011. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2011. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2011. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 2 – 2011. 30s.

Mehl, S, Berg, E. Dingsør, G. and Korsbrekke, K. 2012. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2012. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2012. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 5 – 2012. 32s.

Mehl, S, Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2013. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2013. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2013. Toktrapport/Havforsknings-instituttet/ISSN 1503-6294, Nr. 3 – 2013. 33s.

Mehl, S, Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2014. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2014. Acoustic abundance of saithe, coastal cod and haddock Finnmark–Møre Autumn 2014. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 1 – 2014. 38s.

Mehl, S, Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2015. Akustisk mengdemåling av sei, kysttorsk og hyse Finnmark – Møre hausten 2015. Acoustic abundance of saithe, coastal cod and haddock Finnmark–Møre Autumn 2015 Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 4 – 2015. 38s.

Mehl, S, Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2016. Akustisk mengdemåling av sei, kyst-torsk og hyse Finnmark – Møre hausten 2016. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2016. Toktrapport/Havforsknings-instituttet/ISSN 1503-6294, Nr. 15 – 2016. 38s.

Retur: Havforskningsinstituttet, Postboks 1870 Nordnes, NO-5817 Bergen

HAVFORSKNINGSINSTITUTTET
Institute of Marine Research
Nordnesgaten 50 – Postboks 1870 Nordnes
NO-5817 Bergen
Tlf.: +47 55 23 85 00 – Faks: +47 55 23 85 31
E-post: post@imr.no

www.hi.no

HAVFORSKNINGSINSTITUTTET