Stichting Wageningen Research
Centre for Fisheries Research (CVO)

Evaluation of otolith collection

generic evaluation method and case study BTS plaice

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Summary

During many seagoing activities otoliths from fish are collected. These bony structures are used to identify the age of fish, as age of fish cannot be determined externally.

Otoliths are collected according to a stratified scheme that may vary depending on survey, species, and length class. The origin of the number of otoliths to be collected is often unknown. Given that otolith collection is costly and labour intensive, and each fish is counted as an experimental animal, it is important to evaluate the otolith sampling scheme.

In this study we developed a generic methodology to (a) define the required number of otoliths per length group for age-length keys used in stock assessment, and (b) evaluate the current data collection by species and propose modifications to the sampling plans.

The generic methodology was applied to the plaice (*Pleuronectes platessa*) data from the Dutch beam trawl survey (BTS) in the North Sea. One of the important findings was the need for a spatial split based on longitudinal ranges to ensure comprehensive coverage of age groups. An updated sampling scheme, without over-all otolith reduction, but with a re-division of otolith collection over the sampling area, and an aggregation by length groups instead of centimeter classes was implemented during BTS 2024.

From autumn 2024 to mid-2025, the new BTS plaice sampling scheme will be evaluated, and the generic methodology will be extended to other species in BTS, and in the Sole net survey and Demersal young fish survey conducted by the Netherlands.

1 Introduction

During the fisheries surveys and other seagoing ecosystem research, otoliths from fish are collected to identify the age of fish. The age distributions from these samples, combined with age information from marketed fish, are extrapolated to estimate the age structure of the fish stock. To optimise the extrapolation, sampling is stratified by length groups, allowing age structure to be determined for each length class.

The stratification scheme for collecting otoliths may vary by survey, species, and length class. Even though there are standard protocols describing this scheme, the actual number of otoliths needed is often not initially known. The stratification schemes per survey have often been set at the start of a survey (in 1970's ot 1980's), and are rarely reviewed. As otolith collection is costly and labour intensive, and each fish is counted as an experimental animal, over-sampling is not desirable. Therefore, we evaluated the optimal number of otoliths needed for reliable stock assessment.

In 2021, De Boois & Bleeker, evaluated the otolith collection scheme for plaice and sole in the Dutch Sole net survey (SNS) and Demersal young fish survey (DYFS). However, the methodology used in 2021 included many not-automated actions. For this reason it was not easily adaptable to other surveys or species, prompting the need for further development of the approach.

The objectives of the current study were:

1. To develop a generic methodology to determine the required number of otoliths per length group for age-length keys used in stock assessment.
2. To evaluate the current data collection by species and propose modifications to the current sampling plans.

The work focused on the case study of 'Plaice in the Dutch Beam trawl survey (BTS)', as sufficient data were available for evaluation. Additionally, plaice is one of the target species of the BTS, and is caught in the entire sampling area (North Sea).

2 Sampling plan evaluation and re-design; methods and results

2.1 Analysis of current sampling programme

For the analysis of the current sampling scheme, plaice catches and individual age-length data from the Dutch beam trawl survey (BTS) for the years 2012-2022 were extracted from the ICES Database on trawl surveys (DATRAS[1]).

To model the proportional age-length distribution, a random sample of fish by length (L) was taken from the catches, followed by a subsample of fish for age determination (A) (Annex 1). Early in the evaluation, it appeared that the length at age for plaice was considerably different for plaice in the western and eastern North Sea (Figure 2.1, Figure 2.2). This finding aligns with the observations of age readers and applies to other species as well. The 3°E was chosen as the dividing line based on the logistics of the BTS sampling programme.

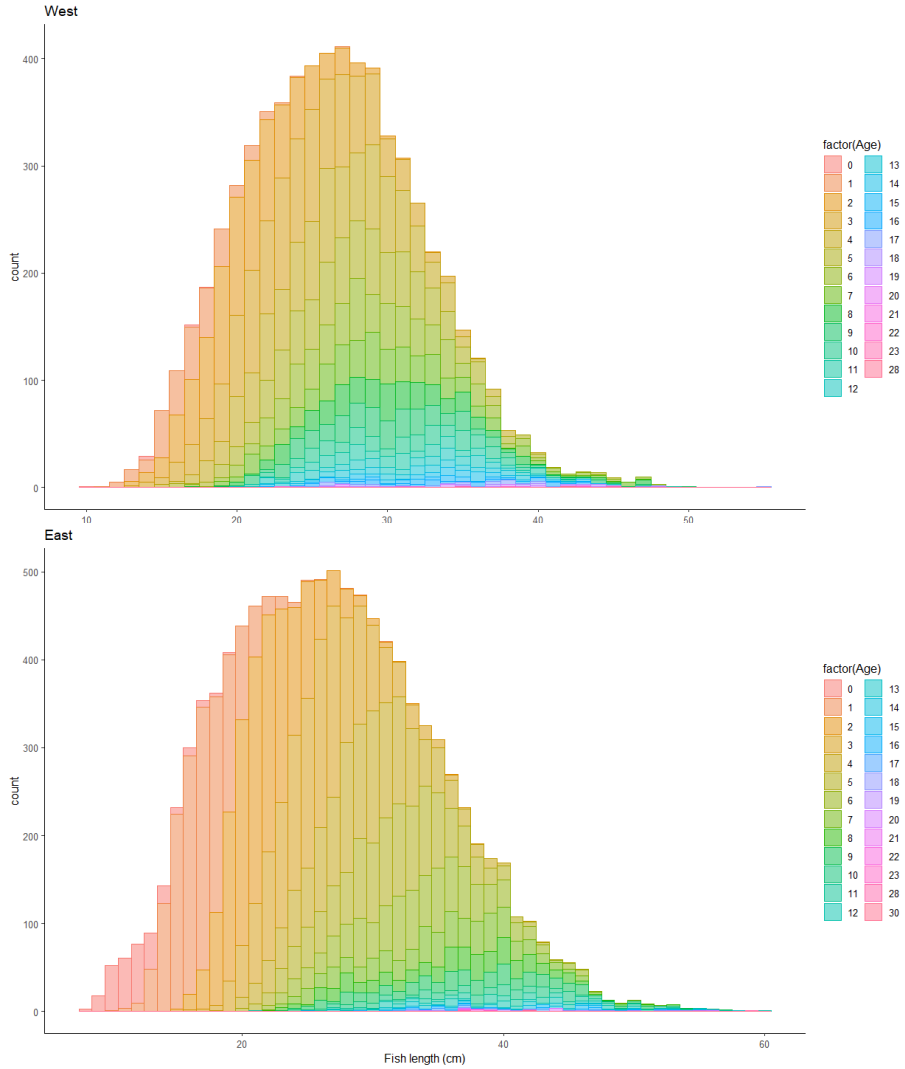

Figure 2.1. Age-length distribution for plaice 2012-2022. A total of 6,408 fish sampled for age reading in the 3°E west part of North Sea (upper histogram), aged ranging from 0- to 28-year-old. A total of 10,682 fish, aged ranging from 0- to 30-year-old in the 3°E east at the North sea (lower histogram).

[1] ICES 2024. Database on Trawl Surveys. DATRAS (ices.dk)

Since the number of samples that can be collected is limited, the recommended strategy in fisheries surveys is to minimize the coefficient of variation (CV) by optimizing the sampling scheme. Currently, there is no target CV for BTS. To get an idea of the absolute lowest CV possible with the existing stratification, we calculated the CV using data from all years 2012-2022, separately for the regions west and east of 3°E (Table 2.1, Figure 2.3).

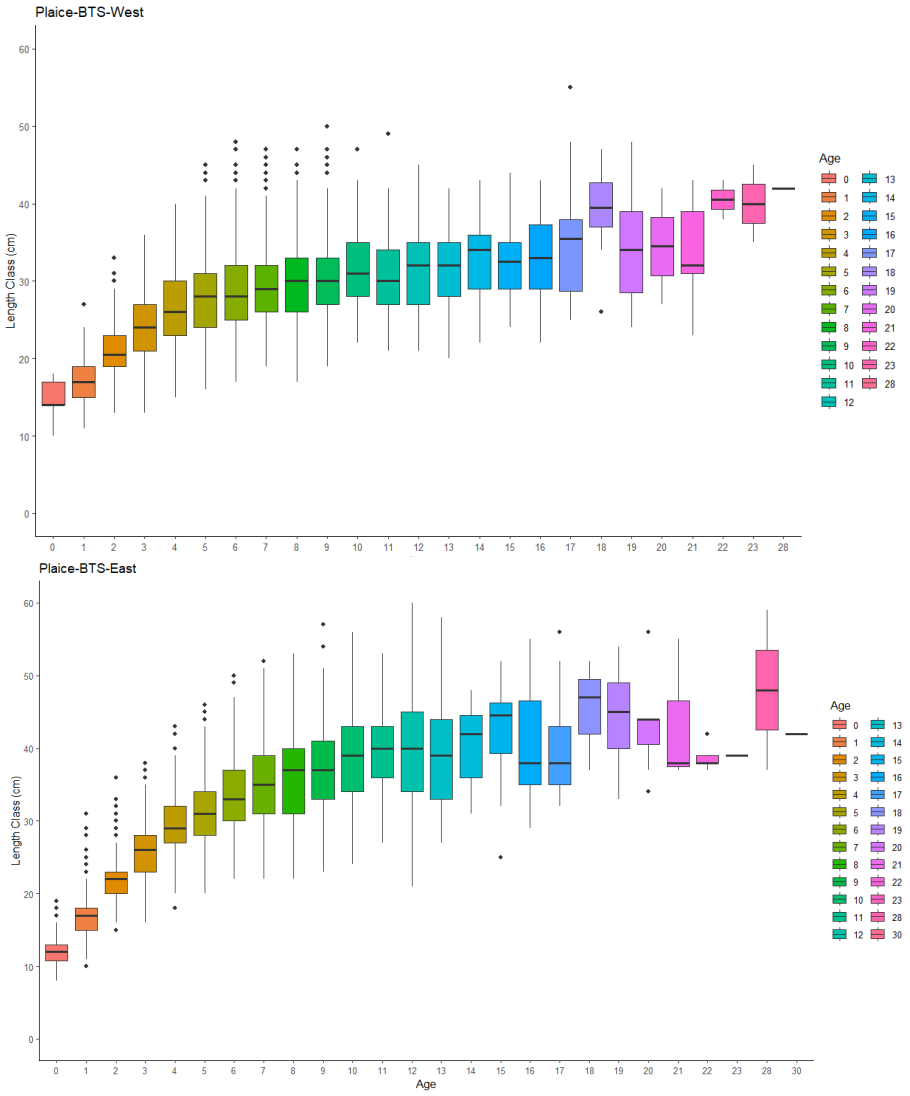

Figure 2.2. Boxplot of age-length distribution for plaice, BTS 2012-2022, including confidence intervals. Upper panel: North Sea west of 3° E, lower panel: North Sea east of 3°E.

$$\widehat{\theta_a} = \sum_l \widehat{\alpha_l}\widehat{\theta_{la}} \equiv \sum_l r_{la}$$

Proportion of age (a) fish; $\alpha_{l(\text{hat})} = L/L$

$$V_a = \sum_l \widehat{\alpha_l}\widehat{\theta_{la}}(1-\widehat{\theta_{la}})$$

Variance within length intervals for proportional allocation

$$B_a = \sum_l \widehat{\alpha_l}(\widehat{\theta_{la}} - \widehat{\theta_a})^2$$

A variance component between length intervals

$$\mathrm{SE}^2 = \frac{V_a}{A} + \frac{B_a}{L}$$

Variance

$$\mathrm{CV}^2 = \left(\frac{V_a}{A} + \frac{B_a}{L}\right)/\widehat{\theta_a^2}$$

CV = Coefficient of variation

Figure 2.3 Calculation of the coefficient of variation (CV) (Terrance et al., 1999)

Table 2.1 CV for the current BTS age sampling scheme for plaice in year 2021 for the target age groups for plaice in the BTS. NB: ages above 10 are considered as 10+ group, age 0 fish is not considered as target group in this survey.

Age	CV west	CV east
1	0.11	0.03
2	0.07	0.08
3	0.06	0.07
4	0.13	0.21
5	0.14	0.18
6	0.19	0.37
7	0.19	0.48
8	0.26	0.42
9	0.25	0.68
10	0.34	0.93

2.2 Designing a new sampling programme

2.2.1 Scenarios

The sampling scheme for BTS plaice up to 2023 is in Annex 2 (Table A.2.1). The number of plaice otoliths collected in the current BTS sampling programme (approx. 2,000 per year) was taken as a maximum. Four new sampling plans were proposed (Annex 2, Table A.2.2) for the target age groups (1-10 years) and length classes, with the following maximum number of otoliths:

a. Same number of otoliths as the current plan (approx. 2,000), but reallocated between the areas west and east of 3°E, and redistributed across length groups;
b. Otolith reduction of 12.5% compared to scenario a (approx. 1,750 otoliths in total);
c. Otolith reduction of 25% compared to scenario a (approx. 1,500 otoliths in total);
d. Otolith reduction of 50% compared to scenario a (pprox. 1,000 otoliths in total).

For all scenarios, CVs were calculated using the BTS dataset from 2012-2022. For each sampling unit (rectangle*length group), the number of planned fish was randomly taken out of the dataset based on the aggregated BTS data from 2012-2022 (11 years). The likelihood of selecting fish from a particular length group was proportional to the number of fish found in that group. Age of the fish was then assigned proportionally for each length class, And the total number of otoliths was sampled accordingly for each scenario.

CVs were calculated using the methodology of Terrance and Deriso (1999) (Figure 2.3; Annex 3 Table A3.1). Due to the selection process and missing records for small and large fish, it was not always possible to calculate a CV , especially the case for small plaice in the west, where few aged fish were available in the 10-14 cm range and above 40 cm.

A CV of 0.25 for the target age groups per sampling area was considered as an appropriate benchmark for the sampling scheme. Another objective was to optimise the CVs compared to the current sampling programme, focusing on the target age groups (1-10) for plaice in the BTS.

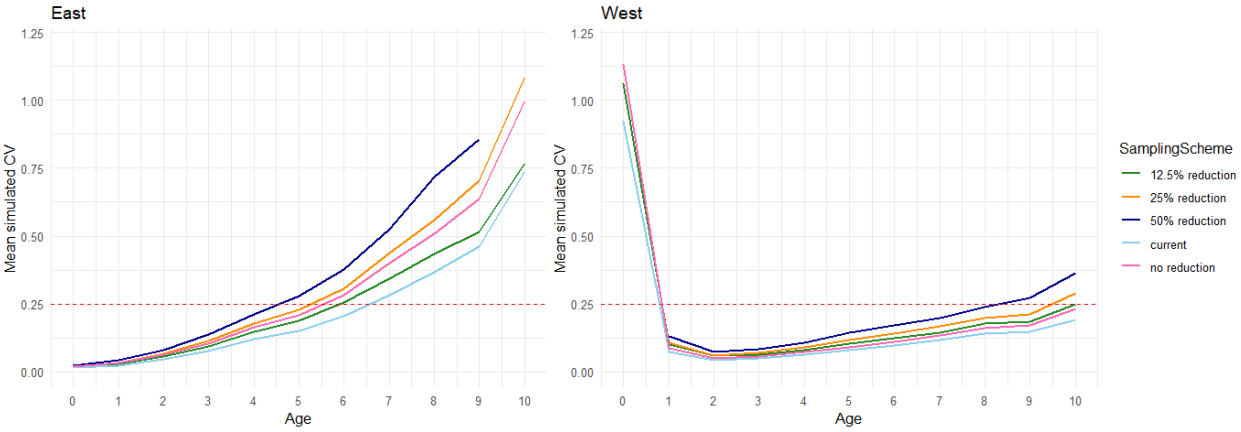

Figure 2.3 CVs of current sampling and by scenario by age; scenario's redividing otolith collection over the sampling area (no reduction); 12.5% reduction; 25% reduction; 50%reduction.

2.2.2 *Refinement*

The first version of the new BTS sampling plan with approx. 12.5% otolith reduction (Annex 2, Table A.2.3) was created based on two aspects:

a. The CVs of the scenarios to set the required number of otoliths;
b. The maximum number of fish that could theoretically be collected, to check if the required number of otoliths would be less than or equal to the realistic estimate of available fish for age sampling. The number was based on a long-term average of the otolith collection.

CVs (Table 2.2) were calculated in line with previous calculations.

Table 2.2 CVs for version 1 of the BTS sampling plan. NA=no data. Grey fields: CV > 0.25

age	Netherlands North Sea BTS west of 3°E	Netherlands North Sea BTS east of 3°E
1	0.08	0.03
2	0.05	0.07
3	0.06	0.11
4	0.09	0.18
5	0.10	0.30
6	0.12	0.38
7	0.15	0.48
8	0.18	0.46
9	0.18	0.76
10	0.23	1.59

The CVs of version 1 were compared to the CVs of the scenarios (Annex 3, Table A3.1), and to the CVs of the current sampling plan (Table 2.1). Based on the comparison, the second version of the BTS sampling plan was created (Annex 2, Table A.2.4), and the CVs were calculated (Table 2.3).

Table 2.3 CVs for version 2 of the BTS sampling plan. NA=no data. Grey fields: CV > 0.25

age	Netherlands North Sea BTS west of 3°E	Netherlands North Sea BTS east of 3°E
1	0.11	0.03
2	0.06	0.06
3	0.08	0.09
4	0.08	0.14
5	0.11	0.19
6	0.12	0.25
7	0.15	0.35
8	0.20	0.45
9	0.18	0.51
10	0.33	0.69

2.3 New sampling plan

Based on the CVs of version 2 of the sampling plan, a final proposal was created, and implemented during BTS 2024: up to 12.5% overall reduction of otoliths, aggregation of otoliths by length group, and a split of the scheme for West and East of 3° E (Table 2.4).

Table 2.4 Sampling plan for BTS plaice 2024; numbers per rectangle, approx. 12.5% reduction of otoliths (200 fish)

		Netherlands North Sea BTS west of 3°E	Netherlands North Sea BTS east of 3°E
aggregation	cmgroups	b modified	b modified
per 10 cm class	5-14	1	1
per 5 cm class	15-19	2	1
per 5 cm class	20-24	3	3
per 5 cm class	25-29	3	4
per 5 cm class	30-34	3	4
per 5 cm class	35-39	3	4
per 1 cm class	>= 40	2	5

3 Discussion

3.1 Spatial split

Early in the evaluation, it appeared that the length at age for plaice was considerably different for plaice in the western and eastern North Sea. This finding aligns with the observations of age readers and applies to other species as well. The 3°E was chosen as the dividing line based on the logistics of the BTS sampling programme. While it is possible that age at length differences for plaice exist on a smaller spatial scale, the sampling scheme must remain practical and achievable during the survey.

The spatial split of sampling schemes may lead to misinterpretation by data users: it may imply that there are different stocks. In this case, the spatial split in the sampling schemes should be treated as optimisation of the insight in the age distribution of the species in the area.

3.2 Choice of scenario

An otolith reduction of 12.5% was considered a reasonable amount to start with. On one hand, from an animal welfare perspective, it is good to minimize the number of otoliths collected. On the other hand, reducing the number of fish sampled for otolith collection also decreases the amount of information available on other biological parameters, such as individual weight, sex ratio, and sexual maturity. The impact of this reduction on the overall data quality and its usage is hard to foresee.

3.3 Iterative development of new sampling programme

As it was the first time a survey otolith data collection programme was evaluated using a model-based approach, some steps were done based on insights that arose during the study. In future evaluations (see also chapter 4), some steps may be skipped, adopting a more straightforward, stepwise model-based approach. However, it remains very important to have a thoroughly examine the outputs at each step, such as spatial consistency of the age-length distribution and CV values by age group. The biology of the fish, and the catchability of a species by a survey gear may change over time, and could severely affect the evaluation outcomes.

3.4 External evaluation

The evaluation method was presented at the ICES Working group on improving use of Survey data for assessment and advice (WGISDAA) as part of the reviewing process. The sampling design should be considered as length stratified design instead of proportionally sampling. This is because, for fish over 40 cm, a higher proportion of individuals were sampled. However, the simulation was mainly based on proportionally sampling design.

The CV for each age-length relation varies depending on sampling scheme design. In eastern North Sea (east of 3°E), the CVs are generally higher for fish aged 5 and older in comparison to the western North Sea (west of 3°E). This is because fish size are in a wider range in east of 3°E. Therefore, in the east, increasing the number of otoliths collected from the length group 20 cm to 39 cm could significantly reduce the CV, even when the total number of otoliths are collected is less than in the west.

The method from Jourdain *et al*. (2020) was highly recommended to be considered as a reference method, which took into account the number of otolith per 5-cm-length group per haul, area-based age-length key, and haul-based age-length keys. Although recommended, it differs largely from the method used in this study, so it has not been applied.

4 Proposed future evaluation set-up

It is strongly advised that data users and survey experts are involved in evaluations of sampling programmes. A sampling plan is always a result of a theoretical starting point, but it also has to be manageable in the field, so practical implementation is an important aspect. Furthermore, the prime data user should be aware of a potential effect of a changed sampling scheme.

It is advised that future evaluations are run following this setup:

1. Evaluation of the length at age distribution, visualised by histograms and age sample tables with a few tentative fixed CVs (similar to the Annex tables A1.3 and A1.4). The age sample tables provide an overview of the desired CVs and estimated number of otoliths to be collected in order to reach precision of the age composition estimation. Note: If a histogram is too unclear (e.g. many age groups on low lengths, or contradictory to expert judgement), splitting up in a regional manner may be necessary. For the North Sea, probably a split between west and east, or maybe north and south, is relevant for some species.
2. Calculation of CVs by age group of the current sampling schemes.
3. Design max. 4 new sampling schemes based on length groups. If the update of the sampling scheme encompasses re-aggregation of areas and/or length groups, it is recommended to at least also prepare a sampling scheme with the same number of otoliths per survey, but divided in a different manner to improve homogeneity or reduce the variability within the sub areas. Other scenario's may include reduction of the number of otoliths. In this step, it is necessary to take the length ranges caught in the survey into account, and check if it is likely that the planned amount by length group may be caught in a survey, e.g. by taking into account the catches of the last five to ten years of the survey catches. Keep in mind that a sampling scheme should also be achievable on board, so keep length groups or spatial data collection areas as constant as possible.
4. Calculate the CVs for all designed scenarios.
5. Choose the most appropriate scenario, based on CV, achievability, and also take into account the other biological data collection that may be affected by the change of the sampling scheme. If there is no optimal sampling scheme, use information from the evaluated schemes, and update the scheme that fits best to the needs.
6. Inform the people collecting, processing and reading the otoliths, as well as the prime data users about the upcoming change and its rationale.
7. Evaluate the data collection after the first, third and fifth year, by taking into account all perspectives: people collecting, processing and reading the otoliths as well as prime data users. If needed, change the sampling scheme after three years. It is not recommended to change after the first year, as one year may not fully show the effect of the changed scheme. Only of the new sampling scheme leads to immediate problems for prime users, it should be changed sooner.

5 Future steps

The future steps will take place between autumn 2024 and summer 2025, depending on available budget and personnel. For steps 3-8 approximately 200 hours will be needed. The other activities are covered in exisiting projects and tasks.

	Topic	survey	Species	When	What	Reporting
1	Evaluation of sampling scheme 2024	BTS	plaice	October 2024	Evaluation of: • experiences of otolith data collectors, processors and age readers; • data (total number of otoliths, division of otoliths over age groups, CVs related to modelled cv).	In Cruise report BTS 2024
2	Present methodology	BTS	Plaice	October, November 2024	Present, possibly use and if needed further develop methodology in ICES working groups WGISDAA in October 2024 and WGNSNETSEA in November 2024	WGISDAA report WGNSNETSEA report
3	Evaluation of CVs	SNS	Plaice, Sole	Autumn 2024-Spring 2025	Apply step 1 and 2 (Chapter 4) to the previous (up and until 2021) and current (2022-2023) and evaluate if CVs are lower than 0.25 for target age groups (1-4)	Over-all report on the evaluation and potential change of the sampling schemes. This is necesasary to be able to refer to the background of the changes, also in future.
4	Evaluation of CVs	DYFS	Plaice, Sole	Autumn 2024-Spring 2025	Apply step 1 and 2 (Chapter 4) to the previous (up and until 2021) and current (2022-2023) and evaluate if CVs are lower than 0.25 for target age groups (0-1)	
5	Evaluation of CVs	BTS	Sole	Autumn 2024-Spring 2025	Apply step 1 and 2 (Chapter 4) to the current sampling scheme, and evaluate	

	Topic	survey	Species	When	What	Reporting
					if there is a reason to re-design the sampling scheme (e.g. spatially), and if CVs are lower than 0.25 for target age groups (1-4)	
6	(Re-)design sampling scheme	BTS, SNS, DYFS	Plaice, Sole	Autumn 2024-Spring 2025	Depending on outcomes actions 3-5	
7	Redesign sampling scheme	BTS	Dab, Lemon sole, Long rough dab	Autumn 2024-Spring 2025	Apply all steps from Chapter 4 to the current Netherlands sampling scheme, and design a sampling scheme by rectangle, if possible by reducing the numbers of otoliths.	
8	Redesign sampling scheme	SNS, DYFS	Dab	Autumn 2024-Spring 2025	Apply all steps from Chapter 4 to the current Netherlands sampling scheme and design a sampling scheme in line with the scheme for plaice and sole, if possible by reducing the numbers of otoliths.	
9	Present methodology	BTS, SNS, DYFS	Plaice, Sole, Dab, Lemon sole, Long rough dab	March 2025	Present, possibly use and further develop methodology in WGBEAM in March 2025. Agree on new sampling schemes, update international manuals.	WGBEAM report
10	Implement new sampling schemes	BTS, SNS, DYFS	Plaice, Sole, Dab, Lemon sole, Long rough dab	Surveys 2025	Implement new sampling schemes in Reisplan, update CVO_h_003.	Cruise plans 2025 CVO_h_003 (Handboek Bestandsopnamen op het zoute water)

6 Quality assurance

6.1 Data used

The data used for the study is retrieved from the ICES data portal DATRAS. Data is quality checked using standardised scripts at WMR (Damme *et al*., 2024; de Boois *et al*., 2023). Upon submission to DATRAS also quality checks (e.g. length-weight) are conducted.

Otolith processing and age reading follow the WMR handbook Leeftijdsbepalingen (Pennock *et al*., 2024). Age reading of otoliths is conducted by trained age readers for the species. All age readers participate in international exchanges and workshops to maintain consistent age reading across countries.

6.2 Data extraction and modelling

6.2.1 General comments

Data extraction was done by using library DATRAS to extract data from http://datras.ices.dk.

All the process was performed with RStudio 4.2.1.

Due to technical issues the scripts could not yet be properly synchronized in WUR gitlab. Currently, the scripts are available at the WMR network drive W:\IMARES\IJmuiden\WOT\WOT Surveys Zout - BTS\projectorganisatie\bemonsteringsprogramma\evaluatie_snijmonsters\Otoliths optimisation\R\scripts. The scripts will be made available via WUR gitlab as soon as possible.

6.2.2 External evaluation

The evaluation method was presented at the ICES Working group on improving use of Survey data for assessment and advice (WGISDAA) as part of the reviewing process.

6.3 ISO certificate

CVO is certified to ISO 9001:2015 (certificate number: 268632-2018-AQ-NLD-RvA). This certificate is valid until December 15th, 2027. The certification was issued by DNV Business Assurance B.V

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Terrance, J. Q., & Deriso, R. B. (1999). Quantitative fish dynamics.

Justification

CVO Report: 24.004
Project number: 4311211071

The quality of this report has been peer reviewed by a colleague scientists and the head of CVO.

Approved by:	S. Sakinan Researcher
Signature:	
Date:	22 November 2024
Approved by:	Ing. S.W. Verver Head Centre for Fisheries Research
Signature:	
Date:	22 November 2024

Annex 1 Age samples needed a set CV

Table A.1.1. Based on BTS plaice from 2012 to 2022 for east of 3°E, the age sample size, A, needed to achieve particular values of the coefficient of variation (CV) for a particular age. The example of the number of age sample sizes achieving a coefficient of variation (CV) of 0.1 and a CV of 0.25 from age 0 to age 15. The numbers in bold are achievable with the corresponding length measurement, showing the numbers of age measurement to have accurate estimated ages with particular CV.

Year 2012-2022		Objective CV = 0.1			Objective CV = 0.25		
		L = 1,000	L = 2,500	L = 5,000	L = 1,000	L = 2,500	L = 5,000
Age	0	**26**	**23**	**22**	**4**	**4**	**4**
Proportional allocation	1	**91**	**82**	**80**	**13**	**13**	**13**
	2	**463**	**402**	**386**	**62**	**61**	**60**
	3	1419	**1131**	**1059**	**168**	**163**	**161**
	4	5258	3327	**2964**	**465**	**442**	**435**
	5	13367	6230	5288	**822**	**768**	**751**
	6	86035	13253	10338	1585	**1439**	**1397**
	7	-73147	31983	21570	3241	2826	**2710**
	8	-57500	59192	35307	5228	4433	**4220**
	9	-57047	116857	57960	8425	6907	6516
	10	81661	81660	81660	13066	13066	13066
	11	186937	186937	186937	29910	29910	29910
	12	166177	166176	166176	26589	26589	26589
	13	338847	338846	338846	54216	54216	54216
	14	759176	759175	759175	121469	121469	121469
	15	1035044	1035044	1035044	165607	165607	065607

Table A.1.2. Based on BTS plaice from 2012 to 2022 for west of 3°E, the age sample size, A, needed to achieve particular values of the coefficient of variation (CV) for a particular age. The example of the number of age sample sizes achieving a coefficient of variation (CV) of 0.1 and a CV of 0.25 from age 0 to age 15. The numbers in bold are achievable with the corresponding length measurement, showing the numbers of age measurement to have accurate estimated ages with particular CV.

Year 2012-2022		Objective CV = 0.1			Objective CV = 0.25		
		L = 1,000	L = 2,500	L = 5,000	L = 1,000	L = 2,500	L = 5,000
Age	0	-11998	-227316	45627	5887	4019	3635
Proportional allocation	1	**599**	**516**	**494**	**78**	**77**	**76**
	2	**277**	**271**	**268**	**43**	**43**	**43**
	3	**366**	**363**	**362**	**58**	**58**	**58**
	4	**666**	**657**	**654**	**104**	**104**	**104**
	5	1142	**1113**	**1104**	**176**	**176**	**175**
	6	1739	**1663**	**1640**	**262**	**260**	**259**
	7	2550	**2420**	**2379**	**379**	**376**	**375**
	8	3774	3503	**3422**	**545**	**539**	**537**
	9	4294	3951	**2848**	**612**	**605**	**603**
	10	9397	7971	7587	1202	**1175**	**1167**
	11	11635	10197	9793	1555	**1526**	**1516**
	12	14619	12142	11493	1819	**1774**	**1760**
	13	25750	20103	18734	2957	2865	**2835**
	14	134224	40662	32995	5087	4679	**4557**
	15	42571	42571	42571	6811	6811	6811

Table A.1.3. BTS Plaice, west of 3°E. Age sample sizes (A) needed to achieve particular values of the CV for a particular age, and summary age sample sizes achieving a CV of 0.1 for at least one age and a CV of 0.25 for important ages, for 5,000 measured fish. The number of length measurements (L) in this sampling area is 6,000 to 8,000 per year.

Year 2010-2022		**Objective: CV = 0.1**	**Objective: CV = 0.25**
	Age	L = 5,000	L = 5,000
Proportional allocation	1	2,164	302
	2	568	89
	3	442	70
	4	534	85
	5	753	120
	6	1,030	164
	7	1,349	215
	8	1,715	273
	9	2,053	325
	10	2,790	439

Table A.1.4. BTS Plaice, east of 3°E. Age sample sizes, A, needed to achieve particular values of the CV for a particular age, and summary age sample sizes achieving a CV of 0.1 for at least one age and a CV of 0.25 for important ages, for 5,000 measured fish. The number of length measurements (L) in this sampling area is 20,000 to 30,000 per year.

Year 2010-2022		**Objective: CV = 0.1**	**Objective: CV = 0.25**
	Age	L = 5,000	L = 5,000
Proportional allocation	1	300	45
	2	400	62
	3	463	73
	4	581	92
	5	714	113
	6	1,016	160
	7	1,537	241
	8	1,971	308
	9	2,858	442
	10	4,602	700

Annex 2 Tested scenario's

Table A.2.1 Sampling scheme until 2023 for plaice Netherlands North Sea BTS

		BTS
aggregation	cmgroups	number of fish
per 1 cm class	5-39	1
per 1 cm class	>= 40	2

Table A.2.2 Number of fish per cm group for four scenario's:

a. Same number of otoliths as the current plan (approx. 2,000), but re-divided over west and east of 3°E, and otolith collection re-divided over length groups;
b. Otolith reduction of 12.5% compared to scenario a (approx. 1,750 otoliths in total);
c. Otolith reduction of 25% compared to scenario a (approx. 1,500 otoliths in total);
d. Otolith reduction of 50% compared to scenario a (pprox. 1,000 otoliths in total).

		Netherlands North Sea BTS west of 3°E				**Netherlands North Sea BTS east of 3°E**			
aggregation	cmgroups	a	b	c	d	a	b	c	d
per 10 cm class	5-14	1	1	1	1	1	1	1	1
per 5 cm class	15-19	3	3	2	1	2	2	1	1
per 5 cm class	20-24	4	4	3	2	3	2	3	1
per 5 cm class	25-29	4	4	3	2	3	3	3	2
per 5 cm class	30-34	5	4	3	2	4	3	3	2
per 5 cm class	35-39	5	4	2	2	4	3	3	2
per 1 cm class	>= 40	2	1	1	1	1	1	1	1

Table A.2.3 Number of fish per cm group, proposed sampling scheme North Sea BTS, version 1

aggregation	cmgroups	**Netherlands North Sea BTS west of 3°E**	**Netherlands North Sea BTS east of 3°E**
per 10 cm class	5-14	1	1
per 5 cm class	15-19	2	1
per 5 cm class	20-24	4	3
per 5 cm class	25-29	5	4
per 5 cm class	30-34	3	4
per 5 cm class	35-39	2	3
per 1 cm class	>= 40	1	3

Table A.2.4 Number of fish per cm group, proposed sampling scheme North Sea BTS, version 2

aggregation	cmgroups	**Netherlands North Sea BTS west of 3°E**	**Netherlands North Sea BTS east of 3°E**
per 10 cm class	5-14	1	1
per 5 cm class	15-19	2	1
per 5 cm class	20-24	3	3
per 5 cm class	25-29	3	4
per 5 cm class	30-34	3	4
per 5 cm class	35-39	2	4
per 10 cm class	40-50	2	5

Annex 3 Modelled CVs for tested scenario's

Table A3.1 CVs by scenario; a=redividing otolith collection over the sampling area; b=12.5% reduction compared to a; c=25% reduction compared to a; d=50%reduction compared to a. NA=no data. Grey fields: CV > 0.25

	Netherlands North Sea BTS west of 3°E				**Netherlands North Sea BTS east of 3°E**			
age	CV a	CV b	CV c	CV d	CV a	CV b	CV c	CV d
1	NA	0.529915	0.631597	NA	0.012105	0.013043	0.017594	0.016604
2	0.073626	0.076323	0.087958	0.093533	0.025092	0.027203	0.033232	0.032950
3	0.046538	0.049488	0.060502	0.063293	0.063786	0.072363	0.064359	0.087064
4	0.051938	0.060102	0.068551	0.089577	0.102973	0.110223	0.110469	0.147660
5	0.075332	0.088957	0.099372	0.093919	0.181467	0.182278	0.177001	0.210430
6	0.106457	0.104812	0.121451	0.149852	0.255801	0.300348	0.24789	0.381315
7	0.138142	0.119092	0.150892	0.153573	0.318740	0.382633	0.328032	0.392724
8	0.151506	0.149921	0.190322	0.208788	0.407963	0.478740	0.465621	0.754386
9	0.176155	0.176944	0.251384	0.304192	0.492760	0.458048	0.638078	0.540728
10	0.181049	0.183305	0.211711	0.340798	0.702432	0.762772	0.818750	1.440995