Rådgivning om bestandsvurdering og TAC for hjertemuslingefiskeri for sæsonen 2024-2025

RÅDGIVNINGSNOTAT FRA DTU AQUA

Til:	Fødevareministeriet, Kontoret for Bæredygtigt Fiskeri
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Anmodning

DTU Aqua anmodes om at udarbejde et forslag til en bæredygtig kvote for hjertemuslinger i Limfjorden for sæsonen 2024-2025.Kvoterådgivningen kan, som i tidligere udarbejdede notater, baseres på en samlet faglig vurdering, hvor de seneste gennemsnitlige landinger pr. sæson bidrager til estimering af kvoten.

DTU Aqua bedes benytte samme model for bestandsundersøgelse og kvoterådgivning som i 2023, jf. vedhæftede rådgivning fra 2023 (journal nr. 23-1009397) og vedhæftede DTU Aqua-notat (journal nr. 24/1003540), punkt 6, side 4 og "option A", side 5.

Resumé

Dette notat præsenterer DTU Aquas vurderinger og anbefalinger i forhold til at fastlægge en kvote for hjertemuslingefiskeriet i Limfjorden for 2024/25 sæsonen. Rådgivningen er givet som en samlet faglig vurdering baseret på de nyeste landingsdata for hjertemuslinger, "blackbox" data og undersøgelser af bestanden i forår-sommer 2024 i muslingeområderne Kås Bredning (MO 9), Salling Sund (syd og nord, MO 11 og 13) og Sønder Bredning (MO 15).

I sæsonen 2023-2024, blev der blev landet 1,875 tons hjertemuslinger i Limfjorden, hvilket er 13.8% under den af Ministeriet for Fødevarer, Landbrug og Fiskeri, Bæredygtig Fiskeri (FVM) udstedte kvote. Landingerne er de lavest siden 2013-2014. Fiskeriet foregik udelukkende på en banke i hovedfiskeriområdet MO 9.

I forhold til den foregående sæson i Kås Bredning (MO 9) faldt det befiskede areal med 43%, mens fiskeriintensiteten (SAR) steg med 9% og fangsteffektiviteten (fangst pr. indsatsenhed, CPUE) steg med 12%. Reduktionen i befisket areal og stigningen i fiskeriintensiteten er sandsynligvis et resultat af flere faktorer: En lav TAC, fraværet af alternative hjertemuslingebanker og fiskeri over en kort periode (7 uger).

I foråret-sommeren 2024 blev hjertemuslingebiomassen i de fire fiskeriområder MO 9, 11, 13 og 15 estimeret til 26.907 tons, hvilket er en markant stigning i forhold til 2023-undersøgelsen. Størstedelen af biomassen med 55% eller 14.693 tons lå dog i område MO 11, mens det historisk vigtigste fiskeriområde MO 9 kun tegnede sig for 26% eller 7.103 tons.

Der blev observeret klare beviser for en betydelig vellykket rekruttering til bestanden i sommeren 2023 i de fire undersøgte områder og hjertemuslingebestandene var næsten udelukkende (99%) 1 år gamle, det vil sige indgik i bestanden i sommeren 2023.

Hjertemuslingerne var i foråret-sommeren 2024 små, idet 86 % af hjertemuslingerne var mindre end minimumsreferencestørrelsen (MRS) på 16 mm skalbredde. Kun i MO 9 (56%) og i mindre grad i MO 13 (31%) var en signifikant andel større end MRS, men kun med få mm. Derfor er den høstbare biomasse (dvs. den fraktion, der er større end MRS) kun 6.907 tons, hovedsagelig i MO 9 på 3.999 tons.

Anbefaling

DTU Aqua anbefaler fortsat en forsigtig tilgang til hjertemuslingefiskeriet i Limfjorden for den kommende sæson 2024-2025 i betragtning af den lave høstbare biomasse i alle undersøgte områder, de generelt små hjertemuslinger og den totale afhængighed af en enkelt 1-årig kohorte.

DTU Aqua anbefaler en TAC på 2.012 tons med en fangstprocent på 33% for de fire fiskeriområder, der blev undersøgt i 2024. Forvaltningen bør kraftigt overveje at begrænse fiskeriet i Salling Sund syd (MO 11) for at beskytte den store og rigelige bestand med en meget stor andel af hjertemuslinger, der er mindre end MRS, og som sandsynligvis vil være det vigtigste produktionsområde i de kommende sæsoner 2025-2026 og/eller 2026-2027.

DTU Aqua kan ikke foreslå TAC'er for ikke-undersøgte områder, da forekomsten og strukturen af hjertemuslingebestanden i disse områder er ukendt. Disse områder kan dog indeholde betydelige hjertemuslingebestande, og FVM kan overveje at tillade hjertemuslingefiskeri i ikke-undersøgte områder efter de overvejelser, der er angivet i notatet.

Contents

1. Introduction

This notat presents DTU Aqua recommendations toward establishing sustainable catch limits for cockle fishing in the Limfjorden in the coming 2024-2025 season, under specific quotas and harvest rules separate from blue mussel fishing as established in 2023 (Notat jnr 2021-153, Bæredygtigt Fiskeri, Ministeriet for Fødevarer, Landbrug og Fiskeri, FVM).

DTU Aqua recommendations for catch limits (Total Allowable Catch, TAC) in the Limfjorden cockle fishery for the coming 2024-2025 season, as in previous years, are based on expert evaluation of two sources of information:

- Fishery dependent information:
    a. Spatial and temporal patterns of cockle landing statistics in recent fishing seasons.
    b. Fishing patterns of the blue mussel/cockle fishery and associated landings obtained from black box (BB) and Elogs (BB - BlackBox R2, Anchor Lab, Copenhagen; Fiskeristyrelsen).
    c. Information about fishing activity, catches and cockle distribution from the fishery association, Foreningen Muslingeerhvervet (FME).
- Fishery independent information:
    d. Spring 2024 stock assessment of cockle populations in the recent four main fishing areas (produktionsområder for muslinger, MO) Kås Bredning (MO 9), Salling Sund syd (MO 11) and nord (MO 13) and Sønder Bredning (MO 15).
    e. The short timeseries of cockle population status, distribution and size-age structure in 2021, 2022, and 2023.

2. Cockle Limfjorden fishery: Status after the last 2023-2024 season

Landings

In the season 2023-2024, cockle fishing occurred only during 7 weeks in the last week of February, in the month of March and first 9 days of April 2024 due to a prolonged renewal process of licenses.

1,875 tonnes live weight of cockles were landed in the Limfjorden (Figure 1 and Table 1). Landings in 2023-2024 were (Figure 1 and Table 1):

- 86.6% of the TAC of 2,165 tonnes for areas MO 9, 11, 13 and 15 (Notat DTU Aqua jnr. 23-1009397; Notat FVM, jnr 2021-153).
- 0.9% of the TAC of 884 tonnes for areas other than MO 9, 11, 13 and 15 (Notat DTU Aqua jnr. 23-1009397; Notat FVM, jnr 2021-153).

- The lowest landings since 2013, following two seasons with the highest and third highest landings.
- 24.5% of mean landings of 7,663 tonnes (±633 tonnes, SE) between 2017 to 2023.

Lower landings in 2023-2024 resulted from the first mandatory TAC for the Limfjorden cockle fishery implemented by FVM in 2023.

The 2023-2024 TAC was low relative to previous mean landings per season due to the low cockle biomass and lack of recruitment observed in the 2023 survey (Notat DTU Aqua jnr. 23-1009397).

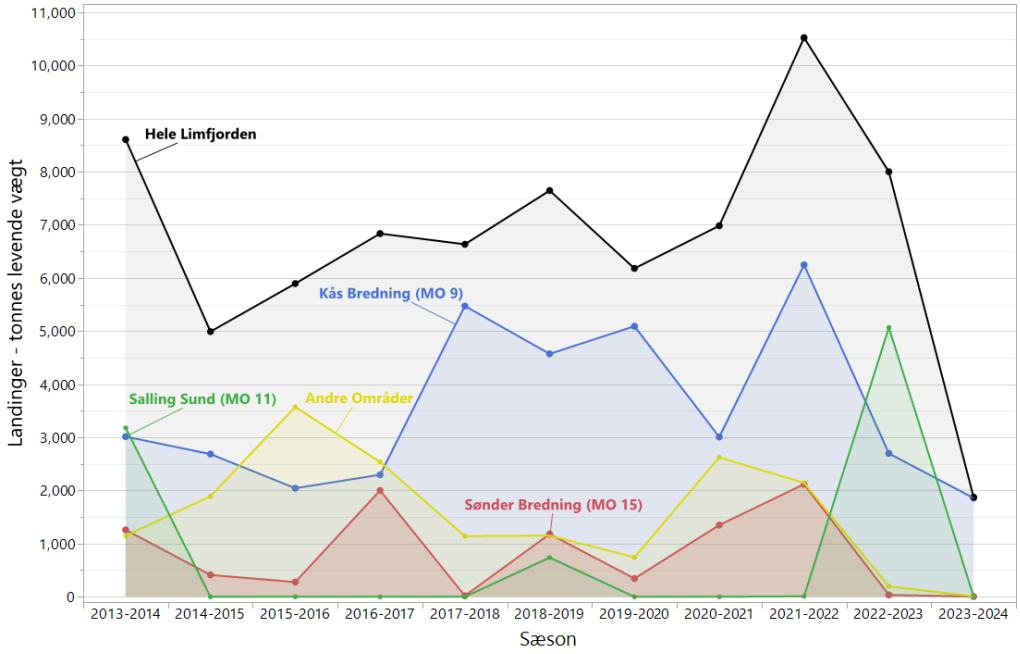

Figure 1. Cockle landings (tonnes live weight) per fishing season from the Limfjorden: total landings from all areas (black); Kås Bredning (MO 9; blue); Salling Sund syd (MO 11; green); Sønder Bredning (MO 15; red); and from other areas (yellow). Data from Fiskeri-styrelsen.

Cockle landings in 2023-2024 were almost entirely from a single area (ca. 99%), the main fishing area of MO 9, with only residual landings from MO 15 and MO 11 and other fishing areas (8 tonnes from Thisted Bredning syd MO 30; Figures 1 and 2, Tables 1 and 2).

Table 1. Limfjorden cockle landings (tonnes of live weight) per fishing area (muslingeområder, MO) and season (September-June) since 2013. Data from Fiskeristyrelsen.

	Fishing Season											
Fishing Area	2023-2024	2022-2023	2021-2022	2020-2021	2019-2020	2018-2019	2017-2018	2016-2017	2015-2016	2014-2015	2013-2014	All
Kås Bredning (9)	1,860	2,699	6,250	3,009	5,093	4,574	5,474	2,298	2,044	2,687	3,016	39,005
Sønder (15)	5	36	2,120	1,350	345	1,182	19	2,003	278	412	1,261	9,010
Salling syd (11)	2	5,068	11	0	0	739	0	0	0	0	3,181	9,000
Visby (25)	0	15	9	0	621	9	72	2,466	1,342	0	0	4,534
Livø Vest (35)	0	7	15	6	13	19	27	34	1,334	1,465	947	3,867
Venø Bugt (7)	0	0	642	1,636	0	1,096	4	0	0	0	0	3,379
Venø Bugt (8)	0	0	0	946	97	28	1,016	0	8	0	0	2,094
Salling nord (13)	0	172	1,289	0	0	0	0	0	0	0	0	1,461
Andre områder	8	4	1809	37	14	0	24	37	891	429	203	1,837
Total	1,875	8,001	10,524	6,985	6,182	7,647	6,636	6,838	5,897	4,993	8,608	74,186

Table 2. Relative landings in percentage of total landings from the Limfjorden per fishing area (muslingeområder, MO) for the last three seasons 2023-2024, 2022-2023 and 2021-2022, reference seasons (2017-2018 to 2021-2023), the first four seasons (2013-2014 to 2016-2017) and all seasons (2013 to 2024).

Fishing Area	2023-2024	2022-2023	2021-2022	2017-2023	2013-2017	All
	%	%	%	%	%	%
Kås Bredning (9)	**99.2**	33.7	59.4	58.9	38.1	52.6
Sønder Bredning (15)	**0.3**	0.5	20.1	11.0	15.0	12.1
Salling Sund syd (11)	**0.1**	63.3	0.1	12.7	12.1	12.1
Salling Sund nord (13)	**0**	2.1	12.3	3.2	0	2.0
Visby Bredning (25)	**0**	0.2	0.1	1.6	14.5	6.1
Livø Bredning Vest (35)	**0**	0.1	0.1	0.2	14.4	5.2
Venø Bugt nord (7)	**0**	0	6.1	7.3	0	4.6
Venø Bugt syd (8)	**0**	0	0	4.5	0	2.8
Other areas	**0.4**	0.1	1.8	0.6	5.9	2.5

The concentration of landings from a single area is interpreted by DTU Aqua, based on results from the 2023 and 2024 surveys and information from FME, to be due to both low cockle biomass and small cockle size in other fishing areas (i.e. MO 11, 13 and 15 or other), and the decision by the fishery not to fish some areas with small cockles that settled the previous summer of 2023 (i.e. MO 11 and 13).

Fishing patterns

Cockle fishing in 2023-2024 was done almost entirely from a single bed in MO 9, roughly corresponding to a bed fished for the third consecutive season (Figure 2), with ca. 25% overlap relative to the previous season (Figure 2 and Table 3). Thus, only fishing in MO 9 is discussed here.

Fished area was smaller than in the previous season (Figure 2 and Table 3), either as bed area (52%), total dredged area (39%; including track overlap) or bottom footprint dredged area (43%; excluding track overlap).

Fishing intensity (SAR, number of times a unit area was dredged) was 3.7 (±0.12, 95% CI) and higher than in the previous season by 9.3% (Table 3) likely due to two factors: 1) fishing occurred on a single bed; and 2) the available time for the fishery to fulfil the TAC was limited to 7 weeks.

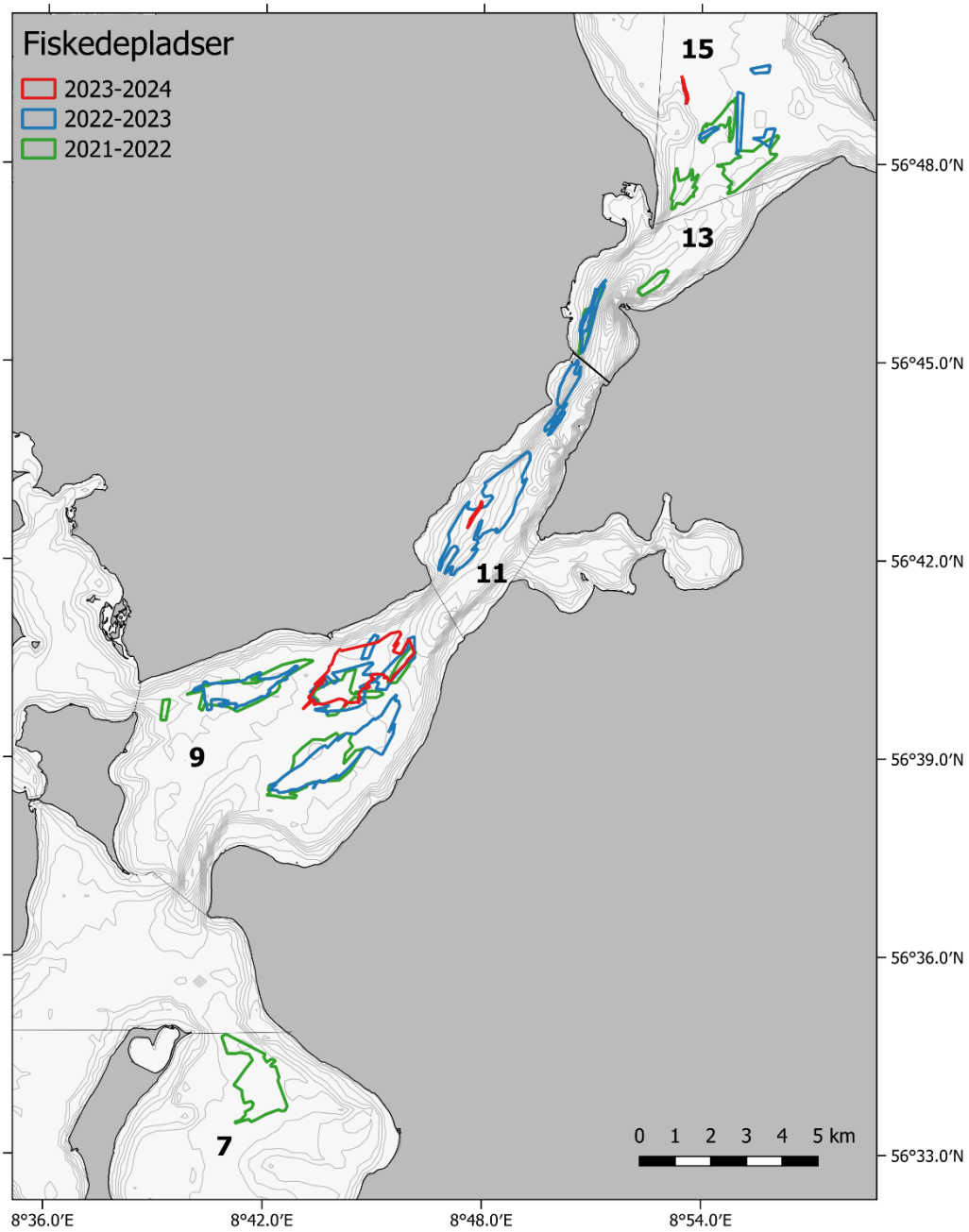

Figure 2. Location of fished cockle beds in the last season of 2023-2024 (red) and the two previous seasons (2022-2023 in blue; 2021-2022 in green) in Venø Bugt (MO 7), Salling Sund syd and nord (MO 11 and 13), Kås Bredning (MO 9) and Sønder Bredning (MO 15). Locations determined from blackbox data and fishing information provided by FME.

Table 3. Fished cockle beds in the 2023-2024 season and the previous 2022-2023 season: number and area of fished beds; % of fishable area dredged (> eelgrass depth limits and excluding N2000 areas); number of dredge tracks per bed area; total dredged area (includes overlap of tracks); bottom footprint dredged area (excludes track overlap); fishing intensity as swept area ratio (SAR, number of times a unit area was dredged); CPUE as landings per total dredged area (tonnes/km^2); and overlap between fished beds in 2023-2024 and the previous season.

Season	2023-2024								2022-2023								Overlap		
	Beds			Dredged Area					Beds			Dredged Area							
Fishing Area	Number	Area (km^2)	Tracks/ km^2	Total (km^2)	Bottom footprint (km^2)	Fishing intensity	% Fishable Area	CPUE (tonnes/ km^2)	Number	Area (km^2)	Tracks/ km^2	Total (km^2)	Bottom footprint (km^2)	Fishing intensity	% Fishable Area	CPUE (tonnes/ km^2)	Number beds	Area of beds (km^2)	%
Kås Bredning (9)	1	2.9	1,339	12.8	3.0	4.3	8.5	145	5	6.1	904	20.6	5.3	3.9	12.0	130	3	1.5	25
Sønder Bredning (15)	1	0.3	51	0.03	0.02	1.5	0.08	169	4	0.2	1,567	0.2	0.2	1,3	0.06	150	0	0	0
Salling Sund syd (11)	1	0.5	30	0.14	0.05	2.7	0.5	15	2	3.3	2,020	18.7	3.0	6.2	24.1	270	1	0.03	1
Salling Sund nord (13)									1	0.3	1,012	0.7	0.2	3.7	2.0	231			
Total	3	3.8	1,063	13.0	3.1	4.2	4.2	144	12	9.9	1,295	40.3	8.6	4.7	8.9	197	4	1.6	16

Catch rate (catch per unit effort, CPUE) averaged 145 tonnes/km^2 dredged in 2023-2024, higher than in the previous season by ca. 11.5% (Table 3), even if fishing intensity was higher.

Initially the fishery targeted a small but abundant area of the bed as observed in the 2023 survey (Notat DTU Aqua 23-1009397; Figure 3) resulting in a catch of 275 tonnes obtained at a high CPUE of 272 tonnes/km^2 in February. In March (Figure 3), fishing covered a larger area, producing most of the catch at 1,137 tonnes but at a low CPUE of 122 tonnes/km^2. In April, fishing occurred partially in new areas (Figure 3) interpreted as a decision by the fishery to fish small young cockles settled in the previous summer of 2023 (size and age data from catch samples and 2024 survey). In April, 448 tonnes were obtained at an intermediate CPUE of 178 tonnes/km^2.

Regarding spatial variation, fishing intensity, catches and catch rate (CPUE) all showed spatial asymmetry (Figure 4): 50% of fishing intensity was on 0.87 km^2 or 22.9% of fished area; while 50% of catches were captured from only 0.58 km^2 or 15.2% of fished area; and the highest 50% of CPUE occurred in 1.11 km^2 or 29.1% fished area (Figure 4).

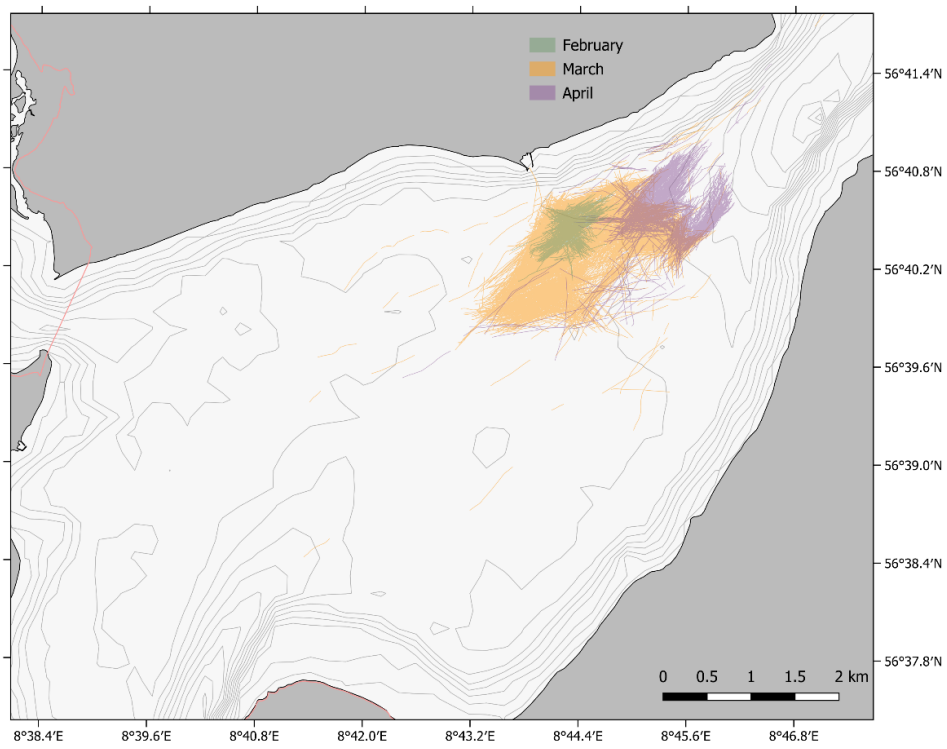

Figure 3. Location of fished tracks from blackbox data in Kås Bredning (MO 9) in each month of 2023-2024 season: last week of February (green), March (orange) and April (purple).

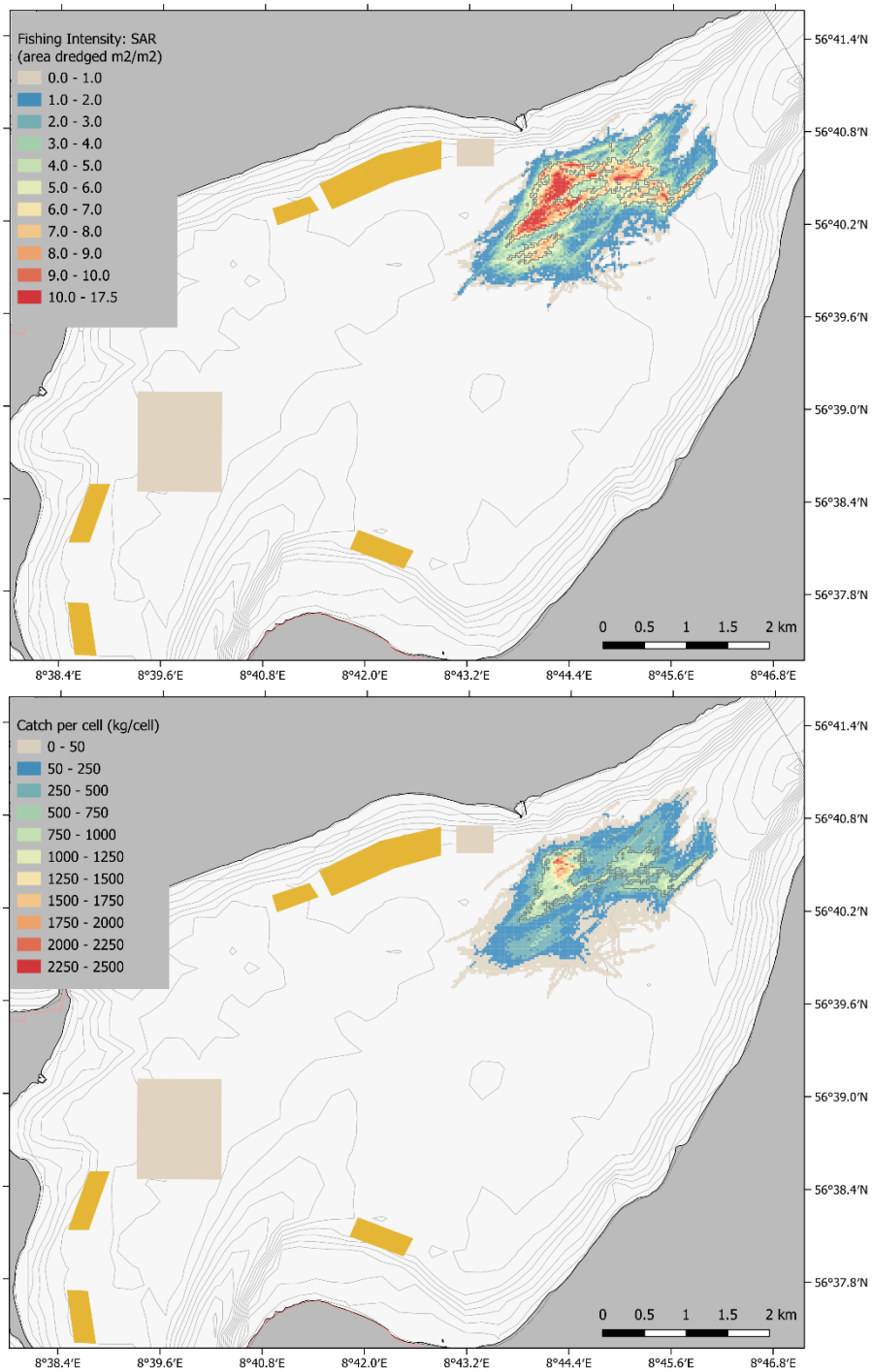

Figure 4. Cockle fishing intensity (SAR) and catches (kg) per 25 m cells in 2023-2024 in Kås Bredning (MO 9). Catches estimated from daily landings of each boat distributed proportionally to track length, i.e. catch rate of each boat was constant in each day whatever the location. Grey line delimits area with 50% highest SAR and catches.

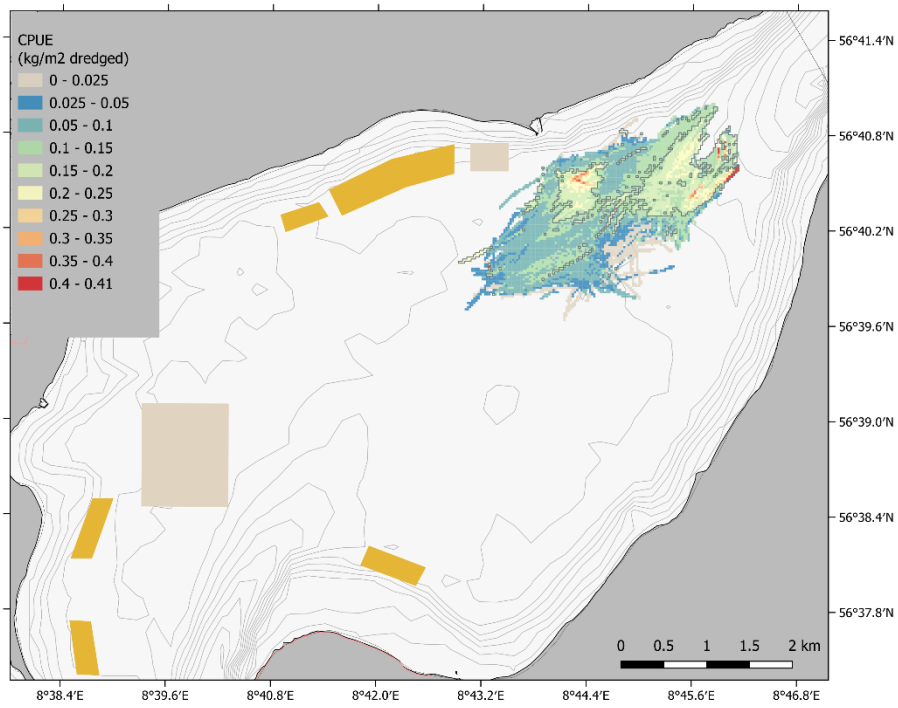

Figure 4 (cont.). Cockle CPUE (kg/m^2 dredged) per 25 m cells in 2023-2024 in Kås Bredning (MO 9). Catch rate of each boat was constant in each day whatever the location. Grey line delimits area with 50% highest CPUE.

3. Cockle populations in the Limfjorden: Spring-summer 2024 status

Spring-summer 2024 survey

In late spring-early summer 2024, DTU Aqua conducted a survey of cockle populations in the Limfjorden, following the request from FVM for advice on a sustainable quota/catch limit for the coming 2024-2025 season.

The survey concentrated on the historically two most important fishing areas MO 9 and MO 15, and on two fishing areas important in the last two seasons, MO 11 and MO 13. Surveyed areas were responsible for 86% of cockle landings in the Limfjorden since 2017-2018 (Table 1). The choice of areas to survey also incorporated information on known cockle populations and possible areas of recent cockle settlement (i.e. in the previous summer of 2023) provided by FME.

The survey used a previous approach (Notat DTU Aqua 23-1009397), with a Day grab but with an 8 mm sieve, to sample 950 stations covering historical fished cockle grounds (Figure 5). A stratified design was used with a 250 m regular grid in MO 9 and a 300 m regular grid in the other three fishing areas, which was then reduced to 212 m

on cockle beds found in these three areas or in areas reported to potentially have cockle populations by FME (Figure 5). The objective of this approach was to maximize surveyed area for the available time, improve accuracy and reduce error of cockle biomass estimates.

Since only a few individuals of the lagoon cockle, *Cerastoderma glaucum*, were collected during the survey, this notat refers only to the common cockle, *Cerastoderma edule*.

Cockle abundance and distribution

Several cockle populations were observed in all four fishing areas surveyed in spring-summer 2024 (Figures 5 and 6). However, only a relatively low number of stations had cockles except in MO 11 (Table 4): 8% of stations in MO 9, 13% of stations in MO 13, 3% of stations in MO 15, and 35% of stations in MO 11.

In the northeastern part of MO 9 and western part of MO 11, cockles generally occurred in areas fished in the last few seasons (Figures 5 and 6). In these two fishing areas, the new cockle beds were of similar in size (2.4 and 2.8 km^2) to beds fished in 2022-2023 season and observed in the spring 2023 survey (Figure 5; Notat DTU Aqua 23-1009397).

In most of MO 13 and Sønder Bredning MO 15, cockles occurred in areas not fished before and were small (0.7 and 0.2 km^2) relative to beds fished in previous seasons (Figures 5 and 6).

The new cockle beds found in the 2024 survey indicate successful cockle settlement occurred one year earlier in the summer of 2023, which lead to significantly increased density and biomass in all areas surveyed in 2024 relative to 2023 (Figure 7 and Table 4; GLM, exponential distribution, $\chi^2(1)$ test, $p < 0.0001$ for all). However, in the main fishing area of MO 9 mean cockle density and biomass in 2024 were still significantly lower than in 2021 (Figure 7; GLM, exponential distribution, $\chi^2(1)$ test, $p < 0.0001$ for both).

Cockle abundance in individual stations within cockle beds in all four fishing areas were extremely high. Density frequently reached values of over 2,300 cockles/m^2 and biomass over 8,300 g/m^2, with maximum values of 6,360 cockles/m^2 and 15,500 g/m^2 (Figures 5 and 6).

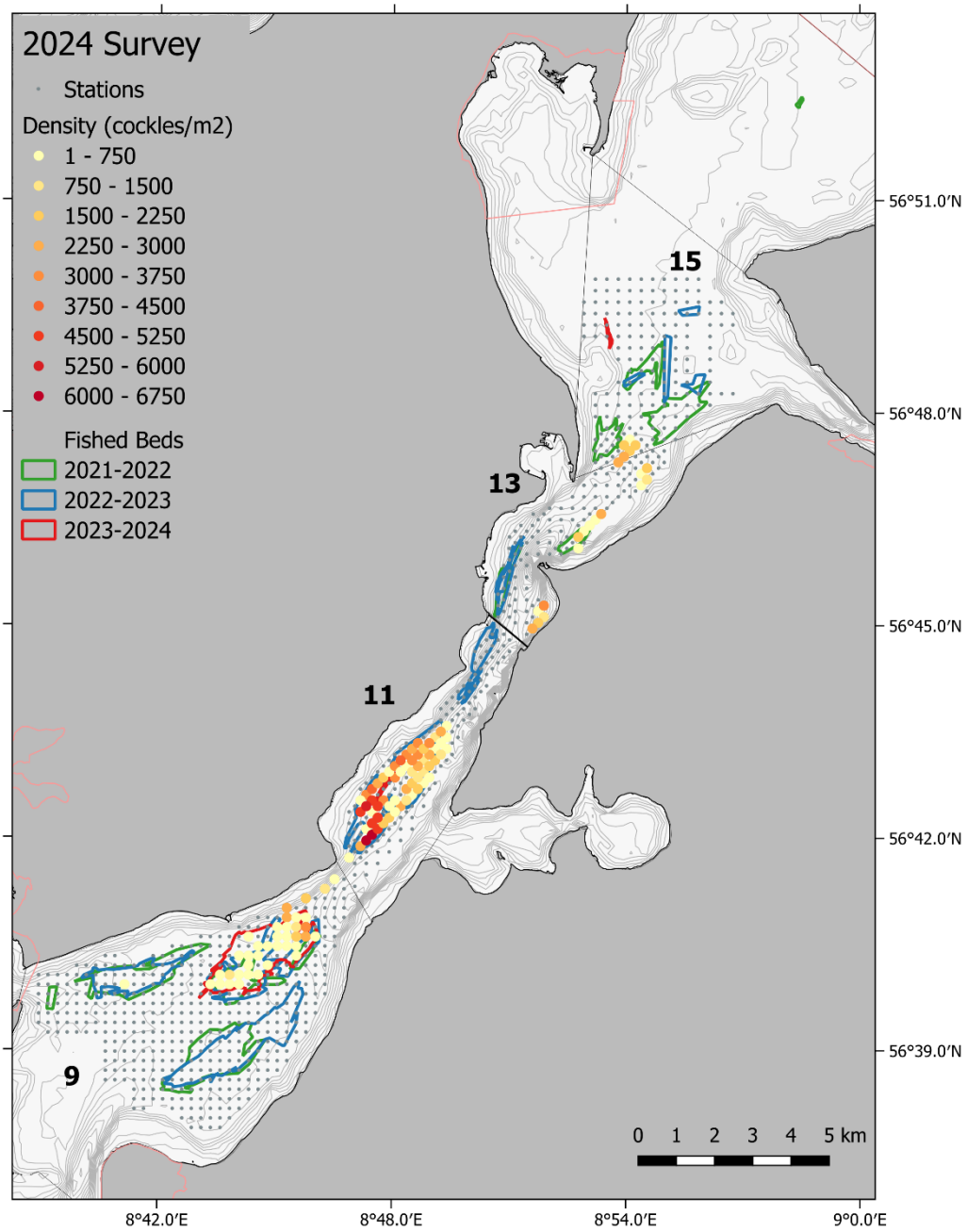

Figure 5. Cockle density (cockles/m^2) in Kås Bredning (MO 9), Salling Sund syd (MO 11), Salling Sund nord (MO 13) and Sønder Bredning (MO 15) in spring-summer 2024. Superimposed are fished cockle beds in 2021-2022 (green), 2022-2023 (blue) and 2023-2024 (red).

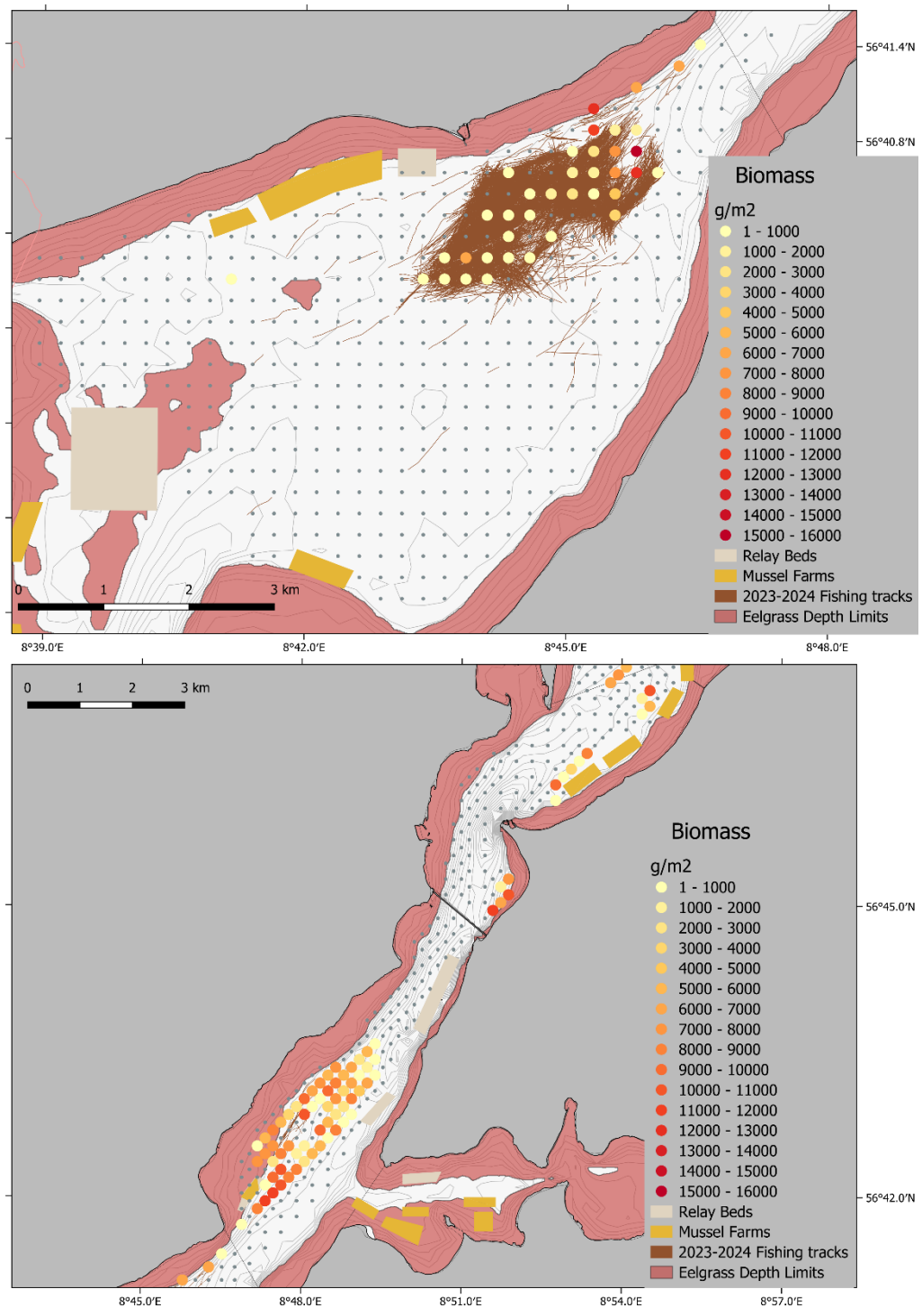

Figure 6. Cockle biomass (g/m^2) in spring-summer 2024: Kås Bredning (MO 9; top), Salling Sund syd and nord (MO 11 and 13; bottom).

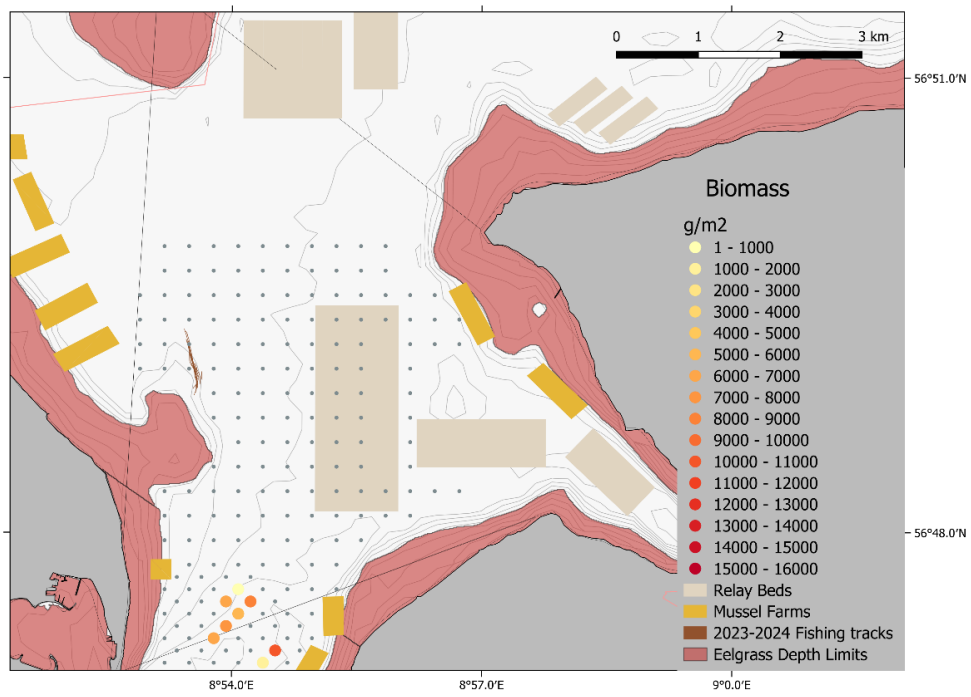

Figure 6 (cont.). Cockle biomass (g/m^2) in spring-summer 2024 in Sønder Bredning (MO 15).

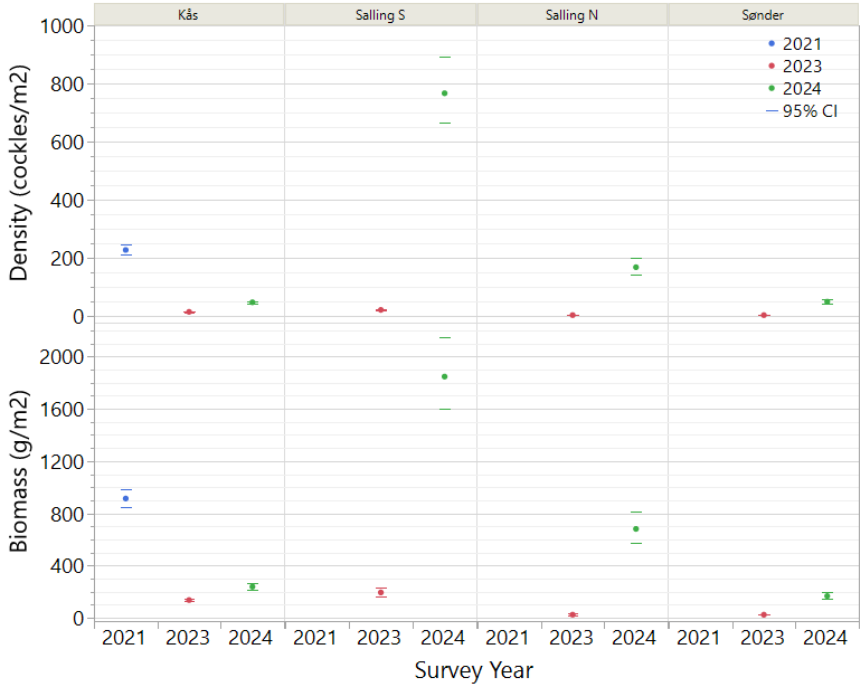

Figure 7. Cockle density (cockles/m^2) in the 2021, 2023 and 2024 surveys. Error is 95% confidence interval of mean.

Stock estimates
Total cockle biomass estimated for summer 2024 was 26,907 tonnes (95% CI: 19,803 – 39,086; Table 4). A significant improvement relative to 2023, increasing in all the four areas surveyed (Notat DTU Aqua jnr. 23-1009397).

The majority of cockle biomass (ca. 55%) was found in MO 11, while the other three fishing areas contained lower biomass (Table 4):

- Kås Bredning (MO 9): 7,103 tonnes (95% CI: 5,252 – 9,937)
- Salling Sund syd (MO 11): 14,693 tonnes (95% CI: 11,570 – 19,050)
- Salling Sund nord (MO 13): 3,832 tonnes (95% CI: 2,436 – 6,534)
- Sønder Bredning (MO 15): 1,279 tonnes (95% CI: 595 – 3,566).

Harvestable biomass is the fraction of the population larger than the minimum reference size of 16 mm shell width (MRS), as used in previous advice from DTU Aqua (Notat DTU Aqua jnr. 21-1033607, Notat DTU Aqua jnr. 22-1008192 and Notat DTU Aqua jnr. 23-1009397). Cockle harvestable biomass in spring-summer 2024 was 6,097 tonnes (95% CI: 4,371 – 9,065):

- Kås Bredning (MO 9): 3,999 tonnes (95% CI: 2,957 – 5,595)
- Salling Sund syd (MO 11): 735 tonnes (95% CI: 578 – 952)
- Salling Sund nord (MO 13): 1,184 tonnes (95% CI: 753 – 2,019)
- Sønder Bredning (MO 15): 179 tonnes (95% CI: 83 – 499).

Relative to historical landings as well as the 2021 survey of MO 9, harvestable cockle biomass in spring-summer 2024 is considered low in all the four areas surveyed (Tables 1 and 4; Notat DTU Aqua jnr. 21-1033607).

For comparison, landings from the four areas surveyed between 2017-2018 and 2022-2023 averaged 6,572 tonnes/season (excluding last season with a low TAC), 475 tonnes above the 2024 harvestable biomass.

Cockle age
Cockle size and age were determined in 92.4% (n = 3,780) of all cockles sampled. Cockles were aged based on the presence of annual winter lines on the shell surfaced (e.g. Richardson, 1980; Jones and Baxter, 1987; Figure 8).

In 2024, cockles were almost exclusively from a single new cohort with 1 year of age, never below 99% of the populations in any fishing area (Figure 9). These cockles originated from successful settlement in the previous summer of 2023, showing a single annual winter growth line in their shells (Figure 8).

Table 4. Cockle populations in spring-summer 2024: Total biomass estimates (tonnes); density (cockles/m^2) and biomass (g/m^2) within cockle beds only and all survey. Intervals are 95% confidence intervals (from exponential distributions due to skewness). N is number of stations.

	N		Density (cockles/m^2)	Biomass (g/m^2)	Total Biomass (tonnes)	Harvestable Biomass (tonnes)
Kås Bredning (MO 9)	38	Beds	574 (360 – 996)	2,991 (2,211 – 4,184)	7,103 (5,252 – 9,937)	3,999 (2,957 – 5,595)
	474	All	46.0 (42.1 – 50.4)	239.8 (219.4 – 262.7)		
Salling Sund syd (MO 11)	62	Beds	2,188 (1,723 – 2,837)	5,273 (4,152 – 6,836)	14,693 (11,570 – 19,050)	735 (578 – 952)
	177	All	766.4 (663.7 – 891.3)	1,847 (1,600 – 2,148)		
Salling Sund nord (MO 13)	16	Beds	1,304 (829 – 2,223)	5,239 (3.388 – 9,086)	3,832 (2,436 – 6,534)	1,184 (753 – 2,019)
	125	All	166.9 (140.7 – 199.9)	682.2 (575.3 – 817.2)		
Sønder Bredning (MO 15)	5	Beds	1,624 (756 – 4,529)	5,670 (2,647 – 15,867)	1,279 (595 – 3.566)	179 (83 – 499)
	169	All	48.0 (41.5 – 56.1)	168.3 (145.3 – 196.5)		
Total	121	Beds			26,907 (19,853 – 39,086)	6,097 (4,371 – 9,065)
	945	All				

Cockles with older ages, were less than 1% of the cockle populations (Figure 9), indicating the disappearance of the 2019 cohort that dominated cockle populations in the Limfjorden since 2021 (Notat DTU Aqua jnr. 21-1033607, Notat DTU Aqua jnr. 22-1008192 and Notat DTU Aqua jnr. 23-1009397).

Figure 8. Variation of 1-year old cockle size in summer 2024. Shell width ranges between (left to right): 23.9 mm, 15.44 mm, 10.9 mm and 9.1 mm. Winter annual growth lines are clearly visible.

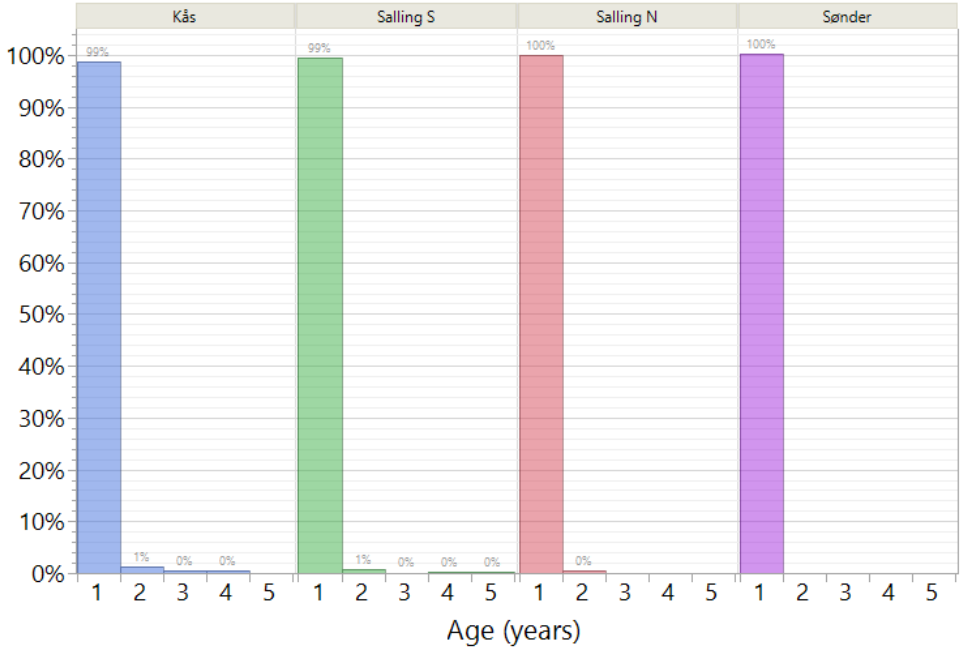

Figure 9. Relative frequency of age cohorts of cockles in the in Kås Bredning (MO 9), Salling Sund syd (MO 11), Salling Sund nord (MO 13) and Sønder Bredning (MO 15) in spring-summer 2024 (weighed by cockle density, 64 stations, n = 2,880). Years are the number of annual winter growth lines.

Cockle size

Cockle populations in spring-summer 2024 were dominated by small cockles with mean shell width 12.9 mm (± 0.1 mm, 95%CI, n = 3,780; Figure 10; for shell dimensions see Appendix 2, Notat DTU Aqua jnr. 23-1009397).

Mean shell width was:

- Kås Bredning (MO 9): 16.4 mm (± 0.2 mm, 95%CI, n = 660)
- Salling Sund syd (MO 11): 12.1 mm (± 0.1 mm, 95%CI, n = 2,340)
- Salling Sund nord (MO 13): 14.6 mm (± 0.2 mm, 95%CI, n = 540)
- Sønder Bredning (MO 15): 14.1 mm (± 0.2 mm, 95%CI, n = 240)

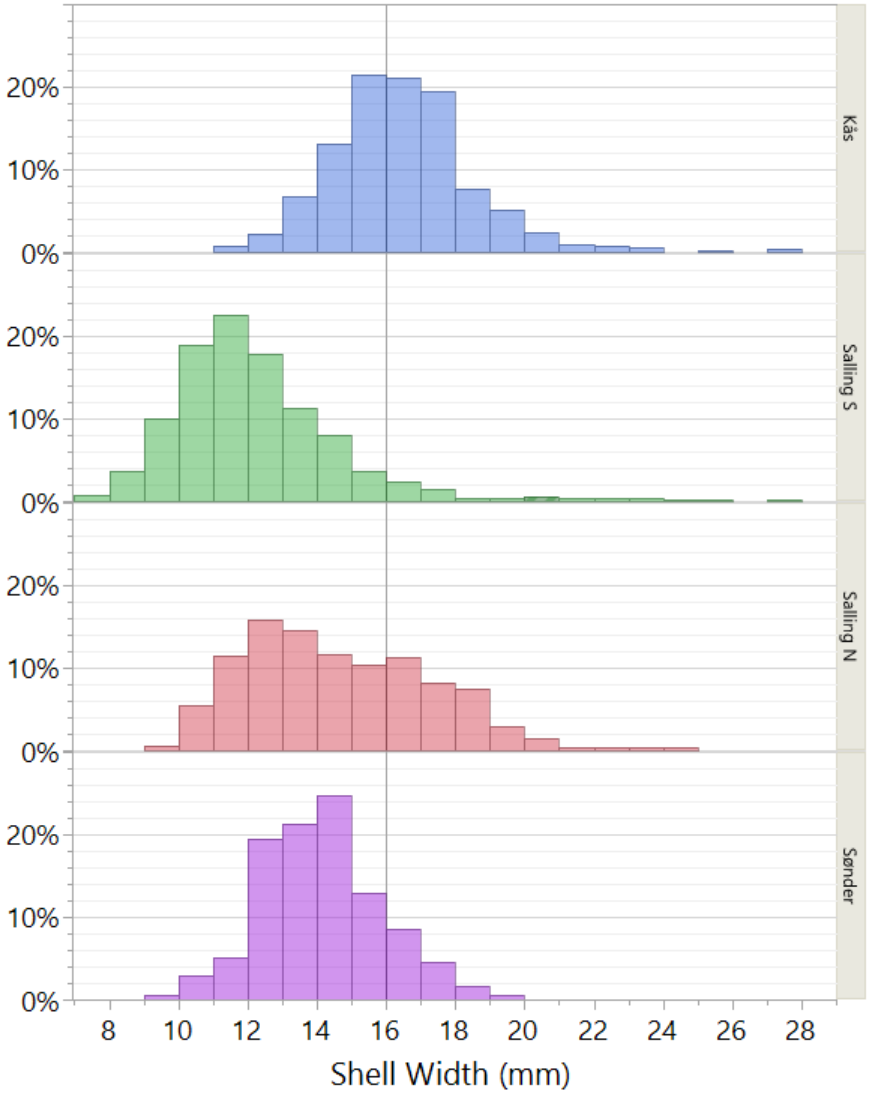

Figure 10. Relative frequency distribution of cockle shell width (i.e. % in each 1 mm size bin) in Kås Bredning (MO 9), Salling Sund syd (MO 11), Salling Sund nord (MO 13) and Sønder Bredning (MO 15) in spring-summer 2024 (weighed by cockle density, 63 stations, n = 3,780). Vertical dashed line is the minimum reference cockle size of 16 mm shell width.

The vast majority of cockles were smaller than the MRS, 85.9% in all four areas surveyed in spring-summer 2024. However, in MO 9 and to a lesser extent in MO 13 a significant fraction of cockles was larger than MRS (Figure 10).

The proportion smaller than MRS was:

- Kås Bredning (MO 9): 43.7%
- Salling Sund syd (MO 11): 95.0%
- Salling Sund nord (MO 13): 69.1%
- Sønder Bredning (MO 15): 86.0%

Even in MO 9 and MO 13, only 16 and 12% were larger than MRS by more than 2 mm (Figure 10). Considering all four areas only 4.4% of cockles were larger than MRS by more than 2 mm (Figure 10). As in the 2021 survey, cockles larger than 20 mm shell width were almost entirely absent from the populations (Figure 10).

The size of 1-year old cockles of the recently settled cockle cohort varied significantly between the four fishing areas (Figures 9 and 10). Cockle size was significantly related to density (non-parametric correlation Spearman ρ = -0,621, $p < 0.0001$; Figure 11). Thus, differences in size between fishing areas were associated with density driven processes, likely food competition or depletion.

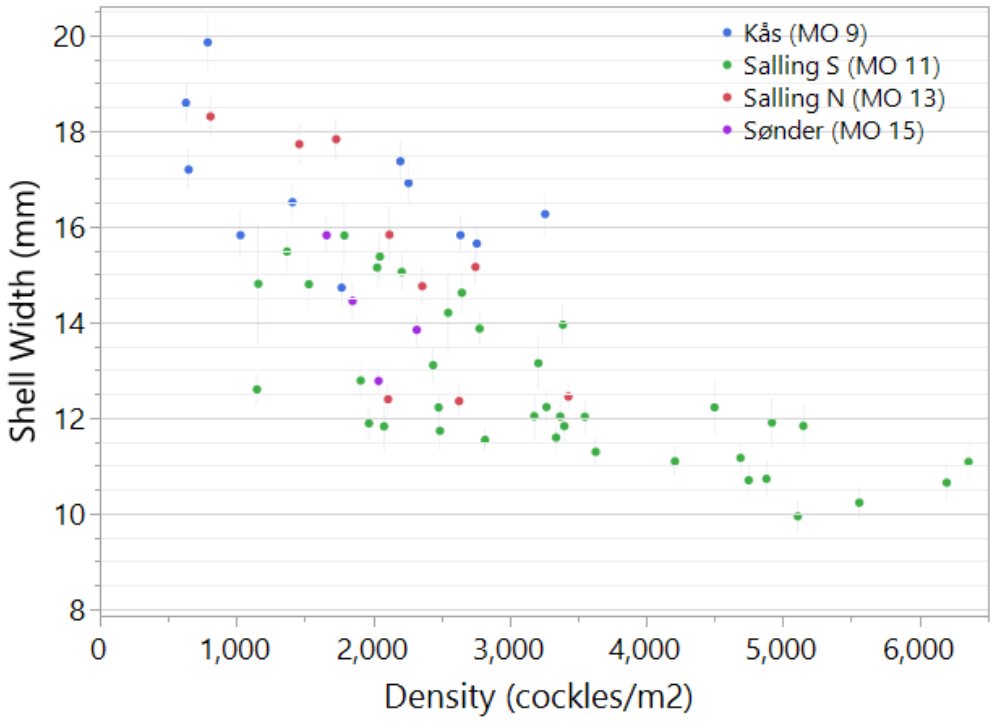

Figure 11. Cockle size (shell width) decreased significantly with cockle density (non-parametric correlation Spearman ρ = -0,621, p < 0.0001). Error bars are 95% confidence intervals.

Recruitment

The almost completely dominance and abundance of small sized, recently settled, single 1-year old cohort (Figures 9 and 10), is clear evidence of significant successful settlement in the previous summer of 2023 in the four surveyed areas.

Settlement success in 2023 was variable between fishing areas (Table 4; Figure 5):

- Most successful in MO 11 covering a significantly large area at very high densities on a bed previously fished in 2022-2023.
- In MO 13 supported a relatively significant abundance observed in 2024, but only on small beds.
- In MO 15 it was relatively poor being limited to a small bed, even if at high densities.
- In the main fishing area MO 9, settlement success was also relatively poor, even if covering a large area of a previously fished bed, since densities were low over most of the bed with high values limited to a small area.

The 2023 cohort will have to support cockle total and spawning biomass as well as fishing in the four surveyed areas in the coming year or years until new successful settlement occurs. Cockle populations are likely also present in other fishing or shallow areas, but its abundance and size-age structure are not known.

4. Considerations for the coming 2024-2025 season

Landings in 2023-2024

- In the last season, cockle landings were the lowest since 2013.
- Landings were almost exclusively caught from one single bed in MO 9.
- Low landings resulted from the low TAC and short fishing period, but also from low biomass in the populations.
- Landings were 13.8% lower than the TAC for the areas MO 9, 11, 13 and 15 and 99.1% lower than the TAC for other areas.

Stock assessment 2024

- Total cockle biomass in the 2024 assessment increased in all four areas to 26,907 tonnes from 6,559 tonnes in the 2023 assessment.
- Total cockle biomass was, however, low in MO 9 and MO 15 relative to the 2021 assessment and historical landings but was significant in MO 11.
- Harvestable cockle biomass in summer 2024 at 6,097 tonnes was low in all areas relative to the 2021 and 2023 assessments and historical landings.
- Successful settlement was observed in all four surveyed areas, as populations were almost entirely a 1-year-old cohort (99%) settled in the summer of 2023.
- Cockles in all four areas surveyed were small, with only 15% larger than MRS.
- Status in summer 2024 is similar to the status between 2021 and 2023, dominated by a single age cohort from 2019:
    - In MO 9, it took 2 years for the 2019 cohort to be fished.
    - In MO 11, it took 3 years for the 2019 cohort to be fished.
    - Likely it will take a similar time for most of the 2023 cohort to become large enough to be available for harvesting by the fishery.
    - Especially in MO 11 where cockles are small.

- It is uncertain if and what proportion of the 1-year-old 2023 cohort reached maturity within their first year and reproduced by summer 2024 due to the small cockle size. Those that did not, can only reproduce for the first time next year in spring 2025, but may be or become large enough to be available to fishing beforehand.

Considerations/Anbefalinger
In the 2024-2025 season, the fishery will rely solely in the surveyed areas on the new 1-year old cohort of small cockles settled in 2023. A status that may continue after next season unless new successful settlement and recruitment occurs.

Total allowable catch (TAC)

- A TAC should be a fraction of harvestable cockle biomass, itself normally a fraction of total biomass, for several reasons (e.g. Dare et al., 2004): ensure spawning biomass for the production of future recruits; with uncertain recruitment, the harvestable cockle biomass in one season may be the main or only fishable biomass the following season; and cockles have multiple ecosystem roles and services, other than just supporting a fishery (e.g. Carss et al., 2020).
- Allowable harvest ratios (catch/biomass) between 20 to 44%, commonly 33%, of the harvestable biomass have been used in several cockle fisheries in Europe (Dare et al. 2004; Hervas et al, 2008; Southall and Tully, 2014; MII and BIM, 2018; IFCA, 1992, 2017).

A TAC in the coming 2024-2025 season for the 4 areas surveyed will thus be well below mean landings per season.

Alternative fishing areas

- Non-surveyed areas may be important to support landings if the fishery can find significant cockle populations.
- Of non-surveyed fishing areas only Venø Bugt (MO 7 and 8) and Visby Bredning (MO 25) have provided significant landings since 2016-2017 (Table 1).
- These three areas produced at most 2,582 tonnes in a single season, with a mean of 1,082 tonnes/season since 2016-2017 (Table 1).
- However, landings from these three areas have decreased every season since a peak in 2020-2021.

5. Catch recommendations for the Limfjorden cockle fishery in 2024-2025

In view of landing records, stock assessment observations, limitations, and uncertainties, as well as the reasoning described above, DTU Aqua for the 2024-2025 season continues to recommend a precautionary approach for cockle fishing in the Limfjorden for the coming season 2024-2025.

DTU Aqua thus recommends a total TAC of 2,012 tonnes using a harvest ratio of 33% in each of the four fishing areas surveyed in spring-summer 2024:

- Kås Bredning (MO 9): 1,320 tonnes
- Salling Sund syd (MO 11): 242 tonnes

- Salling Sund nord (MO 13): 391 tonnes
- Sønder Bredning (MO 15): 59 tonnes

DTU Aqua cannot propose TACs to non-surveyed areas, since the abundance and structure of cockle populations in these areas is unknown. However, a decision to allow cockle fishing in non-surveyed areas can be based either on:

1. Historical trends of landing data as in the previous season 2023-2024. This approach, however, carries a higher probability of being non-sustainable since the abundance and structure of cockle populations is unknown.
2. If no additional surveys are performed, catches from non-surveyed areas are deducted from the TAC set for the four surveyed areas. In this approach, cockle catches in non-surveyed areas replace equivalent catches in surveyed areas. Thus, allowing the fishery to find and fish unknown cockle beds, but with no increase in total cockle biomass harvested/fishing mortality or harvest ratio (% of harvestable biomass that is fished) in the Limfjorden.
3. To allow for fishing in selected and restricted areas (fiskekasser) after additional surveys of well-defined beds to set additional TACs. This will require additional efforts by DTU Aqua to be agreed with FVM.

Management should strongly consider restricting fishing in Salling Sund syd (MO 11) to protect a large and abundant bed with a very large proportion of cockles smaller than MRS. Under the status of cockle populations in the summer 2024, the cockle bed in Salling Sund syd (MO 11) will likely be the main producing area sustaining the fishery in the following seasons of 2025-2026 and/or 2026-2027.

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