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Estimating abundances of 0-group western Baltic cod by using pound net fisheries

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Abstract

Nearshore 0-group western Baltic cod are frequently caught as bycatch in the commercial pound net fishery. Pound net fishermen from Funen, Lolland and Fehmarn have recorded their catches of small cod between September and December 2008. Abundance patterns were analyzed, particularly concerning the influence of abiotic factors (hydrography, meteorology) and the differences between sampling sites. Catch per unit effort (CPUE)differed by site and location, whereas CPUE were highest at Lolland. Wind directions and current speeds seem to affect catches, while wind strengths and current directions did not show close correlations to catches. Finally an algorithm is described to calculate an recruitment index for western Baltic cod recruitment success based of previous analyses.

Key words: Baltic Sea, 0-group cod, recruitment index, joint data collection, wind, currents,pound net, self-sampling

Introduction

Cod is one of the most important fish species for Baltic commercial fisheries. The fishery management distinguishes between a western Baltic (Belt Sea, ICES SD 22-24) and an eastern Baltic cod stock (ICES SD 25-32) (ICES, 2008). Both stocks are separated by spawning area and spawning season (Bleil & Oeberst, 2000; Nissling and Westin, 1997). Deeper waters of the Kiel Bay, the Fehmarn Belt and the Bay of Mecklenburg are the main spawning areas of the western Baltic cod (Bleil & Oeberst, 2000) (Fig 1). Spawning activities of eastern Baltic cod were described for the Gotland Basin, Gdansk Deep and Bornholm Basin. Mixing of both stocks occurs primarily in the Arkona Sea (Nissling and Westin, 1997; Oeberst, 2000).

The spawning success of both stocks is influenced by hydrographical conditions, i.e. salinity, temperature and oxygen. Suitable spawning areas of the eastern Baltic cod stock are currently restricted to a subset of the historical sites (mainly the Bornholm Sea) due to unfavorable hydrographic conditions (Hinrichsen *et al.*, 2008). However, this is not found to be the case for western Baltic cod.

Cod eggs and early juvenile stages are found in the pelagial and their distribution, settling locations and finally survival, especially for the eastern Baltic cod depend on currents and wind-induced drifts (Hinrichsen *et al.,* 2008). Little is known of the spatial and temporal distribution of juvenile Baltic cod.

While the distribution of pelagic stages is influenced by currents, it is assumed that post settled juvenile cod are more aggregated and concentrated in shallow coastal waters. Grant and Brown (1998) found that juvenile cod of Newfoundland remained localized, not moving further than a few hundred meters for several weeks after settling from pelagic habit. Methven and Schneider (1998) found the highest densities of postsettled age 0 cod at depths of 4-7m in coastal Newfoundland. Similar observations were reported by German commercial fishermen.

Therefore, the Baltic International Trawl Survey (BITS) might not adequately cover the area distribution of 0-group cod, resulting in a poor performance of the recruitment index derived from this survey.

Due to high fishing effort, the spawning stock biomass of western Baltic cod stock is dominated by first and second time spawners. This increases the importance of recruitment estimates for the prediction of stock abundance in fishery management (Oeberst & Bleil, 2003). Nevertheless, successful methods to assess the recruitment and the strength of the new year class of the Belt Sea cod are rarely found. Hence, recent approaches were conducted by Bleil and Oeberst (2003) based on fecundity estimates.

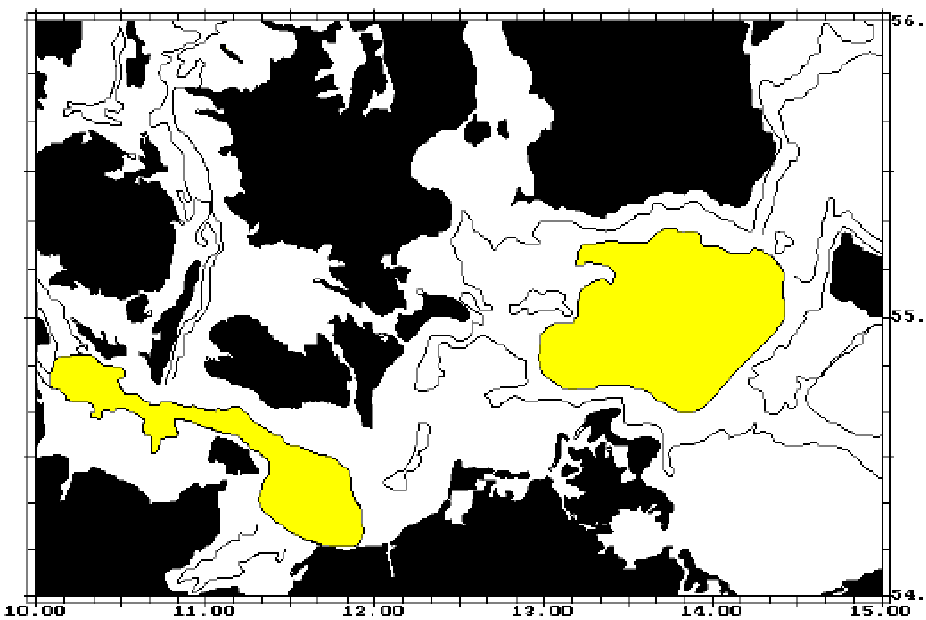


Fig 1: Spawning areas of the western Baltic cod (yellow) (Bleil & Oeberst, 2000).

The aim of this study was to establish a concept to estimate abundances of small cod in western Baltic coastal waters. Since traditional sampling with bottom trawl nets seem to be unsuitable, the data presented in this study are obtained using traditional coastal eel traps (pound net) (Fig 2). These traps are set close to the shoreline and pound net fishermen have reported high abundances of small cod, caught as bycatch, in the past, with most of the bycatch surviving. Sampling was conducted within the framework of JOIFISH/Lot8 ("Joint data collection between the fishing sector and the scientific community in the Baltic Sea"), a project in support of the Common Fisheries Policy. Commercial fishermen from Denmark and Germany were ask to record the bycatch of small cod during the entire pound net fishing season. This approach is the basis to increase the covered area and sampling period and hence to optimize the effort.

Based on this method, we present analyses of catch patterns of juvenile cod in pound nets, in the light of the question on the influence of abiotic factors (hydrography, meteorology) and the differences between sampling sites. Additionally, it has be evaluated, whether the data from pound net fishery could be used as recruitment index for western Baltic cod. If possible, a concept for the estimation of an index has to be developed and discussed.

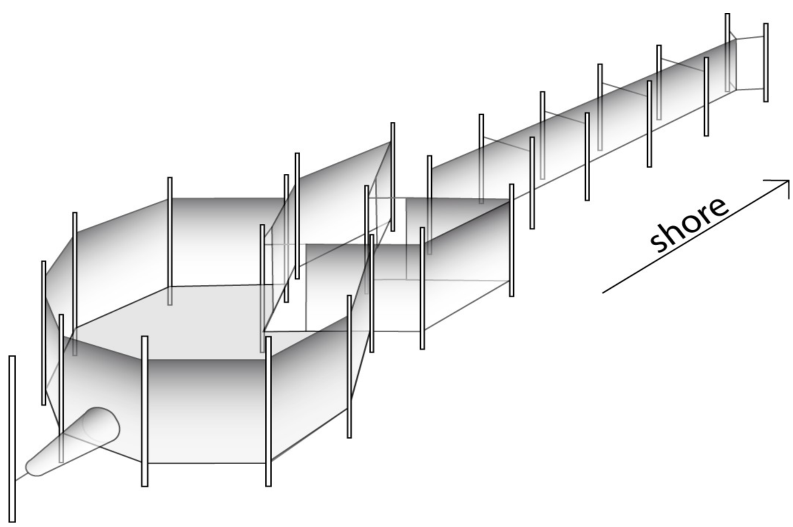


Fig 2: Pound net – fish trap construction. The complex is deployed orthogonal to the coast line. Nets are fixed with picket. A long leading net causes fish to swim away from the coast into a court (pound) by passing a forecourt. Finally fishes are trapped in a bow net.

Material and methods

Catch

Sources of data

The study areas are located in the western Baltic Sea, ICES SD 22. These areas are close to the main spawning areas of the western cod stock (Fig 1) (Oeberst, 2000) and are suggested to provide suitable habitat for 0-group cod.

Samples were carried out by Danish and German fisherman at Funen (Denmark, sites I-III), at Lolland (Denmark, sites IV-VI) and at Fehmarn (Germany, sites VII-XIII) (Fig 3) on a voluntary basis. Fishermen were instructed to complete a protocol after each haul (Appendix 1), whereas the overall design of German and Danish protocols was standardized, some minor differences in the protocol occurred, which resulted in some inconsistencies in the data.

Samples were taken from September to December in 2008. However, sampling periods differed for each site (Table 1). Similarly, catch durations were not constant (Appendix 2), ranging from 24 to 168 hours. Pound nets were used to catch cod (Fig 2). The pound nets differed by the length of the leader net and the numbers of fishing traps. Cod were sorted by length into three different size classes (0-20cm; 20-38cm; >38cm). These size classes were chosen due to results of prior studies, which have shown, that the 0-group in 4th quarter of the year usually include fish with lengths smaller than 20cm. The delimitation between size group 2 and 3 at 38 cm is the minimum landing size. The amount of cod per size group was estimated by fishermen in numbers per size group(0-20cm and 20-38cm) and as weight per size group 3 (>38cm). These data were noted in a protocol (Appendix 1), data about further fish species, like eels were not recorded. After measurements and counting cod were released (size class 1 & 2) or used for commercial purposes by the fishermen (class 3). In addition, samples of small cod (approx. 1kg per sample) were taken regularly for further investigations at the institute. These samples were frozen at -20°C and analyzed at the institute for Baltic Sea Fisheries Rostock (OSF) or at the National Institute of Aquatic Resources, Charlottenlund (DTU-Aqua). The analysis of these samples were conducted for every fish and included length measurement, total weight, gutted weight, and otolith sampling, whereas gutted weight measurements were not consistent. Otoliths were collected for age determination in accordance to ensure, that fish in this size category belong to the 0-group.

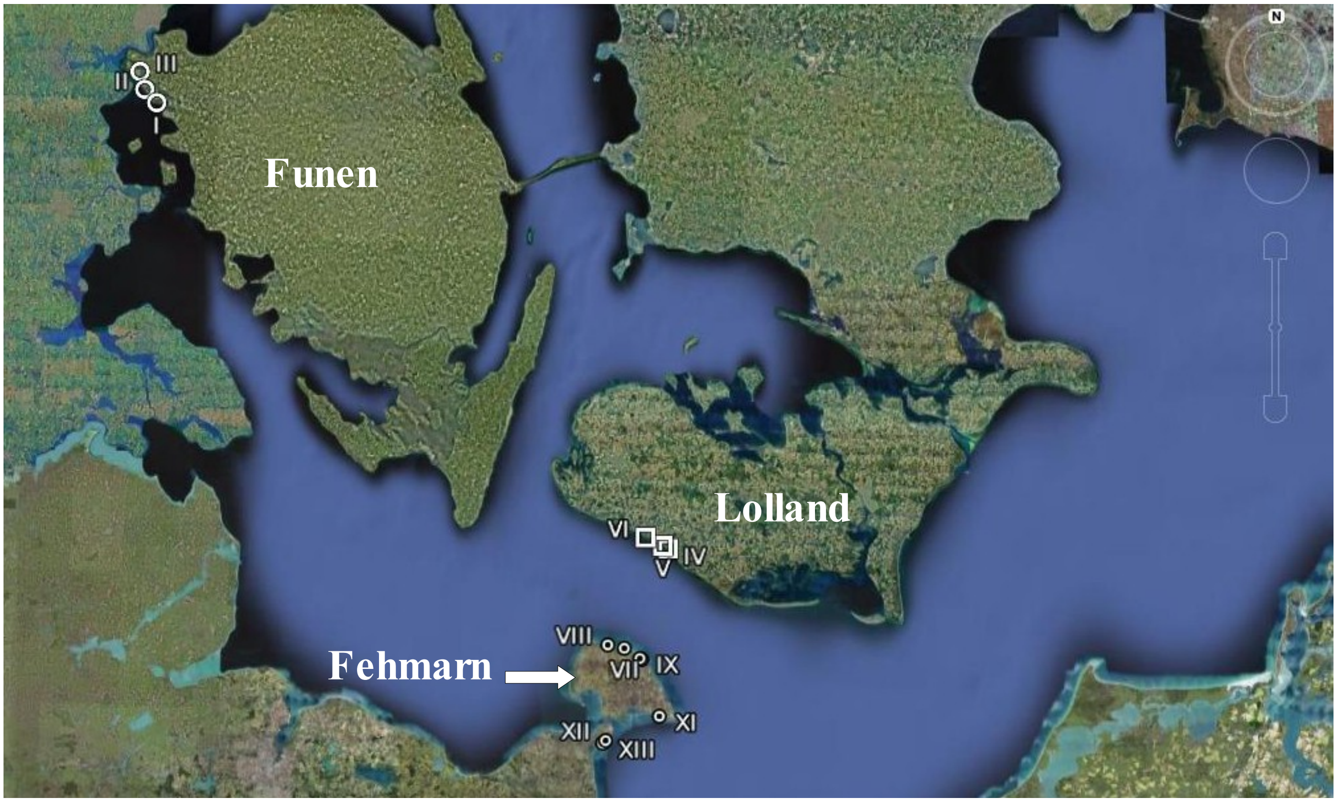


Fig 3: Sample sites of cod recruits in pound net fishery. Sites I-III were located at northwestern coast of Funen Island , next to the Little Belt. Sites IV-VI were located at the southwestern coast of Lolland. Sites from Fehmarn (VII-XIII) are grouped in sites at northern Fehmarn (sites VII-X), southeastern Fehmarn (site XI) and southern Fehmarn (sites XII-XIII). For geographical positions, please refer to Table 1. (source: Google Inc.)

Table 1: Position and depth of the fishing sites grouped by location

site	location	position	depth	sampling period
I	Funen	55°25' N, 9°46' E	2m	13.Oct. - 10.Nov.
II		55°27' N, 9°43' E	3m	13.Oct. - 10.Nov.
III		55°29' N, 9°43' E	4m	13.Oct. - 11.Nov.
IV	Lolland	54°41.03' N, 11°17.69' E	4.5m	05.Oct. - 17.Nov.
V		54°41.26' N, 11°16.72' E	6m	05.Oct. - 22.Nov.
VI		54°42.03' N, 11°13.76' E	6.5m	05.Oct. - 22.Nov.
VII	northern Fehmarn	54°31.502' N, 11°08.780' E	4m	18.Sept. - 28.Nov.
VIII		54°31.850' N, 11°06.284' E	4m	29.Sept. - 12.Nov.
IX		54°30.160' N, 11°14.134' E	4m	19.Sept. - 28.Nov.
X		54°24.600' N, 11°13.170' E	3.5m	28.Sept. - 11.Dec.
XI	southeastern Fehmarn	54°24.441' N, 11°16.018' E	4m	11.Sept. - 11.Dec.
XII	southern Fehmarn	54°22.139' N, 11°07.421' E	3m	11.Sept. - 23.Nov.
XIII		54°21.786' N, 11°06.592' E	4m	11.Sept. - 05.Dec.

Table 2: Sources of additional hydrological and meteorological data

source	location	position	period	intervals	data	unit	data specifications
data logger	northern Fehmarn	54°22.14' N, 11°07.42' E	12.Sept – 6.Dec. 2008	30 min	water temperature	°C	
DWD	Fehmarn, station 10055	54°31.98' N, 11°03.96' E	Sept.-Dec. 2008	24 h	air temperature	°C	max., min. and average values
					wind force	Beaufort	average
wetteronline.de	station Westermarkelsdorf	54°28.02' N, 11°13.20' E	Sept.-Dec. 2008	6 h	wind direction	Degrees	
BSH	Funen	55°27.18' N, 09°43.92' E	Sept.-Dec. 2008	15 min	wind speed	m/s	
	Lolland	54°41.64' N, 11°16.56' E					
	northern Fehmarn	54°31.74' N, 11°08.76' E			wind direction	Degrees	
	southeastern Fehmarn	54°24.24' N, 11°14.58' E			currents	m/s	delivered in x, y and z-directions
	southern Fehmarn	54°21.60' N, 11°07.08' E					

Analyses

Prior to further analysis, it was necessary to standardize the catch data. The catch per unit effort (CPUE) was calculated based on the time of deployment of the net, since increasing catch durations were assumed to be followed by increasing catch. Therefore, catch per 6 and 24 hours were calculated (depending on the type of analysis). Though, according to individual catch durations total catch was divided by the number of 6h or 24hour intervals (e.g. catch duration = 48h; Total catch = 80; Catch per 24h = 40; Catch per 6h = 10). Hence, samples without details about catch duration, first hauls from Denmark were disregarded (Appendix 2). Catch per 24 hours was used to evaluate the underlying hypothesis. Total catch-catch duration and CPUE-catch duration relationships were analyzed for all sample areas. Additionally, varying abundances of different sampling sites and areas and the temporal development of CPUE for all sampling sites were calculated and compared based on 24h-CPUE.

Catch per 6h-intervall was used for analyses concerning wind and current-catch relationships (see below).

Although all laboratory samples were treated, only samples from Fehmarn were analyzed, because at the time of our analysis results from Denmark were not available to us.

Reading otoliths and therefore age determination of cods brought to laboratory was not possible, since distinguishing of false rings and annuli was not feasible (Fig 4).

Since size groups of cod were neither measured nor counted accurately by fishermen, length weight frequencies of laboratory samples were analyzed to determine accuracy of the estimate. Furthermore length frequency distributions including associated median and average length were calculated for each laboratory sample. Fractions greater 20cm were however not excluded by these calculations. Medians of frequency distributions were used to estimate the mean daily growth (DG) of the total sampling period via linear regression. Based on estimated DG, length frequency distributions of laboratory

samples were corrected/shifted to a hypothetical length distribution at closest mid month date (e.g. sampling date = 10.Oct.2008, closest mid month date = 15.Oct.2008).
Length distributions, which are shifted to the same date (15.Sept. 2008; 15.Oct. 2008; 15. Nov. 2008; 15.Dec. 2008) were summarized. Finally length frequency distributions including associated median and average length for each mid-month were calculated. Medians were used to determine temperature dependent growth (see below) and specific growth rate for length per day.

The specific growth equation from Hawkins *et al.* (1985) is given in formula 1:

Formula 1: $G_L = (\ln L_2 - \ln L_1) * t^{-1} * 100$
L_1 and L_2 = subsequent medians of mid-month length frequency distributions. t = time in days.

Fig 4: Otoliths of small cod brought to laboratory

Abiotic data

Temperature

Sources of data

Water temperature at Fehmarn, (site XII Table 1) was recorded every hour with a HOBO PRO V2 water temperature logger (WTL) for almost the entire sampling period (12. Sept. to 06. Dec. 2008).

Air temperature data was obtained from Deutscher Wetterdienst (DWD, www.dwd.de) for DWD-station 10055. This data series contains 24h values of minimum, maximum and average temperature 2m above bottom from 1. September until the end of December 2008 (Table 2).

Analyzes

To estimate temperature dependent daily growth, water temperature values were averaged for each sequenced mid-month to mid-month interval (MMI) (15.Sept.-15.Oct.; 15.Oct.-15.Nov.; 15.Nov.-15.Dec.). Medians of previously calculated mid-month length distributions (see above) were used to estimate absolute growth during MMIs. MMI-averaged temperature-values were plotted against MMI-absolute growth values to determine temperature dependent absolute growth.

Additionally, medians of mid-month length distributions were averaged for each MMI. Percentage growth during MMIs was calculated by dividing MMI-absolute growth values by these averages.

MMI-averaged temperature-values were plotted against MMI-absolute growth values to determine temperature dependent percentage growth.

Secondly, the air and water temperature, as well as temperature changes effects on catch were analyzed:

Water temperature was averaged per day. Linear regression was used to calculate the trend of water and air temperature during the sampling period. Deviations from temperature trend (DTT) were calculated, for both, air and water temperature. DTT-values of previous days were assigned to CPUE-values of juvenile cod (see above) from Fehmarn according to catch duration. Hence, DTT-values were averaged according to catch durations, if catch durations were > 24h.

Wind

Sources of data

Fishermen recorded wind speed (in bft) and wind direction during heaving the nets. No information was given for the catch period itself (often several days; Appendix 2). Hence, additional data were obtained from Deutscher Wetterdienst (DWD, www.dwd.de), WetterOnline Meteorologische Dienstleistungen GmbH (www.wetteronline.de) and Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency, BSH, www.bsh.de) (Table 2).

Apart from air temperature, data from DWD also contained values of wind force in Beaufort scale. Since data about wind direction were not freely available from DWD, these values were acquired from wetteronline.de. However, intervals of wind force (wetteronline.de) and wind direction (DWD) data differed (Table 2), leading to the problem how to average different wind directions per day (e.g. averaging 360° and 20° results in 190°). To avoid this problem a third source which provides wind strength or both, wind direction and wind strength data in shorter intervals was sought. Another problem concerning DWD and wetteronline.de-data was, that these sources did not provide data from Funen and Lolland. All these requirements were achieved by BSH-data (Table 2). Three stations were chosen, one per area, whereas northern Fehmarn-BSH-station was used for all sampling sites around Fehmarn (VII-XIII), since there was assumed that wind directions and strength are similar for these sites.

Analyses

BSH-wind data were averaged per 6h interval using arithmetic mean, whereas wind speed values were converted in Beaufort scale. To analyze the quality of averaged data, estimated 6h-interval values of wind directions were compared with values from wetteronline.de using linear regression and time series plots. Furthermore, the temporal development of measured values were compared with raw data from BSH. Additionally, latter plots were used to evaluate constancy and differences of wind data between areas.

Wind rose diagrams were used to assess the dominance of different wind directions and forces. Distribution patterns of different wind strengths concerning based spatial directions were also analyzed using wind rose diagrams. In both cases 6h-average values based on BSH-data were applied.

Effects of different wind directions and wind forces on juvenile cod abundances were analyzed.

Total catch values were divided by the number of 6h intervals according to catch durations (see above) (e.g. Total Catch = 80; Catch duration = 48h; number of based 6h intervals = 8; catch per 6h-interval= 10). 6h catch values were attributed to the corresponding 6h- wind strength and wind direction data (Table 1). These dataframes were evaluated using wind rose and box-plot diagrams.

Table 3: Example for attributing catch per 6h to averaged (6h) wind directions values depending on identical catch intervals. The last catch interval was calculated by rounding heaving time to next interval limit. Based on this interval prior intervals were determined according to number of catch intervals. The same method was used to attribute catches to wind strength, current direction and current speed values.

interval	date	wind direction [°]	catch
12 AM – 6 AM	10/19/08	280	
6 AM – 12 PM		260	
12 PM – 6 PM		230	10
6 PM – 12 AM		200	10
12 AM – 6 AM	10/20/08	200	10
6 AM – 12 PM		200	10
12 PM – 6 PM		200	10
6 PM – 12 AM		200	10
12 AM – 6 AM	10/21/08	220	10
6 AM – 12 PM		220	10
12 PM – 6 PM		250	
6 PM – 12 AM		240	
12 AM – 6 AM	10/22/08	220	
6 AM – 12 PM		210	
12 PM – 6 PM		230	
6 PM – 12 AM		230	

heaving time	date	catch duration	total catch	catch per 6h
1PM	10/21/08	48h	80	10

number of catch intervals
' =48h / 6 = 8

last catch interval
= 6 AM – 12 PM 10/21/08

Currents

Sources of data

Like wind data, current data were obtained from the operational hydrodynamical model of the BSH. Based on the assumption that currents are area specific, two additional stations were included in current analyzes (Table 2). While northern Fehmarn-BSH-station is located next to sampling stations VII-X, these stations are near sampling stations XI and XII-XIII. Unlike wind directions current data were only available in X, Y and Z-direction [$m*s^{-1}$].

Analyses

Data on currents were averaged per 6h interval. Z-values were not considered, since obtained data belonged to surface, and all Z-values were almost equal to zero. Averaged and untreated current direction values were converted in degrees, using formula 2 and 3.

Formula 3 was applied if the X-value was negative while the Y-value was positive. This was necessary, since otherwise formula 1 had released incorrect achievements.

Formula 2: current direction [°] = ARCTAN2(Y,X) - π/2

Formula 3: current direction [°] = 360 – ARCTAN2(Y,X) - π/2

Formula 4: current speed [m/s] = $\sqrt{X^2 + Y^2}$

Current speeds were computed using formula 4, based on averaged X- and Y-values.

To analyze the quality of averaged data (especially errors due to averaging of directions), 6h-averaged and untreated values of current directions and current speeds were compared using developing and scatter plots. Additionally, latter plots were used to evaluate differences of currents between areas.

Like wind data, 6h-average current values were assigned to corresponding 6h-catches (see above; Table 3) to assess effects on the catch. Only box plots were used for this evaluation.

Results

Catch

A total of 12007 juvenile cod (< 20cm) were caught at Funen, 16355 at Lolland and 10660 at Fehmarn (Table 4), whereas Danish samples provided fewer number of sites and shorter sampling periods, higher numbers of juvenile cod (< 20cm) were caught compared to Fehmarn. Maximum catches of size class 1 were achieved at Lolland, reaching up to 2000 individuals per 24h (CPUE). These catches occurred at the beginning of the sampling period at all sites of Lolland (Fig 5). Regardless these assumed but well supported outliers, average CPUE of Lolland and Funen were significantly higher than those from Fehmarn. Most small (<20cm) and midsize cod (20-38cm) from Fehmarn were caught at sites VII and VIII, which are located in northern part of Fehmarn, i.e. in the Fehmarn Belt. In general, the temporal development of CPUE differed by sites (Fig 5). However, when grouping the sites from Lolland (IV-VI) or southern Fehmarn (XII-XIII) there appeared more or less similar patterns of CPUE-development within each group. Beyond this, there seemed to be no trend in catch development.

The analysis of catch-catch duration relationships shows that the number of small cod increases with longer catch durations (Fig 6). Results from Funen and Fehmarn indicate that catch durations longer than 96h do not provide significant rise of catches This could point at saturation effects or could be caused by poor weather conditions, when nets were not heaved. Moreover, results of linear regression do not support the hypothesis of 1:1 relationship (e.g doubled numbers in catch by doubling the catch durations). However, medians of calculated CPUE values (catch per 24h) of all catch durations were almost equal and do not show a trend, especially for Fehmarn data, whereas CPUE-values from Funen and Lolland showed significant higher variations.

The length-weight-relationship for cod is given in Fig 7. The Figure shows that laboratory samples included small size (<20cm) as well as midsize (20-38cm) cod (88%; 12%).

Length frequencies for each laboratory sample (Fig 8, left column) show that the fraction of midsized cod (20-38cm) increases with time. Additionally, the length distributions show no clear modes or maxima due to low sample sizes. Medians of subsequent samples exhibits no successive increase, although a trend was found. This trend represents mean daily growth (DG) based on the start of the sampling period (Fig 9). DG was used to calculate length frequency distributions at mid-month dates (see above) (Fig 8, right panel).

Table 4: Catches of cod at different size classes and sample sites over the entire sampling period

site	location	depth	< 20cm (number)	20-38cm (number)	> 38cm [kg]
I	Funen	2m	2711	386	15.5
II		3m	6578	760	22.38
III		4m	2718	405	5
	Total		12007	1551	42.88
IV	Lolland	4.5m	3205	600	20
V		6m	8625	1672	50
VI		6.5m	4525	2002	53
	Total		16355	4274	123
VII	Northern Fehmarn	4m	2390	702	156
VIII		4m	2680	590	100
IX		4m	820	393	160
X		3.5m	866	436	339
XI	southeastern Fehmarn	4m	1415	360	139
XII	southern Fehmarn	3m	990	208	50
XIII		4m	1499	400	154
	Total		10660	3089	1098

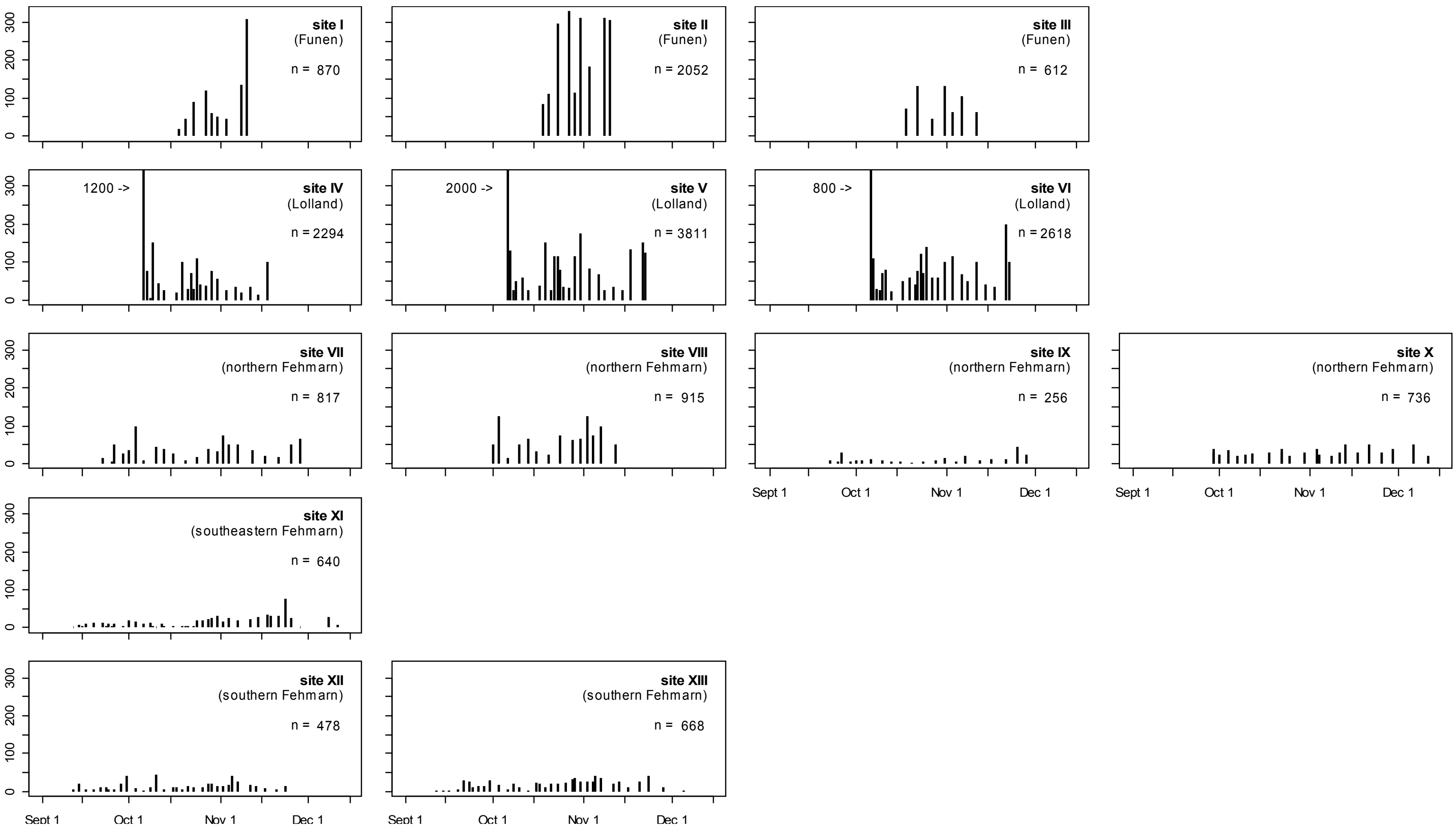


Fig 5: Temporal development of catch per unit effort (24h), shown for every sampling site. Plots from different areas are organized in rows. From top: Funen, Lolland, northern Fehmarn, southeastern Fehmarn, southern Fehmarn. First catches from Lolland exceed the limit of the y-axis. These values are added manually.

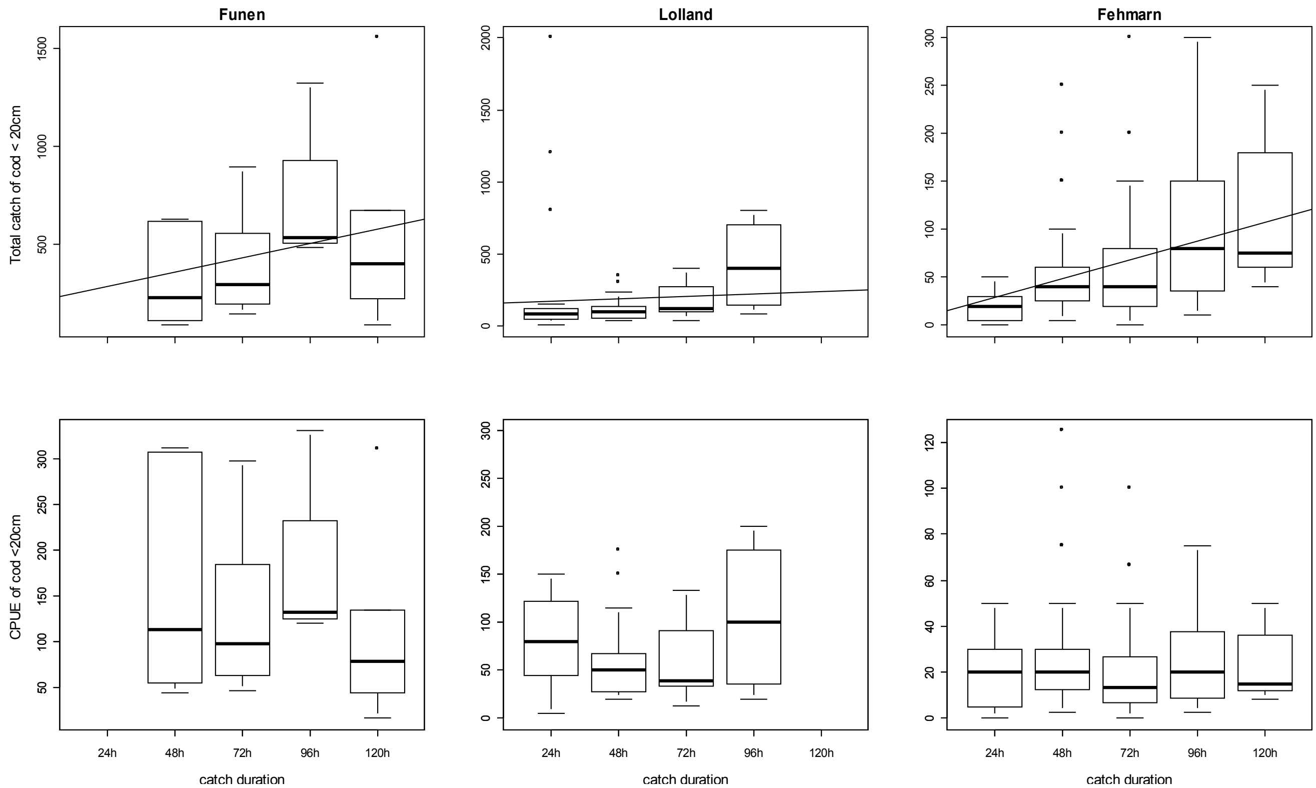


Fig 6: Catch-catch duration relationships. Upper panel: Total catch of juvenile cod; lower panel: CPUE of juvenile cod. Catches with a longer catch duration than 120h occurred in maximum once per location and are not shown.

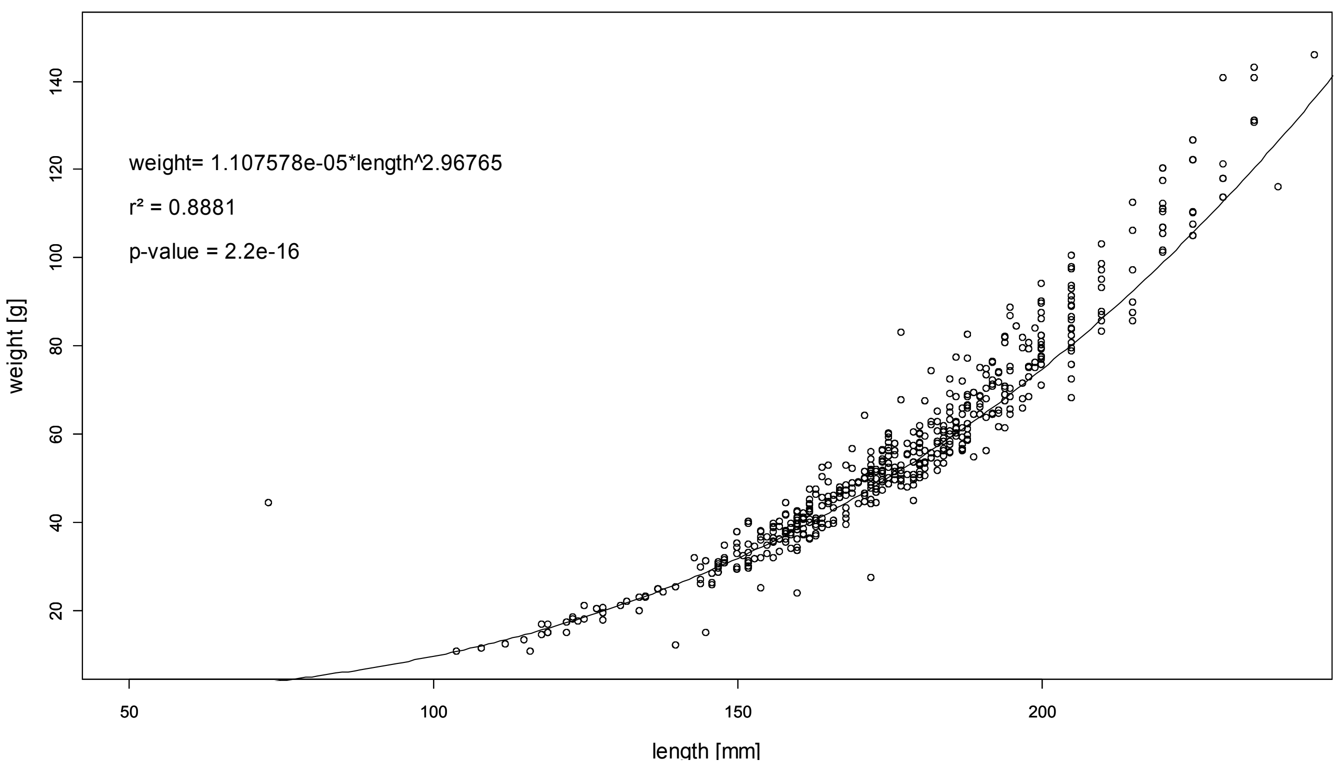


Fig 7: Length-weight relationship of cod caught at Fehmarn, from samples brought to the laboratory

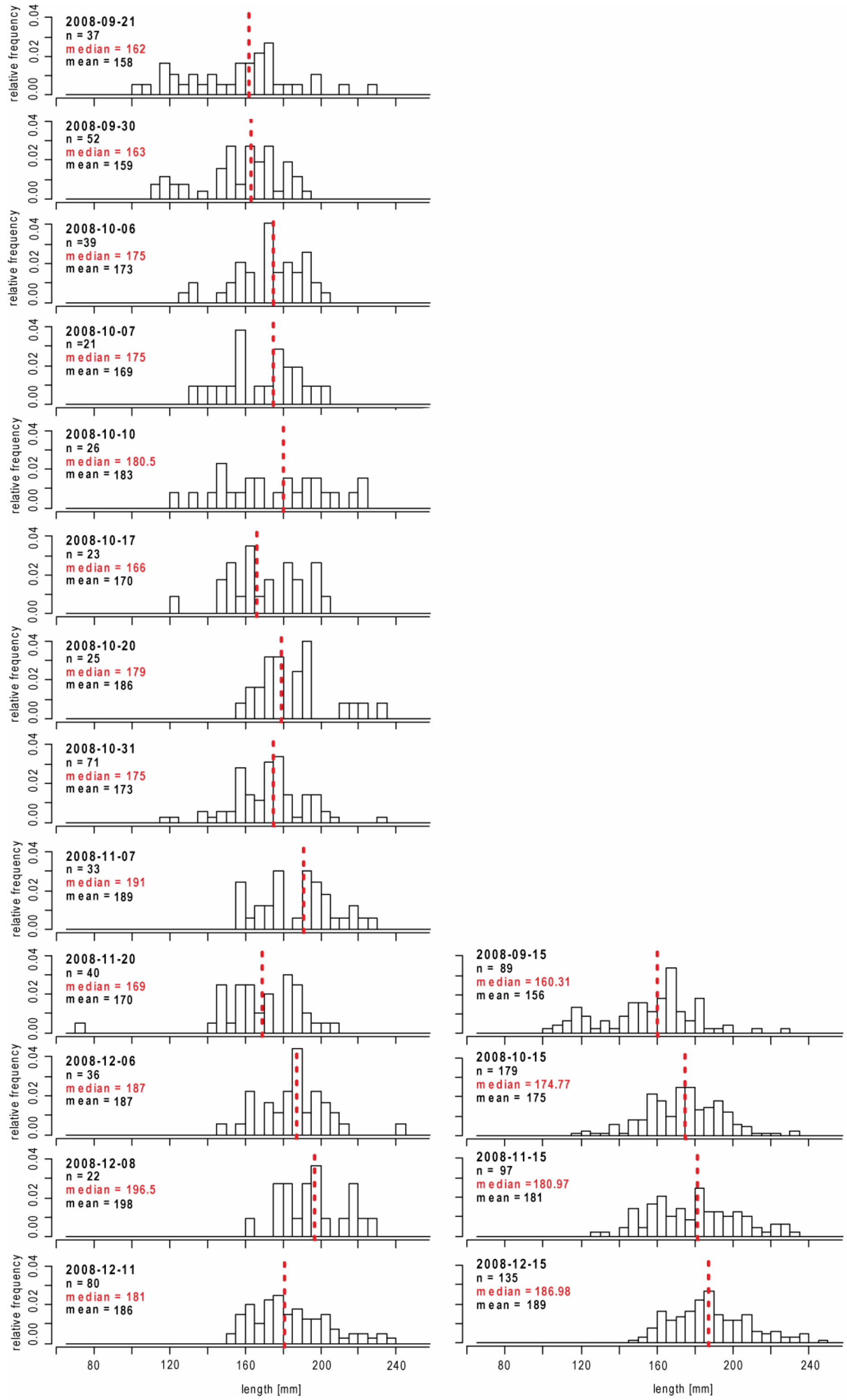


Fig 8: Length frequency distribution for juvenile cod caught at Fehmarn. left column: length frequency distributions for each date were laboratory-samples were taken; right column: length frequency distributions estimated for the middle of each month. The median is indicated by dotted red lines.

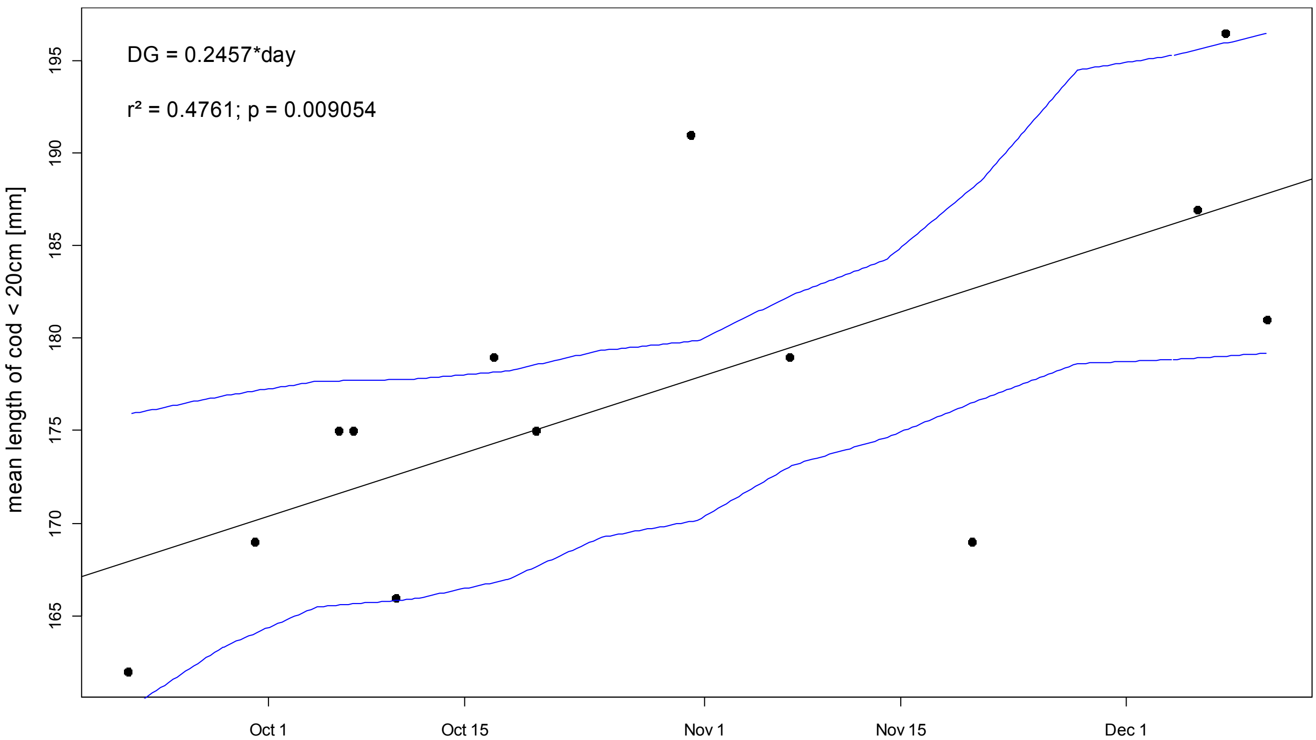


Fig 9: Mean daily growth (DG) of cod (only Fehmarn samples). Estimates are based on the median of length distributions of each sample. Blue lines indicate the confidence interval.

Abiotic data

Temperature

With regard to temperature data, both water and air temperature decreased from the beginning to the end of the sampling period (Fig 10). Both data series show cold snaps and upswings, whereas negative air temperature and water temperature deviations from trend were more intensively then the reverse, reaching to -3.8 and -1.8 °C, respectively (Fig 10). However, 42 and accordingly 45 percent of days within sampling period (1.Sept to 6.Dec 2008) were below the water and air temperature trend. Medians of small cod CPUE were higher by positive deviations from temperature trend (DTT), for both water and air temperature (Fig 12).

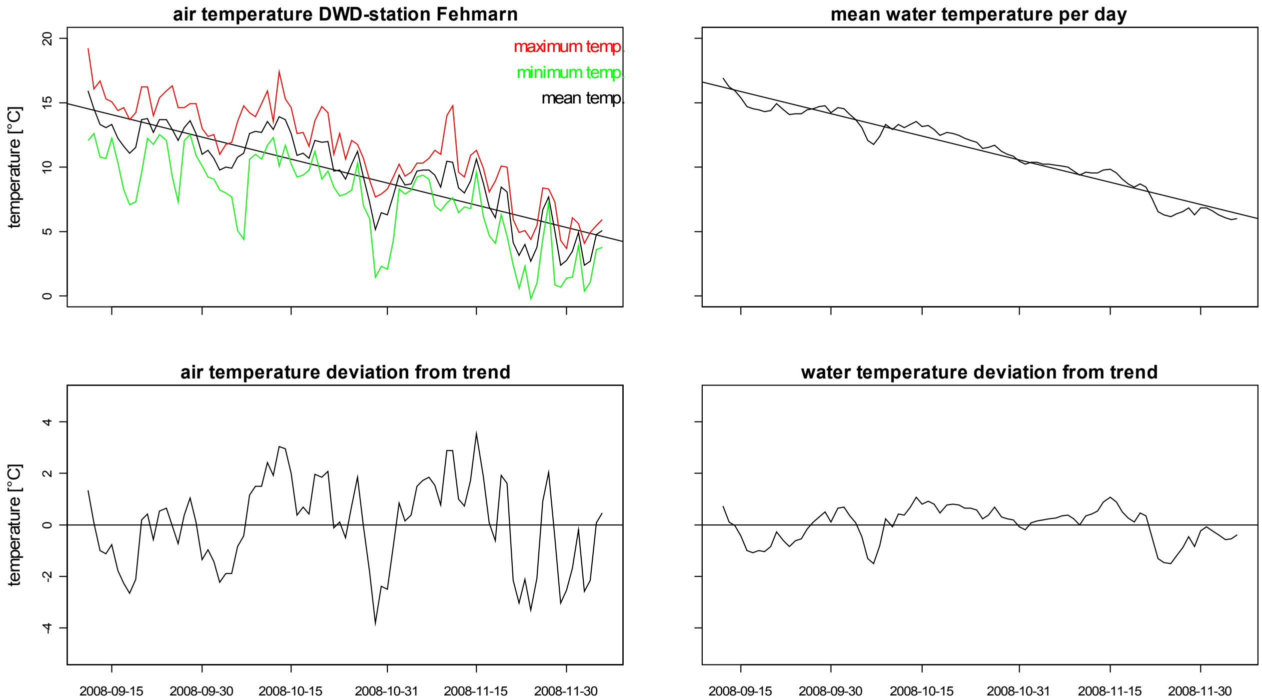


Fig 10: Air temperature, water temperature and deviation from trend from 11.Sept to 6.Dec 2008

Temperature dependent absolute and relative growth of subsequent mid-month dates show no significant trends (Fig 11). Growth between the intervals October-November and November-December were almost equal (absolute growth: 6.19cm and 6.13cm ; relative growth: 0.035 and 0.033). However, the growth decreases strongly from September to October (absolute growth: 14.46; relative growth: 0.086). Hawkins *et al.* (1985) characterized specific growth of juvenile demersal cod from the western Scottish coast. Our results of specific growth values (Sept-Oct: 0.288; Oct-Nov: 0.112; Nov-Dec: 0.111) were within range mentioned in their study(0.0-0.6).

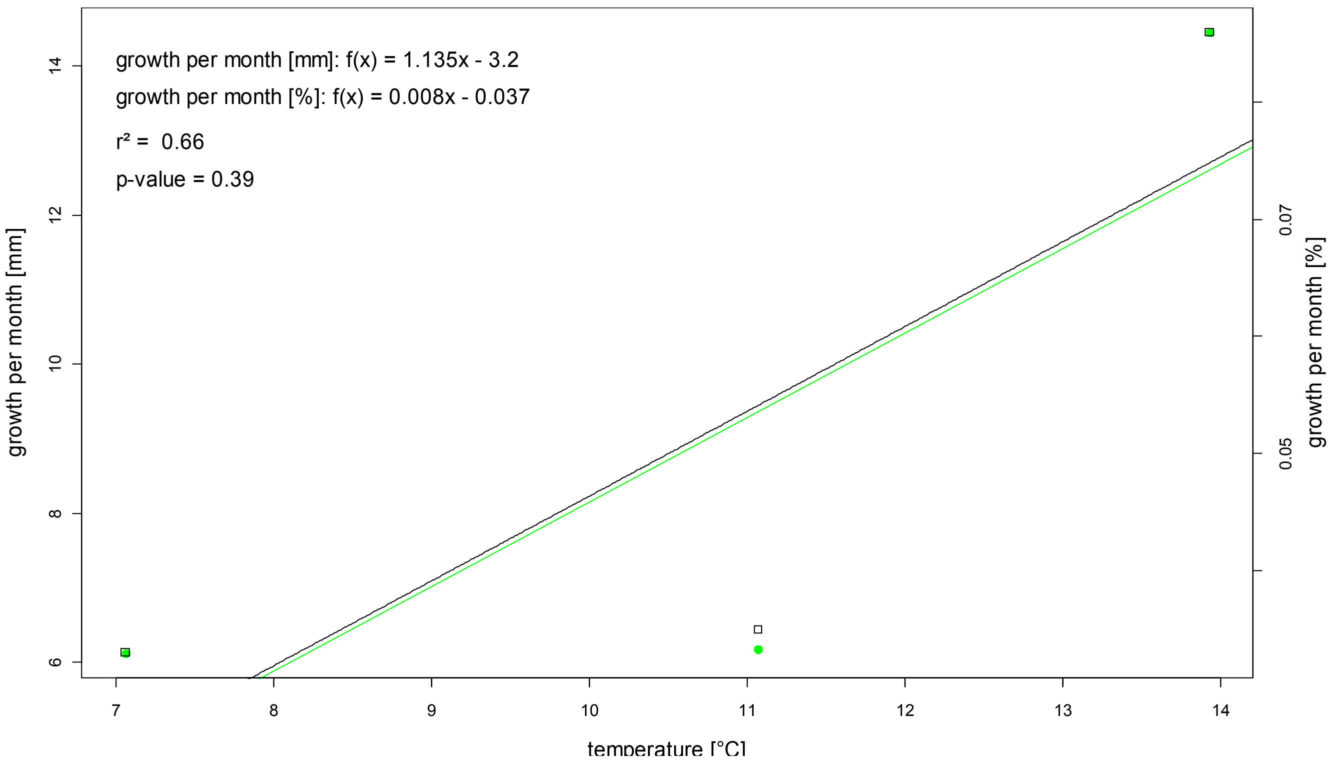


Fig 11: Temperature dependent absolute (black squares) and percentage growth (green points)

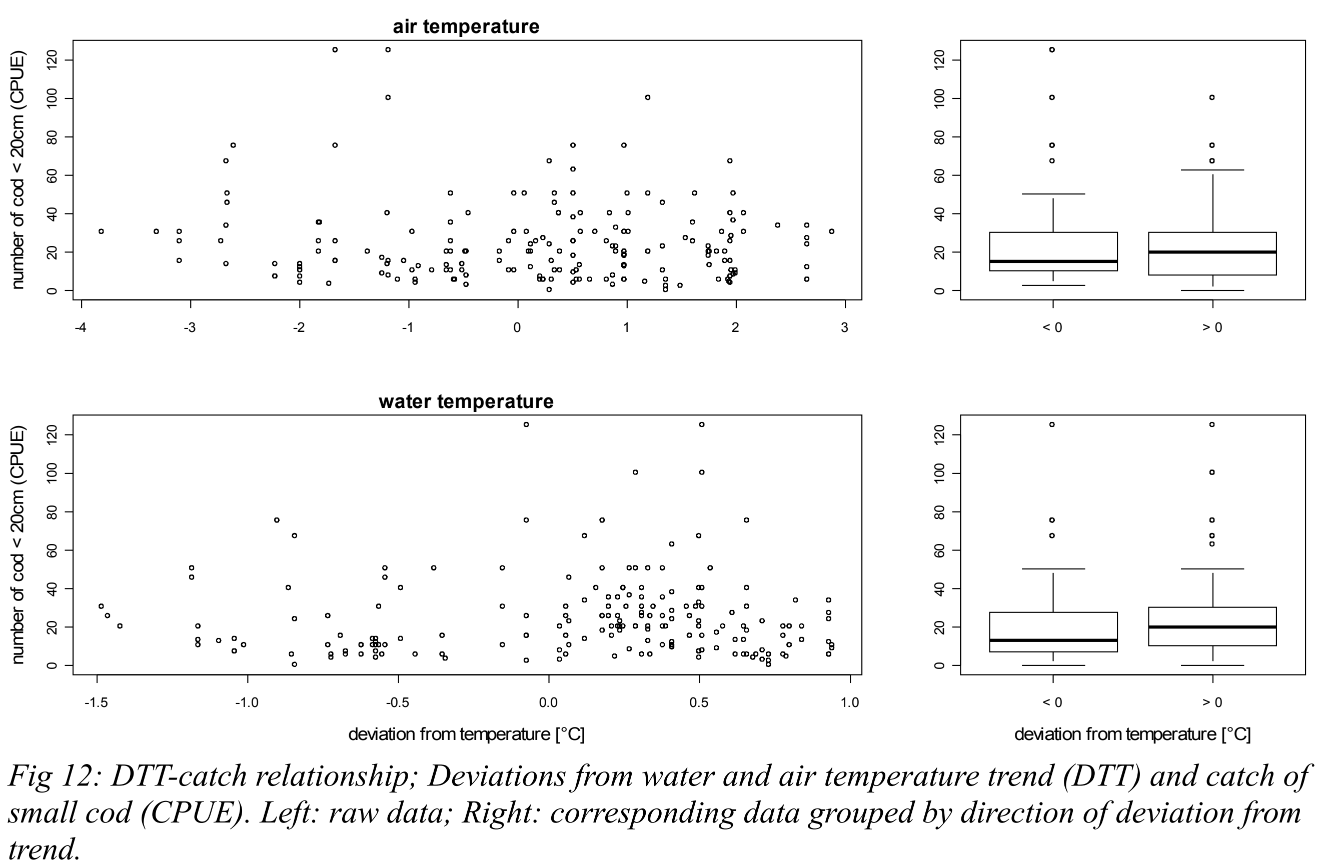


Fig 12: DTT-catch relationship; Deviations from water and air temperature trend (DTT) and catch of small cod (CPUE). Left: raw data; Right: corresponding data grouped by direction of deviation from trend.

Wind

Wind directions from northern Fehmarn obtained from BSH (Table 2) are comparable with data obtained from wetteronline.de (Fig 13). Furthermore, averaged wind direction values mostly appeared to be located in the range of raw values (Fig 14A-C).

All locations show more or less similar patterns concerning wind direction and strength (Fig 14A-C).

Wind directions at all sites were dominated by southwestern and northeastern winds during the sampling periods (Fig 15). Wind strength roses of Lolland and Fehmarn appeared to be quite similar, whereas results from Funen are restricted by the limited sampling period. Wind forces occurred independently from wind direction. However, at Lolland and Fehmarn low wind speeds were more frequent by southerly winds.

Catches from Funen appeared to be less abundant at eastern and southeastern winds (Fig 16 & 17). However, due to the short sampling period, information at several wind directions are not available. This applies also to data from Lolland, where low catches occurred especially at northwesterly and northeasterly winds. Data from Fehmarn represent the longest sampling period and accordingly most wind directions are covered. Here, southwestern winds (45°) seem to result in low catches, regardless which station is considered. Otherwise, westerly winds appeared to result in higher catches at northern and southeastern Fehmarn. In summary, close relationships of catches to wind directions were not quite evident due to high variability at higher catches.

As a result, wind strength data provide less evidence concerning direct effects on catches. Uniform patterns were not apparent (Fig 18).

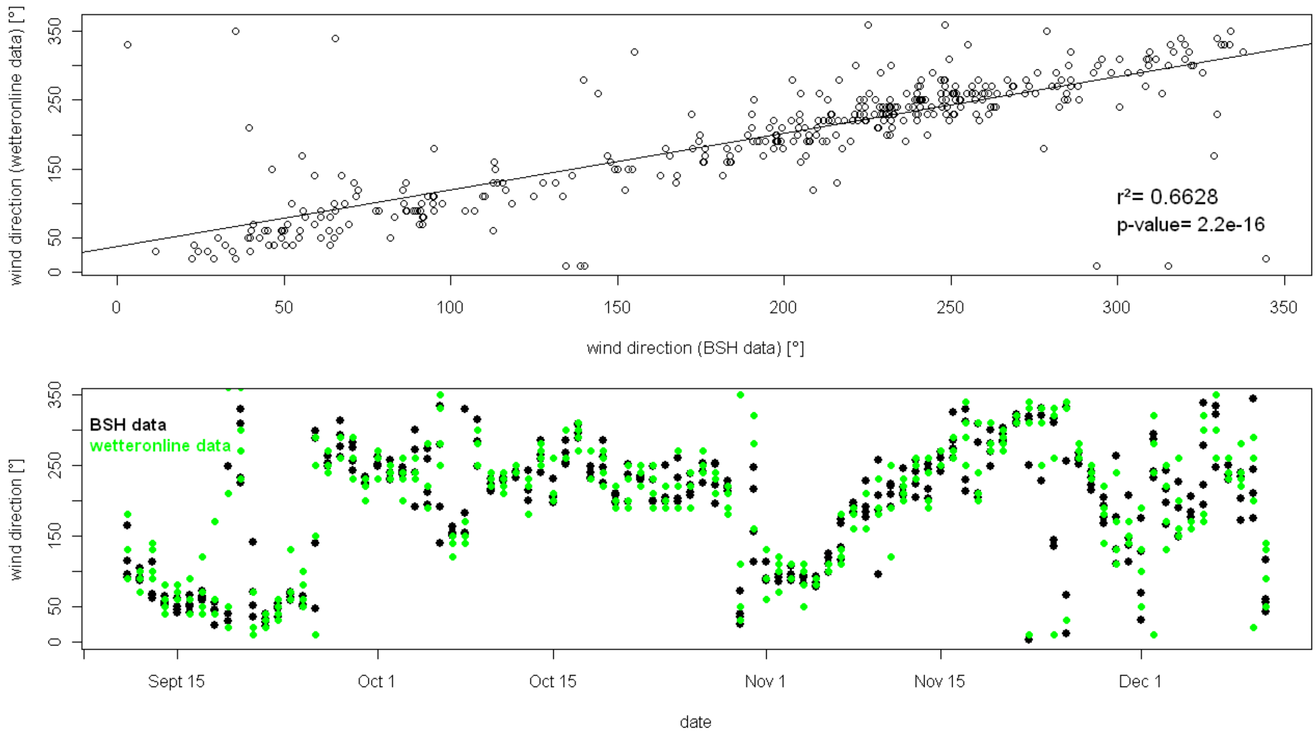
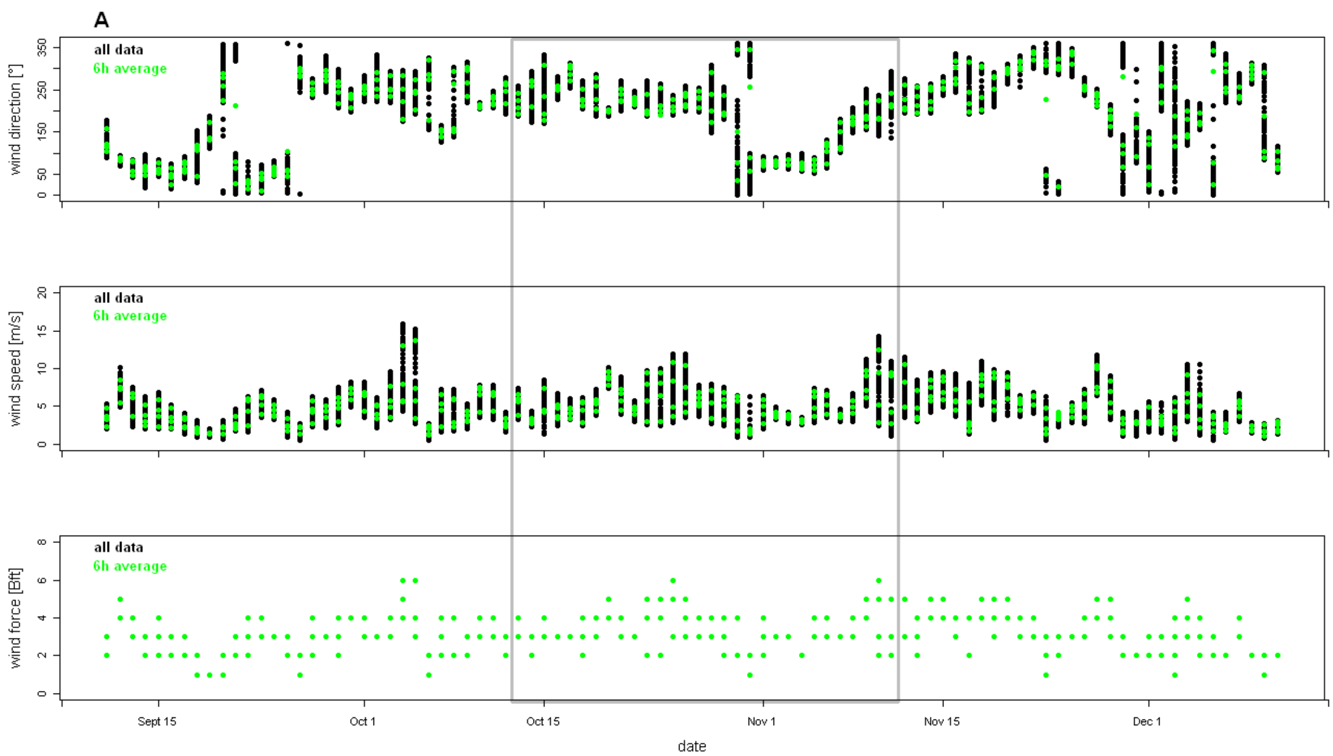


Fig 13: Comparison of 6h average data from BSH (station Fehmarn) and wetteronline.de



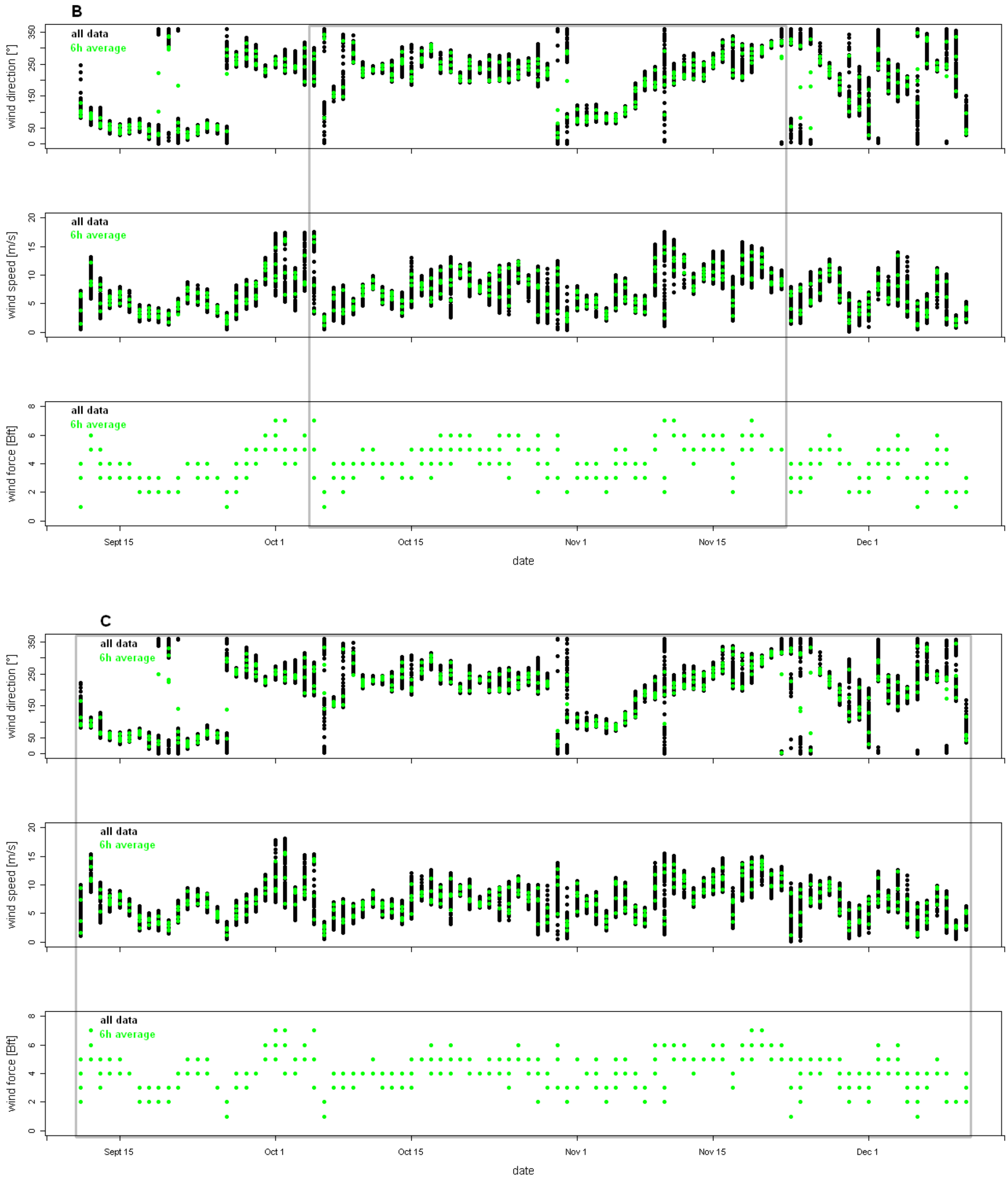


Fig 14: Wind direction, wind speed and wind force at Funen (A), Lolland (B) and Fehmarn © over time. Averaged data in green. Grey frame indicates the sampling period in that area. Positions of stations in Table 1.

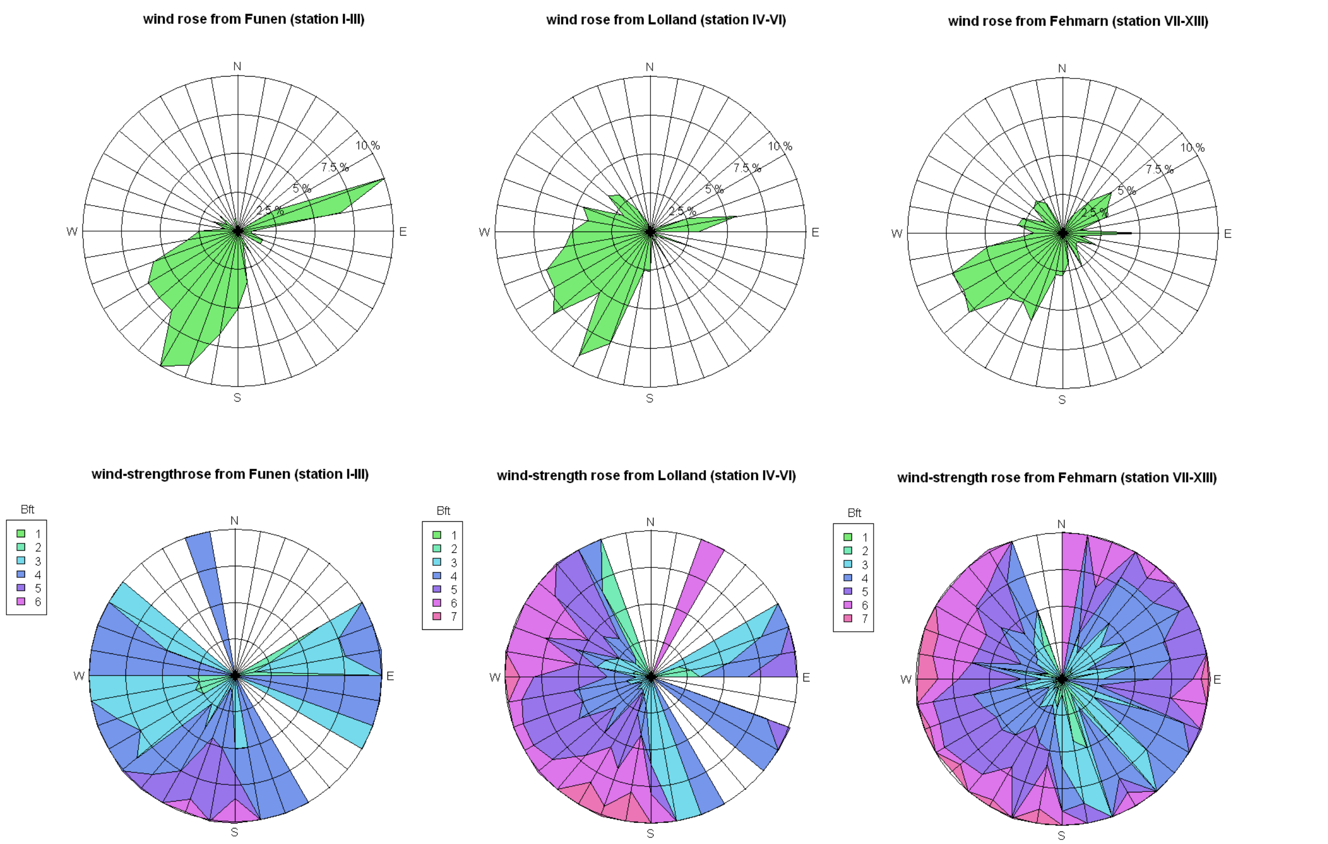


Fig 15: Upper panel: Wind roses for sampling areas indicating the occurrence of all wind directions (intervalls:10°); lower panel: wind-strength roses for each sampling area indicating the proportion of different windspeed (in bft) at specific wind directions.

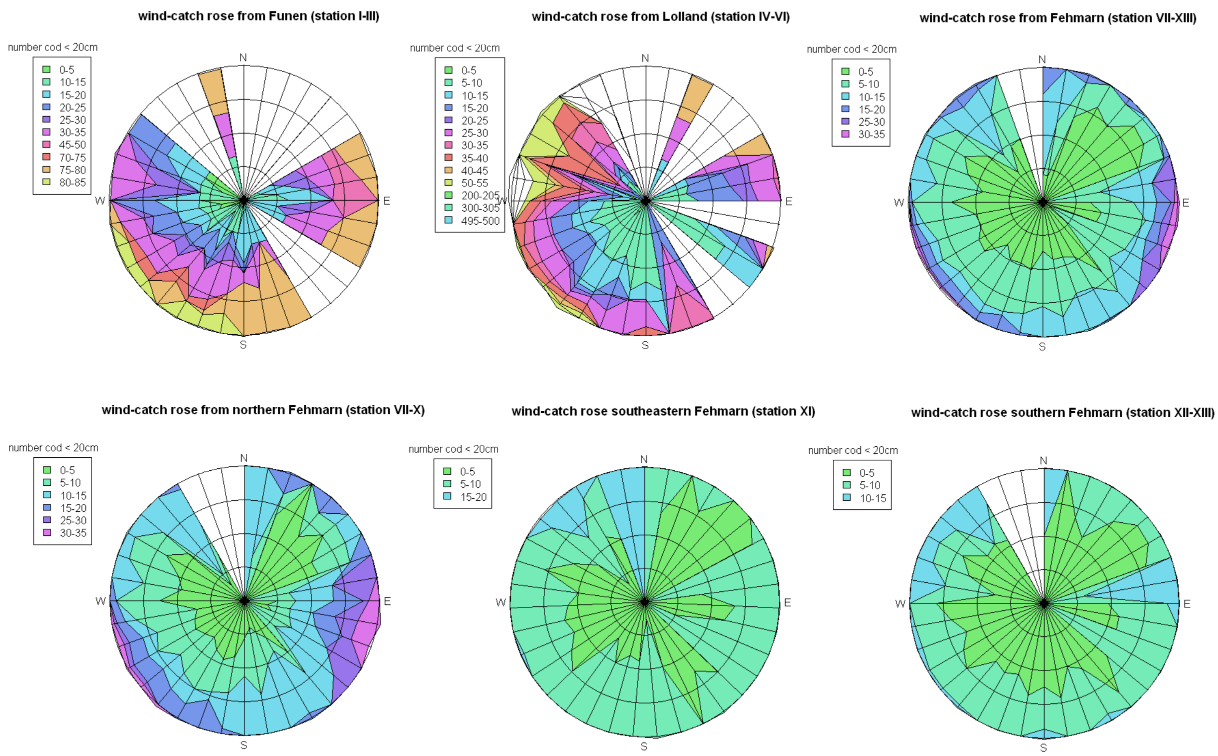


Fig 16: wind-catch roses for each station (proportion of groups of numbers of small cod at given wind direction). Due to different directions of coastlines at sampling stations of Fehmarn, subareas with similar conditions were analyzed separately. Gaps in graphics are caused by less or missing wind directions during sampling periods.

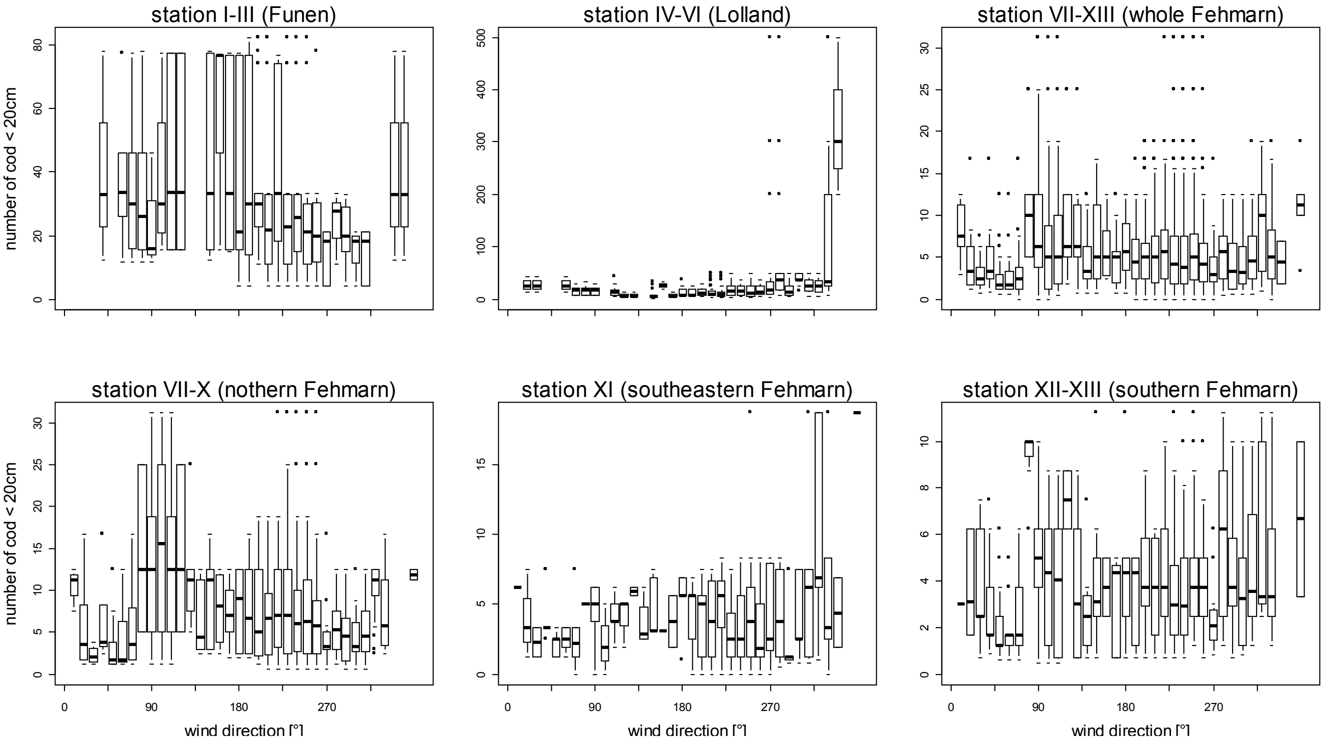


Fig 17: Wind direction-catch relationship. 6h-interval degrees are rounded to one decade.

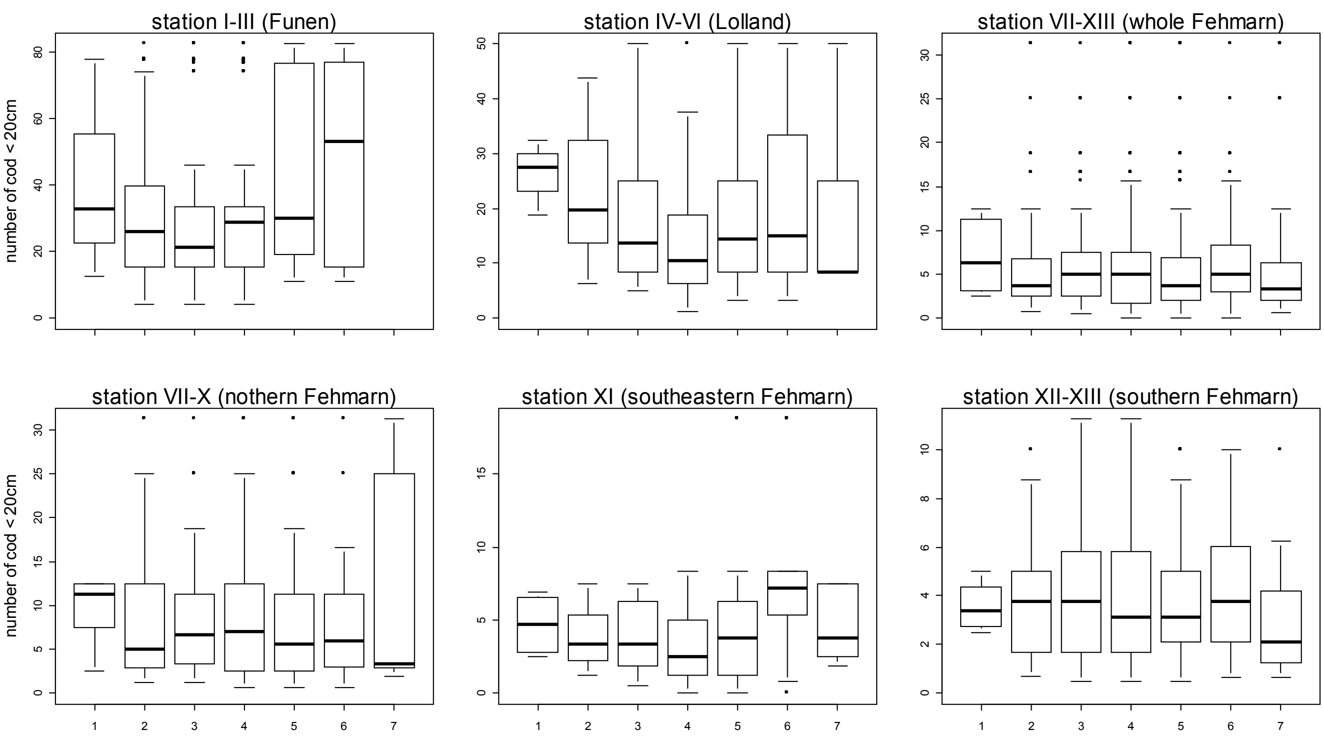


Fig 18: Wind-force catch relationship. Outliers greater 50 are not illustrated for sites of Lolland.

Currents

All stations have shown quite similar patterns concerning current directions and speeds (Fig 19, left panels). Since variability was low, current directions could be separated into two groups, regardless the locations. The second direction was always the approximate opposite direction (+/- 180°) of the first one. However, directions differed from location to location. Main direction groups for each location and their frequencies within the sampling period are given in Table 5. Both directions were constant over several hours. However, current directions often alternated several times per day and one direction group was often more frequent than its counterpart. Current direction-catch relationships for all locations are illustrated in Fig 20.

Table 5: Frequencies for treated and untreated data of current main direction groups at different locations during the maximum sampling period of each location (Table 1).

location	Funen		Lolland		northen Fehmarn		southeastern Fehmarn		southern Fehmarn	
direction group [°]	160-170	340-350	160-180	340-360	90-100	270-290	80-100	260-280	30-40	210-220
untreated data (15min value)	38.0%	59.5%	52.2%	44.8%	44.3%	55.7%	63.2%	28.1%	65.2%	29.3%
treated data (6h average)	39.1%	59.5%	54.1%	44.4%	34.1%	44.7%	59.2%	31.8%	66.6%	29.4%

In most cases high current speeds occurred only within these two groups of current directions, showing typical peaks (Fig 19, right panels). Current speed-catch relationships are given in Fig 21. CPUE-medians increased with increasing current speeds at Funen, Lolland and northern Fehmarn, although catches from northern Fehmarn decreased by exceeding a current speed of 0.25m/s. Current speeds from southern and southeastern Fehmarn have not shown clear trends.

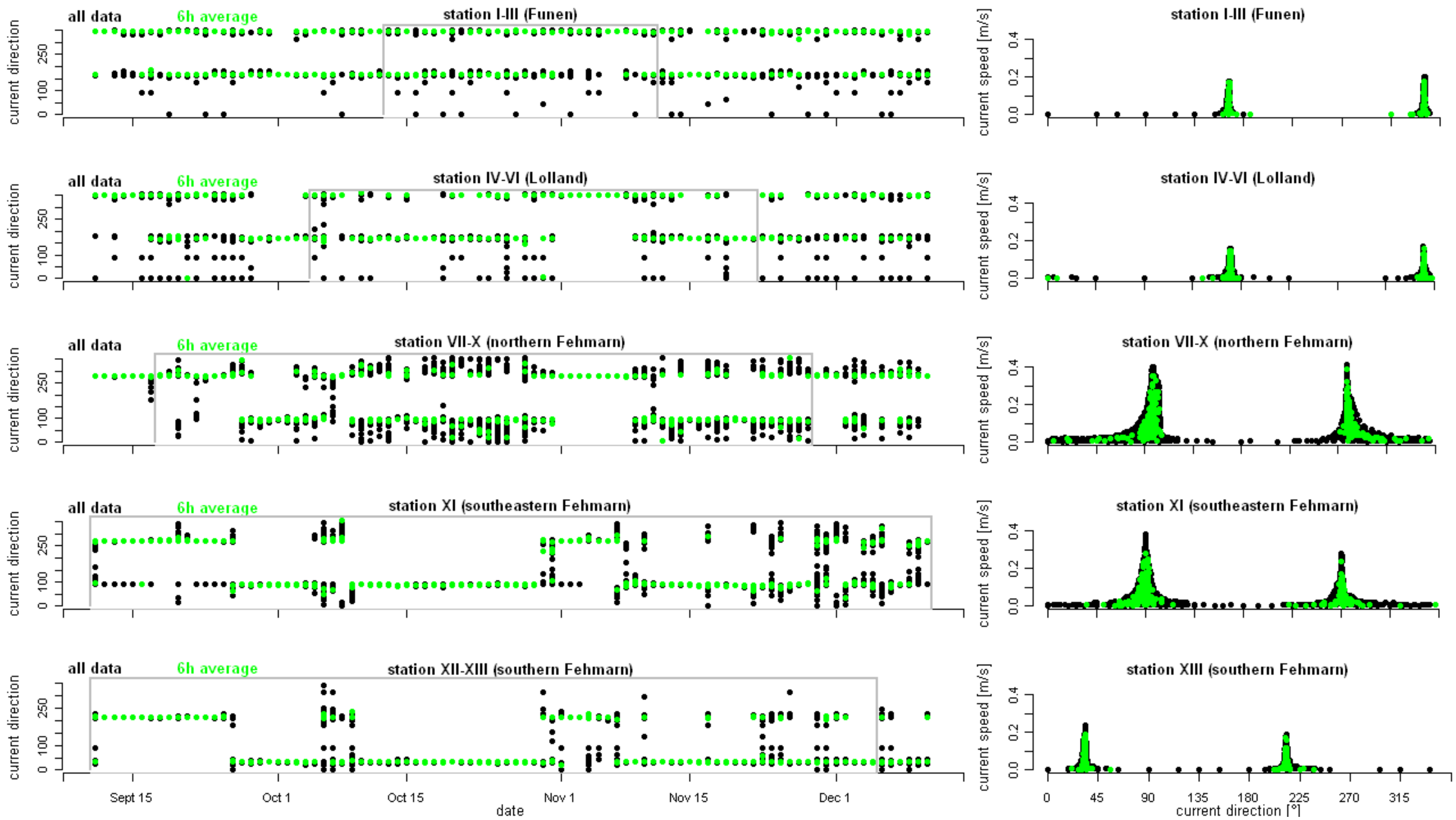


Fig 19: Developing of current direction and current direction-speed relationship. 6h averaged values are illustrated as green points. Grey frames indicate the sampling periods at the specific locations.

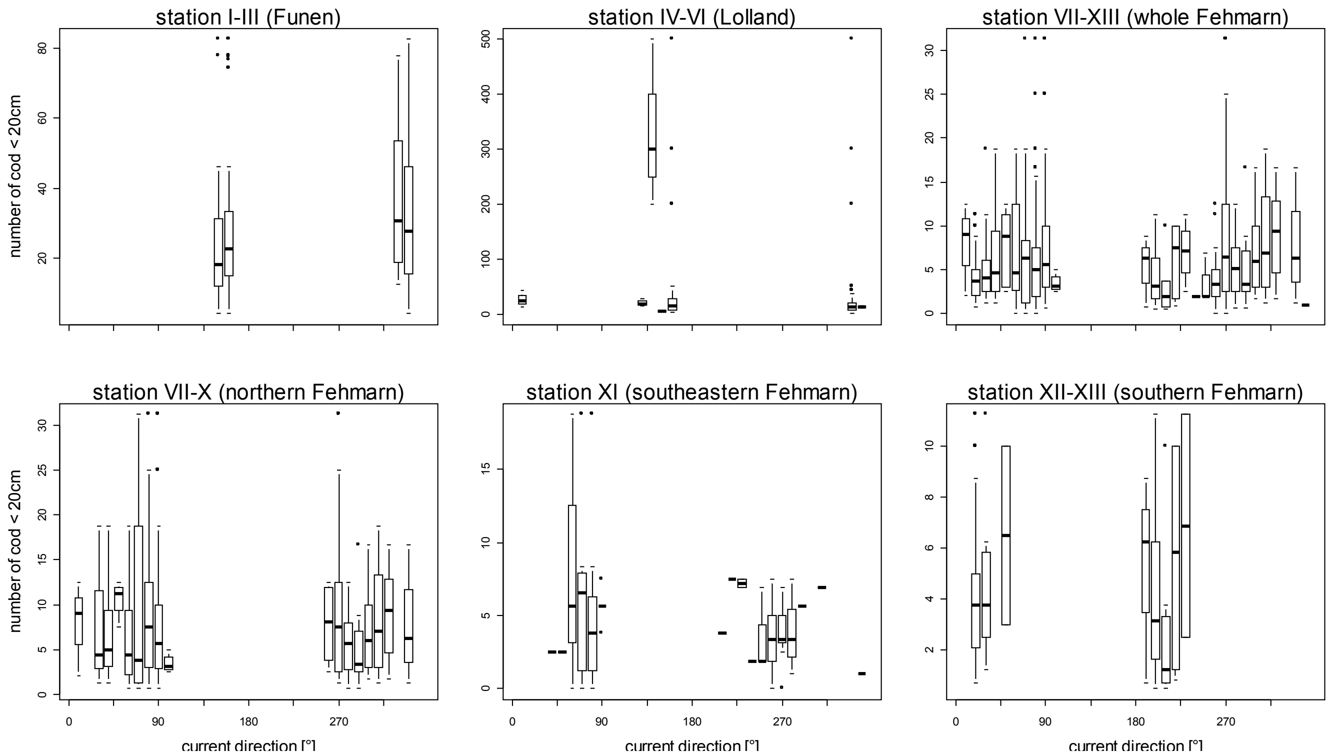


Fig 20: Current direction-catch relationship. 6h-interval directions are rounded to one decade (10°-intervals). Missing box plots indicate missing current directions.

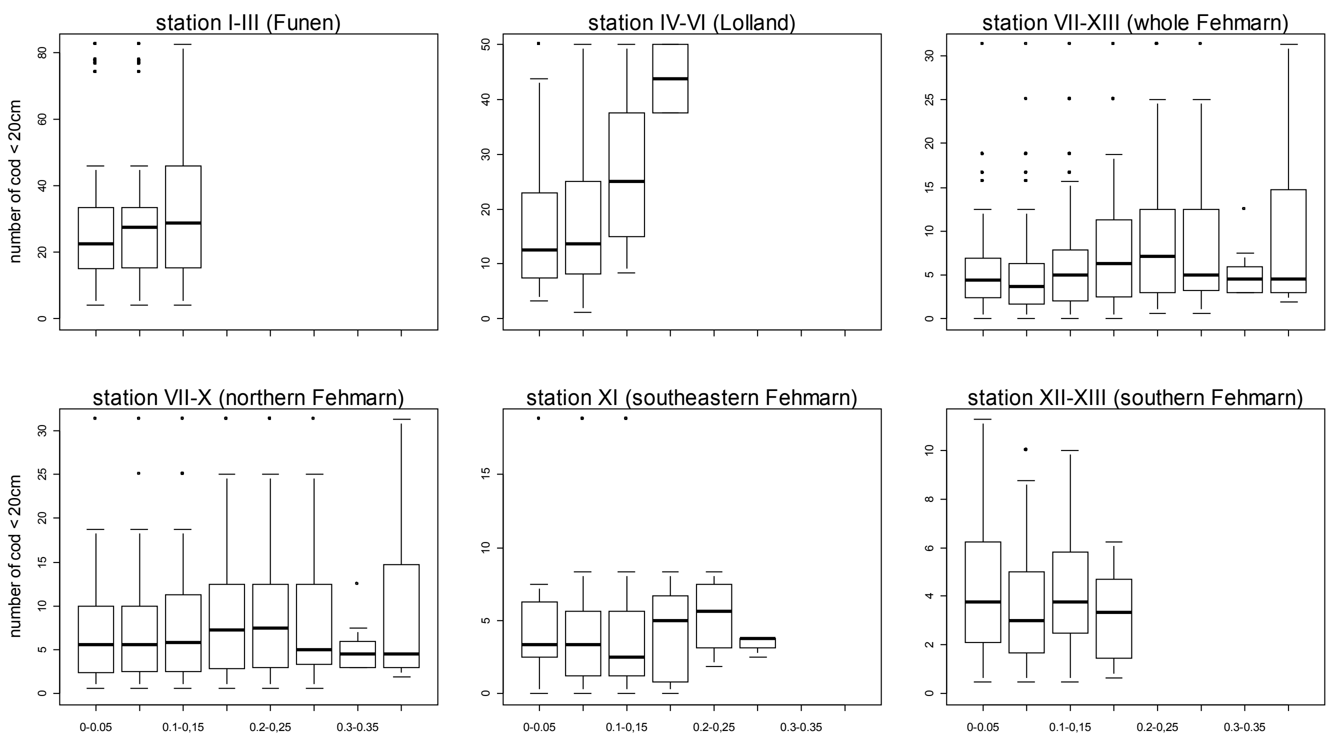


Fig 21: Current speed-catch relationship. Missing box plots indicate missing current speeds. Outliers greater 50 are not illustrated for sites of Lolland.

Discussion

In this study, we have investigated catch data of cod 0-group in the western Baltic Sea, which are collected by self-sampling of fishermen in Denmark and Germany. These catches were conducted using pound nets along the coast of the Islands of Funen, Lolland and Fehmarn. The aim of this study was to

- investigate temporal and spatial patterns of these catches
- investigate the influence of abiotic factors on these catches
- present a way to estimate a recruitment (0-group) index for western Baltic cod based on the investigations mentioned above

The catch per unit effort (CPUE in numbers per 24h) differed by site (i.e. pound net) and location (Funen, Lolland and Fehmarn), although some adjacent sites have shown a similar range of CPUE. The catches from Lolland and Funen exceeded those from Fehmarn by the factor 3-10. Therefore, it can be assumed that habitat utilization for these areas differed. Gregory *et al.* (2003) described an increase in recently settled cod abundance with simulated eelgrass and a corresponding decrease in sites where eelgrass has been removed. Borg *et al.*(1997) pointed out, that during daytime habitat choice of young and large juvenile cod is correlated to vegetation types, while both groups preferred *Fucus vesiculosus* significantly. Hence, further informations concerning habitat structure are necessary. In many studies different behavior of juvenile cod was observed during day and night (Grant and Brown 1998), Methven and Schneider 2004, Borg *et al.* 1997). However these behavior patterns are connected to locations, age and predation pressure (Kamenos *et al.* 2004). Since different behavior during day and night would biased averaging catch data into 6h intervals, knowledge about differences in day and night time behavior (and consequently catch rates) is necessary, but not available for the area of investigation.

The temporal development of CPUE of small cod has not shown a clear trend, regardless which site is considered (Fig 5).

Catch increased significantly with longer catch duration, although a 1:1-relation was not found (i.e. doubled total catch was not achieved by doubling catch durations. Bogstad *et al.* (1994) stated that cod feeds large numbers of their own species, especially those of age 0-2 and reported furthermore intercohort cannibalism between 1- to 3- year old cod. Therefore, one possible explanation could be that reduced CPUE of small cod is caused by cannibalism and predation by other species within the pound net. Reducing catch durations or disregarding of long catch duartions in further analyes should be made to minimize these sources of errors. If this is not possible, diet analyses of midsize (20-38cm) and sized cod (>38cm) should be undertaken to evaluate this potential affect. Longer catch durations caused by periods of bad weather resulting in lower catches could be a second explanation.

Fishermen were asked to take a sample of cod from size group 1 (<20 cm) for later analysis in the laboratory. Length frequencies of laboratory samples show that the later the season, the more cod from size group 2 (20-38cm) were taken in the samples (due to growth of the cohort). This reveals that a) the range of size groups used for the protocols may not be optimal and do not cover the entire length spektrum over the entire season and b) that numbers per size group given in the protocols do not strictly refer to the predefined size groups. Moreover, fishermen seemed to adapt these size groups to the actual size range of the cohort. To encompass the entire cohort of 0-group cod, it is advisable to extent the size limit of small cod to 25cm. The separation of 0-group and (small individuals) of age 1 cod in this extended size group 1 (< 25cm) has to be done using otolith age readings.

By averaging wind direction data in 6h intervals daily variations were covered more broadly and arithmetic errors concerning the averaging method of wind direction were reduced. However, these errors still exist since no method was found, which provides a suitable solution. The comparison of 6h average data from BSH with data from wetteronline.de using linear regression showed significant relation ($r^2 = 0.66$), but suffered from the same problem, not recognizing similarities of high and less degrees (e.g. 350° and 0°). Hence correlation is suggested to be even higher. Similar values and development of wind data at different areas indicate that wind directions and strength are relative constant over greater distances. Therefore, using only one source of wind data for each sampling location can be assumed to provide suitable and authentic values.

Wind directions and strength are known to affect distribution of eggs and larval stages of fish (Margoñski 2000, Hinrichsen *et al.* 2008). Furthermore, Nanami & Endo (2007) have shown that occurrence of adult fish of various species within the surf zone is addicted to wind condition. However, our results indicate effects, though they are less well-defined. Especially wind directions seem to affect catches, whereas catches did not show close correlation to wind strength. Although, wind directions are superimposed by wind strength data and therefore wind strengths might influence wind direction effects on catches. Multiple correlation analyses could improve the understanding of relationships. Such investigations were made by Gibson *et al.* (1993) They developed a “wind factor”, which combines wind directions and wind strengths and relate them to the compass directions of the beach.

As wind conditions, currents can be assumed to affect fish occurrence, particularly since wind can causes currents. Within our study area currents occurred mainly in two groups of directions. Differences concerning effects on catches of both groups were low. Therefore current directions apparently did not impact catches.

Increasing current speeds were attended by increasing catches. However, strong currents (> 0.3 m/s) were accompanied by low catches. Shore structures influence current speeds and directions. Taking one current station to analyze catches of various sampling stations could distort results.

Estimating abundance index of 0-group cod

In the recent assessment of western Baltic cod (ICES 2008), three tuning fleets are used for Baltic cod recruitment estimates (Table 6). These tuning fleets have a poor performance concerning youngest age group (Fig 22). It is assumed, that the surveys do not cover the spatial distribution of 0-group cod appropriately.

Table 6: Tuning fleets of Baltic cod stock assessment (ICES, 2008)

Fleet	Year range	Age range
"Solea", Q4, SD22-24	1994-present	age 1-3
Danish Gilnetters	1994-present	age 2-6
Danish Trawlers	1992-present	age 3-6
"Havfisken", Q1, SD22-23	1995-present	age 1-3
"Havfisken", Q4, SD22-23	1994-present	age 1-3

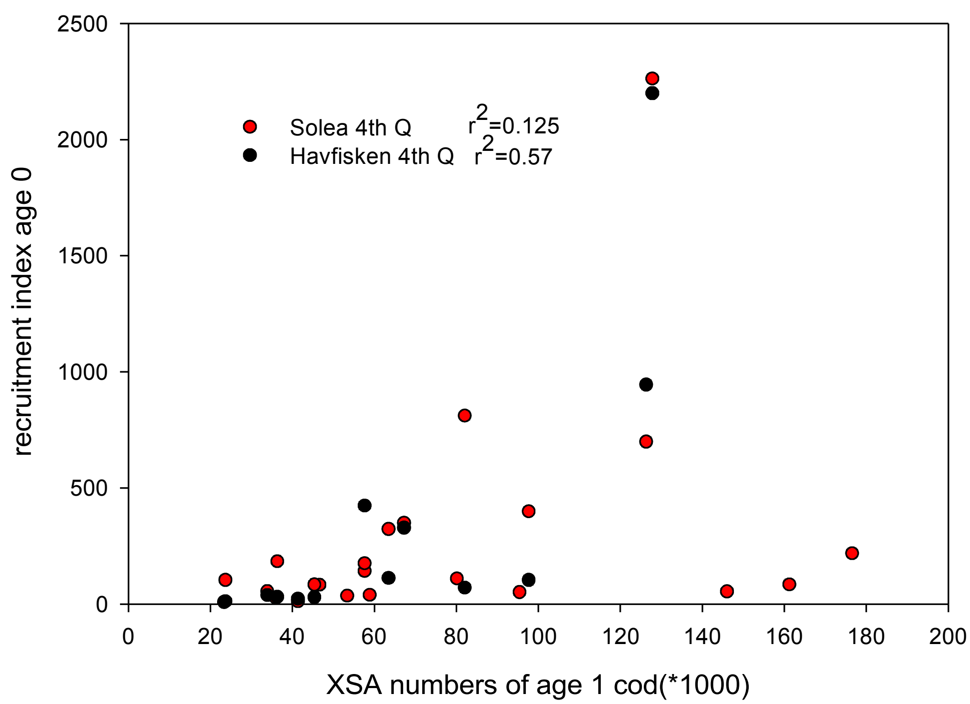


Fig 22: The present correlation between the 0 group from the two scientific surveys and the outcome of age 1 (back shifted) from the assessment. data from ICES(2008); graphic delivered from M. Storr-Paulsen.

Based on our results we present an algorithm to calculate a recruitment index to be used as tuning fleet for the assessment of the western Baltic cod or directly in short term forecast. Though it would be possible to use this index in addition to the already existing young cod index from “Solea” and “Havfisken” or as a separate index. However, we accentuate that this data series was founded in 2008 and utilization for index calclaution is not possible until the time series has a duration of about 5 years. Therefore, the algorithm presented is preliminary and has to be checked and adapted if more data are available (e.g. if variation estimates are available).
For the establishment we took the following considerations into account:

The new data series and hence the recruitment index should meet following requirements:

1. the data series should have a long term perspective
2. the data series should be resistant, concerning changes of the spatial distribution of 0-group western Baltic cod

   <u>Therefore:</u>

   a) we advise to record three different time series of pound net fishery, one for each location (Funen, Lolland, Fehmarn)

   b) it is necessary to gather samples at as much sites per location as possible

3. the size range of 0-group has to be covered totally

   <u>Therefore:</u> size limit of size class I (small cod) should be expanded to 25cm

4. the sample size for laboratory analyzes has to be raised to at least 100 individuals or 5kg per sample, to achieve represent samples (i.e. appropriate length distributions)

Calculation of the indicator:

1. The number of cod in size group 1 (<25cm) potentially include specimen from age group 0 and age group 1. To gather the true number of 0-group cod caught in pound nets, a correction is necessary. The proportion of 0-group cod has to be investigated from otolith readings of laboratory samples.

Equation 1: $$CPUE_{0\text{-group}} = CPUE_{sample} * P_{0\text{-group}}$$

whereby $CPUE_{0\text{-group}}$ is the number of cod of age group 0 per fishing activity; $CPUE_{sample}$ is the number of cod in size group 1, recorded by fishermen; $P_{0\text{-group}}$ is the proportion of small cod in laboratory sample which corresponds to area and date of $CPUE_{sample}$

2. The corrected $CPUE_{0\text{-group}}$ of all sites per location (Lolland, Funen and Fehmarn) should be averaged for the entire season, resulting in mean location CPUE ($CPUE_{loc}$)

Equation 2: $CPUE_{loc} = (\Sigma CPUE_{0\text{-group},loc}) / n_{i,loc}$

whereby $CPUE_{0\text{-group},loc}$ is the number of cod of age group 0 of fishing activity at location loc; $n_{i,loc}$ is the number of recorded catches at location loc

3. For all three locations (Lolland, Funen and Fehmarn), an index ($index_{loc}$) will be calculated

Equation 3: $meanCPUE_{loc} = (\Sigma CPUE_{loc,years}) / n_{loc, years}$

whereby $meanCPUE_{loc}$ is the mean of $CPUE_{loc}$ of all years at this location ($CPUE_{loc,years}$) and $n_{loc, years}$ is the count of years for which $CPUE_{loc}$ are available at this location

Equation 4: $index_{loc} = (CPUE_{loc} / meanCPUE_{loc}) - 1$

example:

$CPUE_{loc}$	$meanCPUE_{loc}$	$index_{loc}$
20	20	0
10	20	-0.5
30	20	0.5

4. An overall index for a given year (index) will be calculated

Equation 5: $index = (\Sigma index_{loc}) / n_{loc}$

whereby $index_{loc}$ are the indices for every location (which is available for this year) and n_{loc} the number of location for which an an index is available for this year.

Recommendation

The Sampling design should be revised in several aspects. Protocols must be completed uniformly. Uniform records and sampling periods are necessary to analyze catches of different study areas. Furthermore sampling periods should start earlier and catch durations should be reduced. Diet analyzes are necessary to study the impact of cannibalism on catches. To estimate growth extensive samples of juvenile cod are needed. Length-frequency analysis show that classifying cod length by fishermen is deficient. Therefore this error must be determined by using length frequency analysis. Although, it is important to consider the fraction of juvenile cod (<20cm) in midsize catch data as well. Laboratory samples of juvenile and midsize cod of each fishermen are necessary to evaluate length class error.

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Appendix 1

Pound net – haul form	**Ship:**	**Captain:**	**Ship code:**	**Filled in from:**

Position	Latitude	Longitude	Water depth
	° ' N	° ' E	m

Net	Typ	Number of meshes	Direction to coast

Haul-Nr.	**Date**	**Time (Start)**	**Time (End)**	**Wind**		**Weather**	**Cod < 20 cm**		**Cod 20 - 38 cm**		**Cod (sized)**		**Comment (e.g. Discard, Specials, Frost sample, etc….)**
	(dd/mm/yy)	(hh:mm)	(hh:mm)	Direction	Force	Code	Number (p.)	Weigth (kg)	Number (p.)	Weigth (kg)	Landing (kg)	☐ vmK ☐ amK	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

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Fig 23: Pound net haul protocol

windforce	wind speed				wave height (m)	
in bft	m/s	km/h	mph	kn	deep sea (Atlantic)	shallow sea (North and Baltic Sea)
0	0,0 – <0,3	0	0 – <1,2	0 – <1	–	–
1	0,3 – <1,6	1 – 5	1,2 – <4,6	1 – <4	0,0 – 0,2	0.05
2	1,6 – <3,4	6 – 11	4,6 – <8,1	4 – <7	0,5 – 0,75	0.6
3	3,4 – <5,5	12 – 19	8,1 – <12,7	7 – <11		
4	5,5 – <8,0	20 – 28	12,7 – <18,4	11 – <16	0,8 – 1,2	1
5	8,0 – <10,8	29 – 38	18,4 – <25,3	16 – <22	1,2 – 2,0	1.5
6	10,8 – <13,9	39 – 49	25,3 – <32,2	22 – <28	2,0 – 3,5	2.3
6	13,9 – <17,2	50 – 61	32,2 – <39,1	28 – <34	3,5 – 6,0	3
8	17,2 – <20,8	62 – 74	39,1 – <47,2	34 – <41	more than 6,0	4
9	20,8 – <24,5	75 – 88	47,2 – <55,2	41 – <48		
10	24,5 – <28,5	89 – 102	55,2 – <64,4	48 – <56	till 20,0	5.5
11	28,5 – <32,7	103 – 117	64,4 – <73,6	56 – <64	more than	
12	>32,7	>118	>73,6	>64	20,0	–

weather	
0	clear, cloudless
1	partial cloudy
2	closed cloud cover
3	sand-,dust- or snow storm
4	fog or heavy smoke
5	drizzel
6	rain
7	sleet or snow
8	show er
9	no notice

fishing gear type	
OTB	Otter Traw l Bottom
PTB	Pair Traw l Bottom
TTB	Tw in Traw l Bottom
OTM	Otter Traw l Midw ater
PTM	Pair-Traw l Midw ater
GNS	Gill Net Set
GND	Gill Net Drift
LLS	Longline Set
FPN	Uncovered Pound Net
FYK	Fyke Net
FPO	Fish Pot

Fig 24: Explanatory notes to pound net haul protocol for fishermen

Appendix 2

Table 7: Sampling periods and catch durations for each sites. Periods are colored, catch durations are given in hours at heaving days. Dates of laboratory sampling are illustrated in the outermost column. Question marks indicate samplings with unknown catch durations (those catches are not used in the analyses).

Date	Funen			Lolland			northern			Fehmarn	southern	southeastern		frozen samples (n)
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
2008-09-11														
2008-09-12											24	24	24	
2008-09-13														
2008-09-14											48	48	48	
2008-09-15											24			
2008-09-16											24	48	48	
2008-09-17														
2008-09-18														
2008-09-19											72	72	72	
2008-09-20														
2008-09-21												48	48	37
2008-09-22							96		72		72			
2008-09-23											24	48	48	
2008-09-24											24	24	24	
2008-09-25							72		72		24			
2008-09-26							24		24		24	48	48	
2008-09-27														
2008-09-28												48	48	
2008-09-29							72		72	24	72			
2008-09-30												48	48	52
2008-10-01							48	48	48	48	48			
2008-10-02														
2008-10-03							48	48	48		48	72	72	
2008-10-04										48				
2008-10-05				?	?	?								
2008-10-06				24	24	24	72	72	72		72	72	72	39
2008-10-07				24	24	24				48				21
2008-10-08				24	24	24					48	48	48	
2008-10-09				24	24	24					24			
2008-10-10						24	96	96	96	48	24	48	48	23
2008-10-11				48	48	24								
2008-10-12											48			
2008-10-13	?	?	?	48	48	48	72	72	72	48	24	72	72	
2008-10-14														
2008-10-15														
2008-10-16							72	72	72		72	72	72	
2008-10-17				96	96	96						24	24	25
2008-10-18	120	120	120							24				
2008-10-19				48	48	48					72	48	48	
2008-10-20	48	48					96	96	96		24			71
2008-10-21				48	48	48					24	48	48	
2008-10-22			96	24	24	24				24				
2008-10-23	72	72		24	24	24					48	48	48	
2008-10-24				24	24	24	96	96	96		24			
2008-10-25				24	24	24				24				
2008-10-26											48	72	72	
2008-10-27	96	96	120	48	48	48								
2008-10-28							96	96	96		48	48	48	
2008-10-29	48	48		48	48	48					24	24	24	
2008-10-30										24				
2008-10-31	48	48	96	48	48	48	72	72	72		48	48	48	33
2008-11-01														
2008-11-02							48	48			48	48	48	
2008-11-03	72	72	72	72	72	72				24				
2008-11-04							48	48	96	24	48	48	48	
2008-11-05												24	24	
2008-11-06			72	72	72	72								
2008-11-07							72	72	72		72	48	48	26
2008-11-08	120	120		48	48	48				24				
2008-11-09														
2008-11-10	48	48												
2008-11-11			144	72	72	72				24	96	96	96	
2008-11-12							120	120	120					
2008-11-13										24		48	48	
2008-11-14				72	72	72					72			
2008-11-15														
2008-11-16							96		96			72	72	
2008-11-17				72	72	72				24	72			
2008-11-18											24			
2008-11-19														
2008-11-20												96	96	40
2008-11-21					96	96	120		120	24	72			
2008-11-22					24	24								
2008-11-23											48	72	72	
2008-11-24														
2008-11-25							96		96	24	48			
2008-11-26														
2008-11-27														
2008-11-28							72		72		72		120	
2008-11-29										24				
2008-11-30														
2008-12-01														
2008-12-02														
2008-12-03														
2008-12-04														
2008-12-05													168	
2008-12-06										24				36
2008-12-07														
2008-12-08											96			22
2008-12-09														
2008-12-10														
2008-12-11										24	96			80