„ The influence of vertical distribution of Baltic herring (*Clupea harengus L.*) and sprat (*Sprattus sprattus L.*) on the abundance estimation with hydroacoustic methods "

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1. ABSTRACT

In the present study various hydroacoustic data collections sampled during the Baltic International Acoustic Spring Surveys “BASS” within the years 1999 until 2009 (apart from 2000) have been analyzed. Main aim of this study is to analyze and compare different methods to estimate *Sprattus sprattus L.* abundances using empirical TS – length methods (to ICES (1983), Ona (2003) and Fässler et al. (2007)). The difference in methodology, using various TS relationships, is one of the major reasons for the variability in TS proposed by mentioned author and thus sprat abundance estimates. This study show that estimates of sprat abundances following depth-independent TS methods proposed by Ona (2003) and Fässler et al. (2007) are about 59 % and even 75 % smaller due to higher TS means for fishes being similar in size compared to those using the traditional TS formula (ICES 1983). These differences between estimated abundances using depth-independent TS – length relationships demonstrate a continuous percentaged disparity over the years. Hence, a low effect of various TS methods on sprat abundances used as indices to assess stock of Baltic clupeids might be assumed. Depending on method used, the mean difference in abundance estimates varied between 4 % and 10 % using depth-independent and depth-dependent TS values. Changes in vertical distribution of clupeids between years are of particular importance for potential calculation of indices to assess stock of Baltic clupeids. Therefore, the importance of using current depth-dependent TS methods for abundance estimates of Baltic clupeids has to be verified by the German contribution to the Baltic International Acoustic Spring Survey.

1. ZUSAMMENFASSUNG

In der vorliegenden Masterarbeit wurden Hydroakustikdaten untersucht, die im Rahmen des internationalen Ostsee-Frühjahrs-Akustik-Surveys „BASS“ in den Jahren 1999 – 2009 (abgesehen von 2000) aufgenommen wurden. Ziel ist es bekannte „Zielmaß (TS) – Längen“ Beziehungen, wie in ICES (1983), Ona (2003) und Fässler et al. (2007) beschrieben, zur Abundanzsabschätzung von *Sprattus sprattus L.* zu analysieren und zu vergleichen. Aufgrund unterschiedlicher Beschreibungen der akustischen Eigenschaften von Fischen durch verschiedene TS Gleichungen, ergeben sich naturgemäß verschiedene Abundanzen für die Ostseesprotte. Die Untersuchung zeigt, dass die, mit tiefenunabhängigen TS-Beziehungen nach Ona (2003) und Fässler et al. (2007), durchgeführten Bestandsabschätzungen 59 % bzw. 75 % geringere Sprott-Abundanzen ergeben. Dies resultiert aus höheren akustischen Zielmaßen bei gleicher Körperlänge von Clupeiden, verglichen mit jenen, die basierend auf der traditionellen „TS – Längen" Beziehung nach ICES (1983) kalkuliert wurden. Beim Vergleich der tiefenunabhängig berechneten Sprott-Abundanzen ergeben sich konstante prozentuale Unterschiede über die Jahre. Für eine im Bestands-Assessment als Index benutzte Sprott-Abundanz dürften die Auswirkungen der Benutzung der verschiedenen Methoden entsprechend gering sein. In Abhängigkeit der angewandten Methode und in den jeweiligen Tiefenverteilungen der Sprotten resultierten mittlere Differenzen zwischen 4 % und 10 % in den Abundanz-Berechnungen, die mittels tiefenunabhängiger und tiefenabhängiger TS – Werte berechnet wurden. Insbesondere die zwischen den Jahren variierende Tiefenverteilung der Sprotten ist für eine potentielle Index-Berechnung von Bedeutung. Aus diesem Grund sollte im Rahmen des „Baltic International Acoustic Spring Surveys" und der Assessment-Arbeitsgruppe überprüft werden, ob für Bestandsberechnungen von Heringsartigen in der Ostsee die tiefenabhängigen TS-Formeln zukünftig berücksichtigt werden sollten.

2. INTRODUCTION

Marine ecosystems provide valuable services, but are under pressure from stressors such as exploitation and climate change. These pressures alter the structure and the composition of marine ecosystems. The consequences of structural and compositional changes are poorly understood. Successful and foresighted management strategies are necessary for conserving marine biodiversity. Acoustic survey techniques are especially suitable for estimates of the abundance and the distribution of fish (Jennings et al. 2001). They are used for assessment purposes. The present study shall enhance the hydroacoustic methods to estimate Baltic clupeid abundances.

2.1 Changes in the fish community of the Baltic Sea

Since 1978 hydroacoustic surveys have a long history in the Baltic Sea to allow estimates of total biomass of the two main small pelagic planktivorous fish species herring (*Clupea harengus L.*) and sprat (*Sprattus sprattus L.*) (ICES 1983). Both species play a major role in the Baltic ecosystem being two of the most important pelagic resources in the Baltic Sea, (i) as a fisheries target species, (ii) as dominating prey for valuable piscivorous species, e. g., fishes, marine birds and mammals (Cardinale & Arrhenius 2000, Bagge et al. 1994, Sparholt 1996), and (iii) significant predators on the zooplankton community and ichthyoplankton communities (Arrhenius & Hansson 1993, Rudstam et al. 1994, Köster & Möllmann 2000a, Möllmann & Köster 2002).

During a regime shift which occurred between the late 1980s and the early 1990s (Alheit et al. 2005, Möllmann et al. 2008) in the Baltic Sea, the stock size of sprat increased drastically to a spawning stock biomass of 910.000 tons in 2007 (ICES 2008). The major reason for the dramatic increase in stock size of Baltic sprat is the limited recruitment success of its predator Eastern Baltic cod (*Gadus morhua*) (Köster & Möllmann 2000a) and the high fishing pressure on this species (Figure 2.1). As result, predation pressure on clupeids was reduced significantly (Köster et al. 2003, Möllmann et al. 2008). Sprat seems to have a significant impact on their prey species and this is especially apparent in the Baltic Sea where food competition with herring (*Clupea harengus L.*) has lead to growth changes in both fish species (Möllmann et al. 2005, Casini et al. 2006). During the regime shift the ecosystem of the Central Baltic Sea changed from a high salinity/oxygen system and relatively low temperatures to a low salinity/oxygen system and comparatively high temperatures, supporting a state of high productivity for sprat.

However, due to several significant Baltic inflow events and reduced fishing mortality, the stock of the Eastern Baltic cod is growing again, which has led to an increase of predation pressure on sprat during the last years. Additionally, Baltic sprat is regulation its own stock size due to egg cannibalism (Köster & Möllmann 2000b).

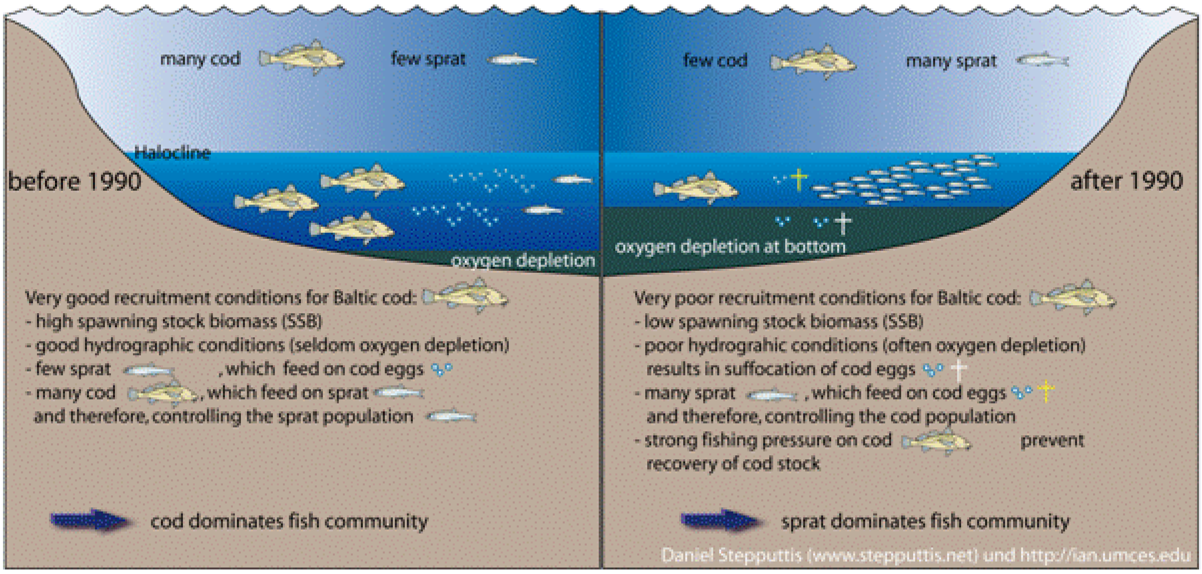


Figure 2.1. Conceptual diagram of conditions that led to a regime shift in the Baltic Sea

2.2 Sprat (*Sprattus sprattus L.*)

The European sprat *Sprattus sprattus L.* (Linnaeus 1758) is a schooling clupeid species, which occurs from the Black and Mediterranean Seas in the South to the Northern European Atlantic shelf, including the North Sea and the Baltic Sea (Muus & Nielsen 1999). Three sub-species have been identified (Whitehead 1985), namely *S. Sprattus sprattus L.* in the North-East Atlantic and North Sea, *S. sprattus balticus* in the Baltic Sea and *S. sprattus phalericus* in the Mediterranean and Black Seas. The sprat population in the Baltic Sea exists at the northern edge of the latitudinal range of this species.

Growth rates of sprat are obviously variable within and between age groups, areas and years. Sprat is a short-living species, which rarely reaches an age of more than five years (Bailey 1980) with a maximum length of 16 cm (Whitehead 1985). Sprat is zooplanktivorous in all exogenous feeding life stages. Adults mainly feed on calanoid copepods (e. g., De Silva 1973, Arrhenius & Hansson 1993, Möllmann et al. 2004, Voss et al. 2003, Dickmann et al. 2007).

Generally, at the age of two years, sprat achieves sexual maturity (Bailey 1980). Being a batch-spawner, females repeatedly release eggs up to 10 times during the spawning season (George 1987). A single female can produce between 100 – 400 eggs per gram body weight (Alheit et al. 1987) and spawn a total of 6.000 to 14.000 pelagic eggs per season (Muus & Nielsen 1999). Spawning occurs in coastal as well as offshore waters (Whitehead 1985). Major spawning areas are the Kiel and Mecklenburg Bays in the west and the main basins (Arkona, Bornholm, and Gotland Basins and the Gdansk Deep) in the central and eastern Baltic (Grauman 1974, Grauman & Krenkel 1986).

The timing of peak spawning, relative fecundity as well as batch fecundity differs significantly between years and regions (Alheit et al. 1987). In most regions, spawning generally takes place at night (Alheit et al. 1987) in surface waters. Water temperatures below 5°C are known to cause significant mortality in sprat eggs (Nissling 2004). Moreover, sprat eggs and larvae are pelagic (Russell 1976, Moksness et al. 1985).

It is well known that the species has an exceptionally expanded spawning season, which takes place from March/April to July/August (Grimm & Herra 1984, Karasiova 2002) depending on water temperature. Baltic sprat has a pronounced migration cycle. After spawning during late spring/early summer adult sprats migrate from spawning grounds in the deeper basins to coastal feeding grounds. Before winter, they migrate back into the deeper areas of the Baltic Sea. The species overwinter in relatively warm water layers below the halocline (Stepputtis 2006). Sprat eggs are spawned in the surface layer but due to their specific gravity, they sink below the low salinity surface waters down to intermediate water depths of 30 to 60 m below the thermocline, where eggs and post-hatched yolk-sack larvae develop (Wieland & Zuzarte 1991). The temperature of the intermediate water in the Bornholm Basin appears to remain relatively constant over the spawning season ranging from approximately 5 °C in April till June to about 6 °C in July. As aforementioned, Nissling (2004) ascertain that sprat eggs which incubated below 5°C were significantly less viable. It seems that early spawning after cold winters could induce substantial egg and early larval mortality and therefore result in relatively weak year classes (Parmanne et al. 1994), whereas warmer years and warmer intermediate layers lead to higher recruitment success (Köster et al. 2003). After the yolk sac stage, sprat larvae migrate into the warmer, more productive surface waters (Dickmann et al. 2007, Voss et al. 2003) where drift of the larvae is influenced primarily by wind-driven surface currents (Baumann et al. 2006).

Due to the extended spawning season and different areas spawning takes place, sprat eggs and larvae develop under a wide range of hydrographical conditions (MacKenzie et al. 2002). This explains the high fluctuations in sprat stock size, the low number of age-classes present and a generally very variable recruitment success (Baumann et al. 2004).

2.3 Acoustic methods

Acoustic methods are widely used to collect data on fish abundance and distribution (Simmonds & MacLennan 2005). Due to schooling behavior of pelagic fish, they can efficiently be detected throughout the water column using echosounders (Fässler et al. 2009). Thus, acoustic-survey techniques are especially suitable for estimates of the abundance and distribution of pelagic fishes that could not otherwise be sampled across large depth ranges (Jennings et al. 2001).

Cooperation between Sweden and the German Democratic Republic in October 1978 constituted the starting point for the first acoustic estimates of total biomass of herring and sprat in the Baltic Sea (Håkansson et al. 1979). Ever since, there have been annual hydroacoustic surveys for herring and sprat stocks mainly for assessment purposes to get the best estimate of total stock abundance (ICES 1983).

The basic principle is based on sound pulses, which are transmitted into the water whose respective echoes are received by a transducer, which is towed from or fixed in the hull of the survey vessel. If a sound pulse meets a scattering object with a density different from water density (such as fish, bottom, air bubbles) echoes will be backscattered. Here, a echo-integrator, which allows for additioning the strengths of many echo returns over a specified depth range and distance, is used. The output can be transformed into estimates of fish densities, if the species composition and the acoustic properties of species are known. The acoustic reflectivity of a fish species is called target strength (TS) and is dependent from fish species and fish length. The target strength is known from calibration experiments (MacLennan & Simmonds 1992, Misund 1997) and can be used to adjust target strength estimates for each species (Jennings et al. 2001). The target strength (TS) is the most reliable key parameter in acoustic-biomass estimation of fish stocks to identify the true level of stock abundance.

2.4 Target strength (TS)

Biomass estimates determined from acoustic surveys depend on accurate target strength values (TS), which are converted into fish numbers (Ehrenberg 1974, MacLennan 1990, Simmonds & MacLennan 2005). The target strength itself is a logarithmic measure of the proportion of the incident energy, which is backscattered by the target. Hence, a fish's TS is a measure of its capacity to reflect sound and depends on a range of variables including fish size (Love 1977, Nakken & Olsen 1977), tilt (Midttun & Hoff 1962, Love 1971, Nakken & Olsen 1977, Blaxter & Batty 1990), physiology (Ona 1990, Ona et al. 2001, Horne 2003) like state of maturity and fat content (Ona 1990, Horne 2003), morphology (Jones & Pearce 1958, Foote 1980) such as swimbladder size as well as swimbladder shape and compression (Ona 1990, Horne 2003), depth (Ona 1990, Mukai & Iida 1996, Gorska & Ona 2003a, 2003b) and acoustic frequency (Haslett 1977, Foote 1985, Horne & Jech 1998, 1999).

Therefore, measurement of target strength is complicated and supposes an improved understanding of both behavioral and environmental influences on the acoustic backscattering by fish (Gorska & Ona 2003).

Nevertheless, present biomass estimation from acoustic survey data in the Baltic is exclusively based on the relationship between TS and fish length (McClatchie et al. 2003). Fish target strength is usually estimated by empirical measurements, often using live fish in cages or *in situ* studies (Misund 1997). Currently, in the Baltic International Acoustic Surveys (BIAS), target strength estimates for Baltic herring and sprat, are based on the traditional depth-independent TS – length relationship (ICES 1983) using a species-specific value for the intercept a_i (see Chapter 3.5.1 "Traditional abundance estimation" for description):

$$\boldsymbol{TS = a_i + b_i \log_{10}(L)} \qquad (1)$$

(where L is the fish length in centimeters), developed 25 years ago, but with no indication of its accuracy.

Due to *in situ* TS measurements at the commonly used frequency of 38 kHz a maximum dorsal-aspect TS of herring at a given length could be determined in 1977 (Nakken & Olsen 1977). The maximum TS values have been rectified (by -6 dB) because of observations of tilt-angle distributions of small herring with mean length of 13 cm. A final TS – length relationship of TS = 13.6 $\log_{10}$ (L) – 62.8 emerged (Nakken & Olsen 1977).

In contrast, Edwards and Armstrong (1981) published mean TS of -33.8 dB kg^{-1} at 38 kHz of herring being 21 – 25 cm in size almost at the same time. Afterwards, Nakken and Olsen's (1977) TS – length relationship has been converted into TS per kg (-34.6 dB kg^{-1}) for herring with a length of 23 cm by the Planning Group on ICES-Coordinated Herring and Sprat Acoustic Surveys (ICES 1983). A comparison between achieved results according to Nakken & Olsen (1977) and Edwards & Armstrong (1981) was being permitted. It was decided to use the mean of both TS estimates (-34.6 dB kg^{-1}) with length-weight data from northwestern North Sea herring (Fässler et al. 2009). Finally, the group recommended TS – length relationship of:

$$\boldsymbol{TS = 20\log_{10}(L) - 71.2\ dB} \qquad (2),$$

(where L is the fish length in centimeters once again) for abundance estimates of Baltic clupeids (ICES 1983). Subsequent *in situ* TS modeling and measurements made during the past seven years established higher values for the parameter a_i (Kasatkina 2009). These a_i values are within the range of -68.9 to -63.6 dB (Ona et al. 2001, Ona 2003, Didrikas & Hansson 2004, Peltonen & Balk 2005, Fässler et al. 2007, Gorska 2007).

Furthermore, since the swimbladder is the most important contributor to the total backscattered sound from a fish (Jones & Pierce 1958, Foote 1980, Blaxter & Batty 1990), it has been suggested to include a depth factor into the TS relationship for herring as well as sprat to account for swimbladder compression caused by increased pressure with depth (Blaxter & Batty 1990, Ona 2003, Gorska & Ona 2003a, 2003b, Fässler et al. 2007) (see Table 3.5; Equations (11) & (12)).

For ray-finned fish, the swimbladder is the main source of scattering. In the ocean, physoclists, e. g. cod (*Gadus morhua*), have a gland that secretes gas into the swimbladder, which they employ to maintain a constant volume of gas in the swimbladder, independent of the depth (Blaxter and Batty 1990). In contrast, physostomes, like sprat and herring, have a pneumatic duct between the gut and the swimbladder, permitting passage of air swallowed at the surface (Diachok 2005). The volume of the swimbladder of physostomes varies inversely with pressure according to Boyle's law (Ona 1990). The amount of gas in adult physostomes' swimbladders isn't constant. This phenomenon results in a marginal, depth dependent reduction in the magnitude of the swimbladder radius and thus, leading to a steady decrease in TS with increasing depth (Gorska & Ona 2003a).

2.5 Goal of this study

In the present study various hydroacoustic data collections sampled during the Baltic International Acoustic Spring Surveys “BASS” within the years 1999 until 2009 (apart from 2000) have been analyzed. Main aim of this study is to analyze and compare different methods to estimate *Sprattus sprattus L.* abundances using empirical TS – length and length and depth-dependent TS methods (to ICES (1983), Ona (2003) and Fässler et al. (2007)). The difference in methodology, using various TS relationships, is one of the major reasons for the variability in TS proposed by mentioned author and thus sprat abundance estimates. The influence of vertical distribution of Baltic clupeids, especially sprat (*Sprattus sprattus L.*) on the abundance estimation with hydroacoustic methods shall be identified. The mentioned TS methods (see Table 3.5. in Chapter “3.5.2 TS calculation according to Ona (2003) and Fässler et al. (2007)” for description) will be used in order to determine the effect of water depth on abundance estimates of Baltic sprat and the dimension of dissimilarity in methods. The present study shall enhance the hydroacoustic methods to estimate Baltic clupeids abundances. The importance of using current depth-dependent TS methods for prospective abundance estimates of Baltic clupeids has to be verified by the German contribution to the Baltic International Acoustic Spring Survey.

3. MATERIALS & METHODS

3.1 Study area and biological sampling

This study is based on hydroacoustic and catch data from the Baltic International Acoustic Spring Surveys (BASS), which are conducted annually since 1999 (with exception of 2000). The surveys have primarily taken place in ICES-Subdivisions 24, 25, 26, 27 and 28 in the Baltic Sea (Figure 3.1). The area is limited by the 10 m depth line.

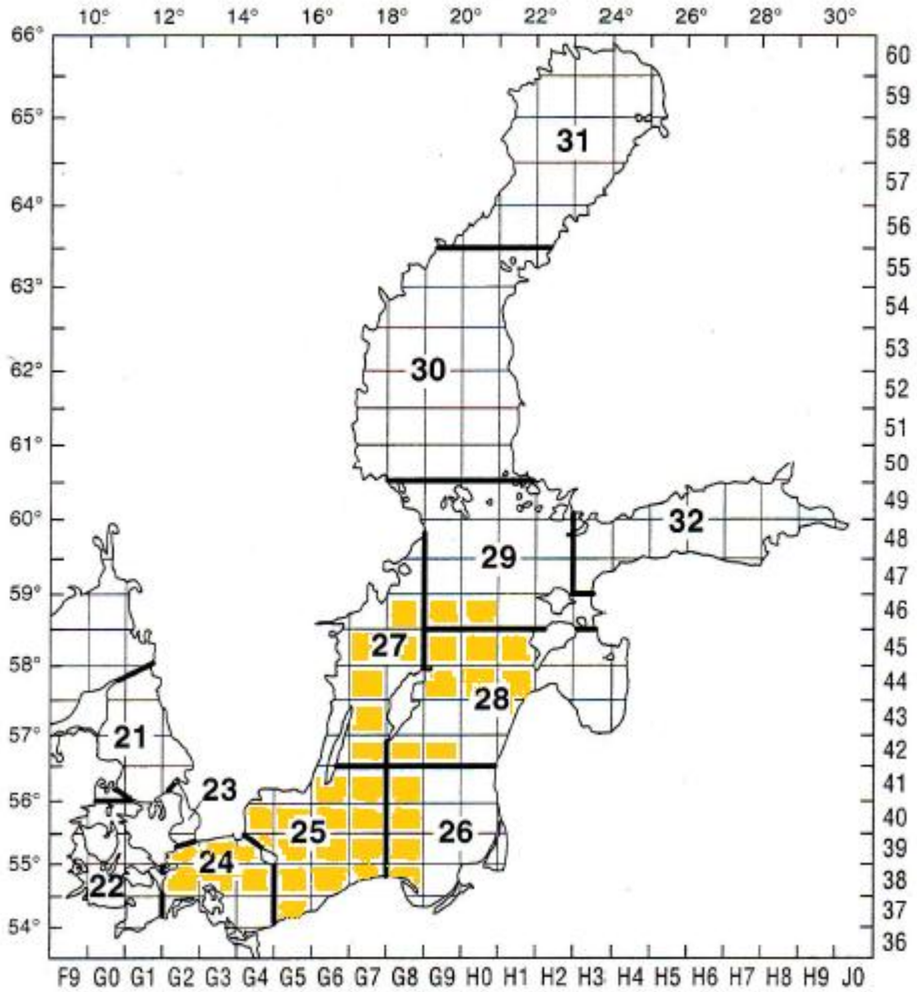


Figure 3.1. ICES-Subdivision borders and ICES-Rectangles of Baltic Sea (ICES 1983). Surveyed area of investigations in 1999 - 2009 is yellow colored.

Sampling includes and combines hydrographic & hydroacoustic measurements and fish catches. In order to collect comparable acoustic data for stock abundance estimations of pelagic planktivorous fish, the study area was generally surveyed in May/June during daytime with FRV "Walther Herwig III" (Table 3.1).

The total distance measured during the surveys 1999 – 2009 is approximately 14.500 nmi long. The main aim was the characterization of the distribution and the biomass estimation of Baltic pelagic fish stocks, primarily *Sprattus sprattus L.*, with hydroacoustic methods.

Table 3.1. Analyzed acoustic survey data of the years 1999 – 2009 (apart from 2000).

SURVEY	VESSEL	SURVEY PERIOD	ICES-SUBDIVISION	MEASURED DISTANCE [nmi]
WH 206	Walther Herwig III	27.05. – 12.06.1999	24 - 28	1653
WH 228b	Walther Herwig III	25.05. – 10.06.2001	24 - 28	1437
WH 239	Walther Herwig III	05.05. – 21.05.2002	24 - 28	1746
WH 251	Walther Herwig III	07.05. – 20.05.2003	24 - 28	1119
WH 263	Walther Herwig III	06.05. – 25.05.2004	24 - 28	1320
WH 275	Walther Herwig III	09.05. – 26.05.2005	24 – 26	801
WH 288	Walther Herwig III	16.05. – 06.06.2006	24 – 27	1735
WH 299	Walther Herwig III	03.05. – 24.05.2007	24, 25, 27	1367
WH 312	Walther Herwig III	05.05. – 26.05.2008	24 – 27, 29	1677
WH 322b	Walther Herwig III	05.05. – 25.05.2009	24 – 28	1587

By the way, the surveys in 1999 and 2001 were carried out within the STORE EU-project “Environmental and fisheries influence on fish stock recruitment in the Baltic Sea”, whereas the surveys in 2002 and 2003 were conducted in context of the GLOBEC Project “Trophic Interactions between Zooplankton and Fish under the Influence of Physical Processes”.

3.2 Hydrography

In order to assess the influence of hydrographic factors such as temperature, salinity, oxygen concentration and saturation on the fish distribution, various vertical profiles of these parameters were recorded using a CTD (Conductivity, Temperature and Depth) profiler, which was generally deployed at least after each fishery (Figure 3.2). Different CTD probes were used during survey years (Table 3.2). Vertical profiles normally covered the whole water column up to 3 - 5 m above the bottom, whereas only the downcast was used for analysis. Water samples have been taken at least once a day from selected stations and different depth-layers using a carousel fitted with 6 or 12 Niskin water bottles. These water samples were used to determine the concentration of oxygen (Winkler 1888b) for calibration purposes of the oxygen probe.

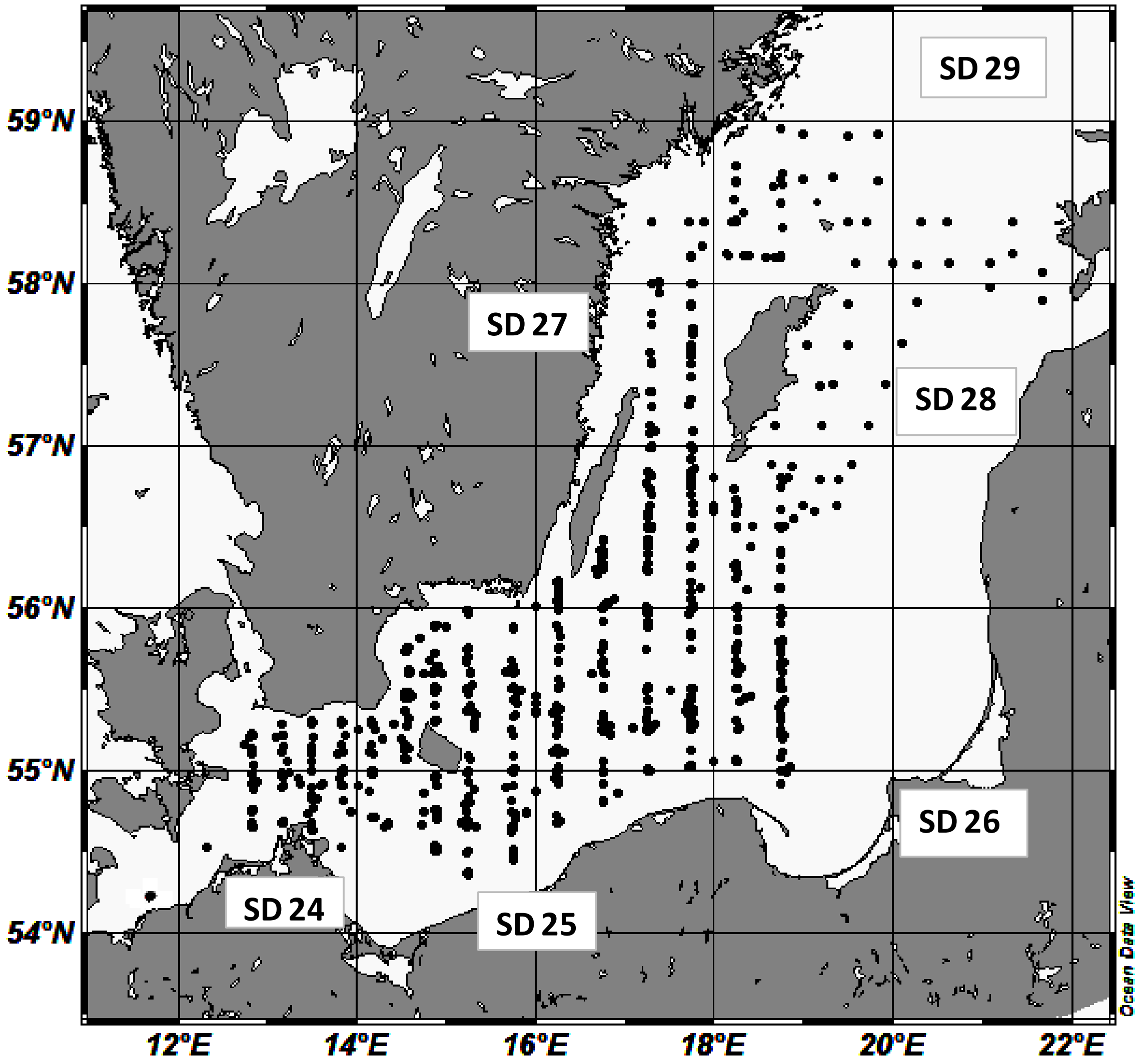


Figure 3.2. Hydrographic stations of WH206 – WH322b in 1999 – 2009.

Table 3.2. Type of CTD profiler was used and quantity of hydrographic stations within survey years.

SURVEY	YEAR	CTD PROFILER	NUMBER OF HYDROGRAPHIC STATIONS
WH 206	1999	TS (ME-KMS3)	47
WH 228b	2001	TS (ME-KMS3)	75
WH 239	2002	AMD	75
WH 251	2003	SST	61
		Seabird	38
WH 263	2004	CTD-O_2 (Seabird 19+)	123
		Seabird	20
WH 275	2005	SST	6
		CTD-O_2 (Seabird 19+)	65
WH 288	2006	CTD-O_2 (Seabird 19+)	127
WH 299	2007	CTD-O_2 (Seabird 19+)	127
WH 312	2008	CTD-O_2 (Seabird 19+)	131
WH 322b	2009	CTD-O_2 (Seabird 19+)	133

3.3 Data analysis

The following data analysis was conducted following the "Manual for the Baltic International Acoustic Survey" (ICES 1983).

3.3.1 Fishery

An essential acoustic property of fish is the target strength. The target strength is species and length dependent. Consequently, it is essential for the conversion of echo energy into fish abundance to know the species composition and the length distribution of echo scatters. Pelagic fish species cannot be distinguished from another by visual inspection of the echogram. Both herring and sprat tend to be distributed in scattering layers or in pelagic layers of small schools. Hence, species allocation was based entirely upon haul composition. Afterwards, the estimates of total fish density were allocated to species according to the trawl catch composition in the corresponding ICES-Rectangle (ICES 1983).

The pelagic trawl "PS205" with a stretched mesh size of 10 mm in cod end was used for fishery hauls. In general, two hauls per Rectangle were sampled. The mean duration of the trawls was 30 minutes with an average fishing speed of 4 knots. Trawling was always done during the day between 06.00 a.m. in the morning and 19.00 – 21.00 in the evening.

3.3.2 Catch treatment

Catches were sorted on board and determined to species level, the corresponding weight per species was registered (ICES 1983). In case of homogenous large catches of clupeids a sub-sample has been taken and sorted for determination of species level. The weight of the sub-sample and the total weight per species were registered (ICES 1983). For all caught fish species length frequency distributions (see Chapter 3.3.4 "Length distribution" for description) were estimated. For herring and sprat, total fish length was measured to the nearest 0.5 cm, for all other species to the nearest 1 cm (ICES 1983). In case of taken sub-samples, the number of caught individuals of the species in the whole haul was calculated by

$$\boldsymbol{N} = \boldsymbol{n} \times \frac{\boldsymbol{W}}{\boldsymbol{w}} \qquad (3),$$

where N is the number of individuals of species in the whole haul, n the number of individuals of sub-sample, W the total weight of caught fish of the species and w weight of sub-sample. Furthermore, otolith samples for age distribution were collected.

3.3.3 Species composition

Relative species compositions were calculated for all hauls accomplished during surveys. Only herring, sprat and cod were accounted for relative species composition because other species were less abundant in catches. All fishery hauls were assigned to ICES-Rectangles in which they have taken place. Marginal fishery hauls which were located between two ICES-Rectangles were assigned to both. Trawl catches within each ICES-Rectangle were combined to give an average species composition of the catch (ICES 1983). Each haul was given equal weight, unless it was decided that a haul is not representative for the fish assemblage sampled. In this case, the particular haul was not used. The species frequency f_i of species i was estimated by:

$$f_i = \frac{1}{M} \sum_{k=1}^{M} \frac{n_{ik}}{N_k} \quad (4),$$

where M is the number of trawl catches within each ICES-Rectangle, n_{ik} the fish number of species i in the trawl k and N_k the total fish number in this haul (ICES 1983).

3.3.4 Length distribution

Only catches containing at least 100 individuals per species were considered to get an representative length frequency distribution. The length frequency f_{ij} in the length class j was calculated as the mean of all hauls M_i containing the species i:

$$f_{ij} = \frac{1}{M_i} \sum_{k=1}^{M_i} \frac{n_{ijk}}{N_{ik}} \quad (5),$$

where n_{ijk} the number of fish within the length class j and N_{ik} the total number of species i in the haul k. A mean number of 17.604 individuals was caught during surveys (Appendix: Table 3.3).

3.4 Hydroacoustics

3.4.1 Acoustic measurements

Hydroacoustic data were recorded onboard the FRV "Walther Herwig III" with a calibrated SIMRAD EK500 scientific echo-sounder (SIMRAD 1997) equipped with a hull mounted 38 kHz split-beam transducer, SIMRAD ES38. During the survey 1999, the post processing system BI500 (SIMRAD 1993) was used to log and broadcast EK500 compatible telegrams from SIMRAD EK500 echo-sounder. Since 2001 the acoustic data were recorded using "Echolog500" (www.echoview.com).

The echo-sounder system was calibrated using the standard reference target method with a copper sphere (Foote et al. 1986; Bethke 1994; ICES 1983). The ambient sound speed was calculated from measured temperature and salinity and applied in the echo-sounder settings during measurements. Instrument settings were conducted according to the "Manual for the Baltic International Acoustic Surveys" (BIAS) (ICES 1983). The average vessel speed was 10 knots during acoustic measurements.

3.4.2 Processing of echo-sounder raw data

Post-processing of data was performed using the post processing system BI500 (SIMRAD 1993) and Sonardata "Echoview" software (version 3.1 and 4.1; www.echoview.com). Echo detection of the bottom topography was corrected when necessary. Noise signals and scattering layers, which were scrutinized as non-fishscatters, were marked in the echograms and excluded from further processing (Prandke & Stips 1987). Echoes located within the upper 10 m layer of the water column were generally disregarded due to possible origin from artificial turbulent effects caused by ship operation.

3.4.3 Integration of echo-sounder data

Within post-processing the "volume backscattering coefficient" (s_V value) was integrated in 1 m depth interval from the 10 m depth layer down to nearly 0.5 m above the bottom. Afterwards, for every "elementary sampling distance unit" (ESDU) a "nautical-area-scattering coefficient" (NASC, also called S_A) was computed (Equation 6). S_A has unit m^2 x $(nmi)^{-2}$ and is defined as:

$$S_A = 4\pi \times 1852^2 \int_{z_1}^{z_2} sv\,dz$$ (Huse & Korneliussen 2000) (6),

where z_1 and z_2 are depth layers and s_v is the volume backscattering coefficient (e.g. Knudsen 1990). The relevant scaling factor is $4\pi(1852)^2$ – for historical reasons, the nautical mile enters the calculation (1 nmi = 1852 m) (MacLennan et al. 2002). Parts in which hydrographic stations have been taken, or when areas were passed twice were excluded from further processing. Several NASC values were accumulated to get a total NASC value (e. g. per ICES-Rectangle or S_{Az} per different depth layers). The total NASC $S_{A(LT)}$ is defined as:

$$\boldsymbol{S_{A(LT)} = \frac{1}{T} \sum_{x=1}^{T} \sum_{y=1}^{L} S_{A(y)}} \qquad (7),$$

where L is a specific number of depth interval and T is the number of integrated miles (EDSU). $S_{A(y)}$ means NASC per depth interval y.

3.5 Analytical methods

A new "Microsoft Office Access" database was set up including all necessary information, such as echo integrals, fish length, number, weight and geographical positions within each haul, ICES-Rectangle, Subdivision and year. This database was used for further calculations and is available from the author.

3.5.1 Traditional abundance estimation

In the Baltic International Acoustic Surveys (BIAS), target strength estimates for the commercially and ecologically important Baltic clupeids, herring and sprat, are based on the traditional depth-independent TS-length relationship (1) (Simmonds & MacLennan 2005). For calculation, species-specific TS parameters (Table 3.4) were used according to ICES (1983).

Table 3.4. Species-specific target strength (TS) parameter according to ICES (1983).

SPECIES	a_i	b_i
Clupea harengus L.	-71.2	20
Sprattus sprattus L.	-71.2	20
Gadus morhua	-67.5	20

The mean length L of fish species i per ICES-Rectangle was calculated by:

$$L = RMLS\ (Rooted\ Mean\ Length\ for\ calculation) = \sqrt{\frac{[\sum(L_i^2 \times n_i)]}{\sum n_i}} \qquad (8),$$

where L_i represents a specific length class per fish species and specific Rectangle and n_i described the number of fish per species i belongs to length class L_i and ICES-Rectangle.

3.5.2 TS calculation according to Ona (2003) and Fässler et al. (2007)

During the past seven years, several new estimates for TS parameter were published (see Chapter "2.4 Target strength (TS)" for detailed description). For comparison, the depth-independent TS was recalculated according to Ona (2003) (Table 3.5 Equation (9)) as well as Fässler et al. (2007) (Table 3.5 Equation (10)). In addition to depth-independent TS-relationships, depth-dependent TS-relationships according to Ona (2003) (Table 3.5 Equation (11)) and Fässler et al. (2007) (Table 3.5 Equation (12)) were used in this study.

Table 3.5. Used target strength equations. Different TS-formulas, sprat TS values (a_i) [dB] as well as contraction-rates ɣ of swimbladder with depth are shown. z is the specific depth layer in 10 m intervals and L is calculated as described (see Eq. 8).

TS AND LENGTH RELATIONSHIP	EQUATION	FORMULA	a_i [dB]	CONTRACTION RATE ɣ
ICES (1983)	(2)	$TS = 20 \log_{10}(L) - 71.2$	-71.2	-
Ona (2003)	(9)	$TS = 20 \log_{10}(L) - 67.3$	-67.3	-
Fässler et al. (2007)	(10)	$TS = 20 \log_{10}(L) - 65.1$	-65.1	-

LENGTH AND DEPTH RELATIONSHIP	EQUATION	FORMULA	a_i [dB]	CONTRACTION RATE ɣ
Ona (2003)	(11)	$TS = 20 \log_{10}(L) - 2.3 \log(1+z/10) - 65.4$	-65.4	2.3
Fässler et al. (2007)	(12)	$TS = 20 \log_{10}(L) - 1.4 \log(1+z/10) - 63.6$	-63.6	1.4

For later comparison, the „mean backscattering cross-section" σ_i [m^2] of fish species i per ICES-Rectangle and σ_{iz} respectively per different depth layers have been derived from depth-independent ((2), (9), (10)) as well as depth-dependent ((11), (12)) TS formula:

$$\sigma_i = 4 \times \pi \times 10^{\frac{TS}{10}} \qquad (13);$$

$$\sigma_{iz} = 4 \times \pi \times 10^{\frac{TS_z}{10}} \qquad (14).$$

Based on σ_i/σ_{iz} and species frequency of species i f_i (4), the weighted backscattering cross-section σ (15) as well as σ_z (16) per depth layer could be ascertained. Hence for a certain area as well as depth layer σ_{total} (17) and σ_{z_total} (18) could be calculated by summation all σ's and σ_z's respectively:

$$\boldsymbol{\sigma = \sigma_{i \times f_i}} \quad (15);$$

$$\boldsymbol{\sigma_z = \sigma_{iz \times f_i}} \quad (16);$$

$$\boldsymbol{\sigma_{total} = \sum \sigma} \quad (17);$$

$$\boldsymbol{\sigma_{z\_total} = \sum \sigma_z} \quad (18).$$

Afterwards, the total number of fish N and per depth layer N_z in chosen ICES-Rectangles was estimated as:

$$\boldsymbol{N = \left[\left(\frac{S_A}{\sigma_{total}}\right) \times A\right]} \quad (19);$$

$$\boldsymbol{N_z = \left[\left(\frac{S_{Az}}{\sigma_{z\_total}}\right) \times A\right]} \quad (20),$$

where S_A is the mean nautical-area-scattering coefficient (NASC) [m^2/nm^2] and S_{Az} is the mean NASC per 10 m depth layer z and ICES-Rectangle. A [nm^2] means area of strata (values of the areas of standard Rectangles in nautical square miles below 10 m depth, ICES 1983). The total abundances ((19); (20)) were split into species classes N_i and respectively N_{iz} (especially in abundance of sprat) by:

$$\boldsymbol{N_i = N \times f_i} \quad (21);$$

$$\boldsymbol{N_{iz} = N_z \times f_i} \quad (22).$$

N_z (20) and N_{iz} (22) values were summed up per ICES-Rectangle and Subdivision:

$$\boldsymbol{N_{total} = \sum N_z} \quad (23);$$

$$\boldsymbol{N_{i\_total} = \sum N_{iz}} \quad (24).$$

Recalculated depth-independent sprat abundance values (1999 – 2009) using TS formula according to ICES (1983) were compared to those calculated according to Ona (2003) and Fässler et al. (2007) as described above. Depth-independent and depth-dependent abundance results estimated using TS formula according to Ona (2003) were cross-compared. Depth-independent and depth-dependent abundance results estimated using TS formula according to Fässler et al. (2007) were also cross-compared.

3.6 Statistical analysis

The abundances derived using different TS-equations, were compared using the t-test (www.sigmaplot.com). Two-sample t-tests with independent random samples were used for a difference in mean values of the comparative sprat abundance results. The confidence interval for difference of means was 95 %.

3.7 Data design

In the present study geographical data were illustrated using "OCEAN DATA VIEW" (Schlitzer 2001) and "SIGMA PLOT 11" (www.sigmaplot.com). Vertical distributions of mean temperature [°C], salinity [PSU], oxygen content [mL/L] and NASC [m^2/nm^2] have been created using "R" (http://cran.r-project.org/). Contour plots of modeled TS and vertical distributions of Baltic sprat as well as accomplished statistical significance tests have also been created using "SIGMA PLOT 11" (www.sigmaplot.com). Mean species frequency composition per catch (1999 – 2009) was analyzed using "BRODGAR STATISTICS" (www.brodgar.com).

4. RESULTS

4.1 Hydrography

During sampling in the years 1999 – 2009 (apart from 2000) the hydrographic situation within the Subdivisions and survey years varied (Figures 4.1 A & B). The mean surface and bottom temperatures decreased in 2003 and 2006/2007 (Figures 4.1 A & B). An increasing temperature and salinity could be observed in the years 2004 and 2007 within Subdivisions (Figures 4.1 A & B). The highest temperature (Figure 4.2), salinity (Figure 4.3) and oxygen (Figure 4.4) values have been measured in the South-Western Baltic Sea (Subdivisions 24/25). On average, the hydrographic values decrease in the eastern Subdivisions (26/27/28).

During 1999 – 2009 the hydrographic situation was normally characterized by a warming surface layer (approximately 8 – 12°C) with a magnitude of nearly 10 – 20 m in all Subdivisions (Figure 4.6). The thermocline separated the relative warm surface water from the colder winter water with a thickness of typically 30 – 40 m (Figure 4.6). Below the thermocline, water temperature decreased until the permanent halocline and generally reached its average minimum about 3 – 4 °C directly above the halocline. The halocline was located in 35 – 40 m depth within the Subdivision 24 and in 55 – 65 m depth in the Subdivisions 25/26/27 and 28 (Figure 4.7). In 2006, water temperature was colder (2 – 3 °C) (Figure 4.5 a), whereas in 2008 water temperature was generally higher-than-average (4 – 6 °C) (Figure 4.5 b) above halocline. Temperatures continuous increased until the bottom (Figure 4.5; 4.6), below thermo-halocline.

As mentioned, in 2003 a remarkable low mean temperature of approximately 4 °C was measured over the entire water column in the Subdivisions 25, 26 and 27 (Figure 4.6). During this survey, the surface and bottom temperatures were approximately 3 °C colder compared to the other years (Figures 4.1 Aa, Ba; 4.2 B1 & B2). The salinity also increased compared to previous years (Figures 4.3 D1 & D2; 4.7) due to the inflow event that occurred in winter 2002/2003. Generally, the salinity was between 5 – 8 PSU at the surface and 10 – 15 PSU at the bottom within the deep Basins of the Southern Baltic (Figures 4.3 C1 & C2; 4.7). A maximum salinity of about 21 PSU has been measured within the Bornholm Basin, Subdivision 25, in 2003 (Figures 4.3 D2; 4.7).

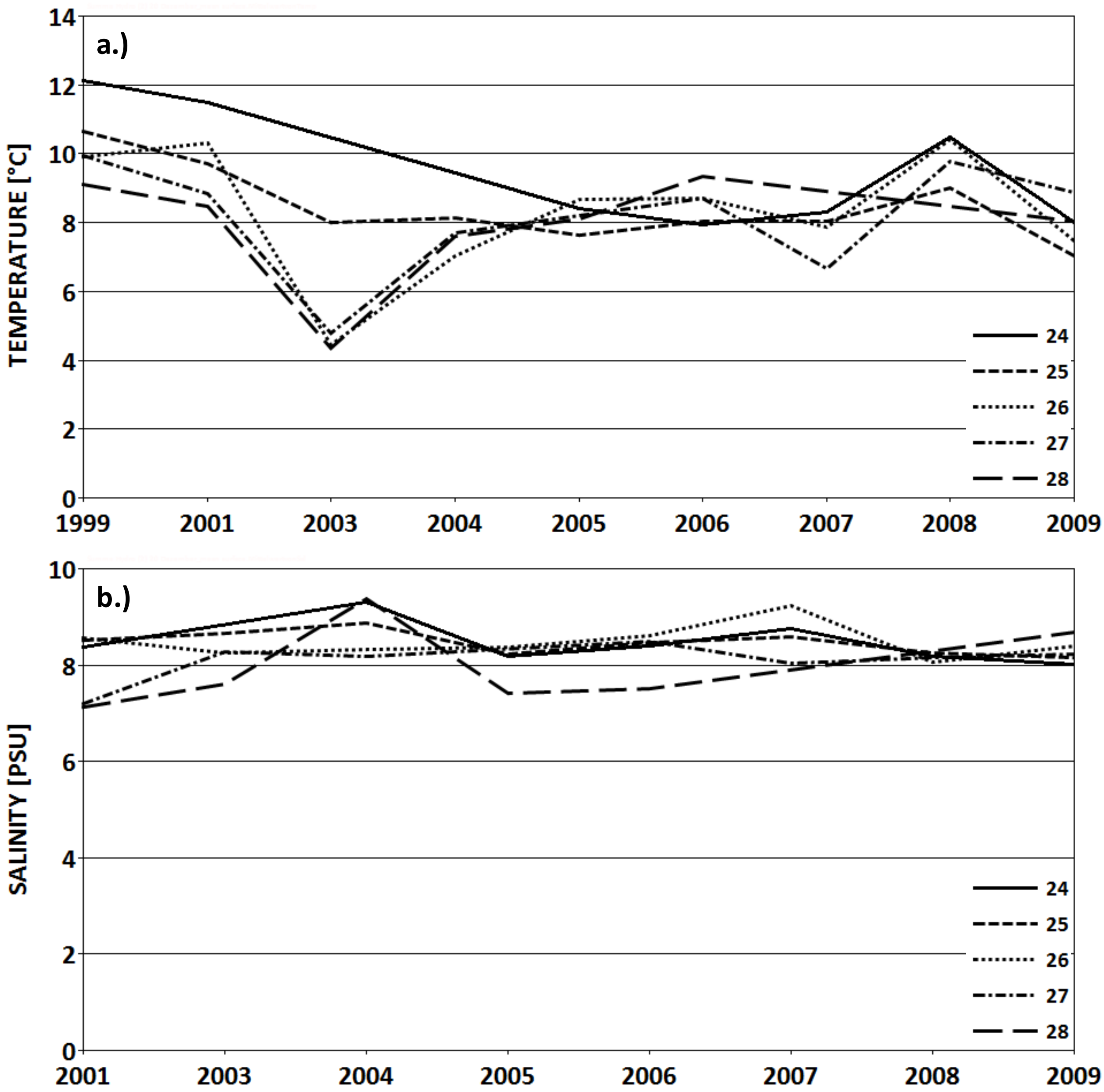


Figure 4.1 A. Mean values of hydrographic variables: a.) surface temperature [°C] and b.) surface salinity [PSU] in ICES-Subdivisions 24 – 28 within the survey years 1999 – 2009 (apart from 2000) are shown. For 2002 no temperature and salinity values were available, thus they are missing. Additionally, only ICES-Subdivision 25 has been comprehensive surveyed during the sampling years. Hence, the hydrographic situations as shown in ICES-Subdivision 25 are more reliable than those presented in ICES-Subdivisions 24/26/27 and 28.

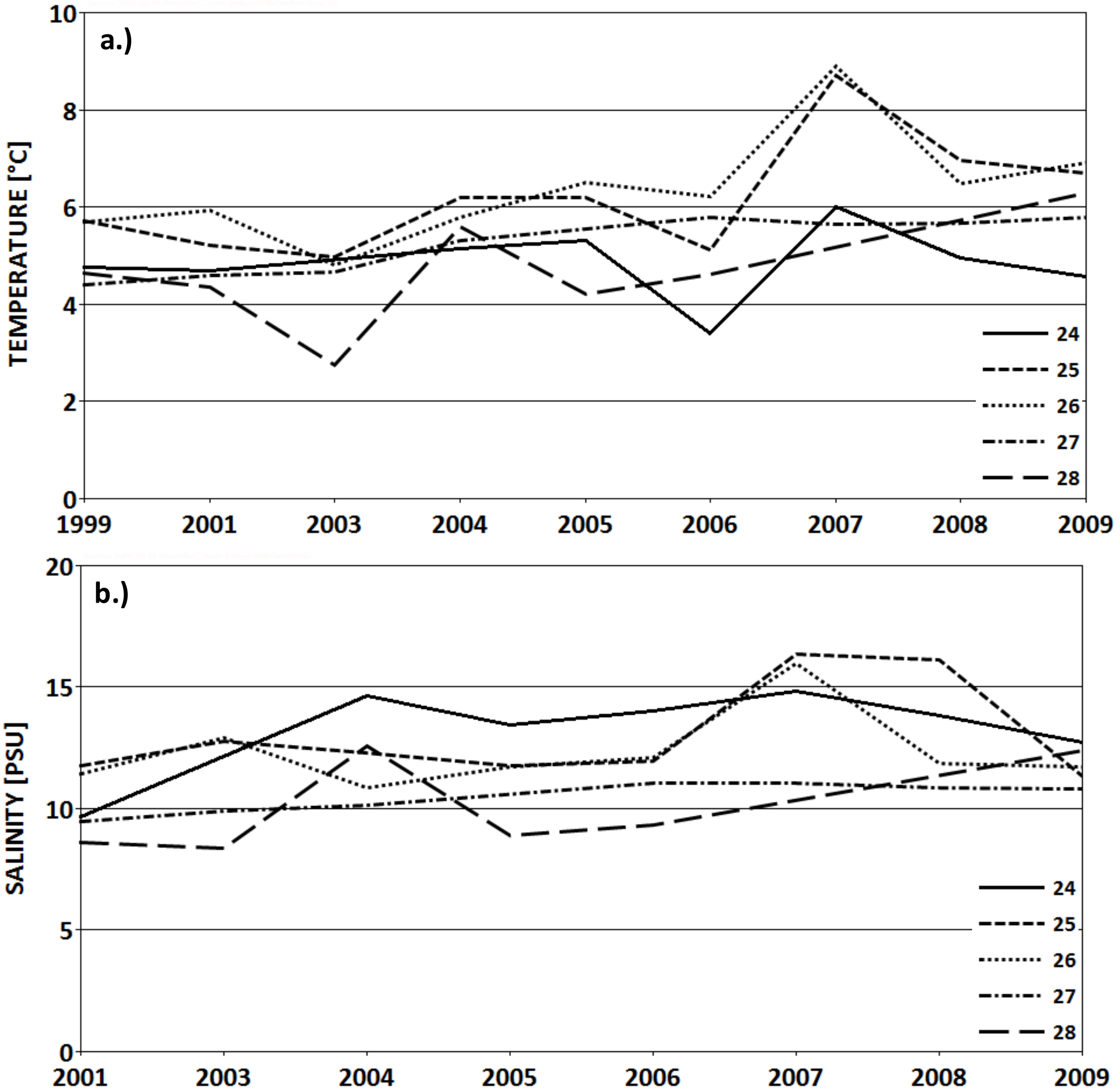


Figure 4.1 B. Mean values of hydrographic variables: a.) bottom temperature [°C] and b.) bottom salinity [PSU] in ICES-Subdivisions 24 – 28 within the survey years 1999 – 2009 (apart from 2000) are shown. For 2002 no temperature and salinity values were available, thus they are missing. Additionally, only ICES-Subdivision 25 has been comprehensive surveyed during the sampling years. Hence, the hydrographic situations as shown in ICES-Subdivision 25 are more reliable than those presented in ICES-Subdivisions 24/26/27 and 28.

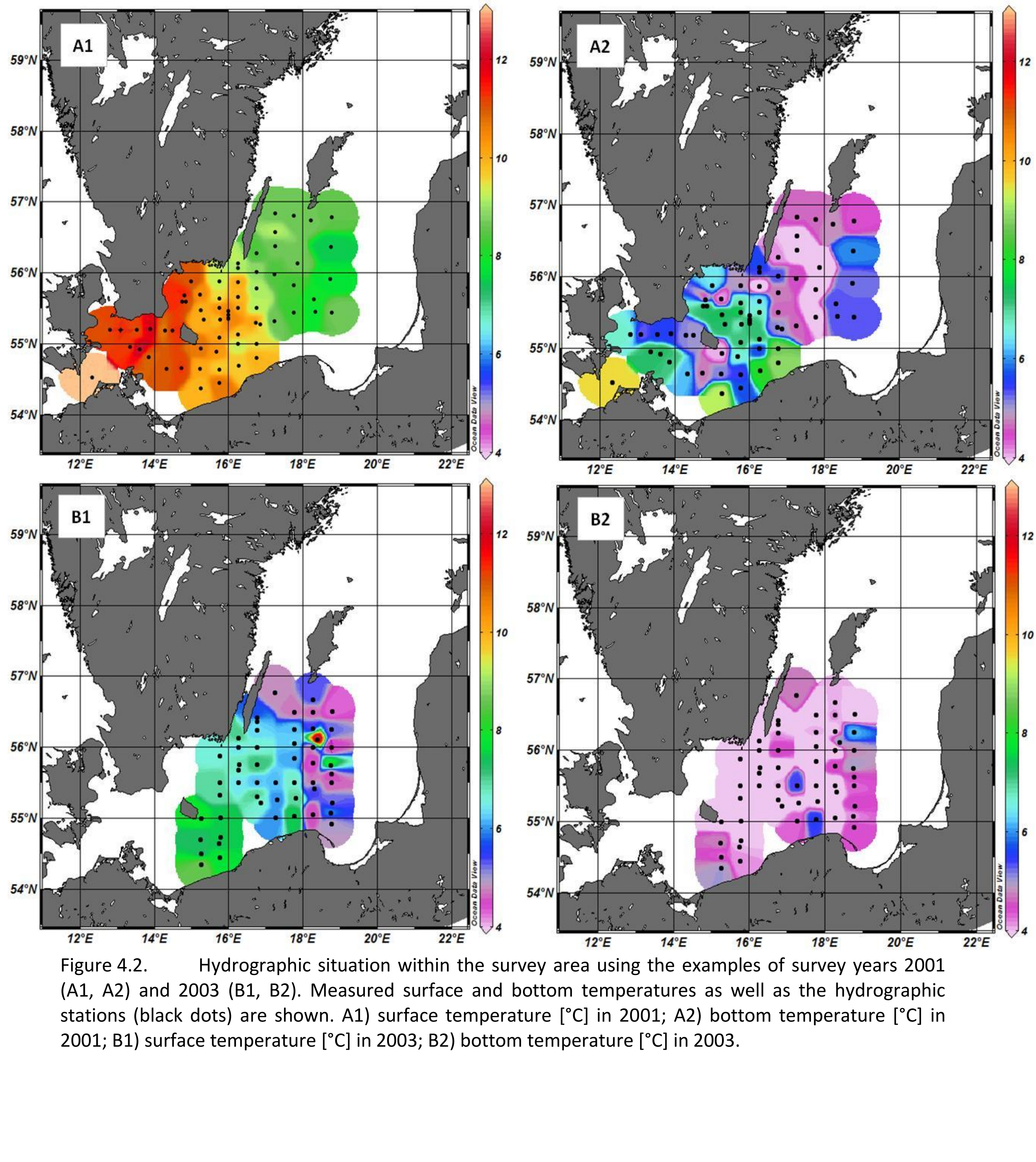


Figure 4.2. Hydrographic situation within the survey area using the examples of survey years 2001 (A1, A2) and 2003 (B1, B2). Measured surface and bottom temperatures as well as the hydrographic stations (black dots) are shown. A1) surface temperature [°C] in 2001; A2) bottom temperature [°C] in 2001; B1) surface temperature [°C] in 2003; B2) bottom temperature [°C] in 2003.

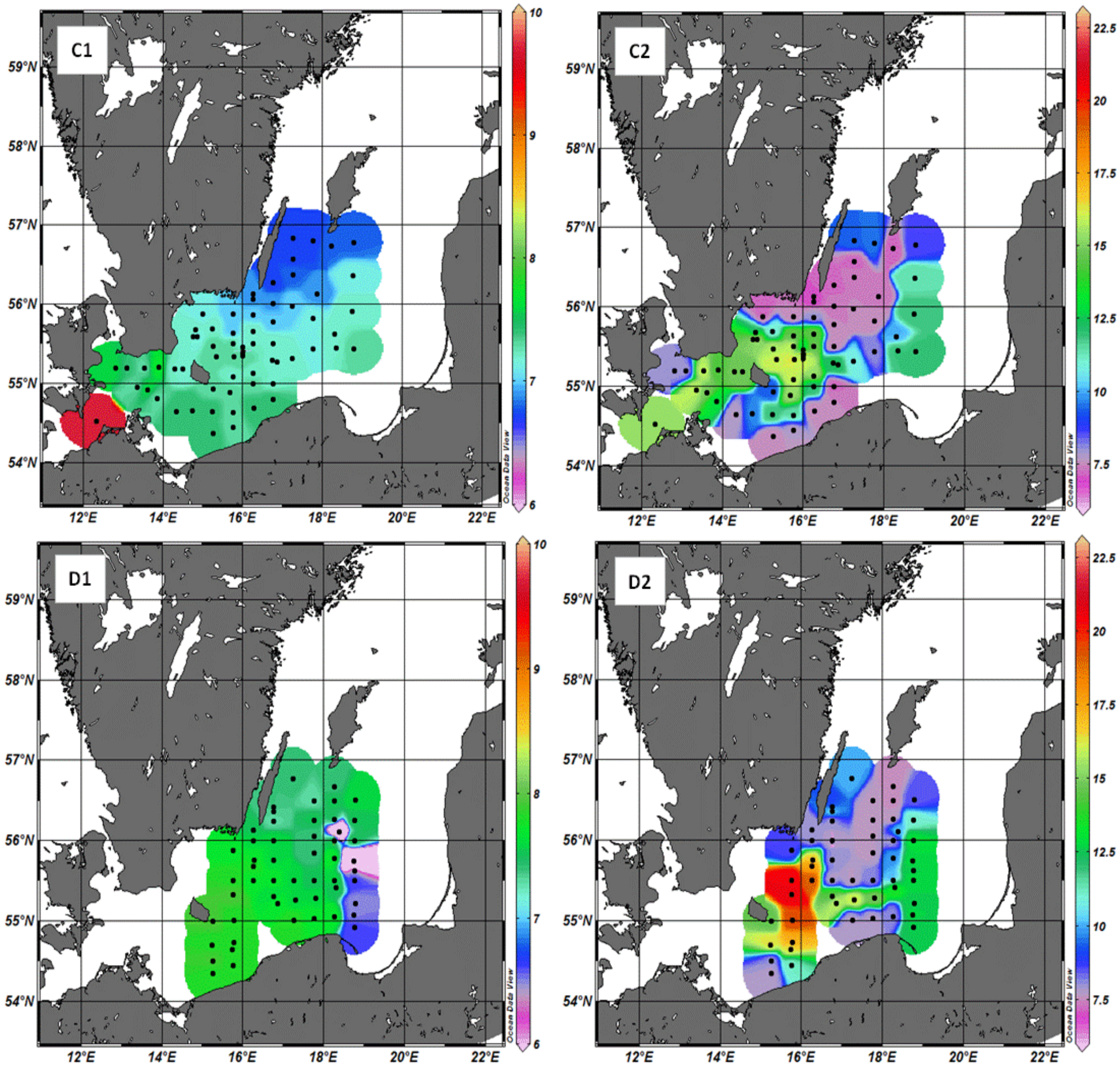


Figure 4.3. Hydrographic situation within the survey area using the examples of survey years 2001 (C1, C2) and 2003 (D1, D2). Measured surface and bottom salinity as well as the hydrographic stations (black dots) are shown. C1) surface salinity [PSU] in 2001; C2) bottom salinity [PSU] in 2001; D1) surface salinity [PSU] in 2003; D2) bottom salinity [PSU] in 2003.

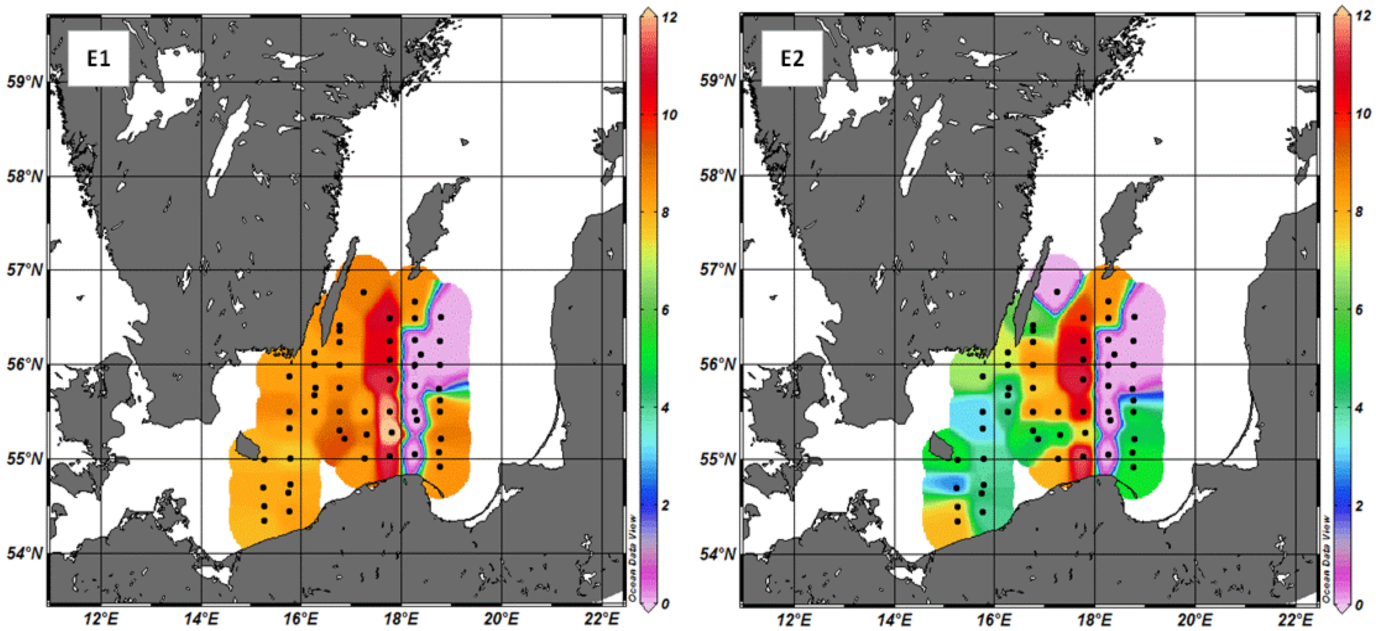


Figure 4.4. Hydrographic situation within the outlier year 2003 (E1, E2). Measured surface and bottom oxygen content as well as the hydrographic stations (black dots) are shown. E1) surface oxygen content [mL/L] in 2003; E2) bottom oxygen content [mL/L] in 2003. For 2001, no oxygen values have been available, thus they are missing, here.

The water layer above the halocline was well oxygenated in all years and Subdivisions (Figure 4.8). Except of Subdivision 25 in the year 2003 (Figure 4.4), the oxygen content decreased significantly below halocline from around 7 mL/L at the surface to often 0 mL/L.

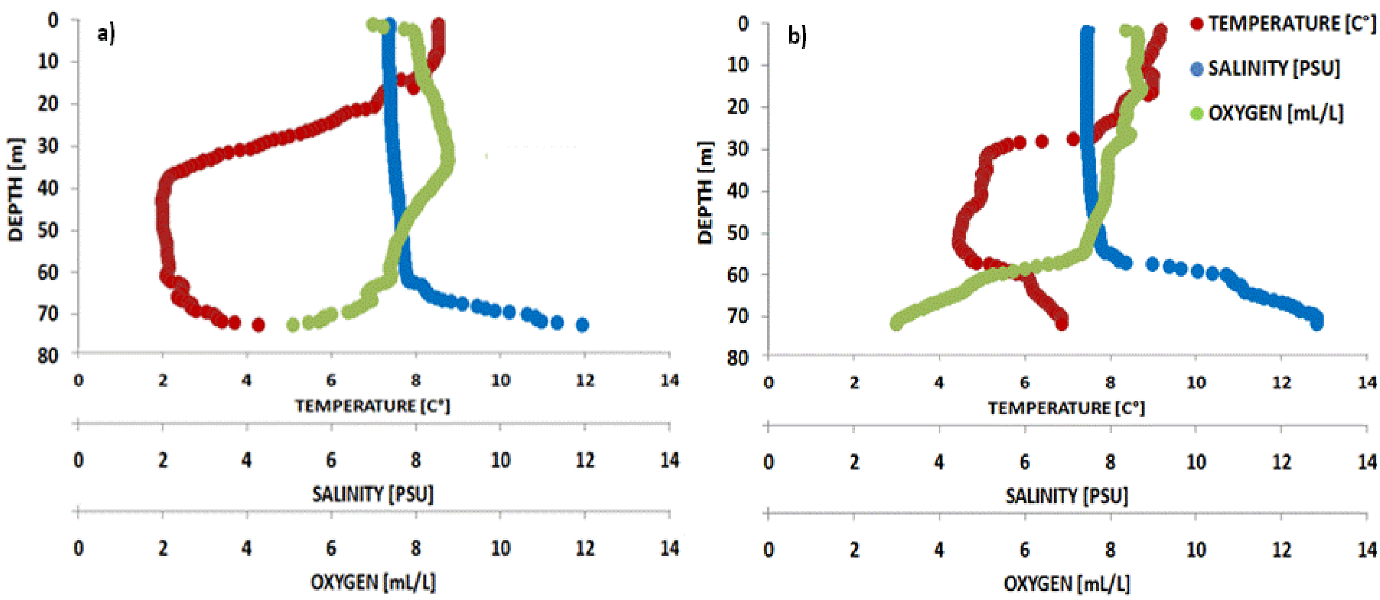


Figure 4.5. Hydrographic vertical profiles in ICES-Rectangle “39G6” (ICES-Subdivision 25), which were recorded during hydroacoustic surveys using the example of positions 55°15’N 16°44’E (2006) and 55°14’N 16°45’E (2008). a) WH288 on 27 May 2006; b) WH312 on 15 May 2008.

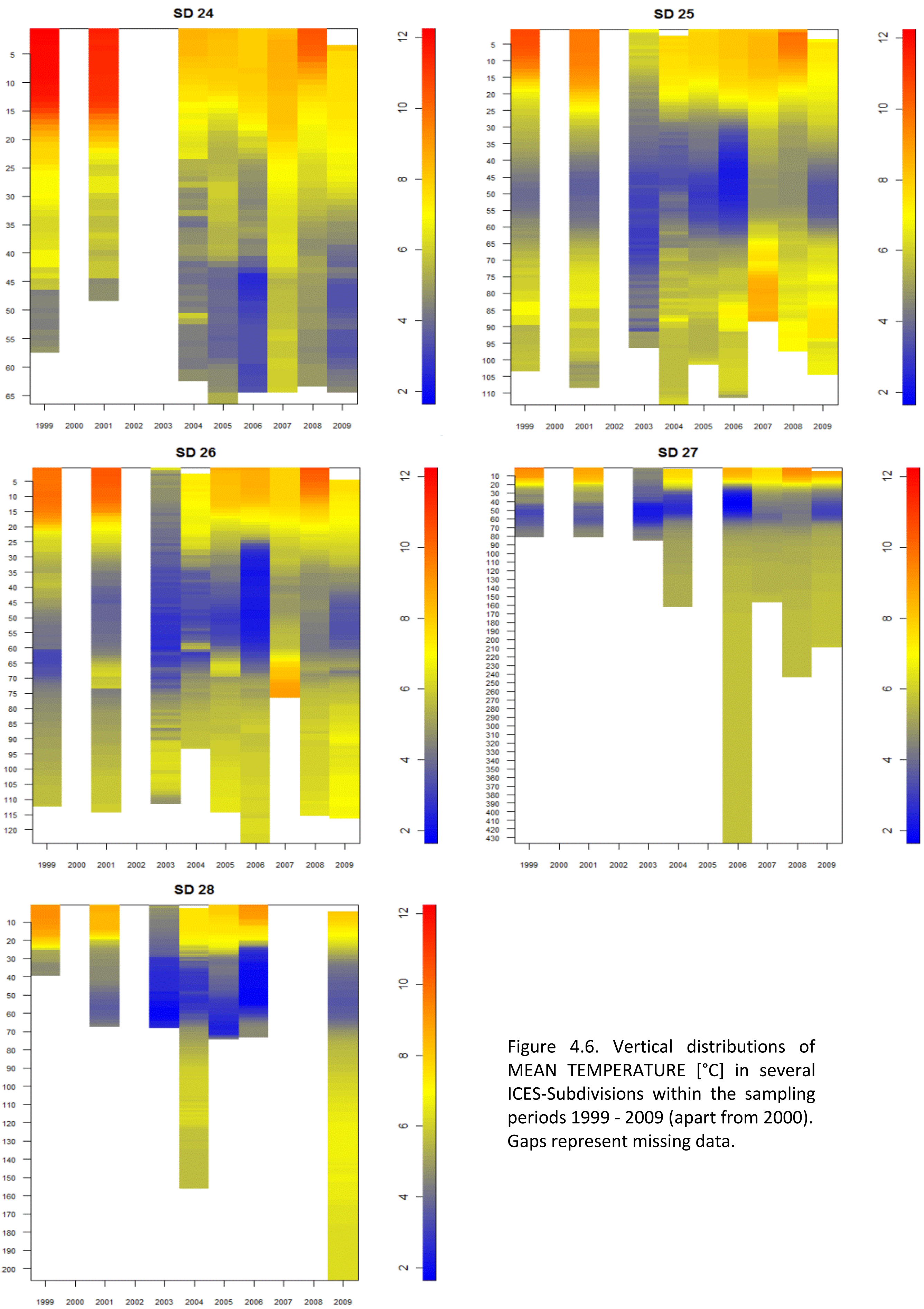


Figure 4.6. Vertical distributions of MEAN TEMPERATURE [°C] in several ICES-Subdivisions within the sampling periods 1999 - 2009 (apart from 2000). Gaps represent missing data.

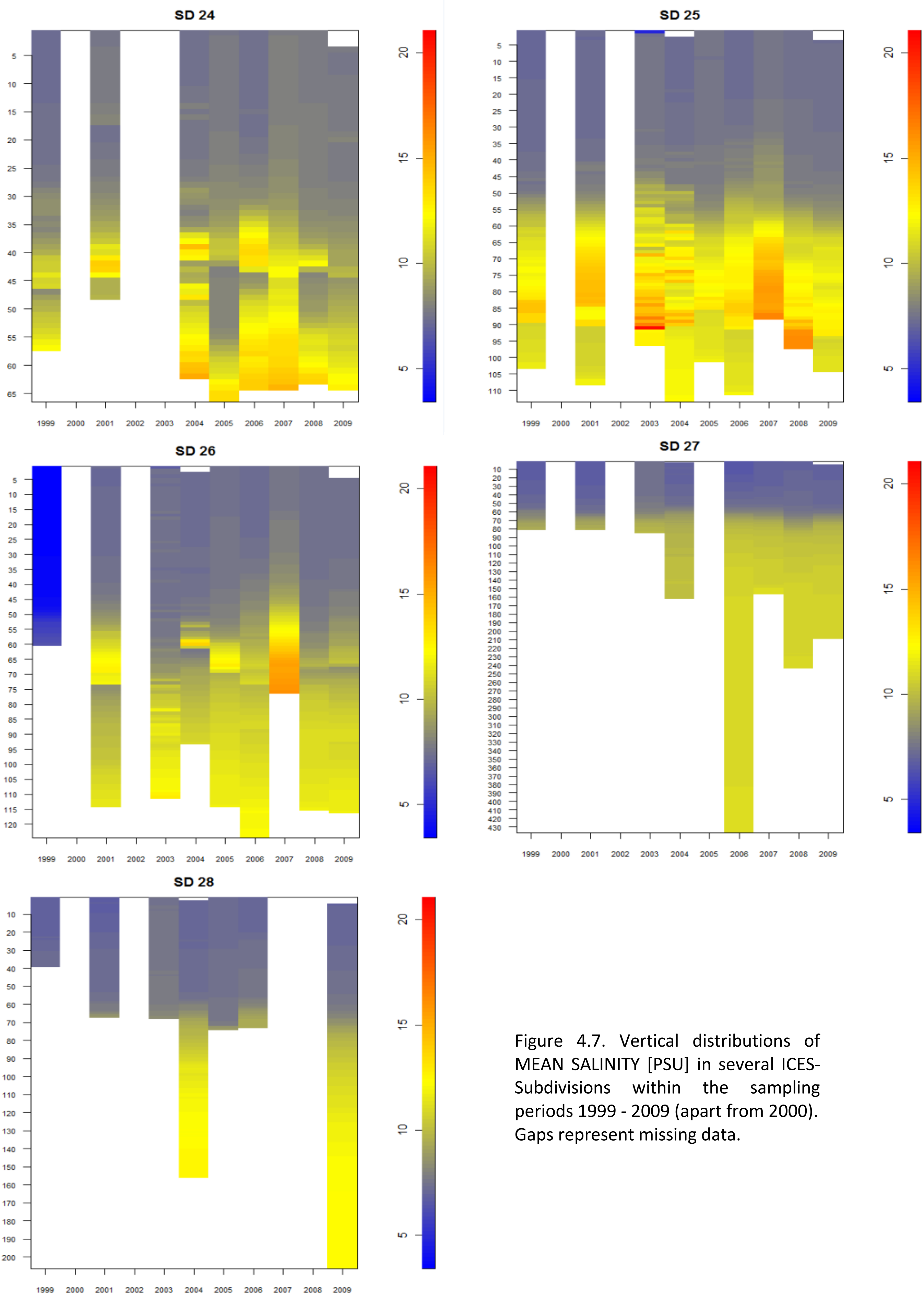
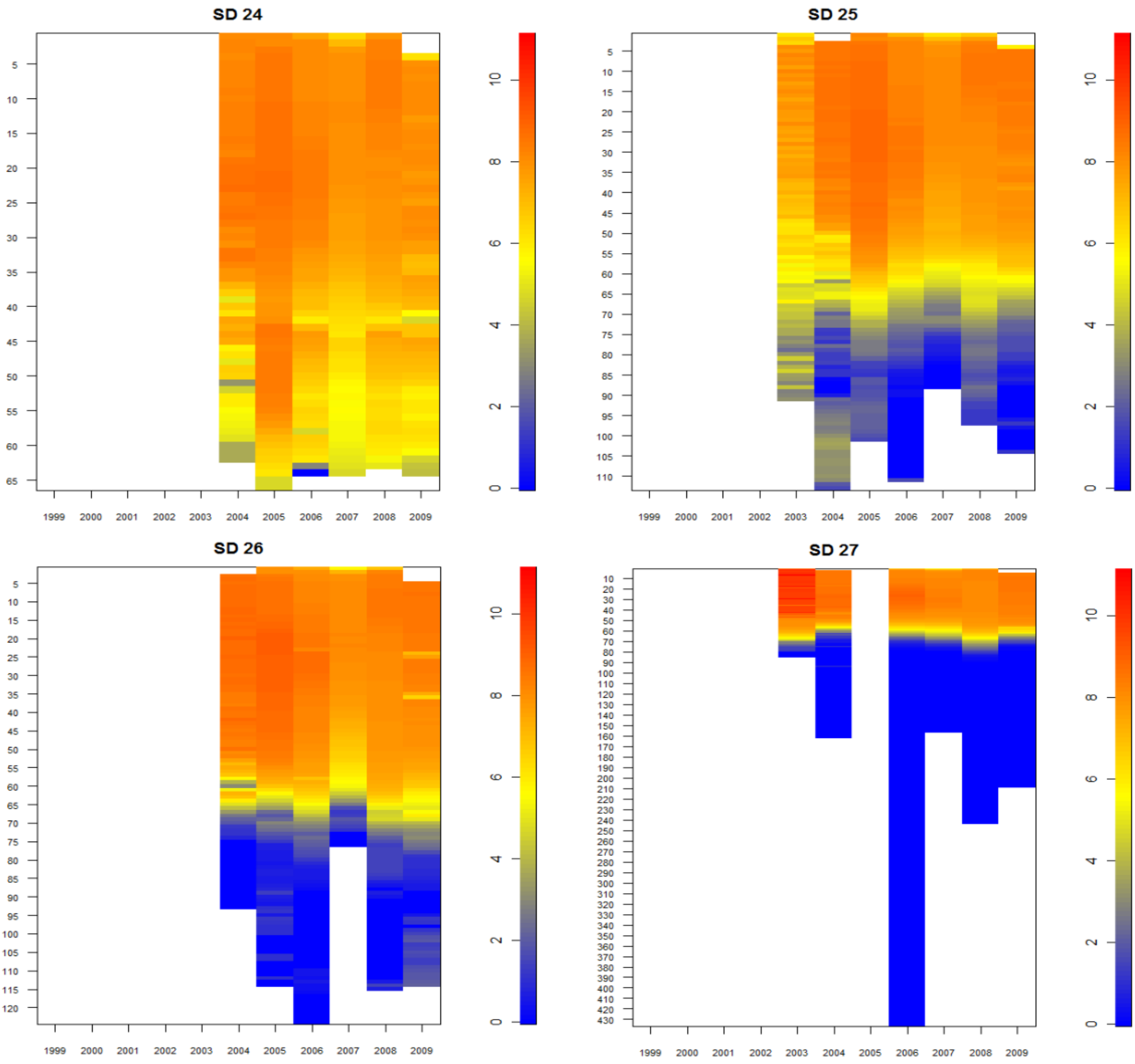


Figure 4.7. Vertical distributions of MEAN SALINITY [PSU] in several ICES-Subdivisions within the sampling periods 1999 - 2009 (apart from 2000). Gaps represent missing data.



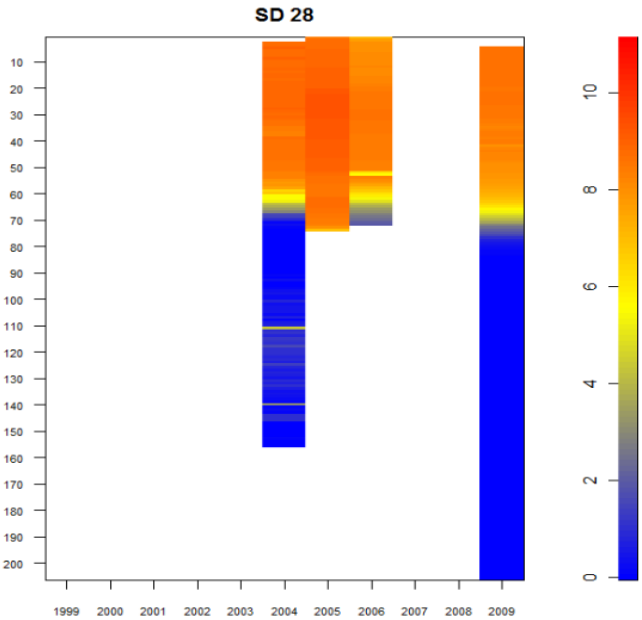


Figure 4.8. Vertical distributions of MEAN OXYGEN [mL/L] in several ICES-Subdivisions within the sampling periods 1999 - 2009 (apart from 2000). Gaps represent missing data.

4.2 Species composition

During the sample periods in May/June 1999 – 2009 sprat dominated the catch compositions. The mean species frequency was 0.968 ± 0.021 standard deviation whereas the averaged herring frequency amounts to 0.028 ± 0.017 standard deviation. The mean cod frequency was 0.001 ± 0.001 standard deviation (Figure 4.9).

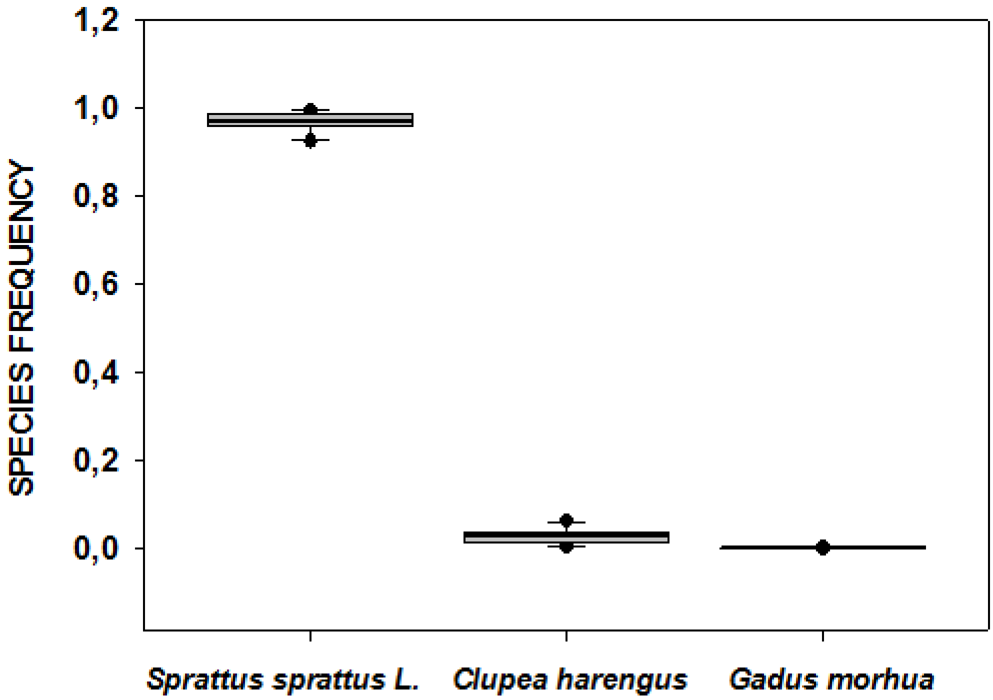


Figure 4.9. Mean species composition in catches (1999 - 2009). The relative mean species frequencies of sprat (*Sprattus sprattus* L.), herring (*Clupea harengus* L.) and cod (*Gadus morhua*) in the total catches are demonstrated. Mean values, standard error and standard deviations are shown.

Generally, sprat was the most abundant species in all hauls which were made in the area of investigation in the years 1999 – 2009. Herring reached the highest mean frequency in the Western Baltic (Subdivision 24). The relative mean frequency of herring was 0.122 during 1999 – 2009 (Subdivision 24). In 2006, the mean species frequency of herring was even about 0.307 in the Subdivision 24 (Figure 4.10). The lowest mean frequency of herring was found in the Eastern Baltic within Subdivisions 26 and 28 (Figure 4.10). *Gadus morhua* played a minor role within the sampling area and time.

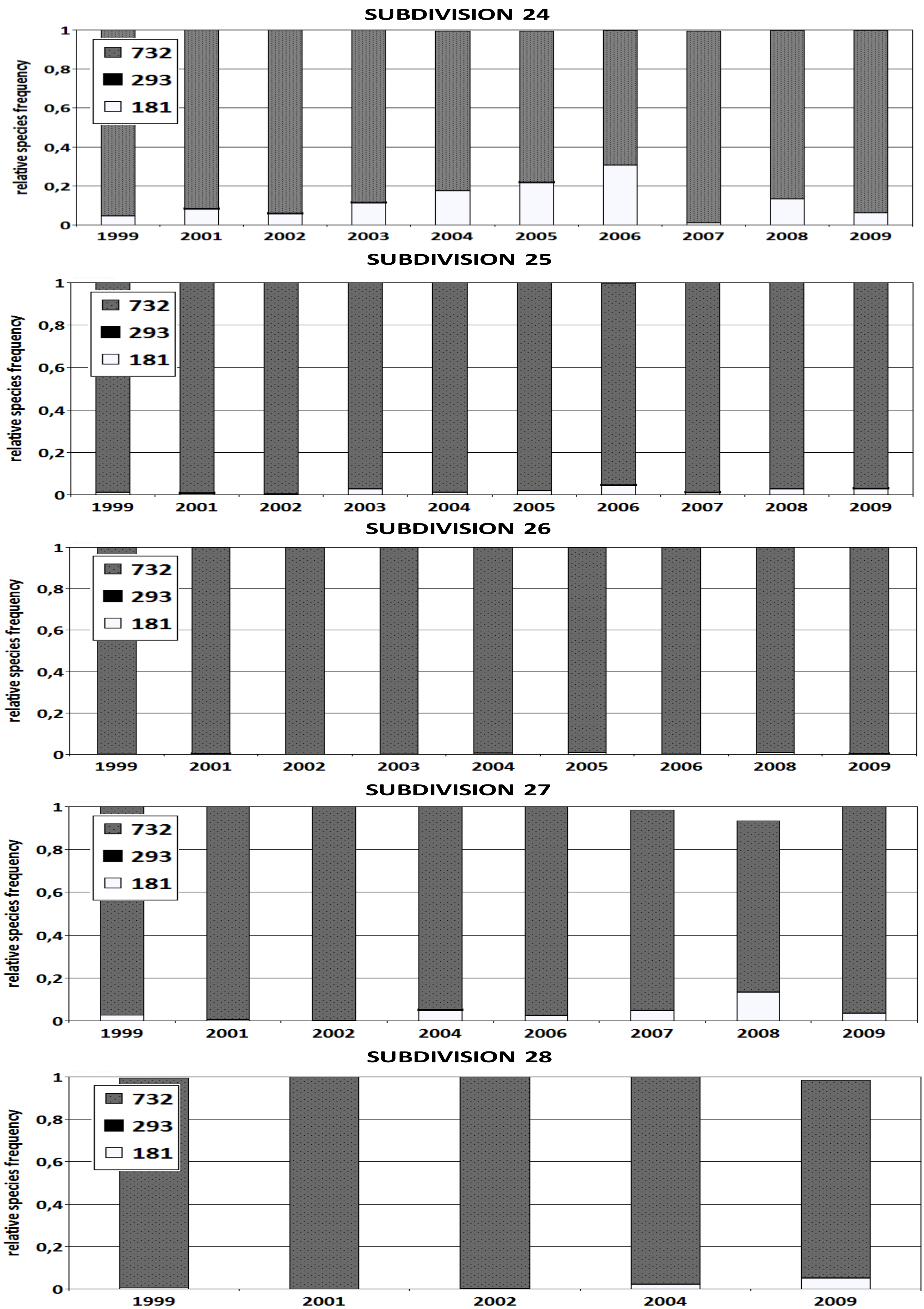


Figure 4.10. Mean species composition in catches during the survey years 1999-2009. The relative mean species frequencies of *Sprattus sprattus* L. (732), *Gadus morhua* (293) and *Clupea harengus* L. (181) are shown within the Subdivisions.

4.3 Length distribution of *Sprattus sprattus L.*

The length distribution of *Sprattus sprattus L.* differed between areas and years and was often characterized by a bimodal distribution with peaks around 9 cm and 12 cm. In some years and areas, one of the peaks was missing, resulting significant lower or higher mean length in this stratum (Figures 4.11).

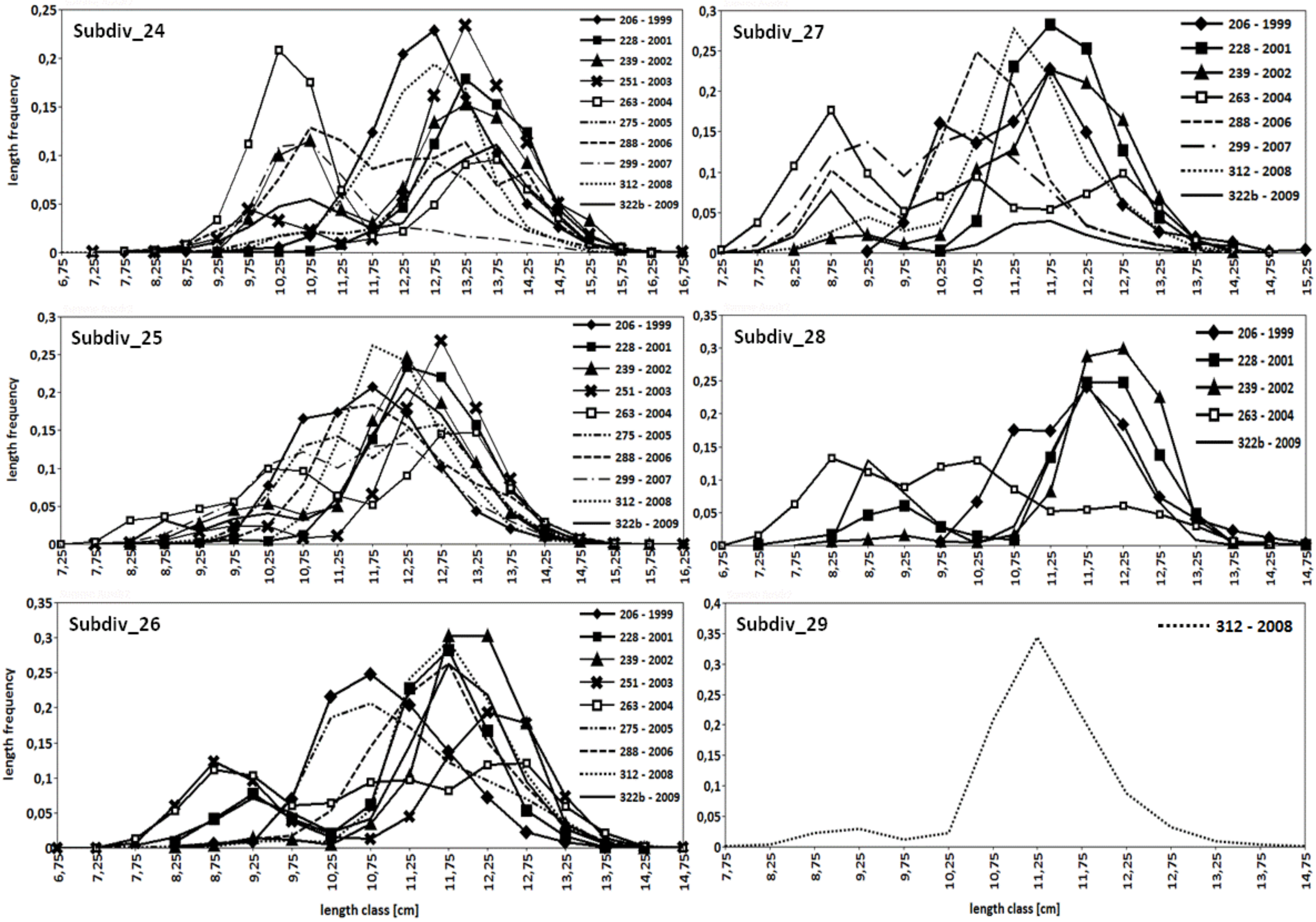


Figure 4.11. Mean length frequency distributions of Baltic sprat within Subdivisions 24 – 29 during the surveys WH206 – WH322b in 1999-2009. Only catches containing at least 100 individuals were considered to get an representative length distribution.

During the entire sampling period in May/June 1999 – 2009 the mean length of sprat observed in the Southern Baltic (Subdivisions 24/25) was around 12.5 cm (Figure 4.12 a & c). In the Eastern Baltic Sea (Subdivisions 26/27/28/29) sprat were generally smaller with a mean length size of around 11.5 cm (Figure 4.12 b & c). Hence, highest mode value of length distributions could be determined in the Southern Baltic Subdivisions 24 and 25 (12.25 – 13.75 cm) compared to the Eastern Baltic Subdivisions 26 – 29 (11.25 – 11.75 cm) in 1999 – 2009. Therefore, length distributions of sprat in ICES-Subdivisions 24 and 25, as well as length distributions in Subdivisions 26 – 29 were summarized in Figure 4.12.

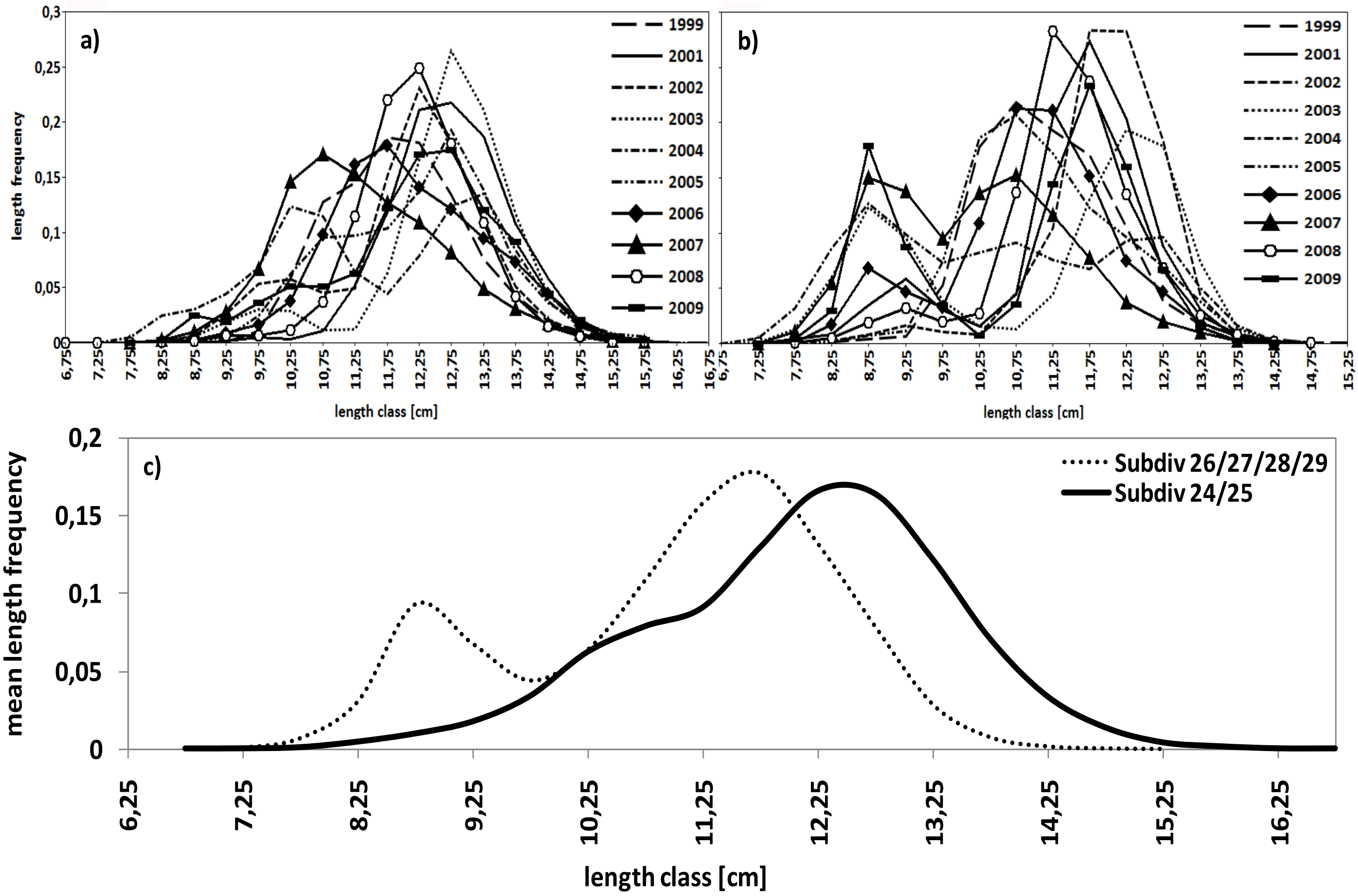


Figure 4.12. Mean length distributions of Baltic sprat in the SD24/SD25 and the Subdivisions 26 – 29. Only catches containing at least 100 individuals were considered to get a representative length distribution. a) Mean length distributions of *Sprattus sprattus L.* in the Southern Baltic (SD 24/25) in 1999 – 2009; b) in the Eastern Baltic (SD 26-29) in 1999 – 2009; c) Mean length distributions of *Sprattus sprattus L.* in the Southern (black line) and the Eastern (dotted line) Baltic (1999 – 2009).

4.4 Distribution and abundance

4.4.1 Horizontal distribution and abundance of *Sprattus sprattus L.*

Within investigations in the years 1999 – 2009 the horizontal distribution patterns of Baltic sprat varied. Along the measured transects, the highest NASC values [m^2/nm^2] were found within Subdivisions 25, 26 and 27. The lowest NASC values were always measured in the Subdivision 24 (Figure 4.13). On the basis of measured NASC highest abundances of sprat were also estimated for the Subdivisions 26 and 27, according to ICES (1983), Ona (2003) and Fässler et al. (2007). The minimum abundances of *Sprattus sprattus L.* were always calculated for the Subdivision 24 (Figure 4.14).

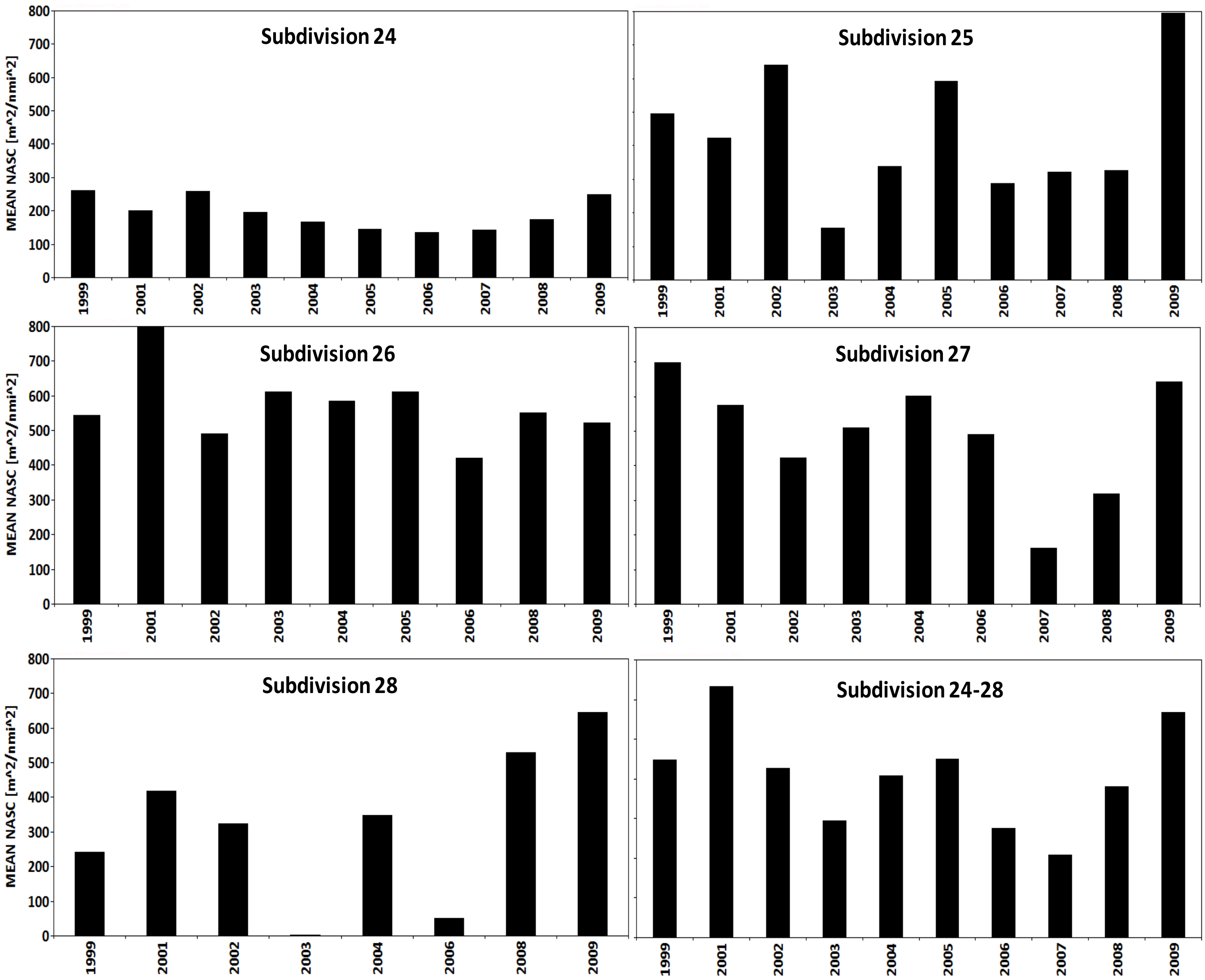


Figure 4.13. Mean NASC values [m^2/nm^2] per ICES-Subdivisions and the survey year as well as mean NASC for 1999 – 2009 are shown. Mean NASC values were summed up per ICES-Rectangle and Subdivision. Afterwards, the mean NASC values per Subdivisions were summed up per year.

Compared to 1999 (3.200 millions of sprat within SD 24 - 28; estimated according to ICES in 1983), estimated sprat stock abundance in 2009 (3.700 millions of sprat within Subdivisions 24 - 28; estimated according to ICES in 1983) increased over the entire investigation period (Figure 4.14).

Nevertheless, continuously increasing sprat abundance over the years can't be confirmed. Mean estimated sprat abundances within ICES-Subdivisions highly varied (Figure 4.14). In the year 2003 within Subdivision 25, estimated sprat abundance was below average (Figure 4.14). A decreasing in abundance of *Sprattus sprattus L.* could also be observed within Subdivision 25 in 2006, whereas the highest mean values could be calculated for the years 2002 and 2009 at the same area (Figure 4.14).

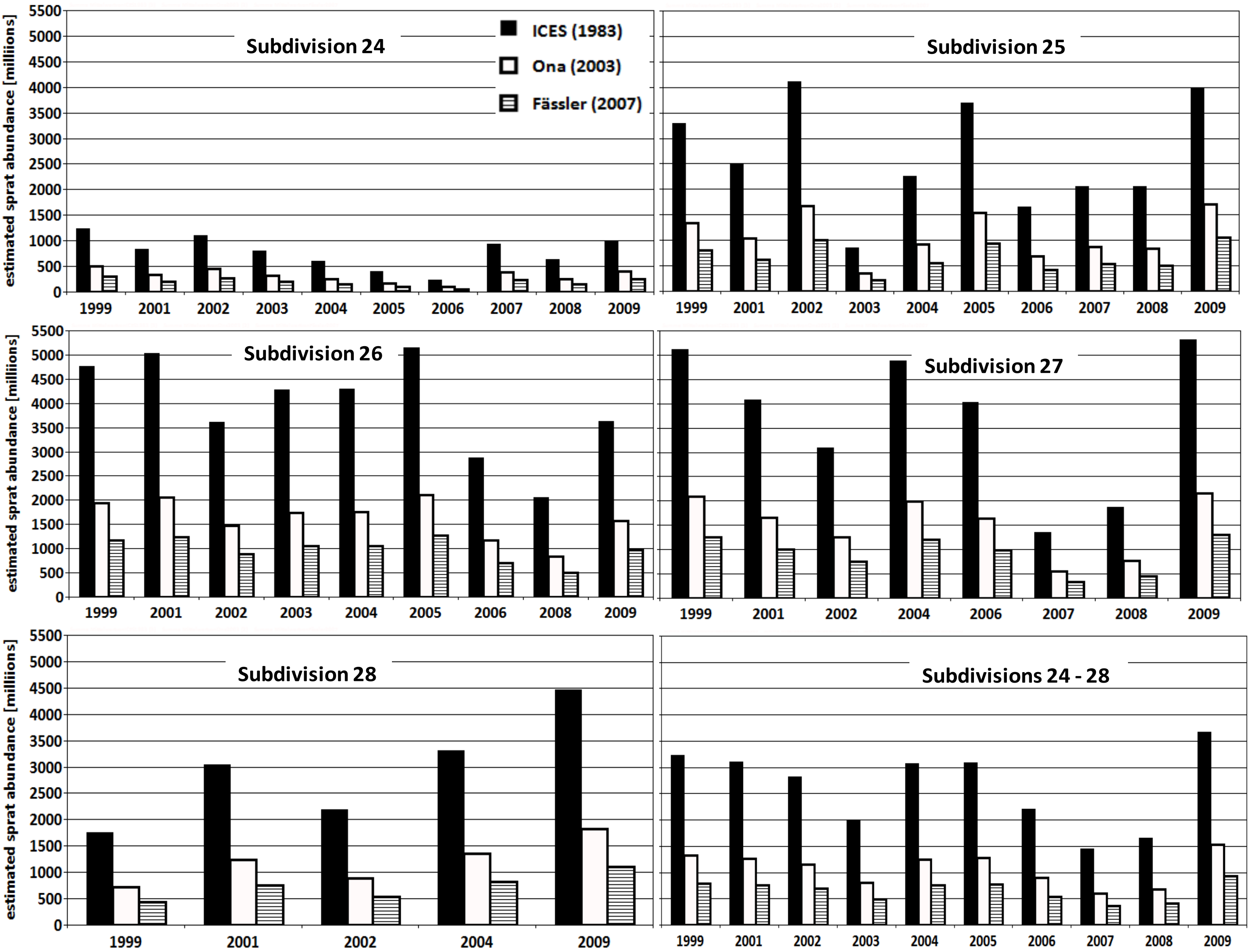
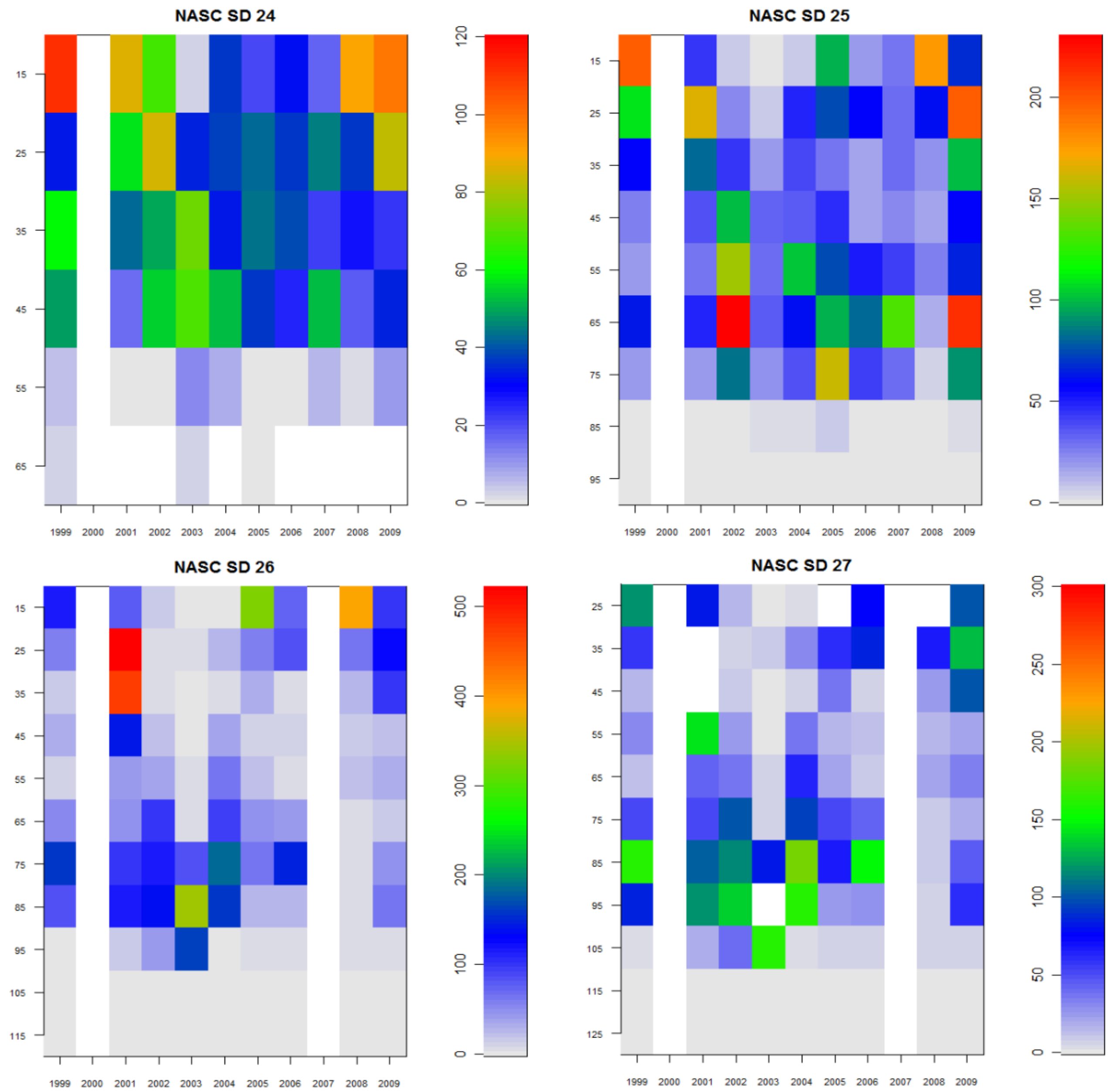


Figure 4.14. Mean values of the estimated depth-independent sprat abundances (in numbers of millions) per ICES-Subdivisions (SD 24/25/26/27/28) in 1999 – 2009 (apart from 2000) as well as summarized mean abundance distributions of each survey year (1999 – 2009) estimated according to ICES (1983), Ona (2003) and Fässler et al. (2007).

4.4.2 Vertical distributions and abundance of *Sprattus sprattus L.*

The vertical distribution of Baltic sprat varied within Subdivisions and survey year. The highest NASC values were measured below the thermo-halocline within Subdivision 25 in several years (such as 2002, 2005, 2007 and 2009) (Figure 4.15). During 2008, the majority of *Sprattus sprattus L.* were located near to the surface in the range of the spring-thermocline in the Subdivisions 24, 25 and 26 (Figure 4.15).

On the basis of measured NASC per depth layer and survey year the highest estimated sprat abundances (according to ICES 1983, Ona 2003 and Fässler et al. 2007) were calculated for the deep basins in depths below the thermo-halocline (approximately in 35 – 45 m depth within SD 24 and below 60 m depth within SD 25/26/27/28) (Figure 4.16).



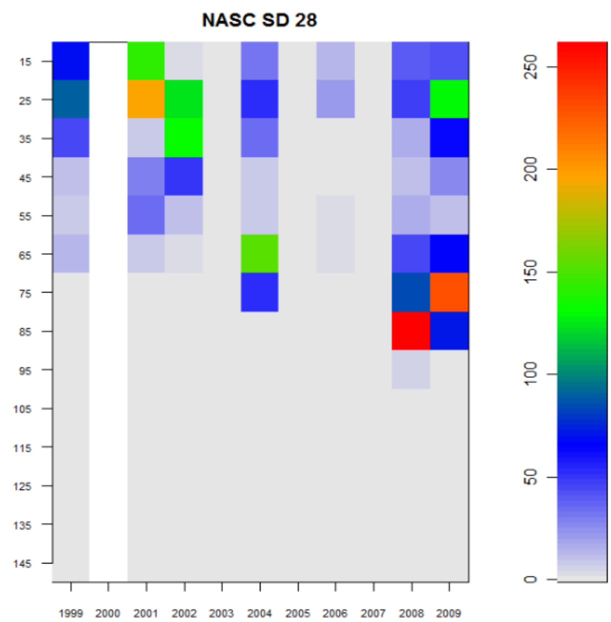
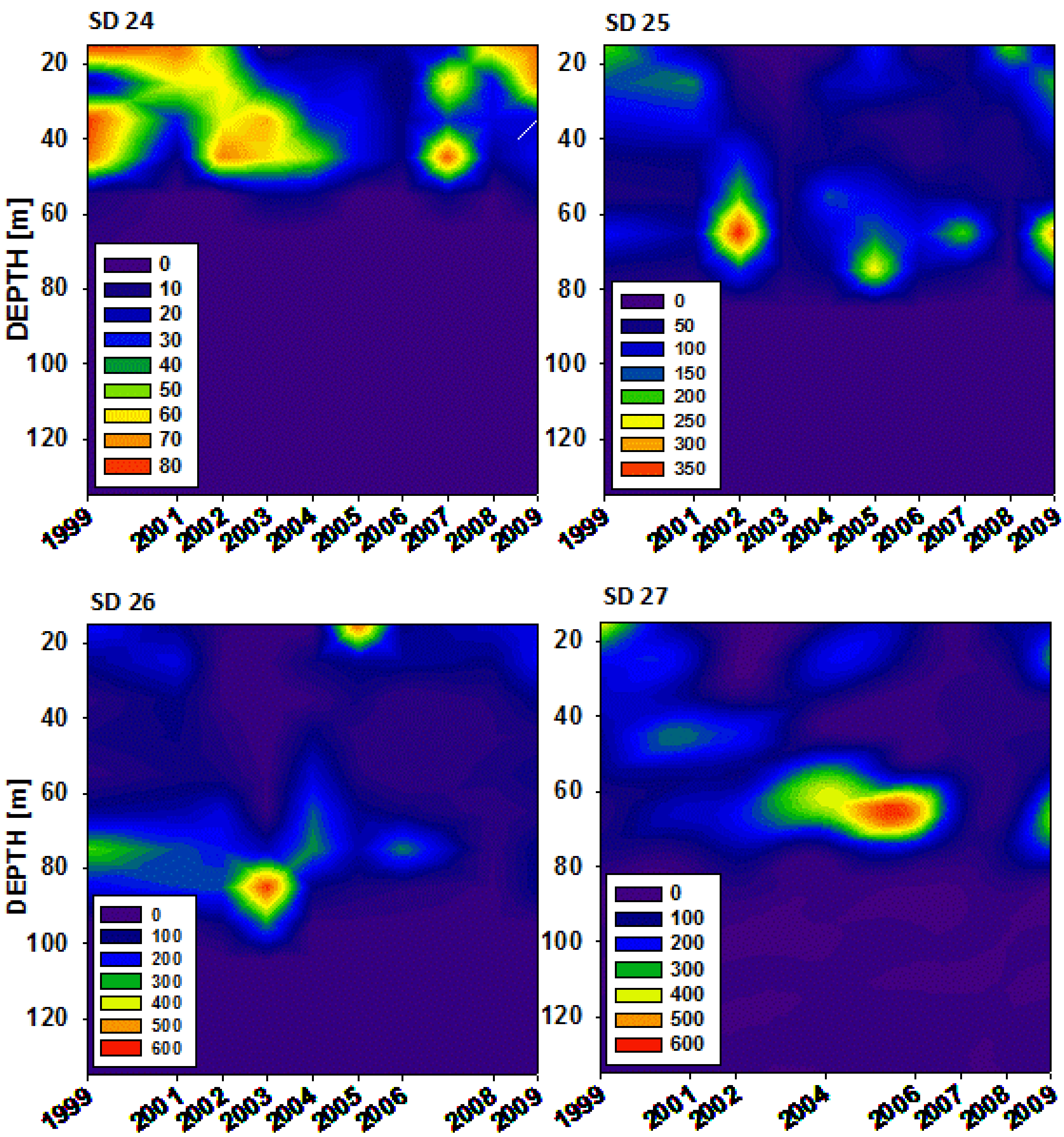


Figure 4.15. Vertical distribution of measured NASC in the ICES-Subdivisions 24 - 28 within the years 1999 – 2009 (apart from 2000). Mean NASC [m^2/nm^2] per depth layer and survey year is shown. Gaps represent missing data.



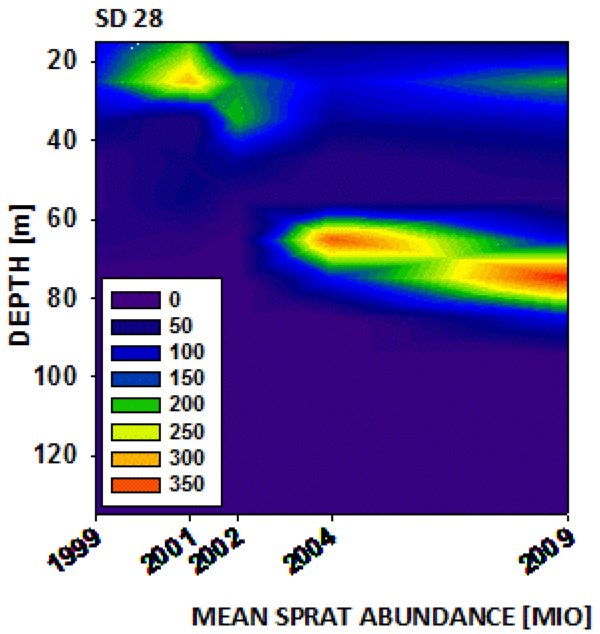


Figure 4.16. Vertical distribution of Baltic sprat in the Subdivisions 24 - 28 within the years 1999 – 2009 (apart from 2000). The estimated abundances were calculated using the length and depth-dependent TS relationship (12) (proposed by Fässler et al. 2007). Mean sprat abundances (in millions) per depth layer and survey year are shown.

4.5 The influence of suitable TS values on sprat abundance estimates

TS values modeled using the depth-independent and depth-dependent TS – length relationships according to ICES (1983), Ona (2003) and Fässler et al. (2007) for Baltic sprat being similar in size show that difference in methodology, is one of the major reasons for the variability in TS values (Figures 4.17 - 4.19) and abundance estimates (Figure 4.20).

The TS values calculated using the depth-independent TS – length relationship according to Ona (2003) are approximately 4 dB higher than those calculated according to ICES (1983) (Figure 4.17). The difference between calculated depth-independent TS according to Fässler et al. (2007) and ICES (1983) is even 6 dB (Figure 4.17). The target strength values calculated according to Fässler et al. (2007) are about 2 dB higher, especially for large fish than those calculated according to Ona (2003) (Figure 4.17).

Thus, the recalculated sprat abundances which based on hydroacoustic data sampled in the years 1999 - 2009 (apart from 2000) considerably varied (Figure 4.21). For example, in 1999, 3.200 millions of sprats were calculated for the Subdivisions 24 – 28 using the TS formula according to ICES (1983) (Figure 4.21). In contrast, at the same time and sampling area only 1.300 millions of sprat were estimated when using the depth-independent method according to Ona (2003) (Figure 4.21). A continuous difference of 59 % could be determined between estimated sprat abundances calculated according to ICES (1983) and results received using the TS formula according to Ona (2003) during 1999 - 2009 (Appendix: Table 4.1). The strongest variance in sprat abundances was between estimates recalculated using the TS – length relationship according to ICES (1983) and Fässler et al. (2007). The recalculated number of sprats determined using the TS formula according to Fässler et al. (2007) results an averaged number of 700 million sprats in 1999 (Figure 4.21). Therefore, the estimated abundance results according to ICES (1983) demonstrate a continuous disparity of 75 % compared to those estimated according to Fässler et al. (2007) (Appendix: Table 4.1). Moreover, the estimated sprat abundances following TS methods proposed by Fässler et al. (2007) differ from those estimated according to Ona (2003) to the amount of 43 % during 1999 – 2009 (Appendix: Table 4.1). As mentioned, the TS values estimated according to Ona (2003) are 2 dB smaller than those estimated according to Fässler et al. (2007). Thus, higher sprat abundances result following methods proposed by Ona (2003) (Figure 4.21). Statistically significant differences between mean values of the comparative sprat abundances could be ascertained (Table 4.2).

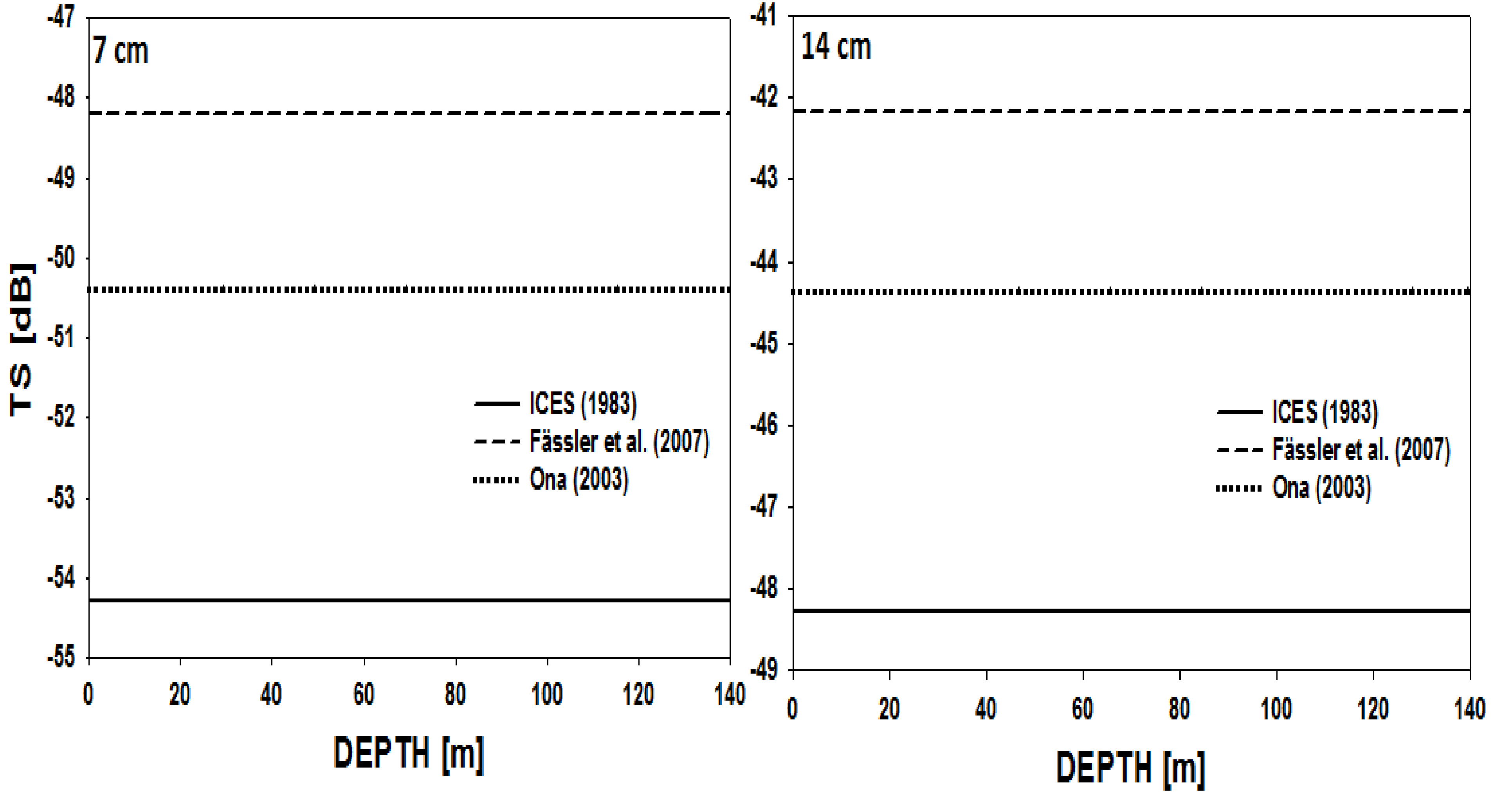


Figure 4.17. Modeled depth-independent target strength values of Baltic sprat standardized to a fish size of 7 cm (left panel) as well as 14 cm (right panel) according to ICES (1983), Ona (2003) and Fässler et al. (2007). The differences in dB due to various TS methods are shown.

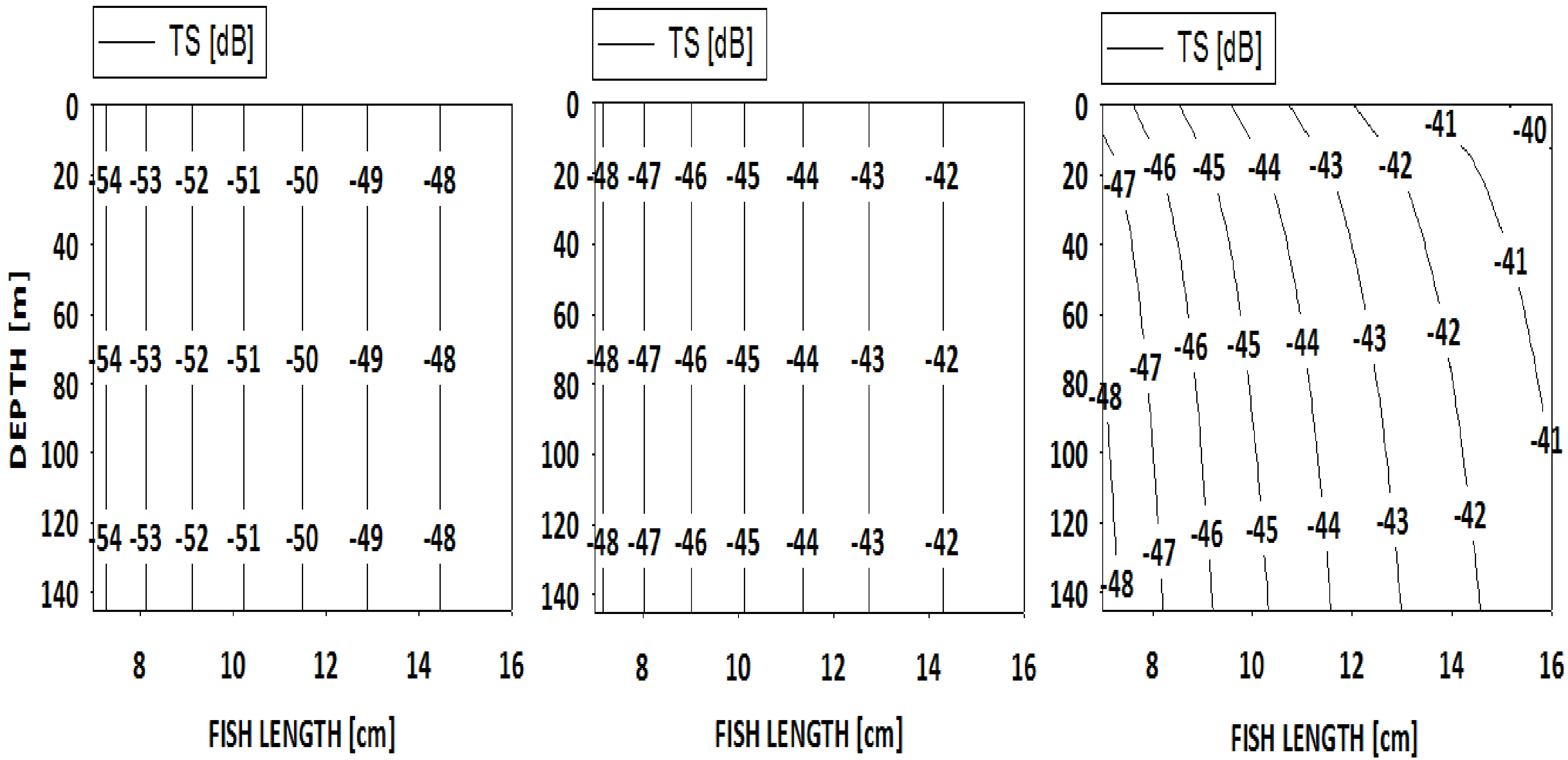


Figure 4.18. Contour plots of modeled TS values. Depth-dependence and -independence of the modeled mean target strength of Baltic sprat at 38 kHz (left panel: depth-independent relationship between TS and fish length proposed by ICES (1983); medium panel: depth-independent relationship between TS and fish length proposed by Fässler et al. (2007); right panel: length and depth-dependent TS relationship proposed by Fässler et al. (2007).

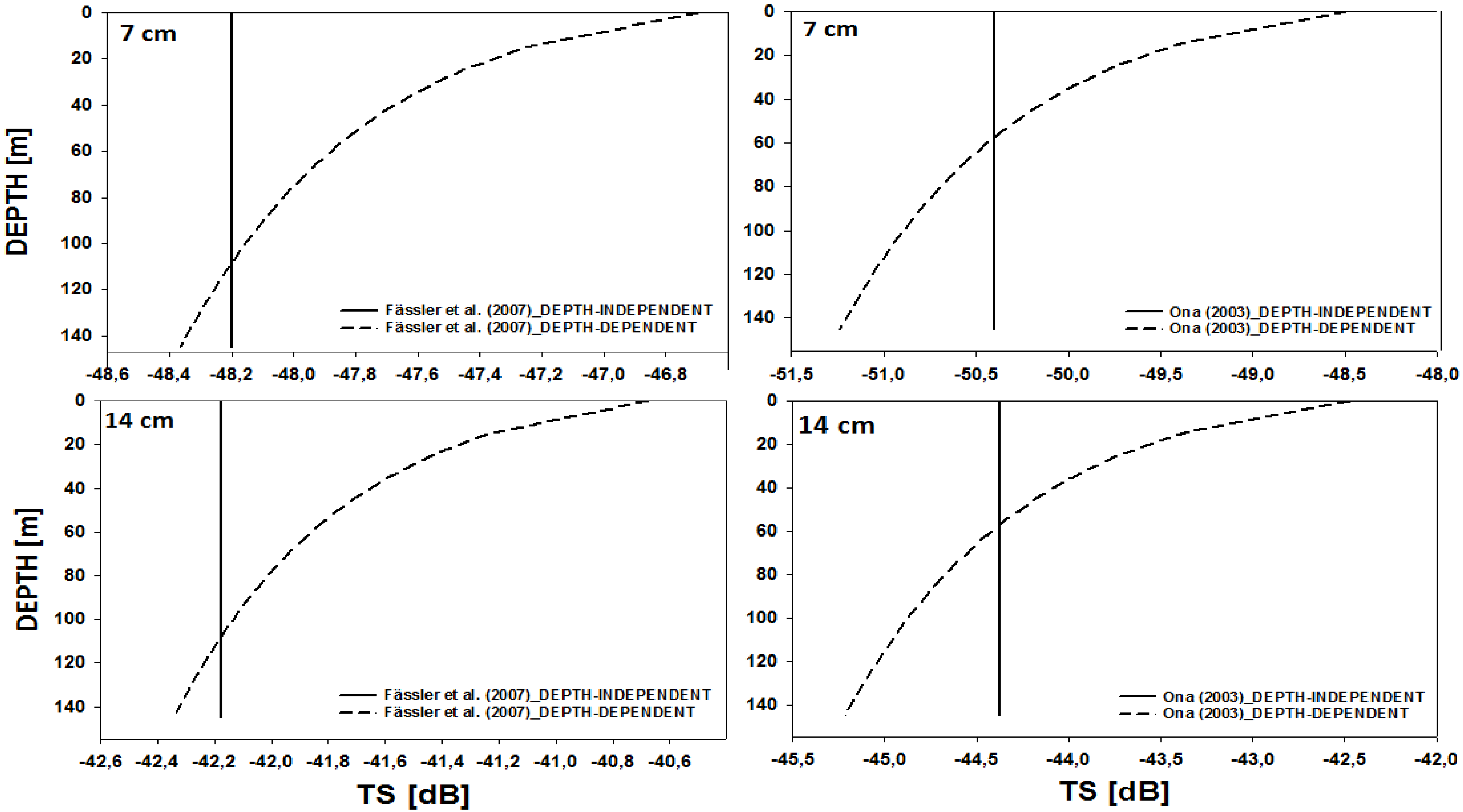


Figure 4.19. Modeled mean target strength [dB] of Baltic sprat standardized to a fish size of 7 cm (upper panels) as well as 14 cm (lower panels) using depth-independent and -dependent TS – length relationships. TS formula according to Ona (2003) (right panels) and Fässler et al. (2007) (left panels) were used. The depth-independent TS [dB] values are equivalent to continuous black lines, whereas depth-dependent TS [dB] values are equivalent to dashed lines.

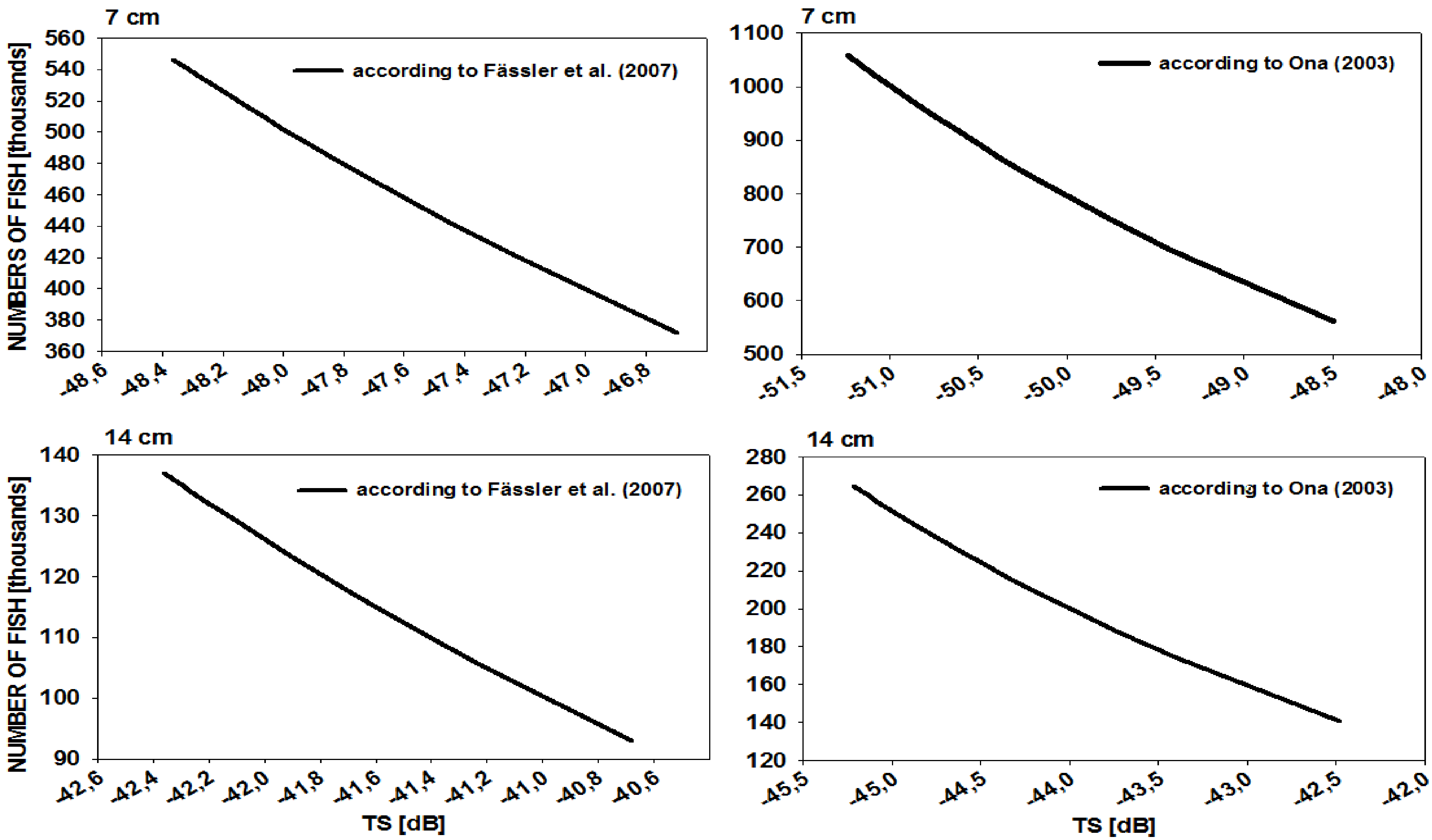


Figure 4.20. Modeled numbers of sprat [thousands] standardized to a fish size of 7 cm (upper panels) as well as 14 cm (lower panels). The depth-dependent TS formulas proposed by Fässler et al. (2007) (left panels) and Ona (2003) (right panels) were used for estimates.

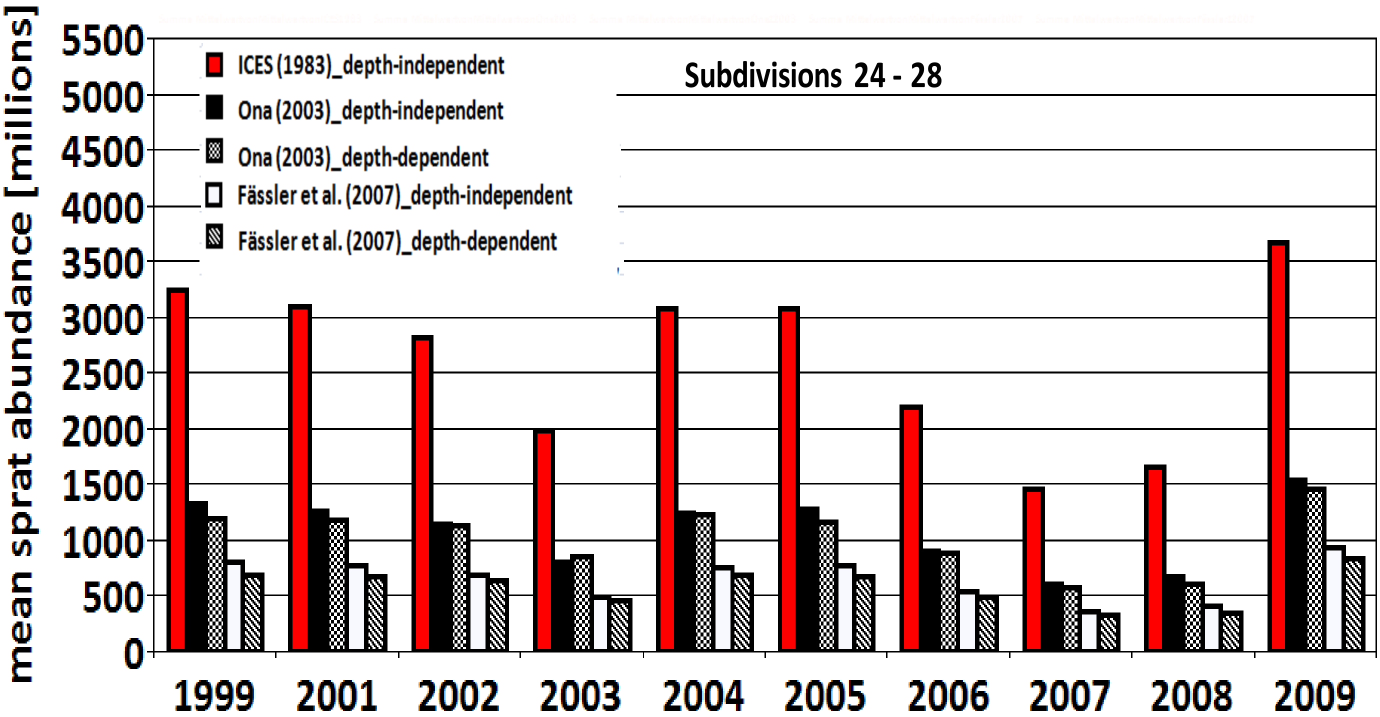


Figure 4.21. Mean values of estimated sprat abundances using depth-independent (equations (2), (9) and (10)) and depth-dependent (equations (11) and (12)) TS relationships according to ICES (1983), Ona (2003) and Fässler et al. (2007) in the years 1999 – 2009 (apart from 2000). Estimated mean abundances (in millions) were summed up per ICES-Rectangle and Subdivision. Afterwards, the mean abundances per Subdivisions were summed up per year.

Table 4.2. Results of the t-test. Statistical probability (p), t-values and degrees of freedom (df) are shown. Starlet (*) emblematizes existing statistically significant difference between mean values of comparative abundance results according to ICES (1983), Ona (2003) and Fässler et al. (2007).

t-test	t-value	df	P-value
ICES vs. Ona_depth-independent	9.974*	500	< 0.001*
ICES vs. Fässler_depth-independent	13.361*	500	< 0.001*
Ona vs. Fässeler_depth-independent	6.197*	500	< 0.001*
Ona vs. Fässler_depth-dependent	6.686*	500	< 0.001*
Ona_depth-independent **vs. Ona**_depth-dependent	0.586	500	0.558
Fässler_depth-independent **vs. Fässler**_depth-dependent	1.367	500	0.172

In order to investigate the influence of vertical distribution on sprat abundance estimate recalculations of abundances have been accomplished using the current length and depth-dependent TS relationships (Equations (11) & (12)) according to Ona (2003) and Fässler et al. (2007).

Generally, the results show lower abundances of *Sprattus sprattus L.* when the depth factor has been considered within calculations (Figure 4.21).

For example, in 2001 mean estimates which were calculated using the TS – length relationships (according to Ona (2003) and Fässler et al. (2007)) show approximately 100 millions of sprat more than those which were accomplished using the length and depth-dependent TS relationships (Figures 4.21).

Differences in vertical distribution of sprat within survey area and year caused a higher variability in cross-compared abundances (Appendix: Tables 4.3; 4.4). The mean dissimilarity in the estimated cross-compared abundances following the methods proposed by Fässler et al. (2007) amounts to 10 % over the years, whereas a maximum difference of 14 % in results could be ascertained in 2008 (Appendix: Table 4.3), where sprat were situated near to the surface (Figure 4.15). The mean difference in cross-compared sprat abundances estimated according to Ona (2003) even amounts to 4 % during years 1999 – 2009 (12 % in 2008) (Appendix: Table 4.4). These differences can be associated with the various TS methods and the various vertical distribution of Baltic sprat between years. In lower depth (near to the surface) the difference between depth-independent and depth-dependent TS values is higher than in depth layers near to the bottom (Figure 4.19; left panels). According to Ona (2003), no difference in depth-independent and –dependent TS value will be observed if clupeids are staying in depths of about 60 m (Figure 4.19; right panels). In contrast, following the methods proposed by Fässler et al. (2007) no difference in depth-independent and –dependent TS caused in the depth layer of approximately 110 m (Figure 4.19; left panels).

A t-test indicates that there is not a statistically significant difference between mean values of the cross-compared abundances estimated using depth-independent and depth-dependent TS relationships (Ona_depth-independent vs. Ona_depth-dependent $P = 0.558$, $t = 0.586$; Fässler_depth-independent vs. Fässler_depth_dependent $P = 0.172$; $t = 1.367$ with 500 degrees of freedom; Table 4.2). The difference in the mean values of the two result groups is not large enough to reject the possibility that the difference is due to random sampling variability.

5. DISCUSSION

5.1 Methodical aspects

5.1.1 Sampling strategy

In the present study various data collections, sampled during several hydroacoustic surveys in the years 1999 until 2009 (apart from 2000), have been analyzed. Data was collected during day time on the spring-surveys (May/June) onboard FRV "Walther Herwig III" (Table 3.1). Hence, seasonally comparable acoustic data being the basis for sprat stock abundance estimations were available.

As proposed by Massé & Retière (1993), the effect of number and location of trawl samples as well as the effect of acoustic transects are of high importance when estimating species' abundance. Therefore, a maximum distance of 15 nautical miles between parallel transects within ICES-Rectangles as well as a transect density of about 60 nmi per 1.000 nmi^2 has been advised by ICES (ICES 1983) for acoustic surveys. The design of the analyzed surveys fulfills the above named requirements according to ICES (Table 5.1). In several years it was not possible to cover the whole survey area due to bad meteorological conditions, technical difficulties like mechanical breakdown, the defect of mooring gear or rather the defect of net or even net sensor. Moreover, due to gillnet and drift-net fisheries within the survey area in 2002 and 2003, it was not possible to perform trawls for species identification in all areas.

A sufficient number of identification hauls is as important as the acoustic surveying strategy, especially if pelagic species form mixed schools in the survey area. Accomplished abundance estimations using hydroacoustic methods require representative fishery hauls (ICES 1983). Due to a mean trawl duration of 30 minutes when using the pelagic gear "PS205" during all surveys (WH206 – WH322b), the catches were directly comparable. Generally, the trawl hauls were performed in the primary layer echo (Figure 4.15) which was located below the halocline. The measured echo strength depends on the school density as well as its vertical dimension in the water column.

The use of different CTD profilers and a variable number of hydrographic stations during the sampling years 1999 – 2009 (Table 3.2) led to different resolutions of the hydrographic data within the survey area between the years (Figures 4.6 – 4.8).

Table 5.1 Covering of several ICES-Rectangles within hydroacoustic surveys (WH206 – WH322b) in 1999 – 2009 using hydroacoustic transects. The density of transects [nmi/1.000 nmi^2] as well as total number of accomplished fishery hauls within surveys are shown.

ICES-SUBDIVISION	ICES-RECTANGLE	WH206	WH228b	WH239	WH251	WH263	WH275	WH288	WH299	WH312	WH322b
24	37G2	-	-	-	-	-	223,5	-	-	-	-
24	37G4	-	-	-	-	-	3,4	-	1,1	-	-
24	38G2	43,2	14,4	20,4	-	31,2	76,8	42,0	34,8	18,0	33,6
24	38G3	142,1	84,3	82,0	73,9	137,5	70,5	77,4	78,5	76,2	88,9
24	38G4	87,0	67,6	68,6	56,0	74,4	91,8	72,5	70,5	80,2	90,8
24	39G2	61,6	39,4	44,3	-	56,6	41,9	64,0	49,2	51,7	64,0
24	39G3	104,6	57,5	71,9	52,3	85,0	31,4	99,3	99,3	109,8	99,3
24	39G4	122,0	51,4	64,8	108,6	122,0	93,4	89,6	83,8	76,2	78,1
25	37G5	35,8	82,5	24,9	17,1	15,6	24,9	17,1	14,0	15,6	15,6
25	38G5	133,2	59,9	115,9	73,4	58,9	123,6	64,7	59,9	69,5	69,5
25	38G6	62,8	46,8	34,0	45,7	27,7	38,3	34,0	30,8	19,1	36,2
25	38G7	31,8	6,4	-	4,2	-	-	-	-	2,1	2,1
25	39G4	66,1	38,3	80,1	55,7	135,7	97,5	80,1	132,3	73,1	111,4
25	39G5	74,6	74,6	148,1	62,3	63,3	97,0	63,3	63,3	62,3	62,3
25	39G6	66,3	352,8	155,0	68,2	58,5	57,5	73,1	61,4	71,2	61,4
25	39G7	69,2	56,5	72,1	83,8	60,4	57,5	66,3	60,4	66,3	73,1
25	40G4	82,7	42,8	79,7	87,1	93,0	90,1	87,1	96,0	101,9	91,6
25	40G5	74,1	83,8	134,5	53,6	120,9	110,1	48,7	49,7	48,7	48,7
25	40G6	137,2	60,2	192,5	69,1	72,1	55,3	64,2	67,1	72,1	74,0
25	40G7	62,2	60,2	62,2	59,2	59,2	-	66,1	68,1	66,1	68,1
25	41G5	-	-	5,3	-	-	-	-	-	-	-
25	41G6	62,8	35,3	77,2	44,5	74,6	22,2	49,7	61,5	53,6	44,5
25	41G7	62,0	64,0	60,0	73,0	81,0	-	80,0	67,0	69,0	74,0
26	38G8	-	4,8	-	8,0	1,6	-	70,4	-	8,0	8,0
26	39G8	71,2	52,6	64,3	55,6	50,7	71,2	86,7	-	61,4	70,2
26	40G8	58,2	59,2	59,2	78,0	58,2	57,3	59,2	-	72,1	65,2
26	41G8	58,0	60,0	60,0	98,0	59,0	73,0	30,0	-	66,0	66,0
27	42G7	60,8	42,6	105,4	52,7	58,8	-	59,8	81,1	59,8	31,4
27	43G7	-	-	-	15,3	64,6	-	65,7	66,8	65,7	32,8
27	44G7	-	-	-	-	68,7	-	66,6	58,3	61,4	31,2
27	45G7	-	-	-	-	-	-	73,7	70,4	74,8	-
27	45G8	-	-	-	-	-	-	63,3	63,3	69,7	-
27	46G8	-	-	-	-	-	-	66,7	44,1	49,7	14,7
28	42G8	73,0	45,5	47,6	30,7	75,1	37,0	14,8	-	-	60,3
28	42G9	-	-	8,1	-	33,4	-	-	-	-	47,6
28	43G8	57,4	-	-	-	-	-	-	-	-	57,4
28	43G9	73,9	-	-	-	-	-	-	-	-	73,9
28	44G9	78,7	-	-	-	-	-	-	-	-	78,7
28	44H0	29,2	-	-	-	-	-	-	-	-	29,2
28	44H1	32,7	-	-	-	-	-	-	-	-	32,7
28	45G9	47,6	-	-	-	-	-	-	-	-	47,6
28	45H0	79,2	-	-	-	-	-	-	-	-	79,2
28	45H1	41,1	-	-	-	-	-	-	-	-	41,1
29	46G9	-	-	-	-	-	-	-	-	65,3	22,5
29	46H0	-	-	-	-	-	-	-	-	53,5	-
number of fishery hauls		48	48	57	36	60	23	54	49	60	63

While in 1999 only 47 hydrographic vertical profiles have been sampled, a minimum of 130 hydrographic stations have been sampled every survey year since 2004 (Table 3.2). Subdivision 25 was completely covered during all survey years. Hence, the hydrographic situations as shown in ICES-Subdivision 25 are more reliable than those presented in Subdivisions 24/26/27 and 28 of the Baltic Sea. An overview of the hydrographic situation is given in the figures 4.6 – 4.8 during 1999-2009 for the present study.

5.1.2 Data processing and evaluation

Hydroacoustics are a cost-effective method for monitoring fish as well as spatial and temporal distribution pattern of dense acoustical objects over a large area, for extended periods of time. Due to the high sample power of acoustic measurements, more data can be collected in a given amount of time than with any other fisheries evaluation technique. Nevertheless, there are principal disadvantages or limitations of hydroacoustic techniques which influence the findings of the investigation (Aglen 1994, MacLennan & Simmonds 1992).

The standard total abundance estimate is based on the assumption that the acoustic signal is proportional to fish density when the backscattering is corrected for fish size (Toresen et al. 1998). However, because of factors such as the acoustic shadowing effect (Zhao & Ona 2003), depth-dependent target strength (Ona 2003) and vessel avoidance (Vabø et al. 2002), abundance estimates derived from hydroacoustic methods may be seriously biased (Aglen 1994).

Systematic changes in acoustically estimated density were reduced due to vessel avoidance, probably caused by a combination of changes in fish orientation and horizontal movement. Avoidance reactions of fish or rather shoals benefit changes in tilt angle because of changing swimming behavior. The presence of any vessel influences the behavior of fish due to vessel noise (Mitson 2000). In this connection, herring's auditory threshold (-30 dB) forms the basis of the reference level. The distances as well as the speed at which several vessels may cause fish avoidance behavior are well-known (Mitson 2000).

For FRV "Walther Herwig III" and a vessel speed of 11 knots, the distance at which its noise may influence fish avoidance behavior amounts to approximately 300 – 400 m (Mitson 2000). During the analyzed acoustic surveys the average vessel speed was 10 knots above the bottom. Present NASC values, which were measured within survey years 1999 – 2009, are only existent in depth up to 145 m. The influence of vessel noise extends over the whole water column within the sampling area. Vessel movements, due to rough weather, could entail variable high echoes (Berg & Lovik 1982). Thus, due to strong movements targets and the bottom sometimes can't be distinguished precisely. In addition, when fishing with a pelagic trawl, avoidance reactions of fish may influence the composition of catches and thus, the resulting *in situ* TS estimates.

Despite the potential bias mentioned above, other factors may complicate the biomass estimates derived from acoustic data. The identification of species may be an important source of bias and uncertainty (Tesler 1989, Aglen 1994, Demer 2004, O'Driscoll 2004). Because of the presence of different species within sampling area, species composition has to be included using abundance estimates. According to MacLennan & Simmonds (1992) separated, grouped echo integration (e.g. per taxa, age class) for accurate abundance calculations are reasonable. Therefore, surveyed echo signals have assigned to particular target group.

Such a classification of measured echoes isn't possible within present sampling area. During the day, reviewed species could be observed in mixed layers. Due to an overlap between echoes appending to single fish and echoes appending to schooling fish during hydroacoustic measurements, MacLennan & Simmonds (1992) suggest an abundance estimation using mean species composition as well as mean length distribution within defined areas (see also ICES 1983).

Hydroacoustic methods usually underestimate fish density because of the "dead zones" (Ona & Mitson 1996) close to the surface and the bottom. Fish distributed close to the bottom are less detectable by the echo sounder (Aglen et al. 1999). Thus, in the present study, individuals standing 50 cm above the bottom have to be disregarded within integration of echo raw data. In addition, during post-processing it is nearly impossible to distinguish fish echoes close to the bottom (e.g. cod or dense shoals) between the bottoms echoes itself (Mitson 1982, Götze et al. 1993, Aglen et al. 1999). Hence, variations in the vertical density profile of fish over the area may differently affect density estimates (Aglen et al. 1999).

Current denoted depth layers underlying measurements of NASC values within hydroacoustic surveys are defective. The depth is determined by the speed of the sound. More precisely, depth is determined by the time the sound needed from the transducer to the target and back again. However, resulting depth is directly based on considered speed of sound. Speed of sound depends on water temperature, salinity and pressure. Therefore, it changes significantly with season, time of the day, depth and geographical position (Clay & Medwin 1977).

Depending on method used, TS estimates vary considerably (MacLennan & Simmonds 1992). Apart from fish length and species, fish behavior affects fish specific acoustic characteristics (Olsen et al. 1982, Orlowski 1997, Alvarez & Ye 1999, Bethke 2000, Huse & Korneliussen 2000, Orlowski 2001). Here, the behavior of shoal as well as the tilt angle of fish plays an important role (Huse & Korneliussen 2000). According to the swimming behavior of fish or rather shoal its tilt angle differs. A maximum of acoustic energy will be backscattered if a fish swim almost horizontally (Foote & Nakken 1978), otherwise the density of backscattering will decrease.

5.2 Species composition

In May/June, peak spawning of Baltic sprat occurs (Wahl & Alheit 1988), especially within the major basins (Arkona, Bornholm, and Gotland Basins as well as the Gdansk Deep) and in the central and eastern Baltic (Grauman 1974, Grauman & Krenkel 1986). It is obvious that *Sprattus sprattus L.* was the main species in the trawls. In contrast, both *Clupea harengus L.* and *Gadus morhua* played a minor role within sampling area and time, basically.

5.3 Length distribution of *Sprattus sprattus L.*

Chronological changes in growth pattern of sprat have been described in the past. Aps et al. (1988) suggested an increase of asymptotic length over the years (about 12 cm in 1955 to nearly 14 cm in 1975). This has been related to a better food supply as well as a decrease of sprat abundance in 1961 – 1981 (Aps et al. 1988). This effect wasn’t found in this study. The length distribution of *Sprattus sprattus L.* differed between areas and years and was often characterized by a bimodal distribution with peaks around 9 cm and 12 cm, for example in the year 2009 (Figure 4.11). These length distributions indicate successful recruited age-1 sprats which were spawned in 2008 due to warmer temperatures (Figures 4.5 b; 4.6). The warmer temperature might be advantaged a higher primary production that cause a better food supply in 2008. Therefore, high abundance estimates were found in 2009 (see also Chapter “5.4.1 Horizontal distribution and abundance of *Sprattus sprattus L.*”).

Previous studies (e. g. Lindquist 1971) could show differences in growth parameters of sprats in various regions. Hence, there is evidence to suggest an existing number of sprat substocks in the Baltic Sea. Lindquist (1971) reported an exceeded length of 1 cm to 2 cm for several sprat groups. In the present study, this can be confirmed. *Sprattus sprattus L.* in the Eastern Baltic was about 1 cm smaller than in the Southern Baltic (Figure 4.12 c).

This can be explained due to a higher food availability caused by appropriate hydrographic conditions in the ICES-Subdivisions 24 and 25. In the Southern Baltic Sea, temperature was warmer (Figures 4.2; 4.6) and salinity was higher (Figures 4.3; 4.7) compared to the Eastern Baltic. The Southern Baltic is directly connected with the North Sea. Therefore, influx incidents of more saline North Sea water are potential. Such inflows have an impact on species abundances and distribution pattern as well as on the food web (Hammer 2006).

Hence, sprat development and productivity in the Southern Baltic was positively influenced by hydrographic conditions (see Figure 4.12).

5.4 Distribution and abundance

5.4.1 Horizontal distribution and abundance of *Sprattus sprattus L.*

Surveyed hydroacoustic data from 1999 – 2009 (apart from 2000) which form the basis of the present study enable a direct comparison between recalculated sprat stock abundance estimates within sampling area (ICES-Subdivisions 24 – 28).

Former investigations suggested that spawning stock biomass strongly correlates with egg abundance and subsequent larval abundance (Köster et al. 2003). Both are influenced by biotic and abiotic factors, which directly affect the amount of successfully recruited survivors. According to Nissling (2004), ambient temperature is one of these factors that seem to be strongly coupled with sprat recruitment, because water temperature colder than 5°C entails significant mortality in sprat eggs. The turbulent winter in 2002/2003 caused an influx event of more saline North Sea water into the Baltic Sea in 2003 (Nausch et al. 2004). As a result, the water temperature in the whole Baltic was below 5 °C (Figures 4.2 B2; 4.6). This might be responsible for induced substantial egg and early larvae mortality and thus has resulted in relatively weak year classes, which led to lower sprat abundances within Subdivision 25 during May/June 2003 (Figure 4.14).

An inflow event in December 2005 (Nausch et al. 2007) could also be the reason for the low sprat abundances in the Baltic Sea in 2006 (Figure 4.14). Decreased sprat abundances within ICES-Subdivision 26 and 27 have been observed ever since (apart from 2009), whereas in the Southern Subdivisions (e.g. SD 25) a continuous increasing of sprat abundance peaked in 2009 at the same time. In 2006 sprat abundance was lower (about 1.500 millions) within Subdivision 25 compared to Subdivisions 26 (nearly 3.000 millions) and 27 (about 4.000 millions of sprats) (Figure 4.14). The higher sprat abundances could have led to intraspecific food competition as well as egg cannibalism that might have entailed the smaller sprat abundance within Subdivisions 26 and 27 at the same time. The influx event into the Baltic in December 2005 was not as intensive as in 2003. Thus, ICES-Subdivision 26 and 27 weren't influenced. Southern Baltic located sprats productivity has been supported due to appropriate hydrographic conditions compared to the conditions in Subdivisions 26 and 27 at the same time.

In 2008 water temperatures above halocline were higher-than-average temperatures (Figures 4.5 b; 4.6). This could have influenced the food supply due to changing planktonic food availability (Voss et al. 2006). Therefore, sprat larvae which were spawned in 2008 developed very well. This could have led to high abundance estimates for *Sprattus sprattus L.* in 2009 (Figure 4.14).

5.4.2 Vertical distribution and abundance of *Sprattus sprattus L.*

Measured echo signals in May/June 1999 – 2009 could be directly correlated with sprat abundances due to the fact that herring and cod were less abundant in the catches (Figures 4.9; 4.10).

Within survey years the vertical distribution of Baltic sprat varied (Figure 4.15). Former studies suggested that sprat avoid areas which are colder than 4 °C (Rechlin 1967, Rechlin 1975, Hoziosky et al. 1989, Karasiova & Zezera 2000). This can also be confirmed in the present study. Highest NASC values were generally measured below thermo-halocline within Subdivision 25 during the years. The thermo-halocline was located in approximately 35 – 40 m depth within Subdivision 24 and in 55 – 65 m depth in Subdivisions 25/26/27 and 28. Water temperature below the thermocline continuously declined until the permanent halocline and reached an averaged minimum of values between 3 – 4 °C above halocline (see Figures 4.6 and 4.7). This might enhance sprats staying below halocline, where temperatures have been higher than 4 °C.

In 2008 vertical distribution of *Sprattus sprattus L.* differed. In this year, the majority of sprats were located near the surface in the range of the spring-thermocline (Figure 4.15). In 2008 the water temperature was higher-than-average (4 – 6 °C) above halocline. Potentially, this could be the reason for higher NASC values near to the surface that were found only in May 2008. Despite missing experimental studies concerning accurate information of oxygen limitation and the influence of salinity on Baltic sprat (Karasiova & Zezera 2000, Rechlin 1975), a relevance of these parameters on sprat's vertical distribution could be assumed based on the findings of the present study. Although, temperatures more than 4 °C have likewise been measured in lower water depth within survey years, sprat generally stayed below halocline during the day. Potentially, illumination might have a direct influence on Baltic sprat staying below halocline (Blaxter & Batty 1990). Higher salinities could also have advantaged sprat being located in deeper layers of the halocline. Nevertheless, better food availability in depths below the halocline could entail sprat behavior.

In addition, an equal habitat selection for *Sprattus sprattus L.* and *Gadus morhua* has been suggested before (Stepputtis 2006). In order to ensure a successful development of cod eggs, a salinity about 11 psu, an oxygen content above 2 mL/L and water temperatures more than 1.5 °C are necessary (Westin & Nissling 1991, Wieland et al. 1994, Hinrichsen & Wieland 1996). In depth below halocline, where sprats were situated within survey years, mentioned requirements met conditions (e. g. SD 25 Figures 4.6 – 4.8). Thus, cod eggs might ensure food availability on sprat.

5.5 The influence of suitable TS values on abundance estimates

In the present study, variable TS - length relationships as well as length and depth-dependent TS relationships according to ICES (1983), Ona (2003) and Fässler et al. (2007) (Table 3.5) have been used in order to recalculate and compare resulting Baltic sprat abundances for 1999 – 2009. A strong variability in the results of the abundance estimates was found (Figure 4.21). This can be directly connected to the different TS-methods that were compared.

The traditional TS - length relationship currently applied to abundance estimates for Baltic clupeid stocks were developed about 25 years ago (ICES 1983). Sprat abundances recalculated according to Ona (2003) and Fässler et al. (2007) are continuously 59 % (ICES vs. Ona) and 75 % (ICES vs. Fässler et al.) lower than those used to assess respective stocks of Baltic clupeids (ICES 1983) over the years. The estimated abundances following depth-independent TS – length relationships proposed by Ona (2003) and Fässler et al. (2007) demonstrate a continuous percentaged disparity over the years. Hence, a low effect of various TS methods on sprat abundances used as indices to assess stock of Baltic clupeids might be assumed.

As described by Fässler et al. (2007) modeled mean TS values for Norwegian spring spawning herring (TS formula according to Ona (2003)) were about 2 dB lower (see Figure 4.17), especially for large fish. The recent TS values proposed by Ona (2003) are approximately 4 dB higher (see Figure 4.19) than that currently applied to estimate abundance of Baltic clupeids (Fässler et al. 2009).

In this connection, differences in fish swimbladder volume and fat content could be the reasons for various mean TS (Fässler et al. 2007). Former studies suggested a decreasing individual weight of *Sprattus sprattus L.* that indicates a food limitation within the Baltic Sea. On the one hand, prey abundances of copepods decreased and on the other hand, due to increasing sprat abundances within the whole Baltic, the intraspecific food competition increased which could have led to decreasing sprat weights (Möllmann et al. 2000, 2004) and fat content. Hence, due to the lower fat content of the fish and lower salinity levels in the Baltic it has been argued that Baltic herring may have larger swimbladders (Fässler et al. 2007).

Compared to herring stocks living in waters with higher salinities, Baltic herring exhibit larger swimbladder volume for a given fish size (Fässler et al. 2007), to maintain neutral buoyancy. This could also be assumed for sprat. In order to maintain neutral buoyancy the swimbladder has to counterbalance the weight of the fish body to match the density of the surrounding sea water. In addition, fat has a lower density than seawater and can therefore contribute to positive buoyancy (Brawn 1969). A larger swimbladder is a better reflector of acoustic energy and entail higher mean TS.

Thus, lower abundances for *Sprattus sprattus L.* of a given length were recalculated using the TS methods according to Fässler et al. (2007), compared to mean TS estimated according to Ona (2003) and those used to assess respective stocks of Baltic clupeids (ICES 1983) in the present study. This could also be confirmed by Fässler et al. (2009).

The swimbladder is the most important contributor to the total backscattered sound from a fish (Jones & Pearce 1958, Foote 1980, Blaxter & Batty 1990). Therefore, it has been suggested to include a depth factor into the TS - length relationship for herring and sprat to account for swimbladder compression caused by increased pressure with depth (Blaxter & Batty 1990, Ona 2003, Gorska & Ona 2003a, 2003b, Fässler et al. 2007). In order to consider the acoustic effect of pressure on fish abundance estimates, depth-dependent TS values were used according to Ona (2003) and Fässler et al. (2007). As suggested in Fässler et al. (2009), herring and sprat TS decreases with depth (see Figure 4.19) whereas the variation in TS depends on fish size (see Figure 4.18).

If the length and depth-dependent TS relationships according to Ona (2003) and Fässler et al. (2007) were used for abundance estimates, this would result in smaller abundances compared to the standard method (according to ICES 1983) due to the included depth factor.

In addition, abundance estimates calculated using the length and depth-dependent TS equations according to Fässler et al. (2007) generate smaller values than those estimated according to Ona (2003) (Figure 4.21). This is due to the different swimbladder volumes and fat content of Baltic clupeids and thus to the various mean TS as mentioned above. Moreover, compared to results estimated according to equations (10) and (12) a minor mean difference (about 4 %) is shown between recalculated sprat abundances according to equations (9) and (11). The reason for this is that caught sprats were generally located in depth of approximately 65 m within 1999 – 2009. The observed influence of depth factor on mean TS has marginal consequences in depth of about 60 m (recalculations according to Ona (2003); Figure 4.19 – right panels). According to Fässler et al. (2007), within lower depth (near to the surface) the difference between depth-independent and -dependent TS is higher than in depth layers near to the bottom. The observed influence of depth factor on mean TS has marginal consequences in depth of 110 m (recalculations according to Fässler et al. (2007); Figure 4.19 – left panels).

Therefore, the higher mean difference (about 10 %) between recalculated sprat abundances using equations (10) and (12) according to Fässler et al. (2007) could be explained. Considering that Baltic sprat is situated in water depths of approximately 65 m within sampling area, the depth-dependent TS method proposed by Ona (2003) have a minor effect on Baltic sprat abundances than those proposed by Fässler et al. (2007). In years where the vertical distribution of sprat varied within sampling area the depth factor included in the depth-dependent TS formula could entail a higher effect on abundances estimates. In this manner, the highest differences in results comparing equations (9) and (11) (variability of 12 %) as well as equations (10) and (12) (variability of 14 %) observed in 2008, where *Sprattus sprattus L.* was located close to the surface, could be explained and might influence the calculation of indices to assess stock of Baltic clupeids. Therefore, the importance of using current depth-dependent TS methods for abundance estimates of Baltic clupeids has to be verified by the German contribution to the Baltic International Acoustic Spring Surveys (BASS).

The results show the importance of suitable TS utilization to enhance assessing Baltic clupeids abundances. If the higher mean TS for Baltic clupeids proposed by Ona (2003) and Fässler et al. (2007) were correct, the depth factor combined with variable vertical distribution of clupeids within several years might be relevant to the use of abundance indices for VPA tuning and for instance by the XSA method of Shepherd (1999), which depends on the index trends in the most recent years (Kasatkina 2009).

5.6 Conclusion

The influence of empirical TS – length and length and depth-dependent TS relationships proposed by ICES (1983), Ona (2003) and Fässler et al. (2007) on abundance estimates of Baltic clupeids have been analyzed and explained here. The difference in methodology, using various TS – length or rather length and depth-dependent TS relationships, is one of the major reasons for the variability in TS proposed by ICES (1983), Ona (2003) and Fässler et al. (2007) and thus for the various observed sprat abundances. The importance of suitable TS utilization to enhance assessing Baltic clupeids abundances could be demonstrated.

The results show that sprat abundances recalculated according to Ona (2003) and Fässler et al. (2007) are continuously 59 % (ICES vs. Ona) and even 75 % (ICES vs. Fässler et al.) smaller than those estimated using traditional TS formula according to ICES (1983). Nevertheless, these continuous percentaged differences over the years might suggest a low effect of various TS methods on sprat abundances used as indices to assess stock of Baltic clupeids.

Moreover, compared to abundances estimated according to TS – length and length and depth-dependent TS relationships proposed by Ona (2003) minor differences (averaged 4 %) are shown than using depth-independent and depth-dependent TS formula according to Fässler et al. (2007) (averaged 10 %). The results show a marginal variability using the depth-independent and the depth-dependent TS method established for the Norwegian spring spawning herring proposed by Ona (2003) in years where Baltic sprat are situated in water depth of about 65 m. Hence, these depth-dependent TS method might rather used to enhance abundance estimates of clupeids living in deeper waters. Due to the abundances result using the length and depth-dependent TS relationship according to Fässler et al. (2007), the importance of using these depth-dependent TS methods for abundance estimates of Baltic clupeids has to be verified by the German contribution to the Baltic International Acoustic Spring Surveys (BASS). Using current depth-dependent TS methods for abundance estimation when changes in vertical distribution of clupeids between years occur might enhance the assessment of clupeid stocks.

5.7 Future prospects

Recently there are many investigations concerning TS estimates in order to enhance hydroacoustic measurements and methods. Present investigations suggest that there are also differences in TS between herring and sprat due to the different morphologies of these two species (Kasatkina 2007, Fässler et al. 2009). Herring's TS is higher compared to sprat's TS of the same length (Fässler et al. 2009). Hence, they advise to avoid using the same TS – length relationships for sprat abundance estimates that are derived for herring > 15 cm. According to Fässler et al. (2009), if the TS – length relationship obtained for herring was applied to sprat abundance estimates, sprat biomass would be underestimated by approximately 40 %. Therefore, different TS – length relationships for each species seems to be essential to enhance assessing future sprat abundances.

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7. LIST OF LITERATURE

Aglen, A. 1994. Sources of error in acoustic estimation of fish abundance. *In* Marine Fish Behaviour. Fishing News Books. Oxford. pp. 107 – 134.

Aglen, A., Engås, A., Huse, I., Michalsen, K. & Stensholt, B. K. 1999. How vertical fish distribution may affect survey results. ICES Journal of Marine Science, 56: 345 – 360.

Alheit, J., Wahl, E., & Cibangir, B. 1987. Distribution, abundance, development rates, production and mortality of sprat eggs. ICES CM/H:45.

Alheit, J., 1988. Reproductive biology of sprat (*Sprattus sprattus*): factors determining annual egg production. J. Cons. Int. Explor. Mer. 44, 162–168.

Alheit, J., Möllmann, C., Dutz, J., Kornilovs, G., Loewe, P., Mohrholz, V. & Wasmund, N. 2005. Synchronous ecological regime shifts in the central Baltic and the North Sea in the late 1980s. ICES Journal of Marine Science 62: 1205-1215.

Alvarez, A. & Ye, Z. 1999. Effects of fish school structures on acoustic scattering. ICES Journal of Marine Science 56: 361 – 369.

Aps, R. A., Shirokov, S. V. & Ustinova, L. A. 1988. Variability of the Baltic sprat growth. Fischerei-Forschung 26: 77-81.

Arrhenius, F. & Hansson, S. 1993. Food consumption of larval, young and adult herring and sprat in the Baltic Sea. Mar. Ecol. Prog. Ser. 96: 125-137.

Bagge, O., Thurow, F., Steffensen, E. & Bay, J. 1994. The Baltic cod. Dana 10: 1-28.

Bailey, R. S. 1980. Problems in the management of short-lived pelagic fish as exemplified by North Sea sprat. Rapp p-v Reun (Dan) 177: 477-488.

Balk, H. 2001. Development of hydroacoustic methods for fish detection in shallow water. Thesis for the degree of Doctoral Scientiarium. Faculty of Mathematics and Natural Sciences, University of Oslo, Oslo, Norway. 309 pp.

Baumann, H., Hinrichsen, H.-H., Köster, F. W., Temming, A. (Hrsg.) 2004. A new retention index for the Central Baltic Sea: long-term hydrodynamic modelling used to improve Baltic sprat, *Sprattus sprattus*, recruitment models. (ICES Council Meeting, L:02, Vigo, Spain), pp. 15.

Baumann, H., Hinrichsen, H.-H., Moellmann, C., Koester, F.W., Malzahn, A.M., & Temming, A. 2006. Recruitment variability in Baltic sprat, *Sprattus sprattus*, is tightly coupled to temperature and transport patterns affecting the larval and early juvenile stages. Can J. Fish. Aquat. Sci. 63: 2191-2201.

Berg, T. & Lovik, A. 1982. Increased precision of echo integration recordings under various weather conditions. FAO Fish. Rep. 300: 45-51.

Bethke, E. 1994. The calibration of echo integrators. (Die Kalibrierung von Echo-integrationsanlagen). Informationen für die Fischwirtschaft 41: 102-107.

Bethke, E. & Wienbeck, H. 1996. Analysis of fright reaction of fishes on ship noise by hydroacoustic methods; Analyse des Fluchtverhaltens von Fischen auf Schiffsgeräusche mit hydroakustischen Methoden. Informationen für die Fischwirtschaft 43: 139-143.

Bethke, E. 2000. Influence of the day-night behavior of fish on hydroacoustic measurements. Einfluss des Tag-Nacht-Verhaltens von Fischen auf das Ergebnis hydroakustischer Messungen. Inf. Fischwirtsch. Fischereiforsch. 47: 139 – 143.

Blaxter J.H.S., Denton E.J., Gray J.A.B. 1979. The herring swim bladder as a gas reservoir for the acoustico-lateralis system. *Journal of the Marine Biological Association of the United Kingdom* 59:1–10.

Blaxter, J.H.S. & Batty, R.S. 1990. Herring behaviour in the light and dark. *In* Light and Life in the Sea. *Edited by* P.J. Herring, A.K. Campbell, M. Whitfield, and L. Maddock, pp. 209-220.

Blaxter, J.H.S. & Batty, R.S. 1990. Swimbladder "behavior" and target strength. Rapport et Procès Verbaux des Réunions Conseil International pour l'Exploration de la Mer, 189: 233-244.

Brawn, V. M. 1969. Buoyancy of Atlantic and Pacific herring. Journal of the Fisheries Research Board of Canada, 26: 2077-2091.

BRODGAR 2.5.7. www.brodgar.com

Cardinale, M. & Arrhenius, F. 2000. Decreasing weight-at-age of Atlantic herring (*Clupea harengus*) from the Baltic Sea between 1986 and 1996: a statistical analysis. ICES Journal of Marine Science, 57: 882-893.

Casini, M., Cardinale, M. & Hjelm, J. 2006. Inter-annual variation in herring, *Clupea harengus*, and sprat, *Sprattus sprattus*, condition in the central Baltic Sea: what gives the tune? Oikos 112: 638-650.

Clay, C. S. & Medwin, H. 1977. An acoustical view of the sea. *In*: Acoustical Oceanography: Principles and Applications. Chapter One: 1-27 pp.

De Silva, S.S. 1973. Abundance, structure, growth and origin of inshore clupeid populations of the west coast of Scotland. J. exp. Mar. Bio. Eco. 12: 119-144.

Demer, D. A. 2004. An estimate of error for the CCAMLR 2000 survey estimate of krill biomass. Deep-Sea Research II, 51: 1237 – 1251.

Diachok, O. 2005. Bioacoustic absorption spectroscopy: a new approach to monitoring the number and lengths of fish in the ocean (chapter 14). In: Medwin, H. and colleagues, Sounds in the Sea. From

Ocean Acoustics to Acoustical Oceanography. Cambridge University Press, Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, pp. 396-410.

Dickmann, M., Möllmann, C., Voss, R. 2007. Feeding ecology of Central Baltic sprat (*Sprattus sprattus* L.) larvae in relation to zooplankton dynamics – implications for survival. Marine ecology progress series 342 (2007), S. 277-289

Didrikas, T. & Hansson, S. 2004. *In situ* target strength of the Baltic Sea herring and sprat. ICES Journal of Marine Science, 61: 378 – 382.

Echoview. www.echoview.com

Edwards, J. I. & Armstrong, F. 1981. Measurement of the target strength of live herring and mackerel. ICES Document CM 1981/B: 26. 5 pp.

Ehrenberg, J. E. 1974. Recursive algorithm for estimation the spatial density of acoustic point scatterers. Journal of the Acoustical Society of America, 56(2): 542-547.

Fässler, S. M. M., Gorska, N., & Ona, E. 2007. Comparison of the swimbladder between Baltic and Norwegian fjord herring: possible consequences for mean target strength. ICES Document CM 2007/H: 03.

Fässler, S. M. M. & Gorska, N. 2009. On the target strength of Baltic clupeids. – ICES Journal of Marine Science, 66: 1184-1190.

Fässler, S. M. M., Brierley A. S. & Fernandes, P. G. 2009. A Bayesian approach to estimating target strength. ICES Journal of Marine Science, 66: 000 – 000.

Foote, K. G. & Nakken, O. 1978. Dorsal aspect target strength functions of six fishes at two ultrasonic frequencies. Fisken Hav. Ser. 3: 1 – 96.

Foote, K. G. 1980. Importance of the swimbladder in acoustic scattering by fish: A comparison of gadoid and mackerel target strengths. Journal of the Acoustical Society of America, 67: 2084-2089.

Foote, K. G. 1985. Rather-high-frequency sound scattering by swimbladdered fish. Journal of the Acoustical Society of America, 78: 688-700

Foote,K.G., Aglen, A., Nakken, O. 1986. Measurement of fish target strength with a split-beam echosounder. The journal of the Acoustical Society of America 80: 612-621.

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

Foote, K. G., Knudsen, H. P., Korneliusen, R. J., Nordbø, P. E., and Røang, K. 1991. Post-processing system for echosounder data. Journal of the Acoustical Society of America, 90: 37 -47.

George, M.R. 1987. Ovarian maturation cycle of sprat, *Sprattus sprattus*. ICES CM/H 47.

Götze, E., Bethke, E. & Oeberst, R. 1993. Hydroacoustic small scale investigations of pelagic fish stocks. ICES Council Meeting Papers 1993. ICES-CM-1993/B:34: 14 pp.

Gorska, N. & Ona, E. 2001. Modelling herring target strength pressure dependence in the frequency domain. ICES CM 2001/Q: 09. 10 pp. (mimeo).

Gorska, N. & Ona, E. 2003a. Modelling the acoustic effect of swimbladder compression in herring. ICES Journal of Marine Science, 60: 548-554.

Gorska, N. & Ona, E. 2003b. Modelling the effect of swimbladder compression on the acoustic backscattering from herring at normal or near-normal dorsal incidence. ICES Journal of Marine Science, 60: 1381-1391.

Gorska, N. 2007. On target strength of Baltic herring. ICES Document CM 2007/H: 07.

Grauman, G. 1974. Investigations on the spawning of Baltic cod in 1986-1970. Rapp P-v-Réun Cons Int Expl Mer 166:7-9.

Grauman, G.B. & Krenkel, K. 1986. Investigations about the dynamics of spawning processes of the Baltic sprat in 1984. ICES CM/J17.

Grimm, S.K. & Herra, T. 1984. Spawning cycles of southern Baltic fishes based on surveys of eggs and larvae. ICES CM 1984/J39.

Hagström, O., Palmen, L.-E., Håkansson, N., Kästner, D., Rothbart, H., Götze, E., Grygiel, W., Wyszynski, M. 1991. Acoustic estimates of the herring and sprat stocks in the Baltic proper October 1990. ICES CM 1991/J:34.

Håkansson, N., Kollberg, S., Falk, U., Götze, E., Rechlin, O. 1979. A hydroacoustic and trawl survey of herring and sprat stocks of the Baltic proper in October 1978. Fischerei-Forschung, Wissenschaftliche Schriftenreihe 17(2):7-23.

Hammer, C. (2006). Der Einstrom in die Ostsee. The inflow in the Baltic Sea. *In:* Hempel et al., Faszination Meeresforschung. Verlag H. M. Hauschild GmbH, Bremen, S. 66-69.

Haslett, R. W. G. 1977. Automatic plotting of polar diagrams of target strength of fish in roll, pitch and yaw. Rapports et Procès Verbaux des Réunions du Conseil Internationale pour l'Exploration de la Mer, 170, 74-81.

Hinrichsen, H. H. & Wieland, K. 1996. Reproduction volume of Baltic cod in the Bornholm Basin estimated from single point measurements. ICES Council Meeting Papers 1996. ICES-CM-1996 / C+J: 7: 10 pp.

Horne, J. K., and Jech, J.M. 1998. Quantifying intra-species variation in acoustic backscatter models. Proceedings of the 135th Meeting of the Acoustical Society of America, Seattle, 20-26 August 1998, pp 1821-1822.

Horne, J. K., and Jech, J.M. 1999. Multi-frequency estimates of fish abundance: constraints of rather high frequencies. ICES Journal of Marine Science, 56: 184-199.

Horne, J. K. 2003. The influence of ontogeny, physiology, and behaviour on the TS of walleye pollock (*Theragra chalcogramma)*. ICES J. Mar. Sci. **60**: 1063–1074.

Hoziosky, S. A., Shvetsov, F. G., & Gradalev, E. 1989. Seasonal distribution, migration, and mortality-component dynamics in sprat of the eastern and southeastern Baltic. Rapp. P. –v. Réun. Cons. Int. Explor. Mer 190: 22-24.

Huse,I. & Korneliussen,R.J. 2000. Diel variation in acoustic density measurements of overwintering herring (*Clupea harengus* L.). ICES Journal of Marine Science 57: 903-910.

ICES 1983. Report of the Planning Group on ICES Coordinated Herring and Sprat Acoustic Surveys. ICES Document CM 1983/H: 12.

ICES 2008. Report of the Baltic Fisheries Assessment Working Group (WGBFAS); ICES CM 2008\ACOM:06, pp. 516-576.

Jennings, S., Kaiser, M.J., Reynolds, J.D. 2001. Marine fisheries ecology. Blackwell Science Ltd.

Jones, F. R. H. & Pearce, G. 1958. Acoustic reflexion experiments with Perch (*Perca fluviatilis* Linn.) to determine the proportion of the echo returned by the swimbladder. Journal of Experimental Biology, 35: 437-450.

Karasiova, E. M. & Zezera, A. S. 2000. On influence of long-term variability of temperature regime in the Gdansk Deep of the Baltic Sea on the Sprat reproduction and the offspring survival. ICES Council Meeting Papers 2000. ICES-CM-2000 / L: 06: 19 pp.

Karasiova, E. 2002. Variability of sprat peak spawning and larvae appearance timing in the southeastern Baltic Sea during the past six decades. Bull. Sea Fish. Inst. Gdynia 156: 57-67.

Kasatkina, S. M. 2007. Target strength of Baltic herring and sprat in relation to changes of their biological characteristics: effects on acoustic abundance indices estimates. ICES Document CM 2007 /H: 06.

Kasatkina, S. M. 2009. The influence of uncertainty in target strength on abundance indices based on acoustic surveys: examples of the Baltic Sea herring and sprat. – ICES Journal of Marine Science, 66: 1404 – 1409.

Knudsen, H. P. 1990. The Bergen Echo Integrator: an introduction. J. Cons. Int. Explor. Mer, 47: 167–174.

Köster, F. W., Möllmann, C., Neuenfeldt, S., Vinther, M., St. John, M.A., Tomkiewicz, J., Voss, R., Hinrichsen, H.-H., Kraus, G., Schnack, D. 2003. Fish stock development in the central Baltic Sea (1976 - 2000) in relation to variability in the environment. ICES J. Mar. Sci. 219: 294-306.

Köster, F.K., Hinrichsen, H.-H., Schnack, D., St. John, M.A., MacKenzie, B.R., Tomkiewicz, J., Möllmann, C., Kraus, G., Plikshs, M., Makarchouk, A., and Aro, E. 2003. Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock-recruitment relationships. Scientia Marina 67 (Suppl.1), 129-154.

Köster, F.W. & Möllmann, C. 2000a. Egg cannibalism in Baltic sprat *Sprattus sprattus*. Mar. Ecol. Prog. Ser. 196: 269-277.

Köster, F.W. & Möllmann, C. 2000b. Trophodynamic control by clupeid predators on recruitment success in Baltic cod. ICES J. Mar. Sci. 57: 310-323.

Lindquist, A. 1971. Contribution to the knowledge of the Baltic sprat (*Sprattus sprattus*). ICES Council Meeting Papers 1971. ICES-CM-1971 / H: 19: 8 pp.

Love, R. H. 1971. Measurements of fish target strength: A review. Fishery Bulletin, 69: 703-715.

Love, R. H. 1977. Target strength of an individual fish at any aspect. Journal of the Acoustical Society of America, 62: 1397-1403.

MacKenzie, B.R., Alheit, J., Conley, D.J., Holm, P. & Kinze, C.C., 2002. Ecological hypotheses for a historical reconstruction of upper trophic level biomass in the Baltic Sea and Skagerrak. Canadian Journal of Fisheries and Aquatic Sciences 59, 173-190.

MacLennan, D.N. 1990. Acoustical measurement of fish abundance. Journal of the Acoustical Society of America, 87: 1-15.

MacLennan, D.N. and Simmonds, E.J. 1992. Fisheries Acoustics. Chapman and Hall, London. 325 pp.

MacLennan, D. N., Fernandes, P. G., and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. – ICES Journal of Marine Science, 59: 365-369.

Massé, J. & Retière, N. 1993. Effect of the number of transects and identification hauls on acoustic biomass estimates when several species are present in an area. ICES Council Meeting Papers 1993 ICES-CM-1993/B:32: 9 pp.

McClatchie, S., Macaulay, G. J. & Coombs, R. F. 2003. A requiem for the use of 20 log 10 Length for acoustic target strength with special reference to deep-sea fishes. ICES Journal of Marine Science, 60: 419 – 428.

Midttun, L. & Hoff, I. 1962. Measurements of the reflection of sound by fish. Fiskeridirektoratets Skrifter Serie Havundersøkelser, 13: 1-18.

Misund, O.A. 1997. Underwater acoustics in marine fisheries and fisheries research. Reviews in Fish Biology and Fisheries, 7: 1-34.

Mitson, R.B. 1982. Acoustic detection and estimation of fish near the sea-bed and surface. FAO Fish. Rep. 300: 27 – 34.

Mitson, R.B. 2000. Fish avoidance: the vessel noise factor. ICES Council Meeting Papers 2000. ICES-CM-2000/K: 16: 1.

Moksness, E., Torstensen, E. 1985. The buoyancy of sprat (*Sprattus sprattus*) eggs and larvae in the Skagerrak area. ICES CM/L:6.

Möllmann C., Kornilovs, G. & Sidrevics, L. (2000). Long-term dynamics of main mesozooplankton species in the Central Baltic Sea. Journal of Plankton Research 22, 2015-2038.

Möllmann, C. & Köster, F.W. 2002. Population dynamics of calanoid copepods and the implications of their predation by clupeid fish in the Central Baltic Sea. J. Plankton Res., 24: 959-977.

Möllmann, C., Kornilovs, G., Fetter, M. and Köster, F.W. 2004. Feeding ecology of Central Baltic Sea herring and sprat. J. Fish. Biol., 65: 1563-1581.

Möllmann, C., Kornilovs, G., Fetter, M. & Köster, F.W. 2005. Climate, zooplankton and pelagic fish growth in the Central Baltic Sea. ICES J. Mar. Sci., 62: 1270-1280.

Möllmann, C., Müller-Karulis, B., Kornilovs, G. & St. John, M.A. 2008. Effects of climate and overfishing on zooplankton dynamics and ecosystem structure regime shifts, trophic cascade and feedback loops in a simple ecosystem. ICES J Mar Sci., doi:10.1093/icesjms/fsm197.

Mukai, T. & Iida, K. 1996. Depth dependence of target strength of live kokanee salmon in accordance with Boyle's law. ICES Journal of Marine Science, 53: 245-248.

Muus, B.J. & Nielsen, J.G. 1999. Seafish. Blackwell Science, Oxford, UK: 1-340 pp.

Nakken, O. & Olsen, K. 1977. Target strength measurements of fish. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 170: 52-69.

Nausch, G., Feistel, R., Lass, H. U., Nagel, K., Siegel, H. 2004. Hydrographisch-chemische Zustandseinschätzung der Ostsee 2003. In: Meereswiss. Ber., Warnemünde 59 (2004).

Nausch, G., Feistel, R., Lass, H. U., Nagel, K., Siegel, H. 2007. Hydrographisch-chemische Zustandseinschätzung der Ostsee 2006. In: Meereswiss. Ber., 70 (2007).

Neuenfeldt, S. 2002. The influence of oxygen saturation on the distributional overlap of predator (cod, *Gadus morhua*) and prey (herring, *Clupea harengus*) in the Bornholm Basin of the Baltic Sea. Fisheries Oceanography, Volume 11, Issue 1, 11-17 pp.

Nissling, A., 2004. Effects of temperature on egg and larval survival of cod (*Gadus morhua*) and sprat (*Sprattus sprattus*) in the Baltic Sea – implications for stock development. Hydrobiologia 514: 115-123.

O'Driscoll, R. L. 2004. Estimating uncertainty associated with acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) in Cook Strait, New Zealand. ICES Journal of Marine Science, 61: 84 – 97.

Olsen, K., Angell, J. & Lovik, A. 1982. Quantitative estimations of the influence of fish behavior on acoustically determined fish abundance. FAO Fish. Rep. 300: 139 – 149.

Ona, E. 1990. Physiological factors causing natural variations in acoustic target strength of fish. Journal of the Marine Biological Association of the United Kingdom, 70: 107-127.

Ona, E. & Mitson, R. B. 1996. Acoustic sampling and signal processing near the seabed: the deadzone revisited. ICES Journal of Marine Science, 53: 677 – 690.

Ona, E., Zhao, O., Svellingen, I., & Fosseidengen, J. 2001. Season variation in herring target strength. In Herring:Expectations for a New Millennium, pp. 741 – 760. Ed. By F. Funk, J. Blackburn, D. Hay, R. Paul, R. Stephenson, R. Toresen, and D. Witherell. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks.

Ona, E. 2003. An expanded target-strength relation for herring. ICES Journal of Marine Science, 60: 493-499.

Ona, E., Vabø, R., Huse, I. & Svellingen, I. 2003. Depth-dependent target strength in herring. ICES Journal of Marine Science, 60: 494-500.

Orlowski, A. 1997. Diel and lunar variations in acoustic measurements of clupeoids in the Baltic Sea. ICES Council Meeting Papers 1997. ICES-CM-1997/S:29: 14 pp.

Orlowski, A. 2001. Behavioural and physical effect on acoustic measurement of Baltic fish within a diel cycle. ICES Journal of Marine Science 58: 1174 – 1183.

Parmanne, R., Rechlin, O. & Sjöstrand, B. 1994. Status and future of herring and sprat stocks in the Baltic Sea. Dana 10: 29-59.

Peltonen, H. & Balk, H. 2005. The acoustic target strength of herring (*Clupea harengus* L.) in the northern Baltic Sea. ICES Journal of Marine Science, 62: 803 – 808.

Prandke, H. & Stips, A. 1987. Echostreuschichten in der Ostsee - Schallreflexionen am Dichtesprung oder Schallstreuung an suspendiertem Material. Beiträge zur Meereskunde 57: 27-36.

"R". http://cran.r-project.org/

Rechlin, O. 1967. Observations on Winter-Concentrations of Sprat (*Sprattus sprattus*) in the Northern Baltic. ICES Council Meeting Papers 1969. ICES-CM-1967 / H: 12: 3 pp.

Rechlin, O. 1975. Untersuchungen zur Biologie des Sprotts (*Sprattus sprattus L.*) und zur Entwicklung der Sprottenfischerei in der östlichen und nördlichen Ostsee. Fischerei-Forschung 13: 69-79.

Rudstam, L.G., Aneer, G. & Hilden, M. 1994. Top-down control in the pelagic Baltic ecosystem. Dana 10: 105-129.

Russell, F.S. 1976. The eggs and planktonic stages of British marine fishes. Academic Press, London. 524 pp.

Schlitzer,R. 2001. Ocean Data View. http://www.awi-bremerhaven.de/GEO/ODV

Shepherd, J. G. 1999. Extended survivors analysis: an improved method for the analysis of catch-at-age data and abundance indices. ICES Journal of Marine Science, 56: 584-591.

SigmaPlot 11. www.sigmaplot.com

Simmonds, E. J. & MacLennan, D. N. 2005. Fisheries acoustics: Theory and Practice, 2nd edition. Blackwell Publishing, Oxford, UK.

SIMRAD 1993. Simrad BI500 Post processing system Instruction manual. Simrad AS.

SIMRAD 1997. Simrad EK 500 Scientific Echo Sounder Operator Manual. Simrad AS.

SonarData 2001. Echoview. www.sonardata.com

Sparholt, H. 1996. Causal correlation between recruitment and spawning stock size of central Baltic cod? ICES J. Mar. Sci. 53: 771-779.

Spearman, C. 1904. The proof and measurement of association between two things. Amer. J. Psychol., 15 , pp. 72–101.

Stepputtis, D. 2006. Distribution patterns of Baltic sprat (*Sprattus sprattus* L.) – causes and consequences. Phd thesis. Leibniz Institute for Marine Research Kiel 198 pp.

Tesler, W. D. 1989. Bias and precision in acoustic biomass estimation. Proceedings of the Institute of Acoustics, 11: 202 – 211.

Toresen, R., Grøsaeter, H. & de Barros, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Müller) and herring (*Clupea harengus* Linne) in the Barents Sea. Fisheries Research, 34: 27 – 38.

Vabø, R. 1999. Measurements and correction models of behaviourally-induced biases in acoustic estimates of wintering herring (*Clupea harengus L.*). DSc thesis, University of Bergen, Norway. Version 0.72. ICES-CM-2001/H:02.

Vabø, R., Olsen, K. & Huse, I. 2002. The effect of vessel avoidance of wintering Norwegian spring spawning herring. Fisheries Research, 58: 59 – 77.

Voss, R., Köster, F.W. & Dickmann, M., 2003. Comparing the feeding habits of co-occurring sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) larvae in the Bornholm Basin, Baltic Sea. Fish Res 1497:1-15.

Voss, R., Clemmesen, C., Baumann, H., Hinrichsen, H.-H., 2006. Baltic sprat larvae: coupling food availability, larval condition and survival. Mar. Ecol. Prog. Ser. 308, 243–254.

Wahl, E. & Alheit, J. 1988. Changes in the distribution and abundance of sprat eggs during spawning season. ICES C. M. 1988 / H: 45.

Westin, L. & Nissling, A. 1991. Effects of salinity on spermatozoa motility, percentage of fertilized eggs and egg development of Baltic cod (*Gadus morhua*) and its implications for cod stock fluctuations in the Baltic. Marine Biology 108: 5-9.

Whitehead, P.J.P. 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1 Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis 125, Vol. 7.

Wieland, K. & Zuzarte, F., 1991. Vertical distribution of cod and sprat eggs and larvae in the Bornholm Basin (Baltic Sea) 1987-1990. ICES CM/J: 31.

Wieland, K., Waller, U. & Schnack, D. 1994. Development of Baltic cod eggs at different levels of temperature and oxygen content. Dana 10: 163-177.

Winkler, L. 1888*b*. The determination of dissolved oxygen in water. (Die Bestimmung des in Wasser gelösten Sauerstoffs). Berichte der Deutschen Chemischen Gesellschaft 21: 28 - 43.

Zhao, X. & Ona, E. 2003. Estimation and compensation models for the shadowing effect in dense fish aggregations. ICES Journal of Marine Science, 60: 155 – 163.

Table 3.3 Total numbers of chaught and measured sprat within Subdivisions 24 - 29 in the years 1999 - 2009. All fishery hauls were assigned to ICES-Rectangles in which they have taken place. Marginal fishery hauls which were located between two ICES-Rectangles were assigned to both. Trawl catches within each Rectangle were combined. Rectangle values were summed up to respective Subdivision.

YEAR	ICES-SUBDIVISION	MEASURED SPRATS [NUMBERS]
1999	24	3285
1999	25	9669
1999	26	2552
1999	27	530
1999	28	779
1999	***TOTAL***	***16815***
2001	24	2861
2001	25	10007
2001	26	1870
2001	27	637
2001	28	845
2001	***TOTAL***	***16220***
2002	24	957
2002	25	10358
2002	26	2285
2002	27	801
2002	28	651
2002	***TOTAL***	***15052***
2003	24	1670
2003	25	8836
2003	26	4101
2003	***TOTAL***	***14607***
2004	24	3625
2004	25	12456
2004	26	3634
2004	27	1759
2004	28	1833
2004	***TOTAL***	***23307***
2005	24	3250
2005	25	4760
2005	26	1663
2005	***TOTAL***	***9673***
2006	24	2262
2006	25	6827
2006	26	2900
2006	27	5257
2006	***TOTAL***	***17246***
2007	24	4253
2007	25	9326
2007	27	5663
2007	***TOTAL***	***19242***
2008	24	3444
2008	25	8531
2008	26	2017
2008	27	3895
2008	29	1595
2008	***TOTAL***	***19482***
2009	24	3475
2009	25	8494
2009	26	2327
2009	27	3020
2009	28	7088
2009	***TOTAL***	***24404***
TOTAL 1999 - 2009		**176048**
Mean 1999 - 2009		***17604***

Table 4.1. Estimated abundances of total fish (N_TOTAL/N_Z_TOTAL) and sprat (N_sprat_TOTAL/N_sprat_Z_TOTAL) using depth-independent and depth–dependent TS – length realationships according to ICES (1983), Ona (2003) and Fässler et al. (2007) as well as calculated differences [%] between several abundance estimates in various ICES-Rectangles of ICES-Subdivisions 24 – 28 in 1999 – 2009. a) 1999 & 2001; b) 2002 & 2003; c) 2004 & 2005; d) 2006 & 2007; e) 2008 & 2009.

a)

YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT N_TOTAL [MIO]					DEPTH-DEPENDENT N_Z_TOTAL [MIO]				DEPTH-INDEPENDENT N_sprat_TOTAL [MIO]					DEPTH-DEPENDENT N_sprat_Z_TOTAL [MIO]			
						Diff [%]				Ona_vs_Fässler					Diff [%]				Ona_vs_Fässler	
			ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]	ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]
1999	24	38G3	2062	840	506	59	75	755	438	317	42	1907	777	468	59	75	699	406	293	42
1999	24	38G4	1327	541	326	59	75	448	268	180	40	1222	498	300	59	75	414	248	166	40
1999	24	39G3	1138	464	279	59	75	433	247	185	43	1129	460	277	59	75	430	246	184	43
1999	24	39G4	741	302	182	59	75	264	155	110	41	693	282	170	59	75	248	146	102	41
1999	24	TOTAL	5269	2147	1293	59	75	1901	1109	792	42	4951	2017	1215	59	75	1791	1046	745	42
1999	25	38G5	901	367	221	59	75	355	200	155	44	841	343	206	59	75	332	188	145	44
1999	25	39G4	1139	464	280	59	75	421	243	178	42	1133	462	278	59	75	420	243	177	42
1999	25	39G5	3697	1506	907	59	75	1464	823	640	44	3654	1489	897	59	75	1448	815	633	44
1999	25	39G6	2826	1151	694	59	75	1075	614	461	43	2754	1122	676	59	75	1048	599	449	43
1999	25	39G7	4331	1764	1063	59	75	1662	946	717	43	4326	1762	1062	59	75	1662	946	716	43
1999	25	40G4	716	292	176	59	75	282	159	123	44	695	283	171	59	75	275	155	120	43
1999	25	40G5	4764	1941	1169	59	75	1754	1015	739	42	4750	1935	1166	59	75	1749	1013	737	42
1999	25	40G6	5156	2100	1266	59	75	1819	1071	749	41	5117	2084	1256	59	75	1806	1064	743	41
1999	25	40G7	2872	1170	705	59	75	1017	598	419	41	2872	1170	705	59	75	1018	599	419	41
1999	25	41G6	5703	2323	1400	59	75	1987	1175	811	41	5701	2322	1399	59	75	1987	1176	811	41
1999	25	41G7	4481	1825	1100	59	75	1564	924	639	41	4474	1823	1098	59	75	1562	924	638	41
1999	25	TOTAL	36585	14904	8981	59	75	13399	7768	5631	42	36317	14795	8915	59	75	13307	7720	5587	42
1999	26	39G8	5274	2148	1294	59	75	2086	1173	913	44	5263	2144	1292	59	75	2083	1171	912	44
1999	26	40G8	5973	2433	1466	59	75	2448	1358	1090	45	5967	2431	1465	59	75	2446	1358	1088	44
1999	26	41G8	3085	1257	757	59	75	1121	652	469	42	3077	1254	755	59	75	1120	651	468	42
1999	26	TOTAL	14331	5838	3518	59	75	5655	3183	2473	44	14307	5828	3512	59	75	5649	3180	2468	44
1999	27	42G7	5254	2140	1290	59	75	1876	1099	778	41	5117	2085	1256	59	75	1828	1071	757	41
1999	27	TOTAL	5254	2140	1290	59	75	1876	1099	778	41	5117	2085	1256	59	75	1828	1071	757	41
1999	28	42G8	1772	722	435	59	75	630	369	260	41	1750	713	429	59	75	623	366	257	41
1999	28	TOTAL	1772	722	435	59	75	630	369	260	41	1750	713	429	59	75	623	366	257	41
TOTAL 1999			63212	25751	15517	59	75	23460	13527	9933	42	62442	25438	15328	59	75	23198	13384	9815	42
2001	24	38G2	218	89	54	59	75	71	43	28	39	194	79	48	59	75	64	39	25	39
2001	24	38G3	793	323	195	59	75	292	169	123	42	743	303	182	59	75	274	159	115	42
2001	24	38G4	3040	1238	746	59	75	1028	615	413	40	2997	1221	736	59	75	1014	608	407	40
2001	24	39G2	315	128	77	59	75	107	64	43	40	280	114	69	59	75	96	58	38	40
2001	24	39G3	548	223	134	59	75	190	113	77	41	454	185	111	59	75	158	94	64	41
2001	24	39G4	394	160	97	59	75	144	84	61	42	307	125	75	59	75	113	66	47	42
2001	24	TOTAL	5307	2162	1303	59	75	1832	1088	744	41	4975	2027	1221	59	75	1720	1024	696	40
2001	25	37G5	2881	1174	707	59	75	1014	598	416	41	2860	1165	702	59	75	1008	594	413	41
2001	25	38G5	1101	515	323	53	71	475	285	190	40	1065	498	313	53	71	460	277	184	40
2001	25	38G6	1289	525	316	59	75	459	269	190	41	1286	524	316	59	75	459	270	189	41
2001	25	39G4	386	157	95	59	75	150	85	65	43	382	155	94	59	75	149	85	64	43
2001	25	39G5	1080	457	278	58	74	438	250	187	43	1057	447	272	58	74	430	246	184	43
2001	25	39G6	2631	1105	671	58	74	1089	615	474	44	2583	1085	659	58	74	1070	605	465	43
2001	25	39G7	3673	1496	902	59	75	1390	796	594	43	3672	1496	901	59	75	1390	796	594	43
2001	25	40G4	833	339	204	59	75	339	189	150	44	824	336	202	59	75	336	188	149	44
2001	25	40G5	3408	1388	837	59	75	1287	737	550	43	3396	1383	834	59	75	1283	735	548	43
2001	25	40G6	3682	1500	904	59	75	1415	805	609	43	3667	1494	900	59	75	1410	803	607	43
2001	25	40G7	3011	1227	739	59	75	1088	635	454	42	3009	1226	739	59	75	1089	635	453	42
2001	25	41G6	5256	2141	1290	59	75	1888	1104	784	42	5253	2140	1289	59	75	1888	1104	784	42
2001	25	41G7	3613	1472	887	59	75	1325	769	557	42	3611	1471	886	59	75	1325	769	556	42
2001	25	TOTAL	32843	13496	8154	59	75	12356	7136	5220	42	32664	13420	8107	59	75	12297	7107	5190	42
2001	26	39G8	6255	2548	1535	59	75	2433	1377	1056	43	6244	2544	1533	59	75	2430	1376	1054	43
2001	26	40G8	5466	2227	1342	59	75	2249	1246	1002	45	5441	2217	1336	59	75	2239	1242	998	45
2001	26	41G8	3453	1406	847	59	75	1357	765	592	44	3413	1390	838	59	75	1343	758	585	44
2001	26	TOTAL	15173	6181	3725	59	75	6039	3389	2650	44	15099	6151	3706	59	75	6012	3375	2637	44
2001	27	42G7	4117	1677	1011	59	75	1581	900	681	43	4081	1663	1002	59	75	1569	894	675	43
2001	27	TOTAL	4117	1677	1011	59	75	1581	900	681	43	4081	1663	1002	59	75	1569	894	675	43
2001	28	42G8	3049	1242	748	59	75	1071	631	439	41	3046	1241	748	59	75	1071	632	439	41
2001	28	TOTAL	3049	1242	748	59	75	1071	631	439	41	3046	1241	748	59	75	1071	632	439	41
TOTAL 2001			60489	24758	14940	59	75	22879	13144	9735	43	59865	24501	14784	59	75	22670	13032	9638	43

b)

YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT N_TOTAL [MIO]					DEPTH-DEPENDENT N_Z_TOTAL [MIO]				DEPTH-INDEPENDENT N_sprat_TOTAL [MIO]					DEPTH-DEPENDENT N_sprat_Z_TOTAL [MIO]			
			ICES 1983	Ona 2003	Fässler 2007	Diff [%] ICES vs Ona	Diff [%] ICES vs Fässler	Ona 2003	Fässler 2007	Ona_vs_Fässler Diff [MIO]	Ona_vs_Fässler Diff [%]	ICES 1983	Ona 2003	Fässler 2007	Diff [%] ICES vs Ona	Diff [%] ICES vs Fässler	Ona 2003	Fässler 2007	Ona_vs_Fässler Diff [MIO]	Ona_vs_Fässler Diff [%]
2002	24	38G3	1910	778	469	59	75	696	405	292	42	1787	728	439	59	75	653	380	273	42
2002	24	38G4	1330	542	326	59	75	472	277	195	41	1274	519	313	59	75	453	267	187	41
2002	24	39G3	322	131	79	59	75	119	69	51	42	242	99	59	59	75	91	53	38	42
2002	24	TOTAL	3561	1451	874	59	75	1288	751	537	42	3303	1346	811	59	75	1197	699	498	42
2002	25	37G5	1879	765	461	59	75	746	419	327	44	1876	764	460	59	75	746	420	326	44
2002	25	38G5	2163	881	531	59	75	898	496	402	45	2143	873	526	59	75	890	493	398	45
2002	25	38G6	526	214	129	59	75	183	108	75	41	524	214	129	59	75	183	109	74	41
2002	25	39G4	1883	767	462	59	75	749	421	328	44	1861	758	457	59	75	741	417	324	44
2002	25	39G5	4154	1692	1020	59	75	1776	970	806	45	4117	1677	1010	59	75	1761	962	798	45
2002	25	39G6	6211	2530	1525	59	75	2619	1438	1180	45	6198	2525	1521	59	75	2614	1436	1178	45
2002	25	39G7	5736	2337	1408	59	75	2371	1312	1059	45	5718	2329	1403	59	75	2364	1309	1056	45
2002	25	40G4	3069	1250	753	59	75	1203	680	523	44	3023	1231	742	59	75	1186	670	516	43
2002	25	40G5	12358	5034	3034	59	75	5030	2801	2229	44	12339	5027	3029	59	75	5024	2798	2226	44
2002	25	40G6	10972	4470	2693	59	75	4428	2474	1954	44	10947	4460	2687	59	75	4419	2469	1950	44
2002	25	40G7	2807	1143	689	59	75	1093	619	474	43	2761	1125	678	59	75	1076	610	466	43
2002	25	41G6	569	232	140	59	75	206	120	86	42	567	231	139	59	75	206	121	86	42
2002	25	41G7	1445	589	355	59	75	561	318	243	43	1436	585	352	59	75	558	317	241	43
2002	25	TOTAL	53771	21905	13199	59	75	21862	12177	9685	44	53509	21799	13135	59	75	21769	12131	9638	44
2002	26	39G8	6021	2453	1478	59	75	2560	1401	1160	45	6014	2450	1476	59	75	2558	1400	1158	45
2002	26	40G8	2872	1170	705	59	75	1214	666	548	45	2871	1170	705	59	75	1214	667	547	45
2002	26	41G8	1934	788	475	59	75	803	443	359	45	1934	788	475	59	75	803	444	359	45
2002	26	TOTAL	10828	4411	2658	59	75	4576	2510	2066	45	10819	4408	2656	59	75	4576	2511	2065	45
2002	27	42G7	3108	1266	763	59	75	1264	704	560	44	3098	1262	760	59	75	1261	703	558	44
2002	27	TOTAL	3108	1266	763	59	75	1264	704	560	44	3098	1262	760	59	75	1261	703	558	44
2002	28	42G8	2196	895	539	59	75	807	468	340	42	2190	892	538	59	75	806	467	339	42
2002	28	TOTAL	2196	895	539	59	75	807	468	340	42	2190	892	538	59	75	806	467	339	42
TOTAL 2002			73465	29928	18033	59	75	29798	16610	13188	44	72920	29706	17900	59	75	29609	16511	13098	44
2003	24	38G3	2175	886	534	59	75	806	466	340	42	1902	775	467	59	75	705	408	298	42
2003	24	38G4	532	217	131	59	75	209	118	91	44	528	215	130	59	75	209	118	90	43
2003	24	39G3	276	112	68	59	75	103	59	43	42	221	90	54	59	75	83	48	35	42
2003	24	39G4	636	259	156	59	75	243	139	104	43	539	220	132	59	75	207	118	88	43
2003	24	TOTAL	3619	1475	888	59	75	1360	781	579	43	3190	1300	783	59	75	1203	693	511	42
2003	25	37G5	171	70	42	59	75	67	38	29	44	167	68	41	59	75	67	38	29	43
2003	25	38G5	1376	561	338	59	75	564	313	251	44	1347	549	331	59	75	553	308	246	44
2003	25	38G6	140	57	34	59	75	53	30	22	43	139	57	34	59	75	53	31	22	42
2003	25	38G7	19	8	5	59	75	6	4	3	41	19	8	5	59	75	7	5	3	36
2003	25	39G4	304	124	75	59	75	123	69	55	44	285	116	70	59	75	117	65	51	44
2003	25	39G5	1152	469	283	59	75	495	270	225	45	1141	465	280	59	75	491	268	223	45
2003	25	39G6	940	383	231	59	75	388	215	173	45	910	371	223	59	75	376	209	167	45
2003	25	39G7	2165	882	531	59	75	895	495	400	45	2156	878	529	59	75	893	494	398	45
2003	25	40G4	578	236	142	59	75	227	128	99	44	559	228	137	59	75	220	125	95	43
2003	25	40G5	752	306	185	59	75	296	167	129	44	670	273	165	59	75	265	150	115	43
2003	25	40G6	2989	1218	734	59	75	1175	663	512	44	2979	1213	731	59	75	1172	662	510	44
2003	25	40G7	1112	453	273	59	75	432	245	187	43	1026	418	252	59	75	400	227	173	43
2003	25	41G6	497	202	122	59	75	193	109	83	43	488	199	120	59	75	190	108	82	43
2003	25	41G7	186	76	46	59	75	67	39	28	42	162	66	40	59	75	59	35	24	41
2003	25	TOTAL	12380	5044	3039	59	75	4982	2786	2196	44	12047	4908	2957	59	75	4863	2725	2138	44
2003	26	38G8	4513	1838	1108	59	75	1992	1075	917	46	4489	1829	1102	59	75	1982	1070	912	46
2003	26	39G8	3607	1469	885	59	75	1595	860	735	46	3585	1460	880	59	75	1587	856	731	46
2003	26	40G8	3789	1544	930	59	75	1669	901	768	46	3785	1542	929	59	75	1668	901	767	46
2003	26	41G8	5281	2151	1296	59	75	2310	1250	1060	46	5265	2145	1292	59	75	2305	1248	1057	46
2003	26	TOTAL	17190	7003	4220	59	75	7567	4086	3480	46	17124	6976	4203	59	75	7542	4075	3467	46
TOTAL 2003			33190	13521	8147	59	75	13909	7653	6255	45	32361	13183	7944	59	75	13608	7492	6116	45

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YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT N_TOTAL [MIO]					DEPTH-DEPENDENT N_Z_TOTAL [MIO]				DEPTH-INDEPENDENT N_sprat_TOTAL [MIO]					DEPTH-DEPENDENT N_sprat_Z_TOTAL [MIO]			
						Diff [%]				Ona_vs_Fässler					Diff [%]				Ona_vs_Fässler	
			ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]	ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]
2004	24	38G2	383	156	94	59	75	132	78	54	41	38	15	9	59	75	13	8	5	40
2004	24	38G3	2086	850	512	59	75	773	446	326	42	1924	784	472	59	75	713	412	301	42
2004	24	38G4	863	352	212	59	75	325	186	138	43	820	334	201	59	75	309	178	131	42
2004	24	39G2	149	61	37	59	75	50	30	20	40	15	6	4	59	75	5	3	2	39
2004	24	39G3	694	283	170	59	75	261	150	111	43	489	199	120	59	75	185	106	78	42
2004	24	39G4	345	141	85	59	75	130	75	55	43	294	120	72	59	75	111	64	47	42
2004	24	TOTAL	4520	1841	1110	59	75	1671	966	705	42	3579	1458	879	59	75	1337	772	565	42
2004	25	37G5	162	66	40	59	75	65	36	29	44	155	63	38	59	75	63	36	28	43
2004	25	38G5	1916	780	470	59	75	776	433	343	44	1837	748	451	59	75	745	416	329	44
2004	25	38G6	204	83	50	59	75	74	43	31	42	187	76	46	59	75	69	40	28	41
2004	25	39G4	630	257	155	59	75	254	142	112	44	612	249	150	59	75	248	139	109	44
2004	25	39G5	2189	910	551	58	75	949	523	426	45	2158	896	543	58	75	936	516	420	45
2004	25	39G6	1815	740	446	59	75	763	420	343	45	1797	732	441	59	75	756	416	340	45
2004	25	39G7	2664	1085	654	59	75	1130	619	511	45	2652	1080	651	59	75	1126	617	509	45
2004	25	40G4	3254	1326	799	59	75	1269	718	551	43	3214	1309	789	59	75	1254	710	544	43
2004	25	40G5	4016	1636	986	59	75	1600	898	702	44	3892	1585	955	59	75	1551	871	680	44
2004	25	40G6	5429	2212	1333	59	75	2097	1192	905	43	5384	2193	1322	59	75	2080	1183	898	43
2004	25	40G7	3539	1442	869	59	75	1294	751	543	42	3531	1438	867	59	75	1292	750	542	42
2004	25	41G6	951	387	233	59	75	345	201	144	42	920	375	226	59	75	335	195	139	42
2004	25	41G7	3002	1223	737	59	75	1109	641	468	42	2994	1220	735	59	75	1107	640	467	42
2004	25	TOTAL	29773	12146	7322	59	75	11726	6618	5108	44	29331	11966	7213	59	75	11563	6532	5031	44
2004	26	39G8	5146	2096	1263	59	75	2120	1174	945	45	5105	2080	1253	59	75	2104	1166	938	45
2004	26	40G8	4486	1828	1101	59	75	1886	1037	849	45	4455	1815	1093	59	75	1874	1031	843	45
2004	26	41G8	3385	1379	831	59	75	1354	759	595	44	3340	1361	820	59	75	1337	750	587	44
2004	26	TOTAL	13017	5303	3195	59	75	5360	2970	2389	45	12899	5255	3166	59	75	5314	2946	2368	45
2004	27	42G7	2449	998	601	59	75	946	537	409	43	2377	968	583	59	75	920	523	397	43
2004	27	43G7	4465	1819	1096	59	75	1778	998	779	44	4183	1704	1027	59	75	1666	936	730	44
2004	27	44G7	8611	3508	2114	59	75	3366	1903	1464	43	8087	3294	1985	59	75	3162	1788	1374	43
2004	27	TOTAL	15524	6324	3811	59	75	6091	3438	2652	44	14646	5967	3595	59	75	5748	3247	2502	44
2004	28	42G8	2259	920	554	59	75	856	490	366	43	2167	883	532	59	75	822	471	351	43
2004	28	42G9	4514	1839	1108	59	75	1822	1017	805	44	4457	1816	1094	59	75	1800	1005	795	44
2004	28	TOTAL	6773	2759	1663	59	75	2678	1507	1171	44	6623	2698	1626	59	75	2622	1476	1146	44
TOTAL 2004			69608	28374	17100	59	75	27525	15499	12026	44	67078	27344	16479	59	75	26584	14973	11612	44
2005	24	38G2	214	87	52	59	75	72	43	29	40	157	64	38	59	75	53	32	21	39
2005	24	38G3	1267	516	311	59	75	467	270	196	42	931	379	228	59	75	343	199	144	42
2005	24	38G4	71	37	24	48	66	33	21	12	37	63	33	21	48	66	30	19	11	36
2005	24	39G2	403	164	99	59	75	142	84	59	41	296	121	73	59	75	105	62	43	41
2005	24	39G3	316	129	78	59	75	117	68	49	42	232	95	57	59	75	87	50	36	42
2005	24	39G4	791	322	194	59	75	293	169	124	42	759	309	186	59	75	282	163	119	42
2005	24	TOTAL	3063	1256	758	59	75	1124	655	469	42	2438	1000	604	59	75	901	527	374	42
2005	25	37G5	91	47	31	48	66	42	26	15	37	80	42	27	48	66	38	24	14	36
2005	25	38G5	1162	564	359	51	69	579	339	240	41	1117	543	345	51	69	558	327	231	41
2005	25	38G6	231	94	57	59	75	85	49	36	42	228	93	56	59	75	85	49	35	42
2005	25	39G4	790	322	194	59	75	295	170	125	42	758	309	186	59	75	284	164	120	42
2005	25	39G5	10766	4476	2712	58	75	4709	2587	2122	45	10593	4404	2669	58	75	4635	2546	2088	45
2005	25	39G6	7462	3040	1832	59	75	2715	1577	1138	42	7337	2989	1801	59	75	2670	1552	1119	42
2005	25	39G7	3129	1482	935	53	70	1272	787	485	38	2934	1389	876	53	70	1194	739	455	38
2005	25	40G4	593	254	155	57	74	250	142	108	43	549	235	144	57	74	232	132	100	43
2005	25	40G5	4040	1646	992	59	75	1633	911	721	44	3891	1585	955	59	75	1574	879	695	44
2005	25	40G6	4302	1785	1081	58	75	1686	964	722	43	4215	1749	1059	58	75	1653	946	707	43
2005	25	41G6	9204	3749	2259	59	75	3548	2018	1531	43	8955	3648	2198	59	75	3453	1964	1489	43
2005	25	TOTAL	41770	17460	10607	58	75	16814	9571	7243	43	40657	16986	10317	58	75	16375	9323	7052	43
2005	26	39G8	4474	1823	1098	59	75	1511	905	606	40	4440	1809	1090	59	75	1501	899	602	40
2005	26	40G8	6460	2632	1586	59	75	2462	1404	1058	43	6349	2587	1559	59	75	2421	1381	1040	43
2005	26	41G8	4688	1910	1151	59	75	1657	974	683	41	4661	1899	1144	59	75	1649	969	680	41
2005	26	TOTAL	15622	6364	3835	59	75	5630	3283	2348	42	15451	6294	3793	59	75	5570	3249	2321	42
TOTAL 2005			60454	25080	15200	59	75	23569	13509	10060	43	58546	24281	14714	59	75	22847	13099	9748	43

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YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT N_TOTAL [MIO]					DEPTH-DEPENDENT N_Z_TOTAL [MIO]				DEPTH-INDEPENDENT N_sprat_TOTAL [MIO]					DEPTH-DEPENDENT N_sprat_Z_TOTAL [MIO]			
						Diff [%]				Ona_vs_Fässler					Diff [%]				Ona_vs_Fässler	
			ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]	ICES 1983	Ona 2003	Fässler 2007	ICES vs Ona	ICES vs Fässler	Ona 2003	Fässler 2007	Diff [MIO]	Diff [%]
2006	24	38G2	91	37	22	59	75	31	18	12	40	0	0	0	59	75	0	0	0	39
2006	24	38G3	1180	481	290	59	75	411	243	168	41	828	337	203	59	75	289	171	118	41
2006	24	38G4	271	110	66	59	75	97	57	40	41	215	88	53	59	75	78	46	32	41
2006	24	39G2	280	114	69	59	75	100	59	41	41	1	0	0	59	75	0	0	0	41
2006	24	39G3	334	136	82	59	75	124	72	53	42	273	111	67	59	75	102	59	43	42
2006	24	39G4	219	89	54	59	75	83	48	36	43	107	44	26	59	75	41	24	17	42
2006	24	TOTAL	2375	967	583	59	75	846	496	350	41	1424	580	350	59	75	511	300	210	41
2006	25	37G5	73	30	18	59	75	28	16	12	43	49	20	12	59	75	19	11	8	41
2006	25	38G5	1589	647	390	59	75	656	363	292	45	1444	588	354	59	75	597	331	266	45
2006	25	38G6	189	77	46	59	75	71	41	30	43	178	73	44	59	75	68	40	29	42
2006	25	39G4	408	166	100	59	75	159	90	69	43	271	110	67	59	75	106	61	46	43
2006	25	39G5	2247	1104	705	51	69	1129	665	464	41	2192	1076	687	51	69	1103	650	453	41
2006	25	39G6	3587	1461	880	59	75	1398	791	607	43	3388	1380	832	59	75	1321	748	573	43
2006	25	39G7	3893	1586	956	59	75	1558	873	686	44	3883	1582	953	59	75	1555	872	684	44
2006	25	40G4	673	274	165	59	75	268	150	117	44	666	271	163	59	75	266	150	116	44
2006	25	40G5	3406	1388	836	59	75	1347	758	589	44	3360	1369	825	59	75	1330	749	581	44
2006	25	40G6	1661	677	408	59	75	656	369	286	44	1500	611	368	59	75	593	334	259	44
2006	25	40G7	429	175	105	59	75	157	91	66	42	264	107	65	59	75	97	57	40	42
2006	25	41G6	2112	860	518	59	75	807	460	347	43	2032	828	499	59	75	777	444	333	43
2006	25	41G7	2498	1018	613	59	75	908	528	380	42	2253	918	553	59	75	820	477	343	42
2006	25	TOTAL	22764	9462	5741	58	75	9142	5196	3945	43	21480	8934	5422	58	75	8653	4923	3730	43
2006	26	38G8	2802	1141	688	59	75	1046	602	444	42	2793	1138	686	59	75	1044	601	443	42
2006	26	39G8	4199	1711	1031	59	75	1593	910	683	43	4194	1708	1029	59	75	1592	910	682	43
2006	26	40G8	2051	836	503	59	75	855	472	383	45	2042	832	501	59	75	852	470	382	45
2006	26	41G8	2470	1006	606	59	75	1054	576	477	45	2469	1006	606	59	75	1054	577	477	45
2006	26	TOTAL	11523	4694	2829	59	75	4547	2559	1988	44	11497	4684	2822	59	75	4541	2558	1983	44
2006	27	42G7	4548	1853	1116	59	75	1856	1032	824	44	4413	1798	1083	59	75	1802	1003	799	44
2006	27	43G7	1410	574	346	59	75	573	319	254	44	1321	538	324	59	75	538	300	238	44
2006	27	44G7	4229	1723	1038	59	75	1750	968	782	45	4136	1685	1015	59	75	1712	947	765	45
2006	27	45G7	5664	2308	1390	59	75	2228	1256	972	44	5470	2228	1343	59	75	2153	1214	939	44
2006	27	45G8	4857	1979	1192	59	75	1908	1076	832	44	4749	1935	1166	59	75	1866	1053	813	44
2006	27	46G8	4167	1697	1023	59	75	1707	948	759	44	4102	1671	1007	59	75	1681	934	747	44
2006	27	TOTAL	24875	10134	6106	59	75	10021	5598	4423	44	24192	9855	5938	59	75	9753	5451	4302	44
TOTAL 2006			61537	25257	15259	59	75	24556	13850	10706	44	58594	24054	14532	59	75	23458	13232	10226	44
2007	24	38G2	415	169	102	59	75	145	86	59	41	405	165	99	59	75	142	85	58	41
2007	24	38G3	1308	533	321	59	75	484	280	204	42	1276	520	313	59	75	473	274	200	42
2007	24	38G4	1091	445	268	59	75	402	233	170	42	1075	438	264	59	75	398	230	167	42
2007	24	39G2	484	197	119	59	75	168	100	68	41	472	192	116	59	75	165	98	67	41
2007	24	39G3	1256	512	308	59	75	469	270	199	42	1225	499	301	59	75	459	265	194	42
2007	24	39G4	1214	494	298	59	75	455	262	193	43	1202	490	295	59	75	451	260	191	42
2007	24	TOTAL	5767	2350	1416	59	75	2124	1230	894	42	5655	2304	1388	59	75	2089	1212	877	42
2007	25	37G5	148	60	36	59	75	53	31	22	41	146	59	36	59	75	53	31	22	41
2007	25	38G5	861	423	270	51	69	420	250	170	40	826	406	260	51	69	404	241	163	40
2007	25	38G6	537	219	132	59	75	191	112	79	41	526	214	129	59	75	189	111	78	41
2007	25	39G4	356	180	116	49	67	181	109	73	40	346	175	113	49	67	177	107	71	40
2007	25	39G5	1973	874	540	56	73	905	511	394	44	1950	864	533	56	73	895	506	389	43
2007	25	39G6	6528	2718	1647	58	75	2779	1544	1235	44	6511	2711	1643	58	75	2773	1541	1232	44
2007	25	39G7	1525	621	374	59	75	612	342	269	44	1515	617	372	59	75	609	341	268	44
2007	25	40G4	1346	656	417	51	69	654	388	267	41	1284	625	398	51	69	625	371	254	41
2007	25	40G5	4085	1732	1056	58	74	1699	964	734	43	4050	1718	1047	58	74	1685	957	728	43
2007	25	40G6	1816	758	460	58	75	737	417	319	43	1801	751	456	58	75	732	415	317	43
2007	25	40G7	1240	505	304	59	75	470	269	201	43	1230	501	302	59	75	467	268	200	43
2007	25	41G6	3709	1511	910	59	75	1345	783	562	42	3684	1501	904	59	75	1337	779	558	42
2007	25	41G7	2947	1201	723	59	75	1039	612	427	41	2824	1150	693	59	75	996	587	409	41
2007	25	TOTAL	27070	11458	6987	58	74	11084	6333	4752	43	26692	11293	6886	58	74	10942	6255	4687	43
2007	27	42G7	2051	836	504	59	75	791	450	341	43	1992	811	489	59	75	769	437	331	43
2007	27	43G7	1921	782	471	59	75	768	431	338	44	1802	734	442	59	75	722	405	317	44
2007	27	44G7	1620	660	398	59	75	666	369	297	45	1507	614	370	59	75	621	345	276	44
2007	27	45G7	1249	509	307	59	75	514	285	229	45	1141	465	280	59	75	470	261	209	44
2007	27	45G8	572	233	141	59	75	244	133	110	45	544	221	133	59	75	232	128	105	45
2007	27	46G8	1278	521	314	59	75	534	294	240	45	1135	463	279	59	75	475	262	213	45
2007	27	TOTAL	8690	3540	2133	59	75	3517	1962	1555	44	8120	3308	1993	59	75	3289	1838	1451	44
TOTAL 2007			41528	17348	10536	58	75	16725	9524	7201	43	40467	16905	10267	58	75	16320	9304	7015	43

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YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT N_TOTAL [MIO] ICES 1983	Ona 2003	Fässler 2007	Diff [%] ICES vs Ona	ICES vs Fässler	DEPTH-DEPENDENT N_Z_TOTAL [MIO] Ona 2003	Fässler 2007	Ona_vs_Fässler Diff [MIO]	Diff [%]	DEPTH-INDEPENDENT N_sprat_TOTAL [MIO] ICES 1983	Ona 2003	Fässler 2007	Diff [%] ICES vs Ona	ICES vs Fässler	DEPTH-DEPENDENT N_sprat_Z_TOTAL [MIO] Ona 2003	Fässler 2007	Ona_vs_Fässler Diff [MIO]	Diff [%]
2008	24	38G2	221	90	54	59	75	74	45	30	40	139	56	34	59	75	47	29	19	39
2008	24	38G3	1486	606	365	59	75	513	305	208	41	1354	552	332	59	75	468	278	190	41
2008	24	38G4	1219	497	299	59	75	417	249	169	40	1040	424	255	59	75	357	213	144	40
2008	24	39G2	155	63	38	59	75	53	31	21	40	97	40	24	59	75	34	20	13	40
2008	24	39G3	543	221	133	59	75	195	114	81	42	493	201	121	59	75	178	104	73	41
2008	24	39G4	756	308	186	59	75	262	155	107	41	644	262	158	59	75	224	133	91	41
2008	24	TOTAL	4381	1785	1075	59	75	1514	898	616	41	3767	1535	925	59	75	1308	778	530	41
2008	25	38G5	3081	1255	756	59	75	1075	635	440	41	3033	1235	744	59	75	1059	626	433	41
2008	25	38G6	2050	835	503	59	75	701	418	283	40	1701	693	418	59	75	583	348	235	40
2008	25	39G4	454	185	111	59	75	161	94	66	41	443	180	109	59	75	158	93	65	41
2008	25	39G5	2266	923	556	59	75	860	492	369	43	2238	912	549	59	75	851	487	364	43
2008	25	39G6	3183	1359	830	57	74	1182	704	478	40	3052	1303	795	57	74	1134	676	459	40
2008	25	39G7	2867	1168	704	59	75	986	586	400	41	2848	1160	699	59	75	980	583	397	41
2008	25	40G4	1117	455	274	59	75	388	230	158	41	1093	445	268	59	75	381	226	155	41
2008	25	40G5	1746	711	429	59	75	631	368	263	42	1437	585	353	59	75	520	304	217	42
2008	25	40G6	2745	1118	674	59	75	974	572	402	41	2533	1032	622	59	75	900	529	371	41
2008	25	40G7	1158	472	284	59	75	403	239	165	41	1157	472	284	59	75	404	240	165	41
2008	25	41G6	2168	883	532	59	75	743	442	300	40	2125	866	522	59	75	729	435	294	40
2008	25	41G7	3181	1296	781	59	75	1082	646	436	40	3043	1240	747	59	75	1036	619	417	40
2008	25	TOTAL	26015	10660	6434	59	75	9187	5425	3761	41	24703	10123	6110	59	75	8735	5163	3572	41
2008	26	39G8	2954	1203	725	59	75	1035	611	425	41	2919	1189	716	59	75	1024	604	420	41
2008	26	40G8	1203	490	295	59	75	470	266	205	43	1185	483	291	59	75	464	263	201	43
2008	26	41G8	2107	858	517	59	75	765	445	320	42	2086	850	512	59	75	759	442	317	42
2008	26	TOTAL	6263	2552	1537	59	75	2271	1322	949	42	6189	2521	1519	59	75	2247	1309	938	42
2008	27	42G7	3181	1296	781	59	75	1104	654	450	41	2566	1045	630	59	75	891	528	363	41
2008	27	43G7	869	354	213	59	75	309	181	128	41	430	175	106	59	75	153	90	63	41
2008	27	44G7	2446	996	600	59	75	906	522	383	42	1874	763	460	59	75	695	401	294	42
2008	27	45G7	3250	1324	798	59	75	1236	706	530	43	2625	1069	644	59	75	999	571	428	43
2008	27	45G8	2395	976	588	59	75	974	542	432	44	1791	729	440	59	75	729	406	323	44
2008	27	46G8	2278	928	559	59	75	937	519	418	45	1929	786	474	59	75	794	441	354	45
2008	27	TOTAL	14419	5874	3539	59	75	5465	3125	2341	43	11214	4568	2753	59	75	4261	2437	1824	43
TOTAL 2008			51079	20871	12587	59	75	18437	10770	7667	42	45873	18747	11307	59	75	16551	9687	6864	41
2009	24	38G2	784	319	192	59	75	259	157	103	40	648	264	159	59	75	215	130	85	39
2009	24	38G3	1731	705	425	59	75	590	352	238	40	1639	668	402	59	75	560	334	225	40
2009	24	38G4	1453	592	357	59	75	531	308	223	42	1394	568	342	59	75	510	297	214	42
2009	24	39G2	442	180	108	59	75	150	90	61	40	365	149	90	59	75	125	75	50	40
2009	24	39G3	1337	545	328	59	75	469	277	192	41	1266	516	311	59	75	445	263	182	41
2009	24	39G4	721	294	177	59	75	268	155	114	42	641	261	157	59	75	239	138	101	42
2009	24	TOTAL	6468	2635	1588	59	75	2268	1338	930	41	5953	2425	1461	59	75	2095	1238	857	41
2009	25	37G5	498	203	122	59	75	185	107	78	42	490	200	120	59	75	183	106	77	42
2009	25	38G5	5260	2304	1418	56	73	2355	1331	1024	43	5196	2276	1400	56	73	2327	1316	1012	43
2009	25	38G6	1488	606	365	59	75	591	332	259	44	1464	596	359	59	75	583	328	255	44
2009	25	39G4	1789	729	439	59	75	706	398	308	44	1239	505	304	59	75	490	276	213	44
2009	25	39G5	7002	3445	2201	51	69	3581	2100	1481	41	6852	3372	2154	51	69	3505	2056	1449	41
2009	25	39G6	2571	1047	631	59	75	1045	582	463	44	2527	1029	620	59	75	1028	573	455	44
2009	25	39G7	4818	1963	1183	59	75	1739	1014	725	42	4656	1897	1143	59	75	1681	981	700	42
2009	25	40G4	3968	1616	974	59	75	1499	859	640	43	3643	1484	894	59	75	1377	790	587	43
2009	25	40G5	5579	2691	1707	52	69	2684	1584	1100	41	5308	2560	1624	52	69	2554	1508	1047	41
2009	25	40G6	6179	2517	1517	59	75	2316	1331	985	43	6068	2472	1490	59	75	2276	1308	968	43
2009	25	40G7	4152	1691	1019	59	75	1469	864	605	41	4131	1683	1014	59	75	1463	861	602	41
2009	25	41G6	6653	2710	1633	59	75	2466	1424	1042	42	6616	2695	1624	59	75	2453	1417	1036	42
2009	25	41G7	3476	1416	853	59	75	1267	736	530	42	3475	1416	853	59	75	1267	737	530	42
2009	25	TOTAL	53432	22939	14062	57	74	21904	12662	9242	42	51664	22184	13600	57	74	21189	12256	8933	42
2009	26	39G8	2285	1230	812	46	64	1115	711	405	36	2188	1177	778	46	64	1069	681	388	36
2009	26	40G8	2264	922	556	59	75	934	517	417	45	2258	920	554	59	75	932	516	416	45
2009	26	41G8	6442	2624	1581	59	75	2398	1382	1016	42	6420	2615	1576	59	75	2391	1378	1013	42
2009	26	TOTAL	10991	4776	2949	57	73	4448	2609	1839	41	10866	4713	2908	57	73	4392	2576	1817	41
2009	27	42G7	5520	2249	1355	59	75	2024	1173	851	42	5314	2165	1304	59	75	1950	1130	819	42
2009	27	43G7	3559	1450	874	59	75	1399	789	609	44	3426	1396	841	59	75	1347	761	587	44
2009	27	44G7	6350	2587	1559	59	75	2492	1406	1085	44	6113	2490	1501	59	75	2399	1354	1044	44
2009	27	46G8	6648	2708	1632	59	75	2672	1494	1178	44	6399	2607	1571	59	75	2573	1439	1134	44
2009	27	TOTAL	22076	8994	5419	59	75	8586	4862	3724	43	21251	8657	5217	59	75	8268	4684	3584	43
2009	28	42G8	3426	1396	841	59	75	1216	714	502	41	3378	1376	829	59	75	1200	705	495	41
2009	28	42G9	3368	1372	827	59	75	1355	757	598	44	3330	1356	817	59	75	1341	750	591	44
2009	28	43G8	367	149	90	59	75	141	80	61	43	360	147	88	59	75	139	80	60	43
2009	28	43G9	3147	1282	772	59	75	1315	724	591	45	3086	1257	757	59	75	1292	712	580	45
2009	28	44G9	2705	1102	664	59	75	1102	613	489	44	2280	929	560	59	75	929	517	412	44
2009	28	44H0	6394	2605	1570	59	75	2637	1460	1177	45	6148	2505	1509	59	75	2536	1405	1131	45
2009	28	44H1	7876	3208	1933	59	75	2902	1679	1223	42	6843	2788	1680	59	75	2522	1460	1063	42
2009	28	45G9	6974	2841	1712	59	75	2995	1633	1362	45	6622	2698	1626	59	75	2845	1552	1293	45
2009	28	45H0	6619	2697	1625	59	75	2776	1527	1249	45	5737	2337	1408	59	75	2407	1324	1083	45
2009	28	45H1	7900	3218	1939	59	75	3043	1730	1313	43	6865	2797	1685	59	75	2645	1504	1141	43
2009	28	TOTAL	48776	19871	11973	59	75	19483	10918	8565	44	44648	18189	10960	59	75	17857	10008	7849	44
TOTAL 2009			141744	59214	35991	58	75	56689	32390	24299	43	134382	56168	34145	58	75	53801	30762	23039	43
TOTAL 1999-2009			*656304*	*270103*	*163310*	*59*	*75*	*257547*	*146477*	*111070*	*43*	*632528*	*260326*	*157400*	*59*	*75*	*248645*	*141475*	*107171*	*43*

Table 4.3. Estimated abundances of total fish (N_TOTAL/N_Z_TOTAL) and sprat (N_spec/N_spec_Z) using depth-independent and depth-dependent TS – length realationships according to Fässler et al. (2007) as well as calculated differences [%] between both abundance estimates in various ICES-Rectangles in the Subdivisions 24 - 28 during 1999 – 2009. a) 1999 & 2001; b) 2002 & 2003; c) 2004 & 2005; d) 2006 & 2007; e) 2008 & 2009.

a)

YEAR	SD	RECTANGLE	FÄSSLER_2007					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
1999	24	38G3	506	438	13	468	406	13
1999	24	38G4	326	268	18	300	248	17
1999	24	39G3	279	247	11	277	246	11
1999	24	39G4	182	155	15	170	146	14
1999	24	TOTAL	1293	1109	14	1215	1046	14
1999	25	38G5	221	200	10	206	188	9
1999	25	39G4	280	243	13	278	243	13
1999	25	39G5	907	823	9	897	815	9
1999	25	39G6	694	614	12	676	599	11
1999	25	39G7	1063	946	11	1062	946	11
1999	25	40G4	176	159	9	171	155	9
1999	25	40G5	1169	1015	13	1166	1013	13
1999	25	40G6	1266	1071	15	1256	1064	15
1999	25	40G7	705	598	15	705	599	15
1999	25	41G6	1400	1175	16	1399	1176	16
1999	25	41G7	1100	924	16	1098	924	16
1999	25	TOTAL	8981	7768	14	8915	7720	13
1999	26	39G8	1294	1173	9	1292	1171	9
1999	26	40G8	1466	1358	7	1465	1358	7
1999	26	41G8	757	652	14	755	651	14
1999	26	TOTAL	3518	3183	10	3512	3180	9
1999	27	42G7	1290	1099	15	1256	1071	15
1999	27	TOTAL	1290	1099	15	1256	1071	15
1999	28	42G8	435	369	15	429	366	15
1999	28	TOTAL	435	369	15	429	366	15
TOTAL 1999			15517	13527	13	15328	13384	13
2001	24	38G2	54	43	19	48	39	18
2001	24	38G3	195	169	13	182	159	13
2001	24	38G4	746	615	18	736	608	17
2001	24	39G2	77	64	17	69	58	16
2001	24	39G3	134	113	16	111	94	16
2001	24	39G4	97	84	13	75	66	12
2001	24	TOTAL	1303	1088	17	1221	1024	16
2001	25	37G5	707	598	15	702	594	15
2001	25	38G5	323	285	12	313	277	12
2001	25	38G6	316	269	15	316	270	15
2001	25	39G4	95	85	10	94	85	9
2001	25	39G5	278	250	10	272	246	10
2001	25	39G6	671	615	8	659	605	8
2001	25	39G7	902	796	12	901	796	12
2001	25	40G4	204	189	8	202	188	7
2001	25	40G5	837	737	12	834	735	12
2001	25	40G6	904	805	11	900	803	11
2001	25	40G7	739	635	14	739	635	14
2001	25	41G6	1290	1104	14	1289	1104	14
2001	25	41G7	887	769	13	886	769	13
2001	25	TOTAL	8154	7136	12	8107	7107	12
2001	26	39G8	1535	1377	10	1533	1376	10
2001	26	40G8	1342	1246	7	1336	1242	7
2001	26	41G8	847	765	10	838	758	10
2001	26	TOTAL	3725	3389	9	3706	3375	9
2001	27	42G7	1011	900	11	1002	894	11
2001	27	TOTAL	1011	900	11	1002	894	11
2001	28	42G8	748	631	16	748	632	16
2001	28	TOTAL	748	631	16	748	632	16
TOTAL 2001			14940	13144	12	14784	13032	12

b)

YEAR	SD	RECTANGLE	FÄSSLER_2007 DEPTH-INDEPENDENT N_TOTAL [MIO]	DEPTH-DEPENDENT N_Z_TOTAL [MIO]	Diff [%]	DEPTH-INDEPENDENT N_spec_ TOTAL [MIO]	DEPTH-DEPENDENT N_spec_Z_ TOTAL [MIO]	Diff [%]
2002	24	38G3	469	405	14	439	380	13
2002	24	38G4	326	277	15	313	267	15
2002	24	39G3	79	69	13	59	53	11
2002	24	TOTAL	874	751	14	811	699	14
2002	25	37G5	461	419	9	460	420	9
2002	25	38G5	531	496	7	526	493	6
2002	25	38G6	129	108	16	129	109	15
2002	25	39G4	462	421	9	457	417	9
2002	25	39G5	1020	970	5	1010	962	5
2002	25	39G6	1525	1438	6	1521	1436	6
2002	25	39G7	1408	1312	7	1403	1309	7
2002	25	40G4	753	680	10	742	670	10
2002	25	40G5	3034	2801	8	3029	2798	8
2002	25	40G6	2693	2474	8	2687	2469	8
2002	25	40G7	689	619	10	678	610	10
2002	25	41G6	140	120	14	139	121	13
2002	25	41G7	355	318	10	352	317	10
2002	25	TOTAL	13199	12177	8	13135	12131	8
2002	26	39G8	1478	1401	5	1476	1400	5
2002	26	40G8	705	666	6	705	667	5
2002	26	41G8	475	443	7	475	444	6
2002	26	TOTAL	2658	2510	6	2656	2511	5
2002	27	42G7	763	704	8	760	703	8
2002	27	TOTAL	763	704	8	760	703	8
2002	28	42G8	539	468	13	538	467	13
2002	28	TOTAL	539	468	13	538	467	13
TOTAL 2002			18033	16610	8	17900	16511	8
2003	24	38G3	534	466	13	467	408	13
2003	24	38G4	131	118	10	130	118	9
2003	24	39G3	68	59	13	54	48	11
2003	24	39G4	156	139	11	132	118	11
2003	24	TOTAL	888	781	12	783	693	12
2003	25	37G5	42	38	10	41	38	7
2003	25	38G5	338	313	7	331	308	7
2003	25	38G6	34	30	12	34	31	9
2003	25	38G7	5	4	16	5	5	-6
2003	25	39G4	75	69	8	70	65	6
2003	25	39G5	283	270	5	280	268	4
2003	25	39G6	231	215	7	223	209	6
2003	25	39G7	531	495	7	529	494	7
2003	25	40G4	142	128	10	137	125	9
2003	25	40G5	185	167	10	165	150	9
2003	25	40G6	734	663	10	731	662	9
2003	25	40G7	273	245	10	252	227	10
2003	25	41G6	122	109	10	120	108	10
2003	25	41G7	46	39	15	40	35	12
2003	25	TOTAL	3039	2786	8	2957	2725	8
2003	26	38G8	1108	1075	3	1102	1070	3
2003	26	39G8	885	860	3	880	856	3
2003	26	40G8	930	901	3	929	901	3
2003	26	41G8	1296	1250	4	1292	1248	3
2003	26	TOTAL	4220	4086	3	4203	4075	3
TOTAL 2003			8147	7653	6	7944	7492	6

c)

YEAR	SD	RECTANGLE	FÄSSLER_2007					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
2004	24	38G2	94	78	16	9	8	15
2004	24	38G3	512	446	13	472	412	13
2004	24	38G4	212	186	12	201	178	12
2004	24	39G2	37	30	17	4	3	15
2004	24	39G3	170	150	12	120	106	11
2004	24	39G4	85	75	12	72	64	11
2004	24	TOTAL	1110	966	13	879	772	12
2004	25	37G5	40	36	8	38	36	6
2004	25	38G5	470	433	8	451	416	8
2004	25	38G6	50	43	14	46	40	12
2004	25	39G4	155	142	8	150	139	8
2004	25	39G5	551	523	5	543	516	5
2004	25	39G6	446	420	6	441	416	6
2004	25	39G7	654	619	5	651	617	5
2004	25	40G4	799	718	10	789	710	10
2004	25	40G5	986	898	9	955	871	9
2004	25	40G6	1333	1192	11	1322	1183	11
2004	25	40G7	869	751	14	867	750	13
2004	25	41G6	233	201	14	226	195	14
2004	25	41G7	737	641	13	735	640	13
2004	25	TOTAL	7322	6618	10	7213	6532	9
2004	26	39G8	1263	1174	7	1253	1166	7
2004	26	40G8	1101	1037	6	1093	1031	6
2004	26	41G8	831	759	9	820	750	9
2004	26	TOTAL	3195	2970	7	3166	2946	7
2004	27	42G7	601	537	11	583	523	10
2004	27	43G7	1096	998	9	1027	936	9
2004	27	44G7	2114	1903	10	1985	1788	10
2004	27	TOTAL	3811	3438	10	3595	3247	10
2004	28	42G8	554	490	12	532	471	12
2004	28	42G9	1108	1017	8	1094	1005	8
2004	28	TOTAL	1663	1507	9	1626	1476	9
TOTAL 2004			**17100**	**15499**	**9**	**16479**	**14973**	**9**
2005	24	38G2	52	43	18	38	32	16
2005	24	38G3	311	270	13	228	199	13
2005	24	38G4	24	21	13	21	19	9
2005	24	39G2	99	84	15	73	62	14
2005	24	39G3	78	68	13	57	50	12
2005	24	39G4	194	169	13	186	163	12
2005	24	TOTAL	758	655	14	604	527	13
2005	25	37G5	31	26	14	27	24	11
2005	25	38G5	359	339	5	345	327	5
2005	25	38G6	57	49	13	56	49	12
2005	25	39G4	194	170	12	186	164	12
2005	25	39G5	2712	2587	5	2669	2546	5
2005	25	39G6	1832	1577	14	1801	1552	14
2005	25	39G7	935	787	16	876	739	16
2005	25	40G4	155	142	8	144	132	8
2005	25	40G5	992	911	8	955	879	8
2005	25	40G6	1081	964	11	1059	946	11
2005	25	41G6	2259	2018	11	2198	1964	11
2005	25	TOTAL	10607	9571	10	10317	9323	10
2005	26	39G8	1098	905	18	1090	899	18
2005	26	40G8	1586	1404	11	1559	1381	11
2005	26	41G8	1151	974	15	1144	969	15
2005	26	TOTAL	3835	3283	14	3793	3249	14
TOTAL 2005			**15200**	**13509**	**11**	**14714**	**13099**	**11**

d)

YEAR	SD	RECTANGLE	FÄSSLER_2007					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
2006	24	38G2	22	18	17	0	0	13
2006	24	38G3	290	243	16	203	171	16
2006	24	38G4	66	57	15	53	46	13
2006	24	39G2	69	59	15	0	0	13
2006	24	39G3	82	72	13	67	59	11
2006	24	39G4	54	48	11	26	24	10
2006	24	TOTAL	583	496	15	350	300	14
2006	25	37G5	18	16	11	12	11	6
2006	25	38G5	390	363	7	354	331	7
2006	25	38G6	46	41	12	44	40	10
2006	25	39G4	100	90	10	67	61	9
2006	25	39G5	705	665	6	687	650	5
2006	25	39G6	880	791	10	832	748	10
2006	25	39G7	956	873	9	953	872	9
2006	25	40G4	165	150	9	163	150	8
2006	25	40G5	836	758	9	825	749	9
2006	25	40G6	408	369	9	368	334	9
2006	25	40G7	105	91	14	65	57	13
2006	25	41G6	518	460	11	499	444	11
2006	25	41G7	613	528	14	553	477	14
2006	25	TOTAL	5741	5196	9	5422	4923	9
2006	26	38G8	688	602	13	686	601	12
2006	26	39G8	1031	910	12	1029	910	12
2006	26	40G8	503	472	6	501	470	6
2006	26	41G8	606	576	5	606	577	5
2006	26	TOTAL	2829	2559	10	2822	2558	9
2006	27	42G7	1116	1032	8	1083	1003	7
2006	27	43G7	346	319	8	324	300	7
2006	27	44G7	1038	968	7	1015	947	7
2006	27	45G7	1390	1256	10	1343	1214	10
2006	27	45G8	1192	1076	10	1166	1053	10
2006	27	46G8	1023	948	7	1007	934	7
2006	27	TOTAL	6106	5598	8	5938	5451	8
TOTAL 2006			15259	13850	9	14532	13232	9
2007	24	38G2	102	86	16	99	85	15
2007	24	38G3	321	280	13	313	274	13
2007	24	38G4	268	233	13	264	230	13
2007	24	39G2	119	100	16	116	98	15
2007	24	39G3	308	270	12	301	265	12
2007	24	39G4	298	262	12	295	260	12
2007	24	TOTAL	1416	1230	13	1388	1212	13
2007	25	37G5	36	31	15	36	31	12
2007	25	38G5	270	250	7	260	241	7
2007	25	38G6	132	112	15	129	111	14
2007	25	39G4	116	109	6	113	107	6
2007	25	39G5	540	511	5	533	506	5
2007	25	39G6	1647	1544	6	1643	1541	6
2007	25	39G7	374	342	9	372	341	8
2007	25	40G4	417	388	7	398	371	7
2007	25	40G5	1056	964	9	1047	957	9
2007	25	40G6	460	417	9	456	415	9
2007	25	40G7	304	269	12	302	268	11
2007	25	41G6	910	783	14	904	779	14
2007	25	41G7	723	612	15	693	587	15
2007	25	TOTAL	6987	6333	9	6886	6255	9
2007	27	42G7	504	450	11	489	437	11
2007	27	43G7	471	431	9	442	405	8
2007	27	44G7	398	369	7	370	345	7
2007	27	45G7	307	285	7	280	261	7
2007	27	45G8	141	133	5	133	128	4
2007	27	46G8	314	294	6	279	262	6
2007	27	TOTAL	2133	1962	8	1993	1838	8
TOTAL 2007			10536	9524	10	10267	9304	9

e)

YEAR	SD	RECTANGLE	FÄSSLER_2007 DEPTH-INDEPENDENT N TOTAL [MIO]	DEPTH-DEPENDENT N Z TOTAL [MIO]	Diff [%]	DEPTH-INDEPENDENT N spec TOTAL [MIO]	DEPTH-DEPENDENT N spec Z TOTAL [MIO]	Diff [%]
2008	24	38G2	54	45	18	34	29	16
2008	24	38G3	365	305	17	332	278	16
2008	24	38G4	299	249	17	255	213	17
2008	24	39G2	38	31	17	24	20	15
2008	24	39G3	133	114	15	121	104	14
2008	24	39G4	186	155	16	158	133	16
2008	24	TOTAL	1075	898	16	925	778	16
2008	25	38G5	756	635	16	744	626	16
2008	25	38G6	503	418	17	418	348	17
2008	25	39G4	111	94	15	109	93	14
2008	25	39G5	556	492	12	549	487	11
2008	25	39G6	830	704	15	795	676	15
2008	25	39G7	704	586	17	699	583	17
2008	25	40G4	274	230	16	268	226	16
2008	25	40G5	429	368	14	353	304	14
2008	25	40G6	674	572	15	622	529	15
2008	25	40G7	284	239	16	284	240	16
2008	25	41G6	532	442	17	522	435	17
2008	25	41G7	781	646	17	747	619	17
2008	25	TOTAL	6434	5425	16	6110	5163	15
2008	26	39G8	725	611	16	716	604	16
2008	26	40G8	295	266	10	291	263	10
2008	26	41G8	517	445	14	512	442	14
2008	26	TOTAL	1537	1322	14	1519	1309	14
2008	27	42G7	781	654	16	630	528	16
2008	27	43G7	213	181	15	106	90	15
2008	27	44G7	600	522	13	460	401	13
2008	27	45G7	798	706	11	644	571	11
2008	27	45G8	588	542	8	440	406	8
2008	27	46G8	559	519	7	474	441	7
2008	27	TOTAL	3539	3125	12	2753	2437	11
TOTAL 2008			12587	10770	14	11307	9687	14
2009	24	38G2	192	157	19	159	130	18
2009	24	38G3	425	352	17	402	334	17
2009	24	38G4	357	308	14	342	297	13
2009	24	39G2	108	90	17	90	75	16
2009	24	39G3	328	277	16	311	263	15
2009	24	39G4	177	155	13	157	138	12
2009	24	TOTAL	1588	1338	16	1461	1238	15
2009	25	37G5	122	107	13	120	106	12
2009	25	38G5	1418	1331	6	1400	1316	6
2009	25	38G6	365	332	9	359	328	9
2009	25	39G4	439	398	9	304	276	9
2009	25	39G5	2201	2100	5	2154	2056	5
2009	25	39G6	631	582	8	620	573	8
2009	25	39G7	1183	1014	14	1143	981	14
2009	25	40G4	974	859	12	894	790	12
2009	25	40G5	1707	1584	7	1624	1508	7
2009	25	40G6	1517	1331	12	1490	1308	12
2009	25	40G7	1019	864	15	1014	861	15
2009	25	41G6	1633	1424	13	1624	1417	13
2009	25	41G7	853	736	14	853	737	14
2009	25	TOTAL	14062	12662	10	13600	12256	10
2009	26	39G8	812	711	13	778	681	12
2009	26	40G8	556	517	7	554	516	7
2009	26	41G8	1581	1382	13	1576	1378	13
2009	26	TOTAL	2949	2609	12	2908	2576	11
2009	27	42G7	1355	1173	13	1304	1130	13
2009	27	43G7	874	789	10	841	761	10
2009	27	44G7	1559	1406	10	1501	1354	10
2009	27	46G8	1632	1494	8	1571	1439	8
2009	27	TOTAL	5419	4862	10	5217	4684	10
2009	28	42G8	841	714	15	829	705	15
2009	28	42G9	827	757	8	817	750	8
2009	28	43G8	90	80	11	88	80	10
2009	28	43G9	772	724	6	757	712	6
2009	28	44G9	664	613	8	560	517	8
2009	28	44H0	1570	1460	7	1509	1405	7
2009	28	44H1	1933	1679	13	1680	1460	13
2009	28	45G9	1712	1633	5	1626	1552	5
2009	28	45H0	1625	1527	6	1408	1324	6
2009	28	45H1	1939	1730	11	1685	1504	11
2009	28	TOTAL	11973	10918	9	10960	10008	9
TOTAL 2009			35991	32390	10	34145	30762	10
TOTAL 1999-2009			163310	146477	10	157400	141475	10

Table 4.4. Estimated abundances of total fish (N_TOTAL/N_Z_TOTAL) and sprat (N_spec/N_spec_Z) using depth-independent and depth-dependent TS – length realationships according to Ona (2003) as well as calculated differences [%] between both abundance estimates in various ICES-Rectangles in the Subdivisions 24 - 28 during 1999 – 2009.
a) 1999 & 2001; b) 2002 & 2003; c) 2004 & 2005; d) 2006 & 2007; e) 2008 & 2009.

a)

			ONA_2003					
YEAR	SD	RECTANGLE	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
1999	24	38G3	840	755	10	777	699	10
1999	24	38G4	541	448	17	498	414	17
1999	24	39G3	464	433	7	460	430	6
1999	24	39G4	302	264	12	282	248	12
1999	24	TOTAL	2147	1901	11	2017	1791	11
1999	25	38G5	367	355	3	343	332	3
1999	25	39G4	464	421	9	462	420	9
1999	25	39G5	1506	1464	3	1489	1448	3
1999	25	39G6	1151	1075	7	1122	1048	7
1999	25	39G7	1764	1662	6	1762	1662	6
1999	25	40G4	292	282	3	283	275	3
1999	25	40G5	1941	1754	10	1935	1749	10
1999	25	40G6	2100	1819	13	2084	1806	13
1999	25	40G7	1170	1017	13	1170	1018	13
1999	25	41G6	2323	1987	15	2322	1987	14
1999	25	41G7	1825	1564	14	1823	1562	14
1999	25	TOTAL	14904	13399	10	14795	13307	10
1999	26	39G8	2148	2086	3	2144	2083	3
1999	26	40G8	2433	2448	-1	2431	2446	-1
1999	26	41G8	1257	1121	11	1254	1120	11
1999	26	TOTAL	5838	5655	3	5828	5649	3
1999	27	42G7	2140	1876	12	2085	1828	12
1999	27	TOTAL	2140	1876	12	2085	1828	12
1999	28	42G8	722	630	13	713	623	13
1999	28	TOTAL	722	630	13	713	623	13
TOTAL 1999			25751	23460	9	25438	23198	9
2001	24	38G2	89	71	20	79	64	19
2001	24	38G3	323	292	10	303	274	9
2001	24	38G4	1238	1028	17	1221	1014	17
2001	24	39G2	128	107	16	114	96	16
2001	24	39G3	223	190	15	185	158	14
2001	24	39G4	160	144	10	125	113	10
2001	24	TOTAL	2162	1832	15	2027	1720	15
2001	25	37G5	1174	1014	14	1165	1008	14
2001	25	38G5	515	475	8	498	460	8
2001	25	38G6	525	459	13	524	459	12
2001	25	39G4	157	150	5	155	149	4
2001	25	39G5	457	438	4	447	430	4
2001	25	39G6	1105	1089	1	1085	1070	1
2001	25	39G7	1496	1390	7	1496	1390	7
2001	25	40G4	339	339	0	336	336	0
2001	25	40G5	1388	1287	7	1383	1283	7
2001	25	40G6	1500	1415	6	1494	1410	6
2001	25	40G7	1227	1088	11	1226	1089	11
2001	25	41G6	2141	1888	12	2140	1888	12
2001	25	41G7	1472	1325	10	1471	1325	10
2001	25	TOTAL	13496	12356	8	13420	12297	8
2001	26	39G8	2548	2433	5	2544	2430	4
2001	26	40G8	2227	2249	-1	2217	2239	-1
2001	26	41G8	1406	1357	3	1390	1343	3
2001	26	TOTAL	6181	6039	2	6151	6012	2
2001	27	42G7	1677	1581	6	1663	1569	6
2001	27	TOTAL	1677	1581	6	1663	1569	6
2001	28	42G8	1242	1071	14	1241	1071	14
2001	28	TOTAL	1242	1071	14	1241	1071	14
TOTAL 2001			24758	22879	8	24501	22670	7

b)

YEAR	SD	RECTANGLE	ONA_2003					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
2002	24	38G3	778	696	11	728	653	10
2002	24	38G4	542	472	13	519	453	13
2002	24	39G3	131	119	9	99	91	8
2002	24	TOTAL	1451	1288	11	1346	1197	11
2002	25	37G5	765	746	3	764	746	2
2002	25	38G5	881	898	-2	873	890	-2
2002	25	38G6	214	183	15	214	183	14
2002	25	39G4	767	749	2	758	741	2
2002	25	39G5	1692	1776	-5	1677	1761	-5
2002	25	39G6	2530	2619	-3	2525	2614	-4
2002	25	39G7	2337	2371	-1	2329	2364	-2
2002	25	40G4	1250	1203	4	1231	1186	4
2002	25	40G5	5034	5030	0	5027	5024	0
2002	25	40G6	4470	4428	1	4460	4419	1
2002	25	40G7	1143	1093	4	1125	1076	4
2002	25	41G6	232	206	11	231	206	11
2002	25	41G7	589	561	5	585	558	5
2002	25	TOTAL	21905	21862	0	21799	21769	0
2002	26	39G8	2453	2560	-4	2450	2558	-4
2002	26	40G8	1170	1214	-4	1170	1214	-4
2002	26	41G8	788	803	-2	788	803	-2
2002	26	TOTAL	4411	4576	-4	4408	4576	-4
2002	27	42G7	1266	1264	0	1262	1261	0
2002	27	TOTAL	1266	1264	0	1262	1261	0
2002	28	42G8	895	807	10	892	806	10
2002	28	TOTAL	895	807	10	892	806	10
TOTAL 2002			**29928**	**29798**	**0**	**29706**	**29609**	**0**
2003	24	38G3	886	806	9	775	705	9
2003	24	38G4	217	209	4	215	209	3
2003	24	39G3	112	103	9	90	83	8
2003	24	39G4	259	243	6	220	207	6
2003	24	TOTAL	1475	1360	8	1300	1203	7
2003	25	37G5	70	67	4	68	67	2
2003	25	38G5	561	564	-1	549	553	-1
2003	25	38G6	57	53	8	57	53	6
2003	25	38G7	8	6	14	8	7	1
2003	25	39G4	124	123	0	116	117	-1
2003	25	39G5	469	495	-5	465	491	-6
2003	25	39G6	383	388	-1	371	376	-2
2003	25	39G7	882	895	-2	878	893	-2
2003	25	40G4	236	227	4	228	220	3
2003	25	40G5	306	296	3	273	265	3
2003	25	40G6	1218	1175	4	1213	1172	3
2003	25	40G7	453	432	5	418	400	4
2003	25	41G6	202	193	5	199	190	4
2003	25	41G7	76	67	12	66	59	11
2003	25	TOTAL	5044	4982	1	4908	4863	1
2003	26	38G8	1838	1992	-8	1829	1982	-8
2003	26	39G8	1469	1595	-9	1460	1587	-9
2003	26	40G8	1544	1669	-8	1542	1668	-8
2003	26	41G8	2151	2310	-7	2145	2305	-7
2003	26	TOTAL	7003	7567	-8	6976	7542	-8
TOTAL 2003			**13521**	**13909**	**-3**	**13183**	**13608**	**-3**

c)

YEAR	SD	RECTANGLE	ONA_2003					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
2004	24	38G2	156	132	15	15	13	15
2004	24	38G3	850	773	9	784	713	9
2004	24	38G4	352	325	8	334	309	7
2004	24	39G2	61	50	17	6	5	15
2004	24	39G3	283	261	8	199	185	7
2004	24	39G4	141	130	8	120	111	7
2004	24	TOTAL	1841	1671	9	1458	1337	8
2004	25	37G5	66	65	1	63	63	0
2004	25	38G5	780	776	1	748	745	0
2004	25	38G6	83	74	11	76	69	10
2004	25	39G4	257	254	1	249	248	1
2004	25	39G5	910	949	-4	896	936	-4
2004	25	39G6	740	763	-3	732	756	-3
2004	25	39G7	1085	1130	-4	1080	1126	-4
2004	25	40G4	1326	1269	4	1309	1254	4
2004	25	40G5	1636	1600	2	1585	1551	2
2004	25	40G6	2212	2097	5	2193	2080	5
2004	25	40G7	1442	1294	10	1438	1292	10
2004	25	41G6	387	345	11	375	335	11
2004	25	41G7	1223	1109	9	1220	1107	9
2004	25	TOTAL	12146	11726	3	11966	11563	3
2004	26	39G8	2096	2120	-1	2080	2104	-1
2004	26	40G8	1828	1886	-3	1815	1874	-3
2004	26	41G8	1379	1354	2	1361	1337	2
2004	26	TOTAL	5303	5360	-1	5255	5314	-1
2004	27	42G7	998	946	5	968	920	5
2004	27	43G7	1819	1778	2	1704	1666	2
2004	27	44G7	3508	3366	4	3294	3162	4
2004	27	TOTAL	6324	6091	4	5967	5748	4
2004	28	42G8	920	856	7	883	822	7
2004	28	42G9	1839	1822	1	1816	1800	1
2004	28	TOTAL	2759	2678	3	2698	2622	3
TOTAL 2004			28374	27525	3	27344	26584	3
2005	24	38G2	87	72	18	64	53	17
2005	24	38G3	516	467	10	379	343	9
2005	24	38G4	37	33	10	33	30	8
2005	24	39G2	164	142	13	121	105	13
2005	24	39G3	129	117	9	95	87	9
2005	24	39G4	322	293	9	309	282	9
2005	24	TOTAL	1256	1124	11	1000	901	10
2005	25	37G5	47	42	12	42	38	9
2005	25	38G5	564	579	-3	543	558	-3
2005	25	38G6	94	85	10	93	85	9
2005	25	39G4	322	295	8	309	284	8
2005	25	39G5	4476	4709	-5	4404	4635	-5
2005	25	39G6	3040	2715	11	2989	2670	11
2005	25	39G7	1482	1272	14	1389	1194	14
2005	25	40G4	254	250	2	235	232	1
2005	25	40G5	1646	1633	1	1585	1574	1
2005	25	40G6	1785	1686	6	1749	1653	5
2005	25	41G6	3749	3548	5	3648	3453	5
2005	25	TOTAL	17460	16814	4	16986	16375	4
2005	26	39G8	1823	1511	17	1809	1501	17
2005	26	40G8	2632	2462	6	2587	2421	6
2005	26	41G8	1910	1657	13	1899	1649	13
2005	26	TOTAL	6364	5630	12	6294	5570	11
TOTAL 2005			25080	23569	6	24281	22847	6

d)

YEAR	SD	RECTANGLE	ONA_2003					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N_TOTAL [MIO]	N_Z_TOTAL [MIO]		N_spec_ TOTAL [MIO]	N_spec_Z_ TOTAL [MIO]	
2006	24	38G2	37	31	17	0	0	14
2006	24	38G3	481	411	14	337	289	14
2006	24	38G4	110	97	12	88	78	11
2006	24	39G2	114	100	12	0	0	11
2006	24	39G3	136	124	9	111	102	8
2006	24	39G4	89	83	7	44	41	6
2006	24	TOTAL	967	846	13	580	511	12
2006	25	37G5	30	28	6	20	19	3
2006	25	38G5	647	656	-1	588	597	-1
2006	25	38G6	77	71	7	73	68	6
2006	25	39G4	166	159	4	110	106	4
2006	25	39G5	1104	1129	-2	1076	1103	-2
2006	25	39G6	1461	1398	4	1380	1321	4
2006	25	39G7	1586	1558	2	1582	1555	2
2006	25	40G4	274	268	2	271	266	2
2006	25	40G5	1388	1347	3	1369	1330	3
2006	25	40G6	677	656	3	611	593	3
2006	25	40G7	175	157	10	107	97	10
2006	25	41G6	860	807	6	828	777	6
2006	25	41G7	1018	908	11	918	820	11
2006	25	TOTAL	9462	9142	3	8934	8653	3
2006	26	38G8	1141	1046	8	1138	1044	8
2006	26	39G8	1711	1593	7	1708	1592	7
2006	26	40G8	836	855	-2	832	852	-2
2006	26	41G8	1006	1054	-5	1006	1054	-5
2006	26	TOTAL	4694	4547	3	4684	4541	3
2006	27	42G7	1853	1856	0	1798	1802	0
2006	27	43G7	574	573	0	538	538	0
2006	27	44G7	1723	1750	-2	1685	1712	-2
2006	27	45G7	2308	2228	3	2228	2153	3
2006	27	45G8	1979	1908	4	1935	1866	4
2006	27	46G8	1697	1707	-1	1671	1681	-1
2006	27	TOTAL	10134	10021	1	9855	9753	1
TOTAL 2006			25257	24556	3	24054	23458	2
2007	24	38G2	169	145	14	165	142	14
2007	24	38G3	533	484	9	520	473	9
2007	24	38G4	445	402	9	438	398	9
2007	24	39G2	197	168	15	192	165	14
2007	24	39G3	512	469	8	499	459	8
2007	24	39G4	494	455	8	490	451	8
2007	24	TOTAL	2350	2124	10	2304	2089	9
2007	25	37G5	60	53	12	59	53	11
2007	25	38G5	423	420	1	406	404	0
2007	25	38G6	219	191	12	214	189	12
2007	25	39G4	180	181	-1	175	177	-1
2007	25	39G5	874	905	-4	864	895	-4
2007	25	39G6	2718	2779	-2	2711	2773	-2
2007	25	39G7	621	612	2	617	609	1
2007	25	40G4	656	654	0	625	625	0
2007	25	40G5	1732	1699	2	1718	1685	2
2007	25	40G6	758	737	3	751	732	3
2007	25	40G7	505	470	7	501	467	7
2007	25	41G6	1511	1345	11	1501	1337	11
2007	25	41G7	1201	1039	14	1150	996	13
2007	25	TOTAL	11458	11084	3	11293	10942	3
2007	27	42G7	836	791	5	811	769	5
2007	27	43G7	782	768	2	734	722	2
2007	27	44G7	660	666	-1	614	621	-1
2007	27	45G7	509	514	-1	465	470	-1
2007	27	45G8	233	244	-4	221	232	-5
2007	27	46G8	521	534	-3	463	475	-3
2007	27	TOTAL	3540	3517	1	3308	3289	1
TOTAL 2007			17348	16725	4	16905	16320	3

e)

YEAR	SD	RECTANGLE	ONA_2003					
			DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]	DEPTH-INDEPENDENT	DEPTH-DEPENDENT	Diff [%]
			N TOTAL [MIO]	N Z TOTAL [MIO]		N spec TOTAL [MIO]	N spec Z TOTAL [MIO]	
2008	24	38G2	90	74	18	56	47	16
2008	24	38G3	606	513	15	552	468	15
2008	24	38G4	497	417	16	424	357	16
2008	24	39G2	63	53	16	40	34	15
2008	24	39G3	221	195	12	201	178	12
2008	24	39G4	308	262	15	262	224	15
2008	24	TOTAL	1785	1514	15	1535	1308	15
2008	25	38G5	1255	1075	14	1235	1059	14
2008	25	38G6	835	701	16	693	583	16
2008	25	39G4	185	161	13	180	158	13
2008	25	39G5	923	860	7	912	851	7
2008	25	39G6	1359	1182	13	1303	1134	13
2008	25	39G7	1168	986	16	1160	980	15
2008	25	40G4	455	388	15	445	381	14
2008	25	40G5	711	631	11	585	520	11
2008	25	40G6	1118	974	13	1032	900	13
2008	25	40G7	472	403	14	472	404	14
2008	25	41G6	883	743	16	866	729	16
2008	25	41G7	1296	1082	17	1240	1036	16
2008	25	TOTAL	10660	9187	14	10123	8735	14
2008	26	39G8	1203	1035	14	1189	1024	14
2008	26	40G8	490	470	4	483	464	4
2008	26	41G8	858	765	11	850	759	11
2008	26	TOTAL	2552	2271	11	2521	2247	11
2008	27	42G7	1296	1104	15	1045	891	15
2008	27	43G7	354	309	13	175	153	12
2008	27	44G7	996	906	9	763	695	9
2008	27	45G7	1324	1236	7	1069	999	7
2008	27	45G8	976	974	0	729	729	0
2008	27	46G8	928	937	-1	786	794	-1
2008	27	TOTAL	5874	5465	7	4568	4261	7
TOTAL 2008			**20871**	**18437**	**12**	**18747**	**16551**	**12**
2009	24	38G2	319	259	19	264	215	19
2009	24	38G3	705	590	16	668	560	16
2009	24	38G4	592	531	10	568	510	10
2009	24	39G2	180	150	16	149	125	16
2009	24	39G3	545	469	14	516	445	14
2009	24	39G4	294	268	9	261	239	8
2009	24	TOTAL	2635	2268	14	2425	2095	14
2009	25	37G5	203	185	9	200	183	8
2009	25	38G5	2304	2355	-2	2276	2327	-2
2009	25	38G6	606	591	2	596	583	2
2009	25	39G4	729	706	3	505	490	3
2009	25	39G5	3445	3581	-4	3372	3505	-4
2009	25	39G6	1047	1045	0	1029	1028	0
2009	25	39G7	1963	1739	11	1897	1681	11
2009	25	40G4	1616	1499	7	1484	1377	7
2009	25	40G5	2691	2684	0	2560	2554	0
2009	25	40G6	2517	2316	8	2472	2276	8
2009	25	40G7	1691	1469	13	1683	1463	13
2009	25	41G6	2710	2466	9	2695	2453	9
2009	25	41G7	1416	1267	11	1416	1267	10
2009	25	TOTAL	22939	21904	5	22184	21189	4
2009	26	39G8	1230	1115	9	1177	1069	9
2009	26	40G8	922	934	-1	920	932	-1
2009	26	41G8	2624	2398	9	2615	2391	9
2009	26	TOTAL	4776	4448	7	4713	4392	7
2009	27	42G7	2249	2024	10	2165	1950	10
2009	27	43G7	1450	1399	4	1396	1347	3
2009	27	44G7	2587	2492	4	2490	2399	4
2009	27	46G8	2708	2672	1	2607	2573	1
2009	27	TOTAL	8994	8586	5	8657	8268	4
2009	28	42G8	1396	1216	13	1376	1200	13
2009	28	42G9	1372	1355	1	1356	1341	1
2009	28	43G8	149	141	6	147	139	5
2009	28	43G9	1282	1315	-3	1257	1292	-3
2009	28	44G9	1102	1102	0	929	929	0
2009	28	44H0	2605	2637	-1	2505	2536	-1
2009	28	44H1	3208	2902	10	2788	2522	10
2009	28	45G9	2841	2995	-5	2698	2845	-5
2009	28	45H0	2697	2776	-3	2337	2407	-3
2009	28	45H1	3218	3043	5	2797	2645	5
2009	28	TOTAL	19871	19483	2	18189	17857	2
TOTAL 2009			**59214**	**56689**	**4**	**56168**	**53801**	**4**
TOTAL 1999-2009			**270103**	**257547**	**5**	**260326**	**248645**	**4**

Erklärung

Hiermit versichere ich, dass die vorliegende Masterarbeit mit dem Titel:

„ The influence of vertical distribution of Baltic herring (*Clupea harengus L.*) and sprat (*Sprattus sprattus L.*) on the abundance estimation with hydroacoustic methods “

selbstständig und ohne fremde Hilfe verfasst wurde.

Die von mir genutzten Quellen und wörtlich oder inhaltlich entnommenen Stellen anderer Werke sind als solche kenntlich gemacht.

Ich bin damit einverstanden, dass diese Arbeit sowohl in einer öffentlichen Bibliothek, als auch in den Einrichtungen der Universität Hamburg ausgeliehen werden kann.

Glückstadt, den 28. Dezember 2010

Sinah Nagel