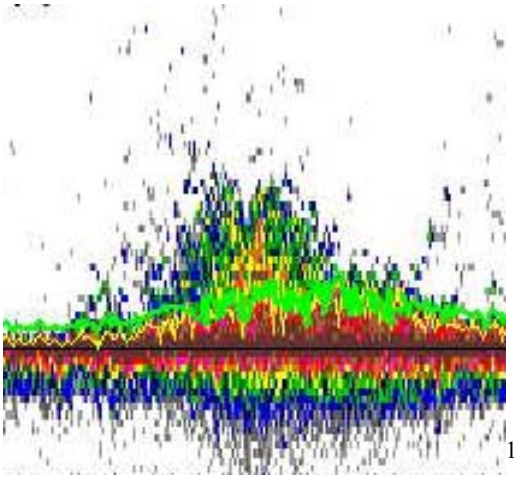
Acoustic Survey Cruise Report

ICES Divisions VIaS and VIIb

 [1]

NORTHWEST HERRING ACOUSTIC SURVEY 2006

4th – 24th January

Report by

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FSS Pelagics

Fisheries Science Services, Marine Institute, January 2006

[1] A 15m tall mark of spent herring recorded North of Lenadoon, Co. Mayo.

Introduction

The northwest and west coast herring acoustic survey programme was first implemented in 1994. Prior to this a larval survey programme was carried out between 1981 and 1986. In the early 1990s, the ICES herring working group (HAWG) identified the need for a dedicated herring acoustic survey in this area (Anon, 1994). The stock in this area is composed of 2 spawning components (autumn and winter), covering a large geographical area. Spawning may extend over a 4 month period from late September through to late March (Molloy *et al*, 2000).

Traditionally fishing activity has targeted spawning and pre-spawning aggregations, no summer matje fishery exists in this area, as is the case in the Celtic Sea. In VIaS, fishing has traditionally taken place in late October and continues until late February (winter spawners). Traditionally in VIIb, fishing is mainly concentrated on the later months of the year and would be concluded by the early part of the new year (Autumn spawners). The protracted spawning period of herring and the overlap between the two spawning stocks in this area (October to February) is highly dynamic with variations between annual spawning events of up to 3 weeks. Accurate survey timing is a key component of the design to cover the overlap of peak spawning events.

A project is currently underway to describe stock structure and discrimination of herring around Ireland. The results of this project may have implications for the design of this survey and for the stock assessment. However, since 1994, acoustic surveys have been carried out, and currently are the only tuning indices available. The current survey makes up the 13th in the time series. The design and execution of this survey has evolved from summer feeding phase surveys, in the mid 1990s until its present winter spawning state. This is the third survey of this stock carried out by the *Celtic Explorer*.

Materials and Methods

Area coverage

The winter 2006 survey covered the area to the east of Malin Head (Figure 1) in Co. Donegal (Division VIaS) and extended west and south along the northwestern seaboard covering the main bays and inlets into VIIb. The survey was started in the south and worked in a northerly direction to facilitate the migrations of the spawning components contained within the survey confines.

The survey area was divided into 7 strata (Figure 2). Strata 1 covered the north Mayo and Donegal Bay coastlines, this area has been identified as containing the earliest spawning components of the stock, with spawning events extending from late October until mid January. Strata 2 incorporated the northern side of Donegal Bay and extends along the western fringes of Co. Donegal. This area is characterised as containing a mixture of early and mid spawning stock components, this area was further subdivided into strata 2a focusing on a known spawning box (Glen Head area). Strata 3, included the northern Donegal coastline and comprises the later spawners. Spawning in this area may extend from early late December until mid March. Strata 3 was also subdivided into strata 3a to concentrate effort on the Tory spawning box. The decision to further stratify along the north coast was an affect of weather downtime and temporal continuity rather than herring distribution.

A parallel transect design was adopted with transects running perpendicular to the coastline and extending up to 54 nmi (nautical miles) offshore. Transect spacing was set at 2 nmi throughout the survey. For Killala Bay (strata 1) a single zigzag transect approach was used to optimise coverage. In total the combined survey transect length was in the order of 2,552 nmi.

Acoustic data acquisition

Settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FSS on previous surveys. The settings used on the *Celtic Explorer* acoustic array are shown in Table 1.

The acoustic data were collected using the Simrad ER60 scientific echosounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3m below the vessels hull or 8.8m below the sea surface.

While on the survey track the vessel was cruising using DC twin electric motor propulsion, supplied from 1 main diesel engine, so in effect providing “silent cruising” as compared to normal operations (ICES, 2002). However, it should be noted that during fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys (Table 1). The “RAW files” were logged via a continuous Ethernet connection as “EK5” files to the vessels server and

the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on DVD. Sonar Data's Echoview® Echolog (Version 3.2) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for of each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

Calibration of Acoustic equipment

No system calibration was carried out during this survey. The ER 60 was last calibrated in Irish coastal waters some 11 weeks prior to the survey start (O'Donnell *et al,* 2005). The beam models had not been adjusted since this time. The system is due to be calibrated again in March 2006. Should any major discrepancies arise data will be corrected as necessary.

Biological Sampling

A single pelagic midwater trawl with the dimensions of 19m in length (LOA) and 6m at the wing ends and a fishing circle of 330 m was employed during the survey (Appendix 1). Mesh size in the wings was 3.3 m through to 2 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 15 m, which was observed using both a cable linked "BEL Reeson" netsonde (50 kHz). The net was fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls was sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than herring were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 100 fish sample from each trawl haul, where possible. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used onboard and its manoeuvrability in relation to the vessel power allowed samples at or below 2m from the bottom to be taken in areas of clean ground.

Acoustic data analysis

Acoustic data was backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 3.2) post processing software for the previous days work. Partitioning of data into the above categories was largely subjective and was viewed and agreed upon by 2 scientists experienced in viewing echograms. Where no directed trawling

had taken place, biological data from the nearest neighbour was used to determine the size classification of the echotrace.

The NASC (Nautical Area Scattering Coefficient) values from each herring region were allocated to one of 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition and trace recognition were as follows:

1. "Definitely herring" echo-traces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echo-traces directly, and on large marks which had the characteristics of "definite" herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in mid-water and in the case of spawning shoals very dense aggregations in close proximity to the seabed).

2. "Probably herring" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" herring traces.

3. "Herring in a mixture" were attributed to S_A values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul which had been carried out on similar echo-traces in similar water depths.

4. "Possibly herring" were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

The "EK5" files were imported into Echoview (Version 3.2) for echo post-processing. The echograms were divided into transects. Echo integration was performed on a region which were defined by enclosing selecting marks or scatter that belonged to one of the four categories above. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The following TS/length relationships used were those recommended by the acoustic survey planning group (Anon, 1994):

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

The survey area was stratified into 3 main areas and within these further strata were made to reflect the different transect spacings and gaps. The strata were 1, 2 and 2a, 3, 3a, 4, and 5. Strata 2a and 3a covered the areas where a second survey was done and this was accommodated as an area with approximately half the transect spacing. Strata 4 and 5 were needed because some transects were missed out due to poor weather.

The analysis produced density values of numbers and biomass per nautical mile squared for each transect and mark category. These were then averaged over each stratum (weighted by transect length) and a biomass and abundance estimated by applying the stratum area and summing the strata estimates. Note that interconnecting inshore and offshore inter-transects were not included in the analysis. Total estimates and age and maturity breakdowns were calculated. Coefficient of variation (cv, standard error divided by the estimate) was estimated in the usual way after assuming that the transects were identically distributed within a stratum and that they were statistically independent. Cvs were not reported for quantities that were unlikely to be used in a stock assessment (e.g., biomass of spent fish),

Biomass was calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

Herring weight (grams)	$= 0.0016 * L^{3.4647}$ (L = length in cm)
Mackerel weight (grams)	$= 0.0018 * L^{3.3801}$ (L = length in cm)
Sprat weight (grams)	$= 0.0034 * L^{3.2853}$ (L = length in cm)
Scad weight (grams)	$= 0.0017 * L^{2.7414}$ (L = length in cm)

Hydrographic data collection

Hydrographic stations were carried out during the survey at predetermined locations along the track (Figure 1). Data on temperature, depth and theta sigma (water density) were collected using a Seabird 911 sampler at 2m subsurface and 5m above the seabed. Coverage was broken down into 3 strata with CTD casts undertaken on selected transects in each of the 3 strata. Hydrographic stations were equally spread at 6nmi spacing on each transect.

In addition to CTD casts, vessel underway data was also collected over the entire survey area providing salinity, temperature and ambient Chlorophyll A levels in the surface waters (to 5m).

Results

Herring stock size

The overall TSB (total stock biomass) estimate was generated from a total of 215 positively identified schools. Of which, over 75% was of the definitely herring category, relating to 96 positively identified schools. A much smaller contribution was made to the total by the probably and mixed schools categories, with over 20% contribution (18 schools) and over 4% (101 schools) respectively. Of the overall TSB estimate 82% was made up of 5 large schools and indeed 90% of the TSB estimate was made 10 schools.

Survey data were analysed to produce an estimate of herring abundance within the survey area and results were partitioned as follows:

Herring	Millions	Biomass (t)	% Weight
TSB Estimate			
Definitely	152.1	20900	75.3
Probably	41.7	5700	20.5
Mixture	9.1	1100	4.2
Total estimate	202.9	27770.5	100
CV	48.8	47.1	
Possibly	5.1	671.5	
Possible estimate	208.0	27828.3	
SSB Estimate			
Definitely	148.0	20507.6	75.4
Probably	40.4	5597.4	20.6
Mixture	7.6	1051.8	3.9
SSB estimate	195.9	27200	100
CV	-	48.7	

A full breakdown of the estimate is presented by biomass and abundance at age (Tables 5 & 6) and by maturity (Tables 7 & 8). The length frequency profile and age length key generated from trawl catches are present in Tables 3 & 4 respectively.

Herring distribution

A total of 26 trawl hauls were carried out over the course of the survey (Figure 1 & Table 2). Of this, 16 contained herring and 8 contained over 50% of herring by weight of the bulk catch.

The first herring encountered were in strata 1 at the start of the survey, on the north Mayo coastline (Figure 2) and were composed of mainly late autumn and early winter

spawners. Of the 4 shots carried out in strata one, all yielded herring (Table 2). This strata yielded 3 single high density herring marks, contributing a large proportion to the overall herring abundance estimate.

Maturity state of individuals in strata 1 was dominated by actively spawning fish (Hauls 2 & 3), spent and recovering individuals (Haul 1) and juvenile herring (Haul 4). The dominant length classes of mature individuals encountered was 27cm, second to 25cm. Results from maturity samples indicate that spawning was indeed still taking place in this area. This is consistent with existing knowledge of this stock component and also with anecdotal evidence from the pelagic fleet and commercial landings data which indicate that spawning was later this year compared to 2005. The high occurrence of recovering individuals (Stage 8) taken from Hauls 1, 5 and 6 (Table 2). These fish may have spawned as early as October and now appear to be migrating out of the spawning areas.

When surveyed in 2005, strata 1 contained relatively low levels of herring, comprising mainly of small marks of spent individuals indicating main spawning event(s) had taken place and outward migration from the spawning grounds was underway.

In the south of division VIaS, in strata 2, the first herring encountered were those thought to be migrating away from strata 1 after spawning (Hauls 5-
7). During the first snapshot of strata 2, marks within the main spawning areas were sparse. During the second snapshot (strata 2a, see Figures 1 and 2) some 5 days later a number of single medium density marks were encountered, although catchability was low. Information from the pelagic fleet, working this area, confirmed the difficulty of catching targeted herring marks. This may have been due to the number of vessels (up to 3 pairs of vessels of up to 10,000Hp) targeting shoals in a very localised area causing marks to break up when a vessel approached.

Samples taken within this area were composed of pre spawning and spawning individuals in the main, as would be expected from this area at this time of year.

As the survey moved north into strata 3, no commercial activity was observed. This area is associated with the latest of the winter spawning fish along the northwest coast and this run of fish maybe present until late February or early March. It was decided to start surveying strata 3 from the east and work west in the hope that the extra days would allow for the migration of herring into the main spawning areas (Limeburner and Tory grounds) associated with this strata. The eastern component of strata 3 contained some medium and large single high density herring marks. Herring in this area were found to be composed of pre-spawning and spent individuals. This indicates some level of spawning had already taken place around the Limeburner spawning box.

In the west of strata 3 (Tory Island), this area was surveyed last in the hope that herring schools had appeared on the grounds. However, few single herring marks were encountered. When surveyed in 2005, this area contributed a large proportion of the final herring abundance estimate. As a result a second snapshot was undertaken in this area, as in strata 2 to provide a final transect resolution of 1 nmi (Figures 1 and 2).

Herring stock composition

In total 599 herring were aged, 3316 length measurements and 1544 length weights were taken.

Herring samples from trawls indicated ages ranging from 1-9 winter rings (Tables 4, 5 & 6). The dominant year classes as determined from the survey were 3 and 4-year old fish, representing 37% and 30% respectively by weight and 43% and 28% by numbers of the TSB. The 5 and 6-year old fish made up 16% and 10% by weight and 14% and 8% of the estimate by numbers respectively.

Strata 1 and 4 were found to contain the broadest range of year classes (1-9), with strata 4 containing the greatest by both numbers and weight overall.

Secondary pelagic species

Mackerel were the second most frequently encountered species. Of the mackerel encountered low background levels dominated the estimate (Table 2 and Figure 4). Of those that did occur, single larger echotraces of mackerel were found in deeper offshore waters commonly along the 70-90m depth contours. Of the estimate 103 schools made up 90% of the total estimate, with one school in particular making up 8% of the estimate, with the remaining larger schools accounting for 3% or less. Size ranged between 16-36 cm, with mean length occurring at 18cm. The low density but wide spread distribution of mackerel within this size range (2-3 years old) is consistent with findings from an earlier acoustic survey in the Celtic Sea in October 2005 (O'Donnell *et al.,* 2005). Indeed, anecdotal evidence suggests a high occurrence of mackerel of this size within Irish coastal waters since early October.

The mackerel estimate of abundance was generated solely from the 38KHz frequency data, higher frequencies were used only as an aide for identification of mackerel schools.

Mackerel	Millions	Biomass (t)	% weight
Total estimate			
Definitely	180	6171.9	47.5
Probably	105.8	6830.0	52.5
Mixture	0	0	
Total estimate	285.8	13001.9	100

Hydrography

During the survey nine CTD transects (45 casts) were carried out to examine the vertical distribution of temperature, salinity and density (Figures 7-15). Apart from Transect 5, temperature, salinity and density ranges were quite narrow throughout the survey. Temperatures ranged between 9.0°C and 10.6°C, the warmest areas being the offshore stations outside the influence of colder freshwater input. The variation across transects ranged between 0.4 and 1.3 degrees throughout the water column. Salinities showed a similar pattern, ranging from 34.3ppt to 35.4ppt. Salinity differences over the transects ranged between 0.2 and 0.8 ppt. Evidence of stratification was strong only at Transect 5, with a weaker band appearing at Transect 4. Some evidence of coastal freshwater was found in the innermost stations of all transects in Strata 2.

The survey was divided into five strata. Strata 1 comprised Transects 1 to 5 (Figures 7-11), along the north coast of Mayo and Sligo, northwards to 54° 35N. Transects 6, 7 and 9 (Figures 12,13 &15 respectively) were located in Strata 2, off the west coast of Donegal, running westwards to 9°40W. Transect 8 (Figure 14), in Strata 3, started northwest of Bloody Foreland, running northwards to 56°N, along acoustic track 48.

Transects 1 to 4 consisted of three stations each, with Transect 5 having only 2. Transect 1 was carried out north of Porturlin with station intervals of four miles. Depths ranged from 40m to 96m. Transects 2, northwards from Lacken, and 3, northwards from Lenadoon, were carried out east and west of the Moy estuary. Stations for Transect 2 were at 4.5 mile intervals and depths ranged from 41m to 88m. Stations for Transect 3 were 5 miles apart with depths from 30m to 72m. Transect 4 was north of Roskeeragh Point, in Sligo. Depths ranged from 23m to 76m, and again station intervals were 5 miles. Transect 5 ran northwards from Bundoran, with depths of 21m and 26m.

Transects 1 and 2 showed little change in temperature, salinity or density through the water column. In Transect 3 changes in surface temperature and salinity were found, showing the impact of the river Moy. These changes are only found at station 7, where a colder, freshwater layer can be seen extending down to 20m. This freshwater influence did not extend very far offshore. Across transect 4 a surface layer of cold, freshwater can be seen, extending down to 15m. Station 12, the northern station, reflects this the most. This possibly indicates the path taken by freshwater from the river Erne, in Ballyshannon, and other Donegal rivers, under the influence of the strong southeasterly wind prevailing at that time. Transect 5, the most inshore of the survey, shows the greatest variation in all three parameters. The range in temperature values is nearly 3°C, and in salinity is nearly 4ppt. Strong stratification in temperature and salinity can be found at 9m. Once again the northern station, station 14, shows the greatest impact of the freshwater.

Transect 6 ran westwards from Glen Head, consisting of 6 stations, seven miles apart, ranging in depth from 50m to 100m. Transect 7 ran west of Dungloe, and consisted of 7 stations, again, seven miles apart, with depths ranging from 29m to 92m. Transect 9 comprised 7 stations, at eight mile intervals, ranging in depth from 48m to 116m, running west from Gweedore. While all three Transects showed the influence

of some coastal freshwater at their innermost stations, the deeper stations showed little variation in temperature or salinity throughout the water column. The three transects showed similar patterns with the warmest, most saline, water being recorded in the most westerly, deeper, stations.

Transect 8 consisted of 10 stations, ranging in depth from 84m to 133m, at intervals of six miles. While this transect recorded the highest values for temperature and salinity in the survey, the range in temperature and salinity along the transect was quite narrow, similar to those found in Transects 1 and 2. There was no sign of a freshwater influence.

Concluding remarks

Overall the survey was deemed a success. The acoustic component of the survey was completed with only a small degree of temporal and spatial interruption due to poor weather conditions. The hydrographic component had to be cut short to allow for completion of the acoustic transects and as a result only surface data from the vessels underway data collection system was obtained over the entire survey area.

The survey area was stratified into a number of components, most notably sub areas 2a and 3a. Sub-stratification was carried out provide a second snapshot in areas of known herring occurrence, with each snapshot separated by a number of days. Samples taken from commercial landings and geographical fishing effort indicated that herring in the northern survey area had yet to arrive in any significant numbers. This was also confirmed by information from skippers actively targeting the fleet. Overall, this suggested that herring schools were up to 3 weeks later in arriving in 2006 as compared with the same time last year.

The arrival of schools into the survey area was observed when the vessel had to return to port for a scheduled port call, on arrival back into the area, it was evident that herring were present by the presence of relatively large schools in a known spawning area (Limeburner spawning box).

The year on year variation, which may be up to one month, of the arrival of herring schools highlights the important of accurate timing. Timing is vital is therefore vital when trying to estimate a number of sub components within a known stock. This is reflected in the almost 50% difference between TSB estimates between 2005 and 2006, when survey timing was consistent.

Acknowledgments

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We would also like to thank Frankie Griffin (Gear Consultant) for his help and invaluable advice on the fishing gear.

References

Anon. (1994). Report of the planning group for herring surveys. *ICES C.M. 1994/H:3*

Anon (2002) Underwater noise of research vessels. Review and recommendations. 2002. ICES No. 209

Breslin, J.J. (1999). The location & extent of the main herring, *Clupea harengus*, spawning grounds around the Irish Coast. *M.Sc. Thesis*

Dalen, J. and Nakken, O. (1983) "On the application of the echo integration method" *ICES CM 1983/B:19*

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.* 82: 981-987

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N. and Simmonds, E.J. (1987). Calibration of acoustic instruments for fish density estimation: a practical guide. *Int. Coun. Explor. Sea. Coop. Res. Rep.* 144: 57 pp

MacLennan, D. N & Simmonds, E. J. 1991. *Fisheries Acoustics*. Chapman Hall, London,England.

Molloy, J., Kelly, C. & Mullins, E. 2000. Workshop report of a meeting with industry. Review of fisheries and biological information on herring in VIaS and VIIbc. Marine Institute internal publication.

O'Donnell, C., Griffin. K., Clarke, M., Lynch. D, Ulgren. J., Goddijn, L., Wall. D., and Mackay, M. (2004). Celtic Sea Herring Acoustic Survey Report, 2004.

O'Donnell, C., Doonan, I., Johnston, G., Lynch, D., Dransfeld, L. & Wall, D. Celtic Sea Herring Acoustic Survey Cruise Report. 2005.

O'Donnell, C., Mullins, E., Power, G., Goddijn, L., & Mackay, M. Blue Whiting Acoustic Survey Cruise Report. 2005

List of Participants

FSS	Leg
Ciaran O'Donnell (SIC)	1 & 2
Deirdre Lynch	1 & 2
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Robert Bunn	1
John Boyd	1
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Afra Egan	2
Kieran McCann	2
Oral Hanniffy	2

Other

Frankie Griffin (Fishing gear consultant)

Table 1. Settings for the Simrad ER 60 echosounder, employed during the Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey, January 2006.

Echo sounder:	Simrad ER 60
Frequency:	38 kHz
Transducer:	ES 38B- Serial
Absorption Coefficient:	0.067 dB/Km (manual)
Pulse length:	1.024 m/s
Bandwidth:	2.425 KHz
Transmitting Power:	2000 W (Max)
Angle Sensitivity:	21.9 dB
2- way beam angle:	-20.6
Gain:	25.98
S_A Correction:	-0.67
3 dB Beam Width:	
Alongship:	6.96°
Athwartship:	7.04°
Max Range:	500m

Table 2. Northwest herring acoustic survey 2006. Position, water depth, depth of trawling and percentage species composition of fishing hauls. (* denotes: non pelagic species and invertebrate catch).

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Others* %
1	05-Jan	54 32.58	9 47.64	18:15	97	0	650	100				
2	06-Jan	54 28.87	9 05.29	20:39	65	10	170	100				
3	07-Jan	54 24.63	9 02.22	00:20	57	0	3000	100				
4	07-Jan	54 33.09	8 30.43	17:50	57	5	29	22			47	31
5	08-Jan	54 40.87	9 38.18	10:36	104	0	500	58.3	41.7			
6	08-Jan	54 42.94	9 35.35	12:55	102	0	2000	31.46	68.54			
7	09-Jan	54 49.07	9 01.66	04:03	78	0	9	26	53			21
8	09-Jan	54 52.88	8 36.17	14:08	47	0	0					
9	09-Jan	54 33.29	8 59.82	18:00	76	0	0					
10	11-Jan	55 05 47	8 48.21	05:55	88	0	0					
11	11-Jan	55 33.73	8 52.70	17:37	102	0	5	2.5	38.46			59
12	12-Jan	55 59.61	8 48.00	23:50	134	4	11		1.78	65.19		33.03
13	13-Jan	56 00.2	8 48.00	08:44	133	8	750		98.9	1.1		
14	15-Jan	55 34.02	07 21.29	11:05	59	7	25	0.79	2.64			96.65
15	16-Jan	55 35.20	7 21.31	13:25	62	10m - 35m	0					
16	17-Jan	54 47.68	09 5.02	08:50	89	4	2	28.22			17.18	54.6
17	17-Jan	54 49.71	8 54.29	12:40	83	3	0					
18	17-Jan	54 52.02	8 57.70	16:48	73	15	71	99.43	0.53		0.03	0.01
19	17-Jan	54 54.10	8 52.51	21:35	72	22	48	97.97	0.41			1.62
20	18-Jan	55 31.54	7 39.62	14:55	68	8	1	74.24	15.15			10.6
21	19-Jan	55 28.66	7 46.76	00:46	62	4m-12m	250	100				
22	20-Jan	55 45.33	7 54.19	14:36	97	10	1500		4.9	94.9		0.2
23	21-Jan	55 26.64	8 12.18	06:00	80	11	0					
24	21-Jan	55 50.15	8 15.68	13:10	154	9	1700	6.26	93.67		0.06	
25	21-Jan	55 39.89	8 19.61	17:45	98	6	250		100			
26	22-Jan	55 45.95	8 30.60	13:12	115	6	57	18.24	78.47	3.26		

Table 3. Length Frequency of Herring measured per survey haul in actual numbers of individuals measured. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006. Note: Com indicates data from a commercial catch used for validation.

Length (cm)	1	2&3	5&6	24	21& Com	Grand Total
13						0
13.5						0
14						0
14.5						0
15						0
15.5						0
16						0
16.5						0
17						0
17.5						0
18						0
18.5						0
19						0
19.5						0
20						0
20.5						0
21				2	1	3
21.5			2	6	2	10
22			2	7	4	13
22.5	1		3	3	2	9
23	2	3	18	4	5	32
23.5	6	15	34	4	7	66
24	9	28	62		20	119
24.5	15	48	78	3	28	172
25	32	88	90	3	43	256
25.5	31	84	109	11	48	283
26	39	70	92	13	80	294
26.5	37	67	67	5	61	237
27	50	112	76	5	85	328
27.5	60	58	65	4	74	261
28	45	38	48	1	54	186
28.5	15	15	19	3	44	96
29	6	6	7	1	18	38
29.5	4	1			11	16
30	1		2		5	8
30.5				1	2	3
31					3	3
31.5					1	1
32					0	0
32.5					0	0
33					0	0
33.5					1	1
Grand Total	353	633	774	76	599	2435

Table 4. Herring Age length key, determined from survey haul samples. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006.

Length (cm)	0	1	2	3	4	5	6	7	8	9	Total
13											
13.5											
14											
14.5		3									**3**
15		4									**4**
15.5		4									**4**
16		9									**9**
16.5		2									**2**
17		2									**2**
17.5		1									**1**
18											**0**
18.5											**0**
19											**0**
19.5											**0**
20											**0**
20.5											**0**
21			1								**1**
21.5			4								**4**
22			4								**4**
22.5			3								**3**
23			3	1							**4**
23.5			1	6							**7**
24			1	15							**16**
24.5		1	1	27							**29**
25			1	36	2	1					**40**
25.5				38	9						**47**
26				42	23	3	1				**69**
26.5				21	34	12	1				**68**
27				2	44	21	5	1			**73**
27.5				1	33	25	16	1	1		**77**
28					20	18	15	6			**59**
28.5				1	5	7	16	4			**33**
29					1	7	7	6			**21**
29.5							2	2	1		**5**
30						1		1	1	1	**4**
30.5							2	1	1		**4**
31								1	2		**3**
31.5									1		**1**
32											**0**
32.5											**0**
33											**0**
33.5									1		**1**
34											**0**
34.5									1		**1**
Total	**0**	**26**	**19**	**190**	**171**	**95**	**65**	**23**	**9**		**599**

Table 5. Numbers of individuals (millions) by age (winter rings) class per strata. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006.

Strata/Rings	0	1	2	3	4	5	6	7	8	9	Total
1	0	1.3	1.7	40.4	30.6	15.9	9.3	2.6	0.4	0.1	102.4
2	0	0.1	0.8	15.8	6.8	3	1.7	0.5	0.1	0	28.8
2a	0	0	0.2	4.1	2.8	1.5	1	0.3	0.1	0	10
3	0	0	2.1	3	1.6	0.6	0.4	0.1	0	0	7.9
3a	0	0	0	0.4	0.2	0.1	0.1	0	0	0	0.8
4	0	0.1	2	21.6	14.6	6.3	3.2	1.2	0.7	0.2	49.8
5	0	0	0.1	1.3	0.9	0.4	0.2	0.1	0	0	3.2
Total	0	1.6	6.9	86.7	57.5	27.9	16	4.8	1.3	0.2	202.9
%	0	0.8	3.4	42.7	28.4	13.7	7.9	2.4	0.6	0.1	100
CV (%)	0	92.9	37.8	42.8	50.9	54.9	58.4	57.8	57.6	75.5	0.7

Table 6. Biomass (tonnes) by age class per strata. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006.

Strata/Rings	0	1	2	3	4	5	6	7	8	9	Total
1	0	48.2	160.8	4827.9	4565.2	2508.2	1569.5	465.8	73.7	10.9	14230.4
2	0	12.5	77.5	1844.4	985.7	467.7	287.1	88.1	12.6	0.6	3776.2
2a	0	2.7	19.2	489.2	420.6	240.6	169	58.3	12.1	1.9	1413.6
3	0	1.2	157.9	360.3	219.1	91.1	74.2	22.6	6.9	0	933.3
3a	0	0.2	2.7	42.8	34.5	17.5	11.3	4.5	2	0.4	115.9
4	0	9.6	170.2	2635.4	2098.5	982.7	547.3	222.4	161.2	34.3	6861.5
5	0	0.7	10.2	162.4	131	66.2	42.8	17.1	7.5	1.6	439.5
Total	0	75	598.4	10362.4	8454.6	4374.1	2701.3	878.8	276.1	49.8	27770.5
%	0	0.3	2.2	37.3	30.4	15.8	9.7	3.2	1	0.2	100

Table 7. Biomass (tonnes) by maturity stage per strata. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006.

Strata	Immature	Mature	Spent	SSB
1	0.2	8.4	5.6	14
2	0.1	2.2	1.5	3.7
2a	0	0.9	0.5	1.4
3	0.1	0.5	0.3	0.8
3a	0	0.1	0	0.1
4	0.2	4.2	2.5	6.7
5	0	0.3	0.2	0.5
Total	0.6	16.5	10.6	27.2
%	2.2	59.6	38.2	100

Table 8. Numbers of individuals (millions) by maturity stage per strata. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey 2006.

Strata	Immature	Mature	Spent	SSN
1	3	59.5	39.8	99.4
2	0.8	16.7	11.3	28.0
2a	0.2	6.0	3.8	9.8
3	1.3	4.5	2.1	6.6
3a	0.0	0.5	0.3	0.8
4	1.6	29.7	18.6	48.2
5	0.1	1.9	1.2	3.1
Total	7.0	118.7	77.2	195.9
%	3.4	58.5	38.0	100

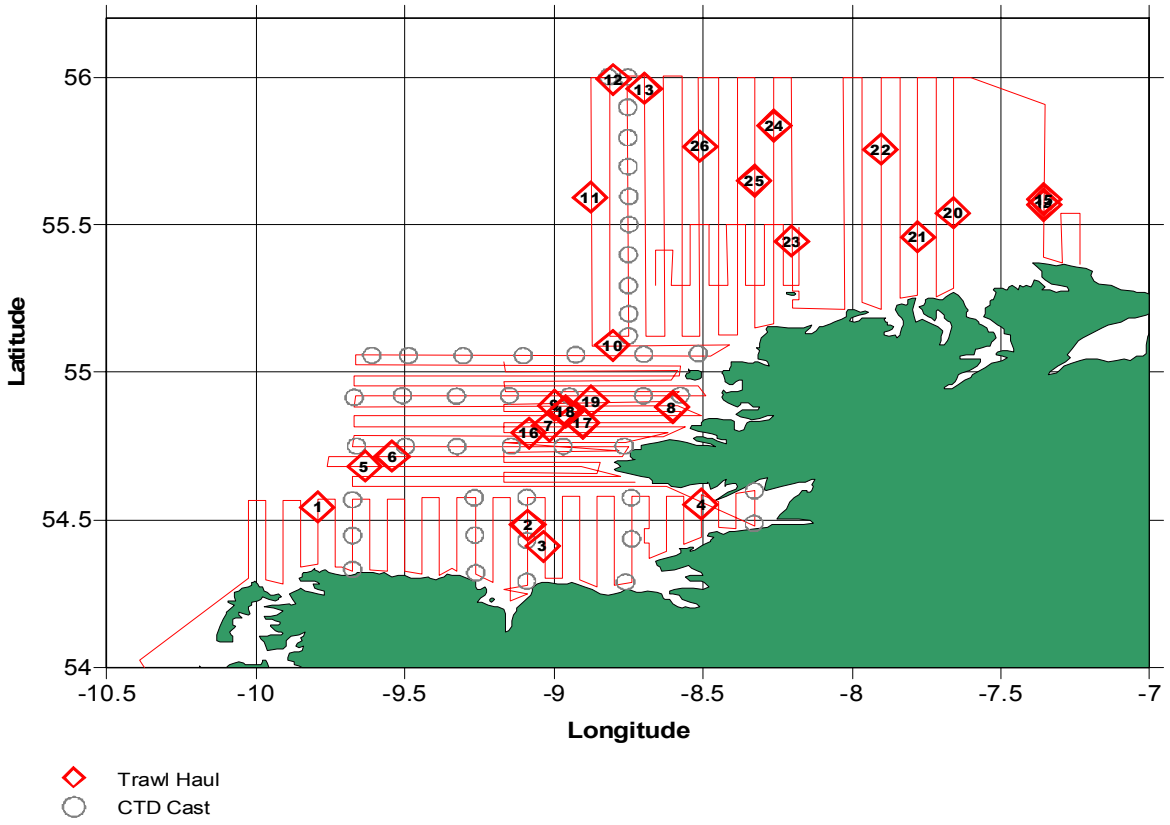


Figure 1. Acoustic cruise track showing survey haul positions and CTD stations. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey, January 2006.

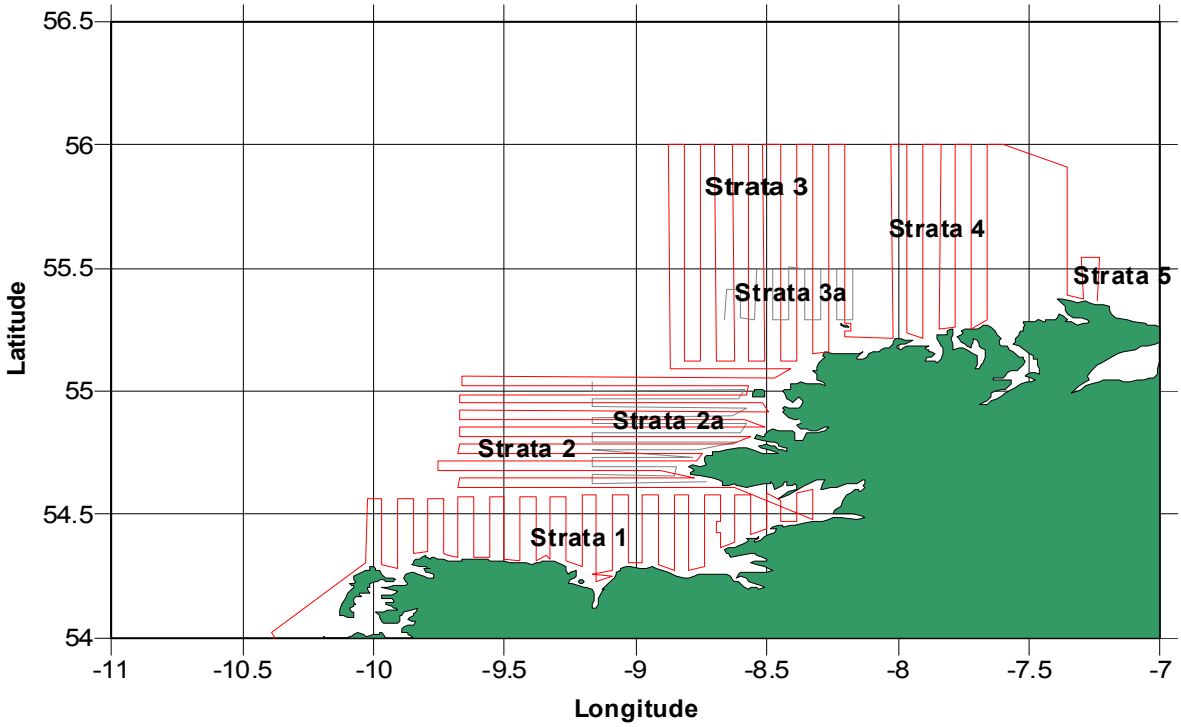


Figure 2. Survey area as stratified for species abundance estimation. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey, January 2006.

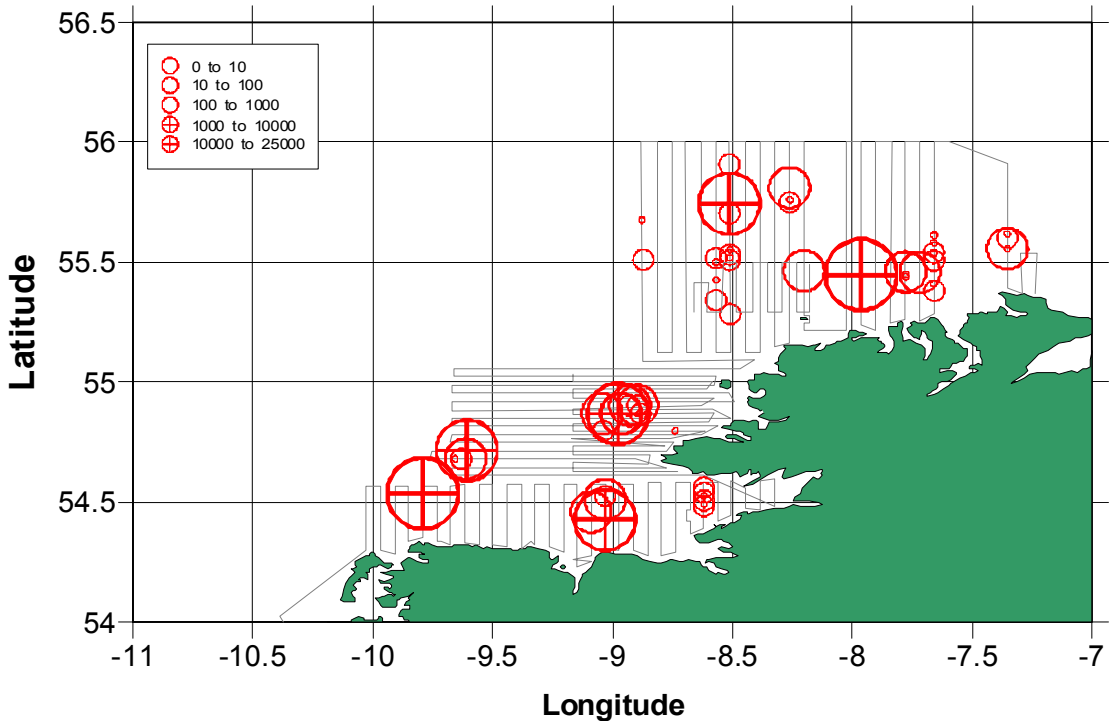


Figure 3. Post plot of herring NASC values of "Definitely" and "Probably" herring categories only. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey, January 2006.

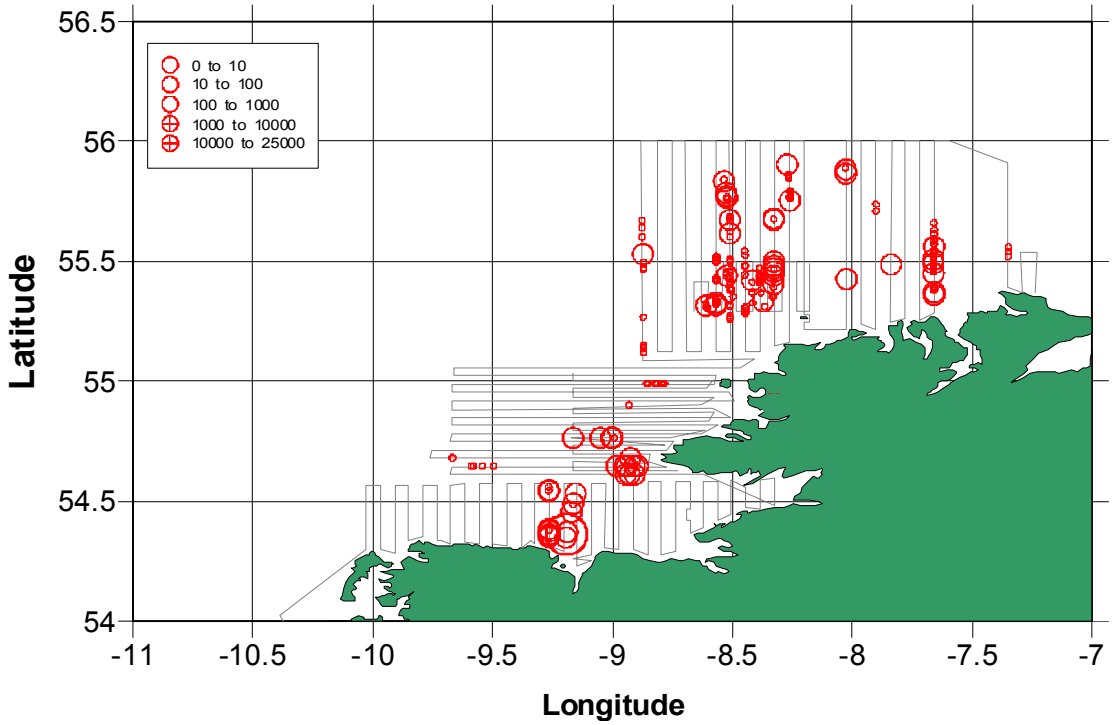
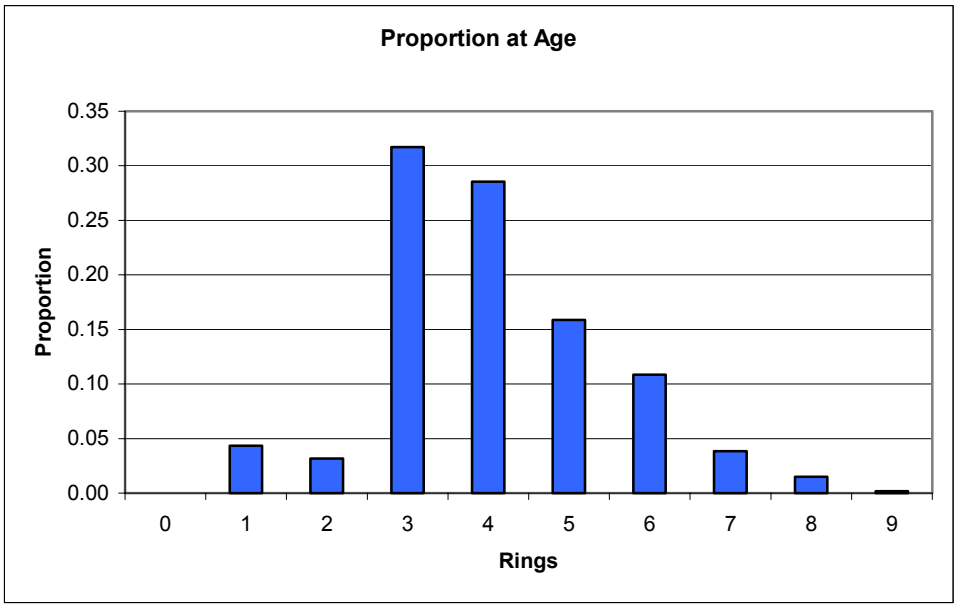


Figure 4. Post plot of mackerel NASC values of "Definitely" and "Probably" herring categories only. Northwest and west coast (Divisions VIaS and VIIb) herring acoustic survey, January 2006.



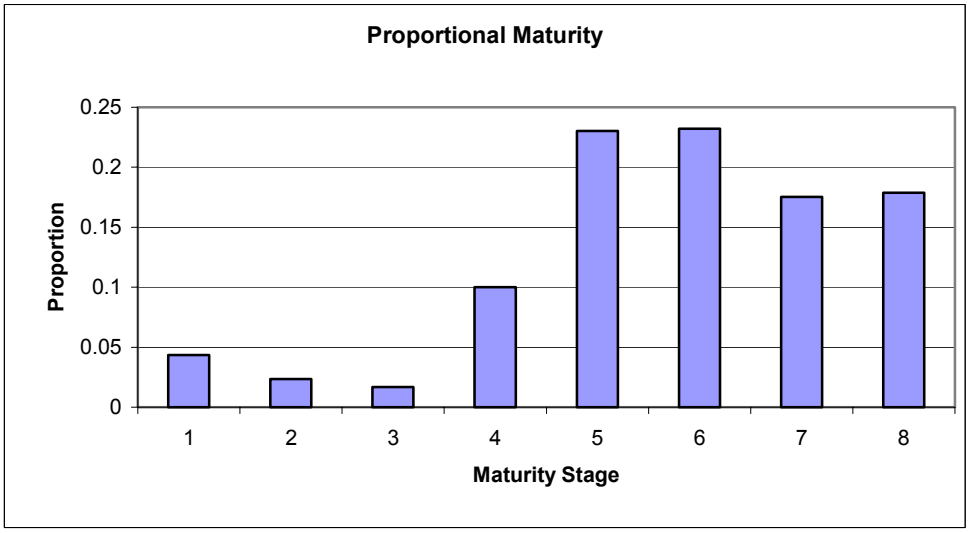
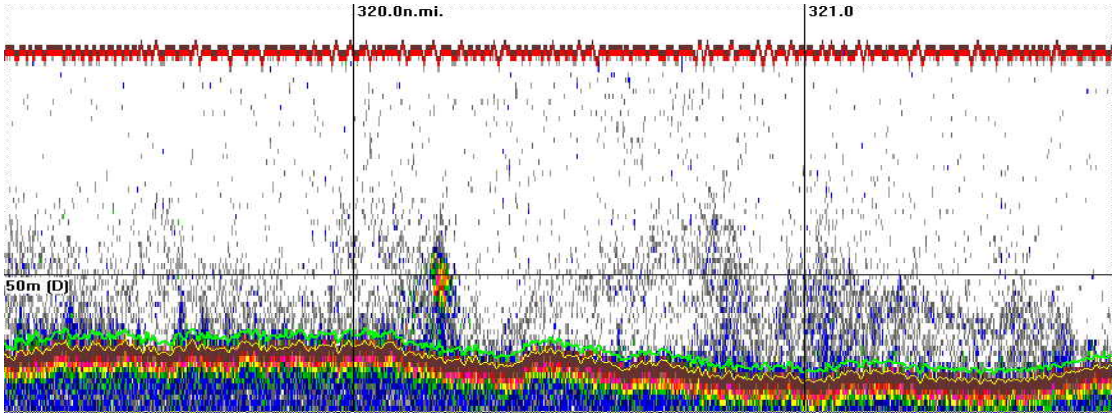
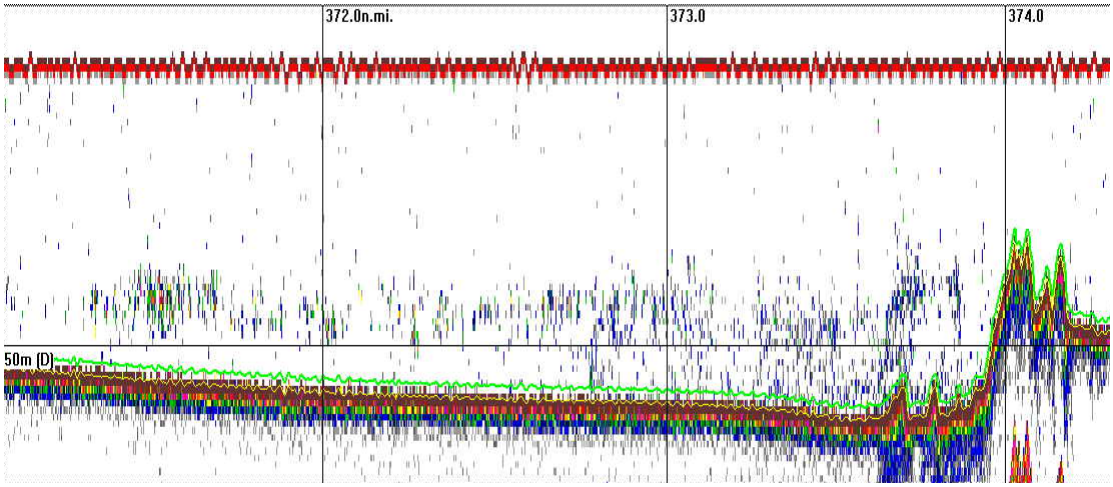


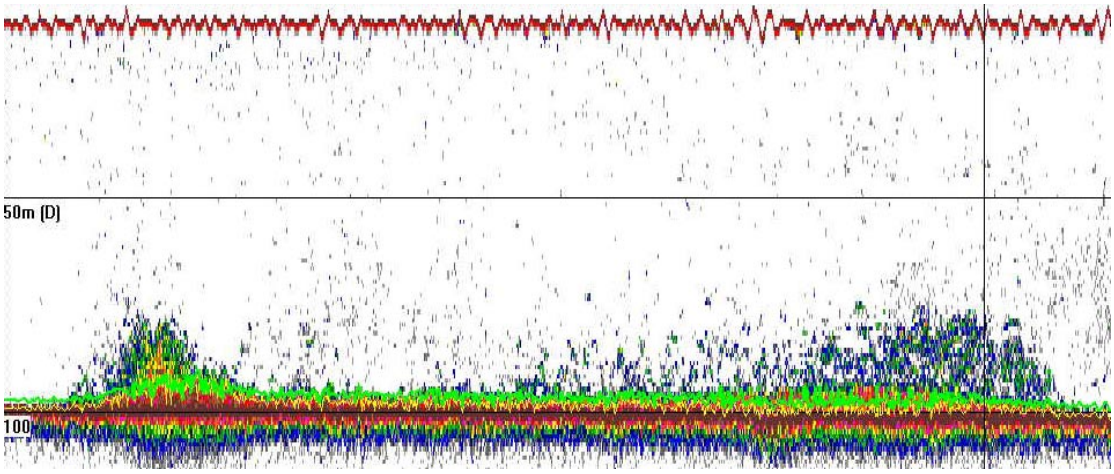
Figure 5. Proportion at age and maturity of stock derived from survey and a single commercial sample. Northwest Herring Acoustic Survey, January 2006.



a). Herring mark 10m off the bottom and approx 12m tall. 100% herring all stage 6 spawners. Location: 11.2nmi N of Leenadoon at 18:00. Haul 02.

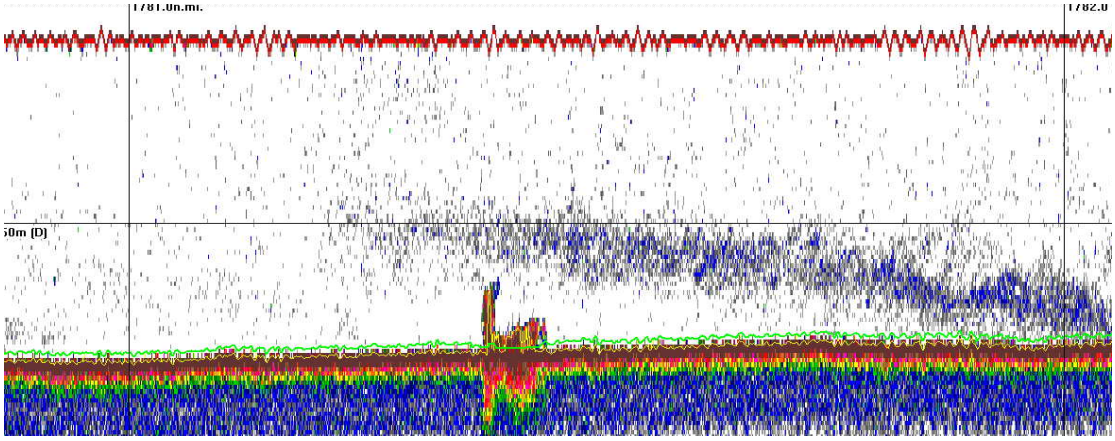


b). Juvenile herring mark and sprat mix 5-15m off the bottom. Location 1.8 nmi SW of St Johns Point at 17:50. Haul 04.

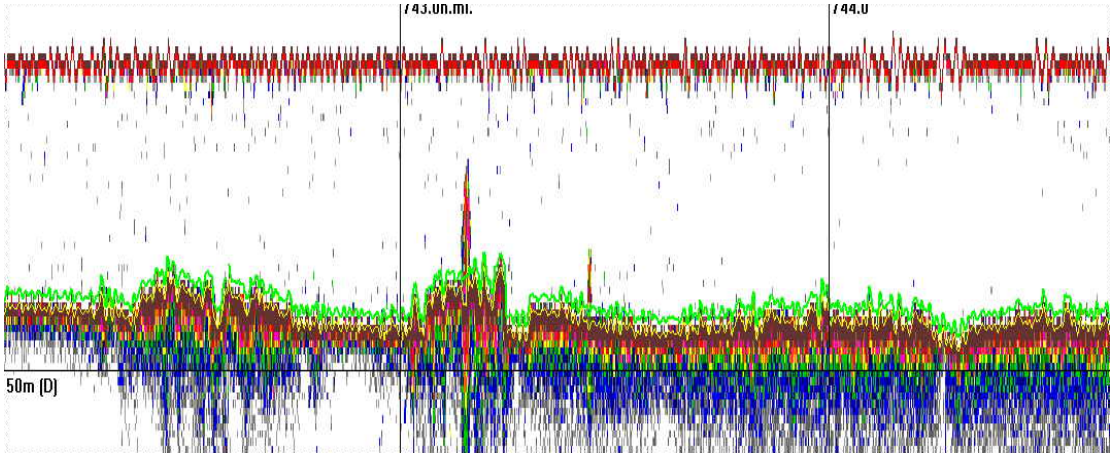


c). Spent herring mark 12m tall on shooting. Location 11.2 nmi N of Benwee Head at 18:15. Haul 01.

Figure 6. Echograms recorded on track and during trawling operations. Northwest Herring Acoustic Survey, January 2006.



d). Herring mark, very difficult to catch 9m tall on shooting. Location 12 nmi NW of Roanish Island at 08:50. Haul 16. Poor catchability also report by commercial operators working in the same area



e). Small mackerel (19-24cm range)15m tall, numerous spikes found over rough ground. Location 3 nmi WNW of Roanish Island at 14:08. Haul 08. Very difficult to catch.

Figure 6. Continued.

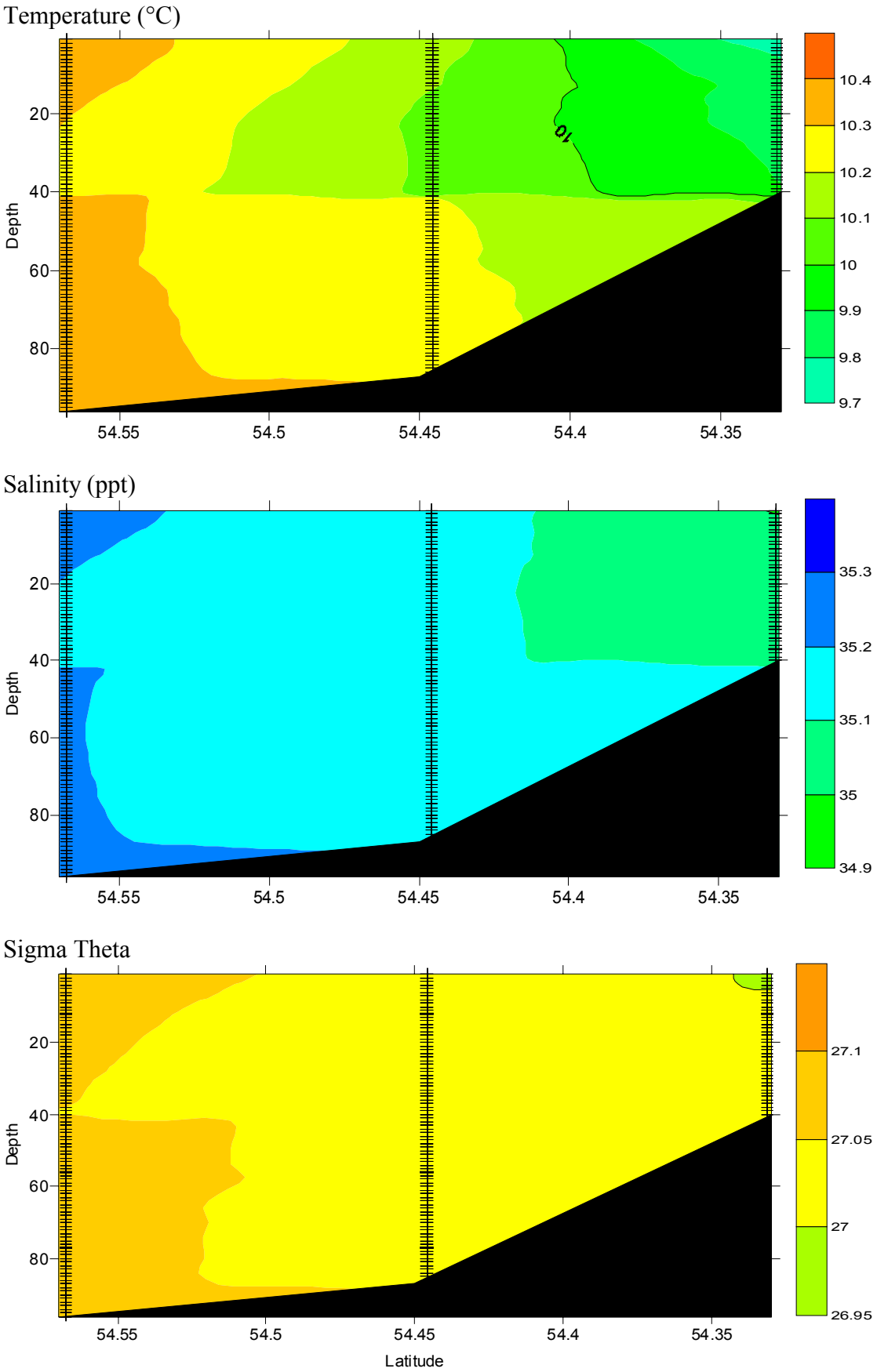


Figure 7. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T1, sites 1-3.

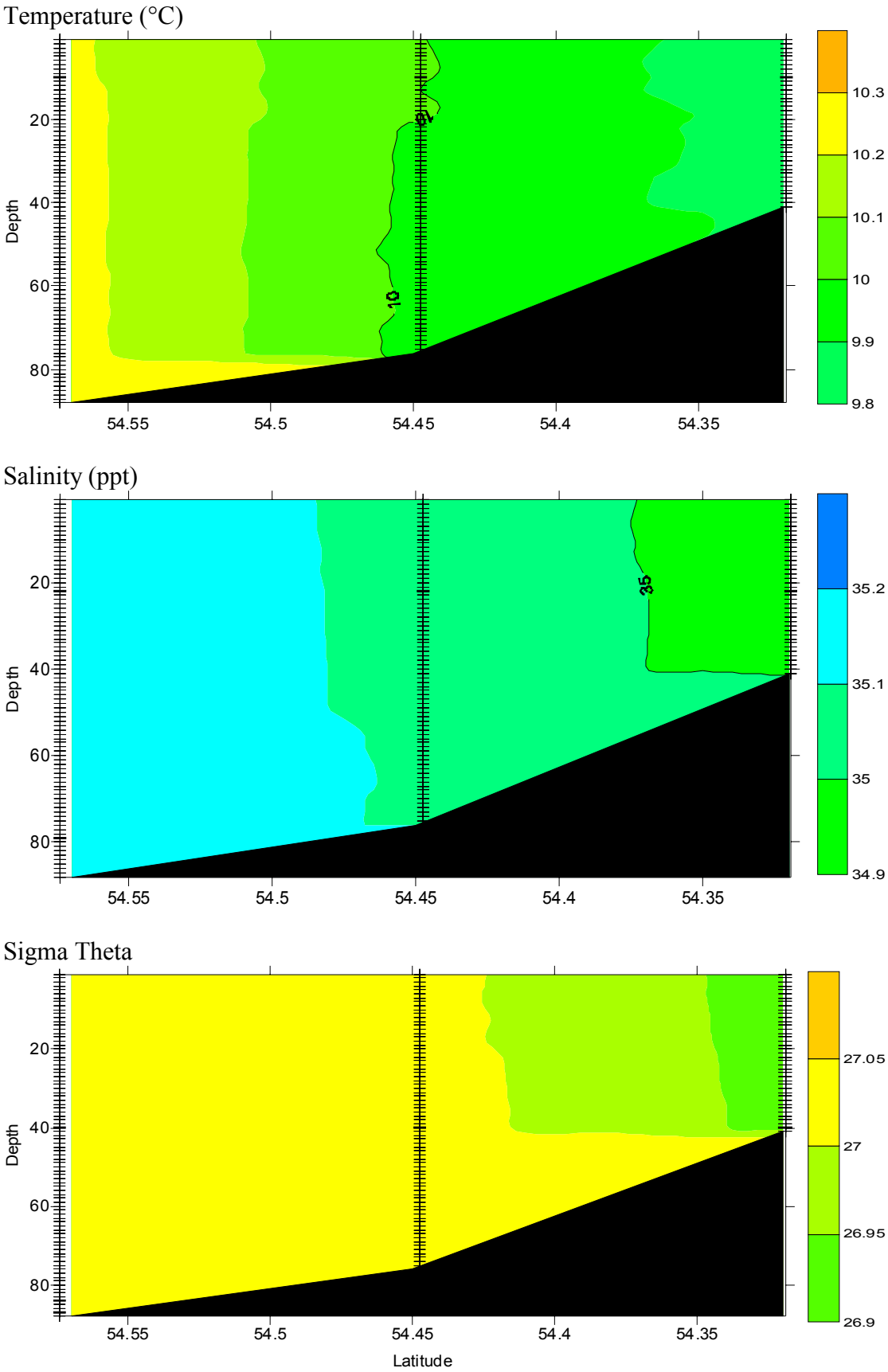


Figure 8. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T2, sites 4-6.

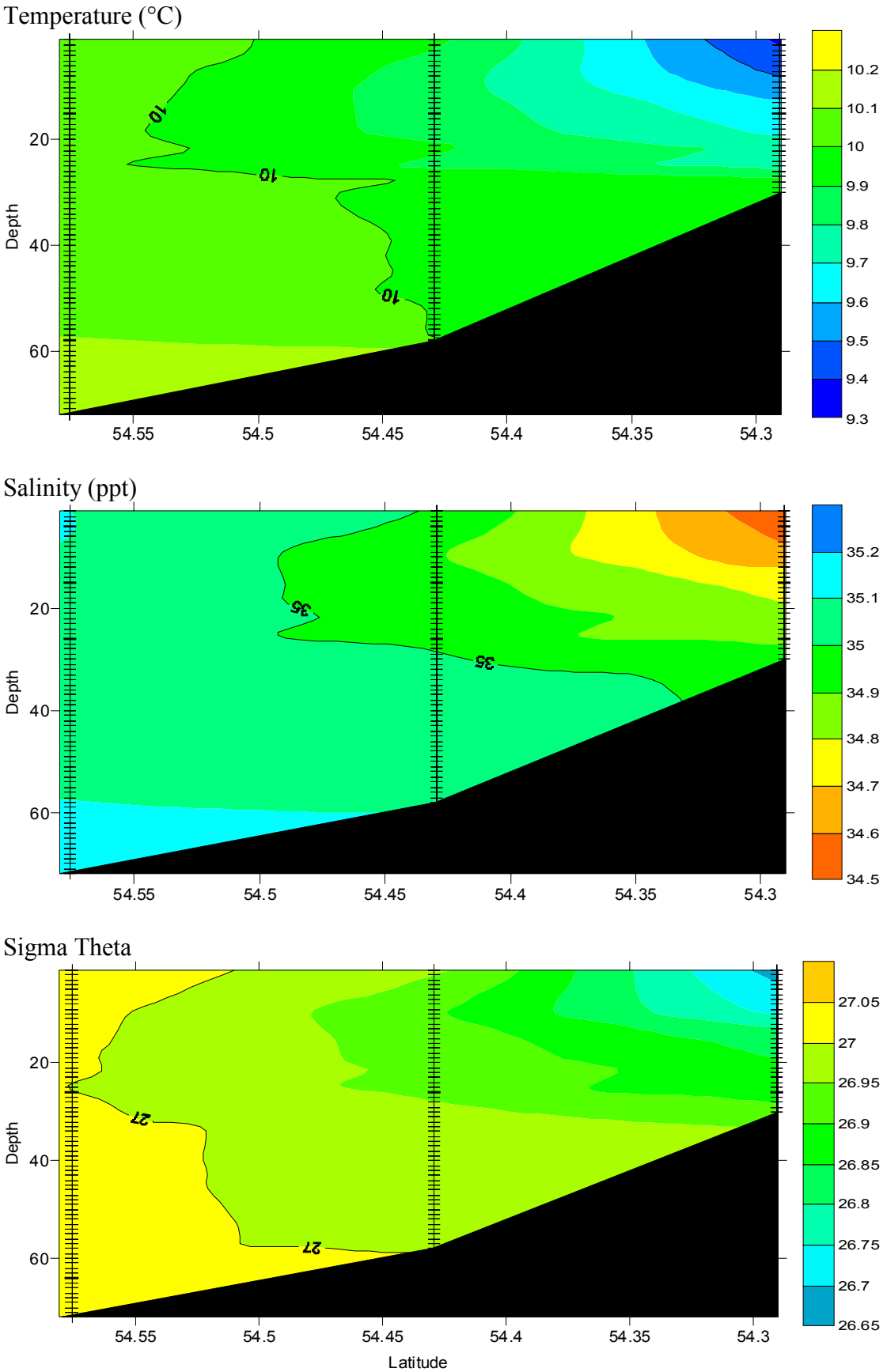


Figure 9. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T3, sites 7-9.

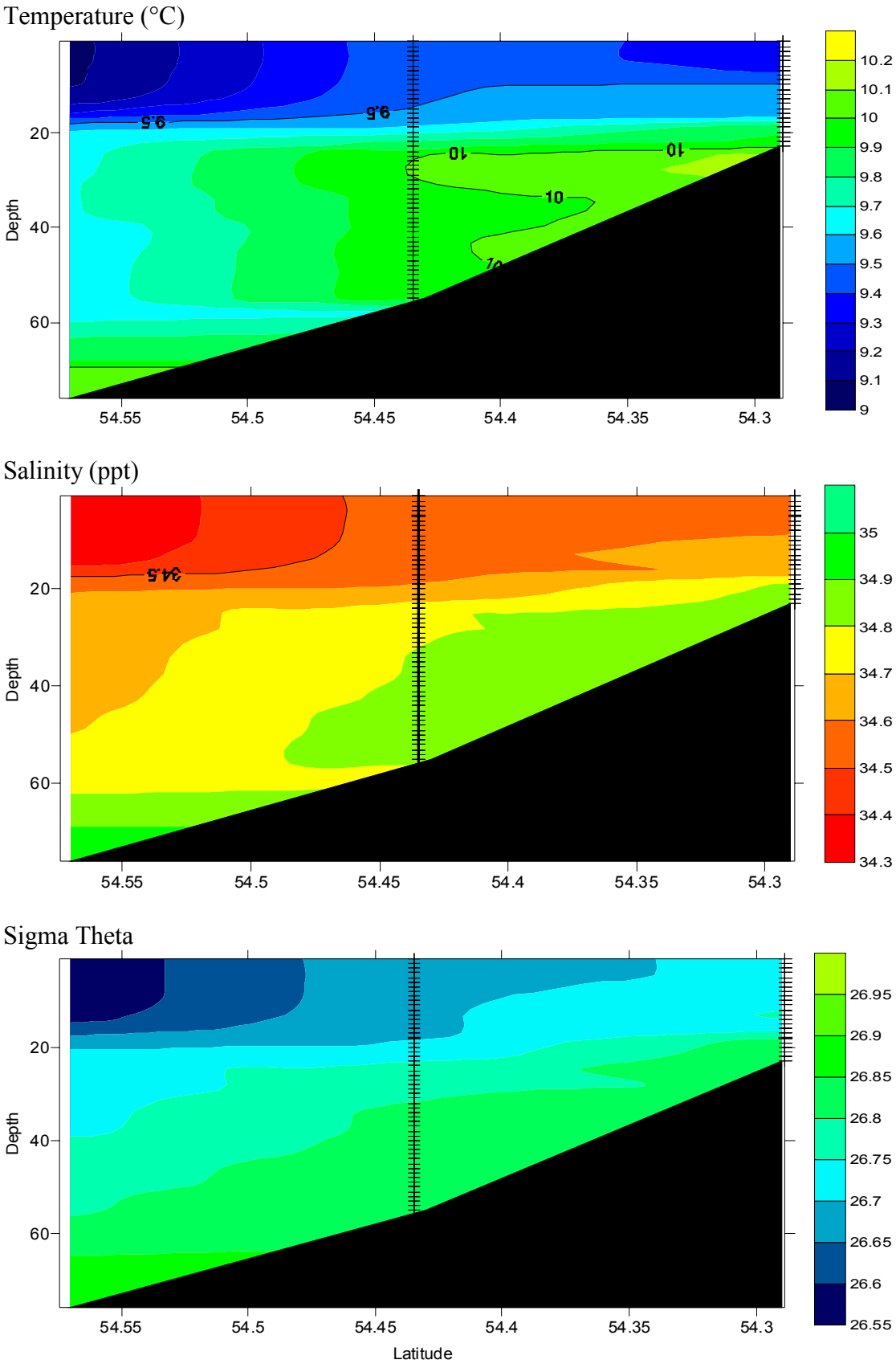


Figure 10. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T4, sites 10-12.

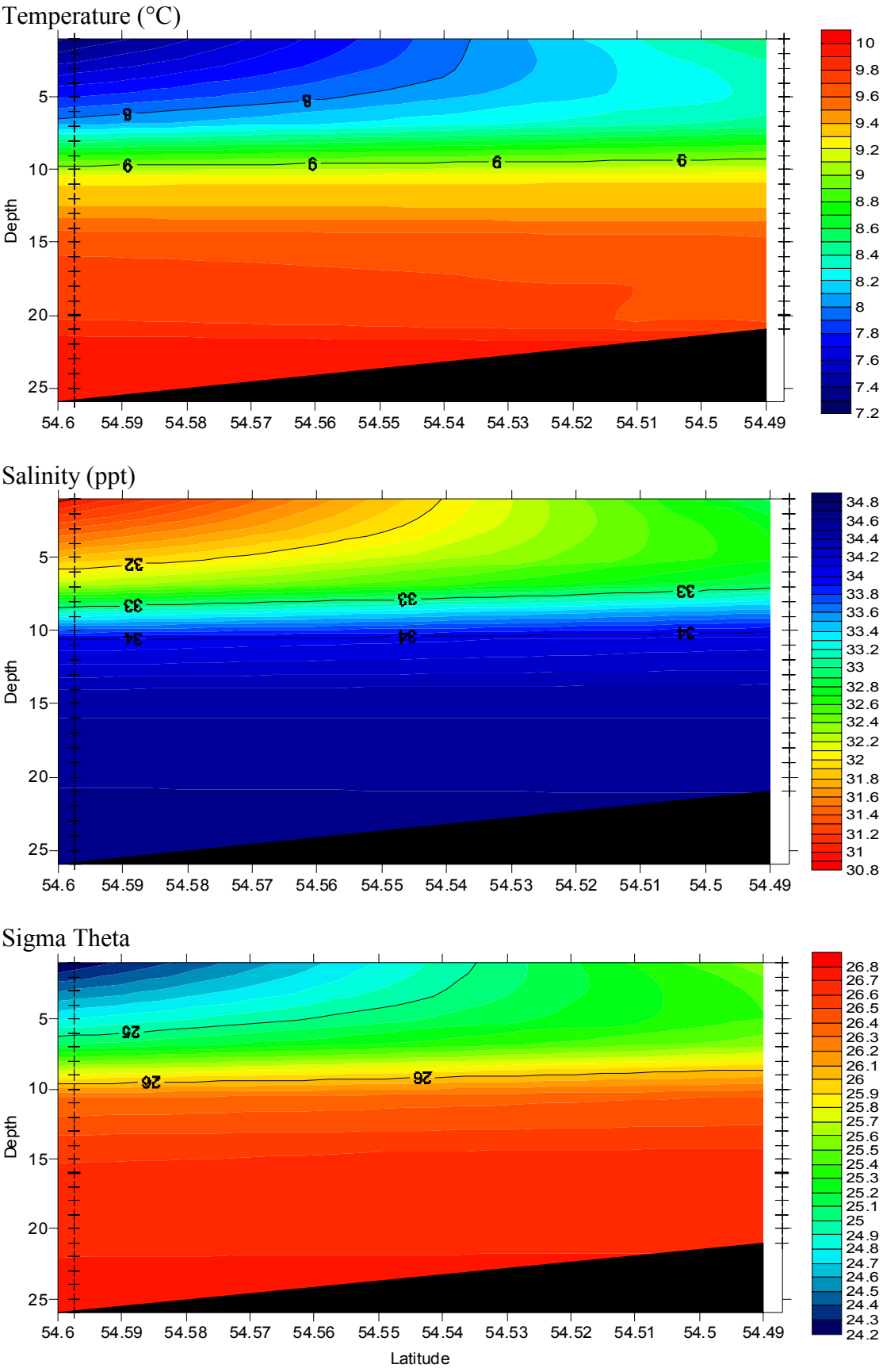


Figure 11. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T5, sites 13-14.

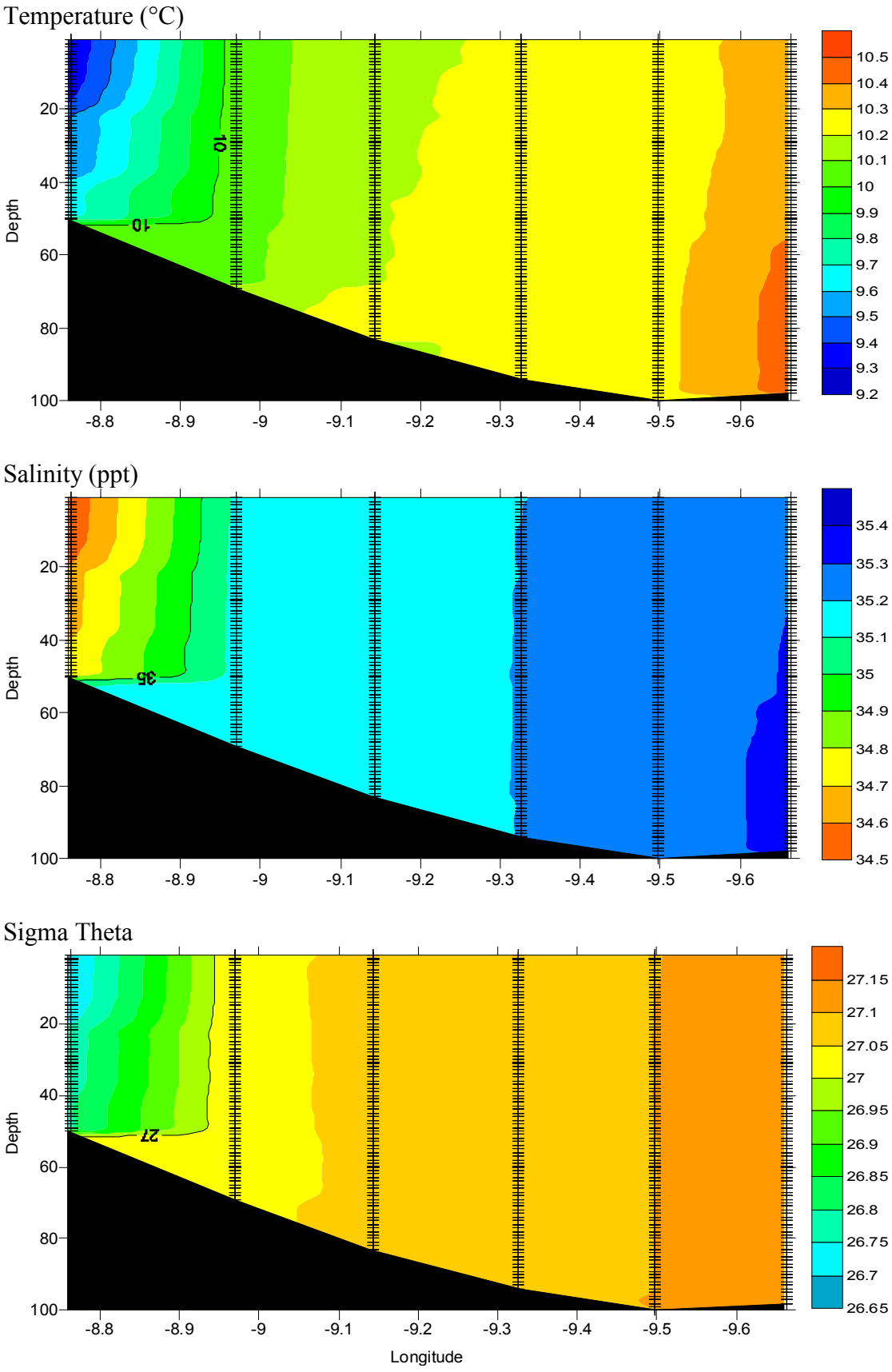


Figure 12. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T6, sites 15-20.

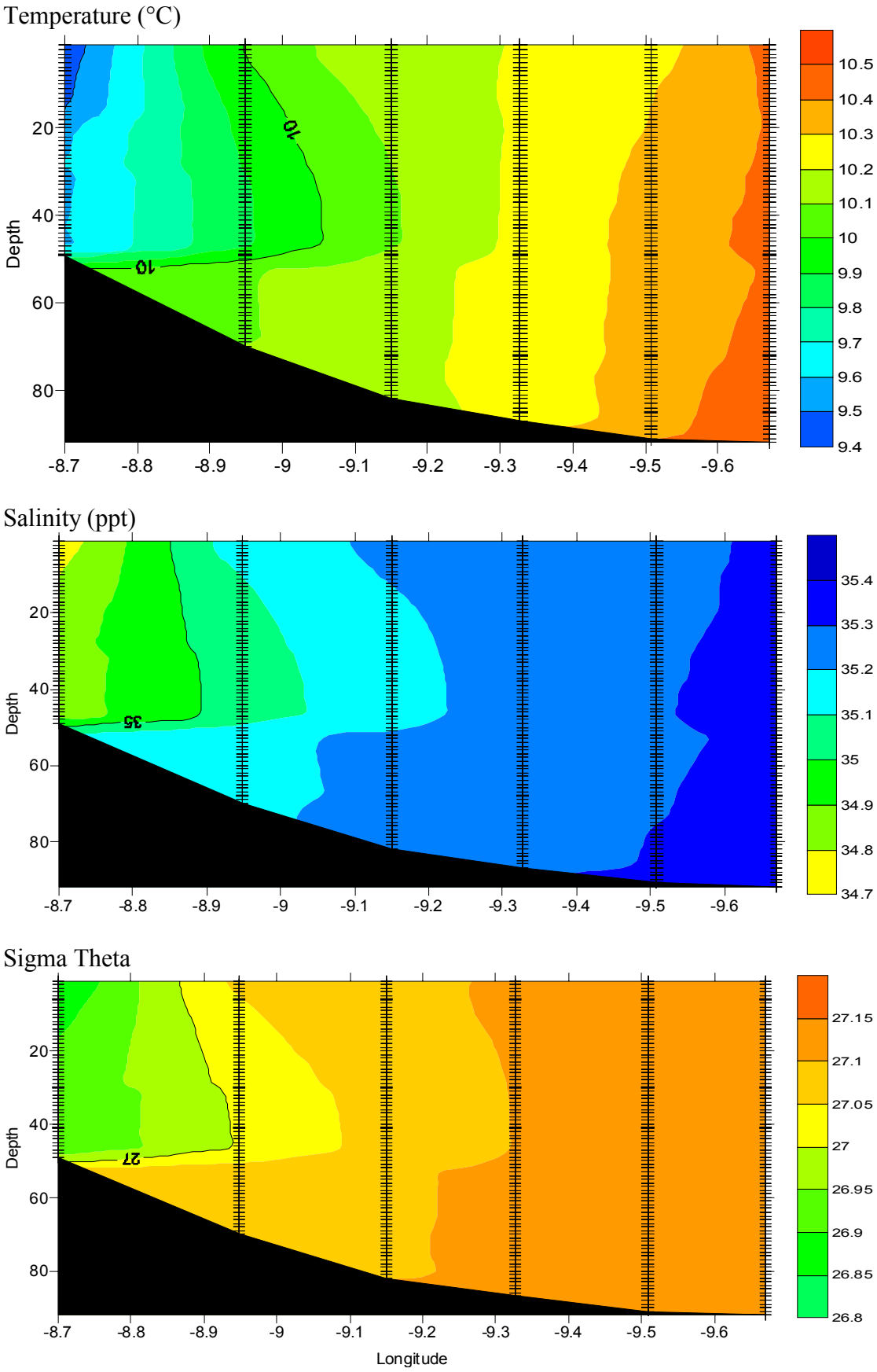


Figure 13. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T7, sites 21-27.

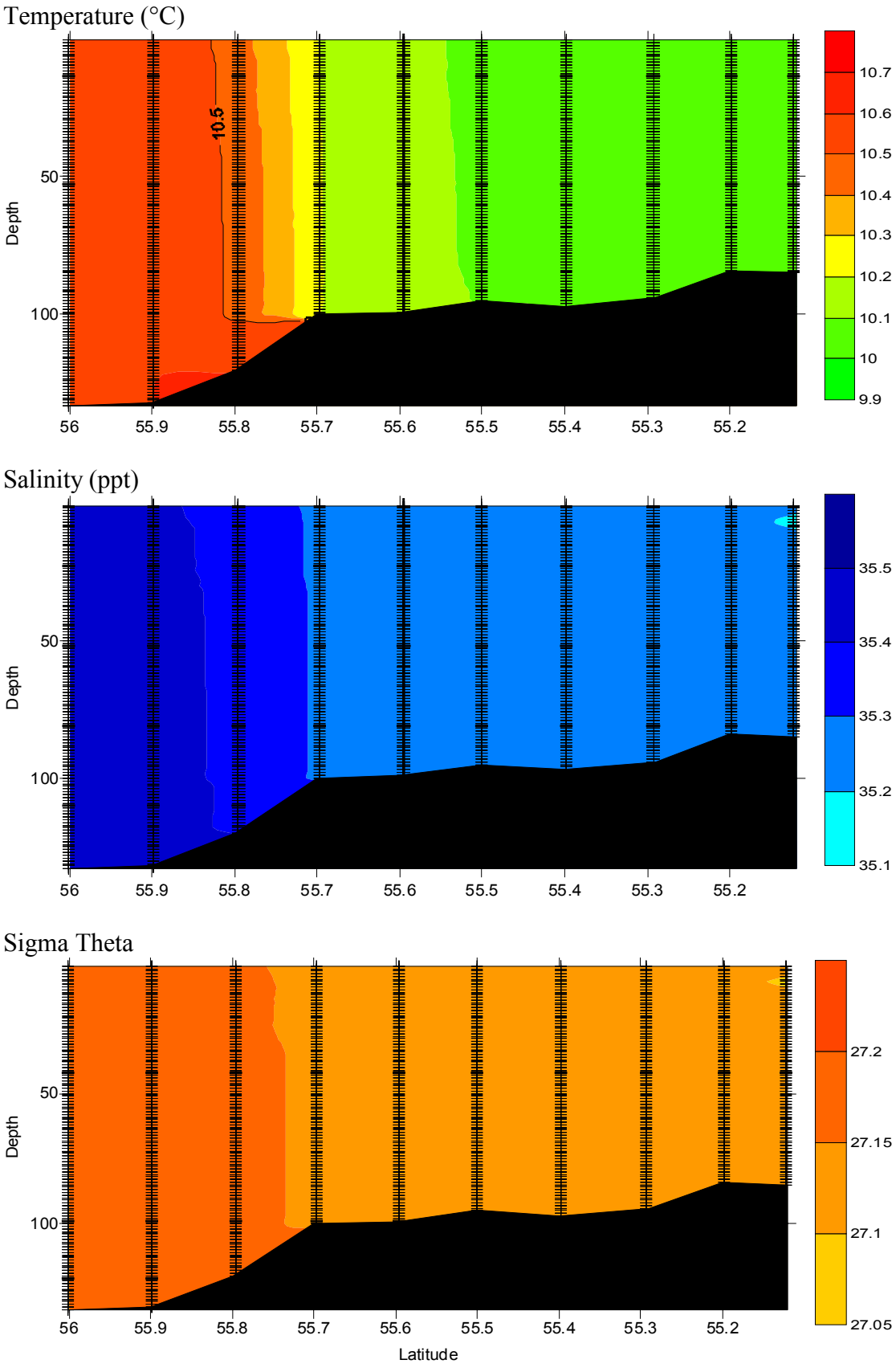


Figure 14. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T8, sites 29-38.

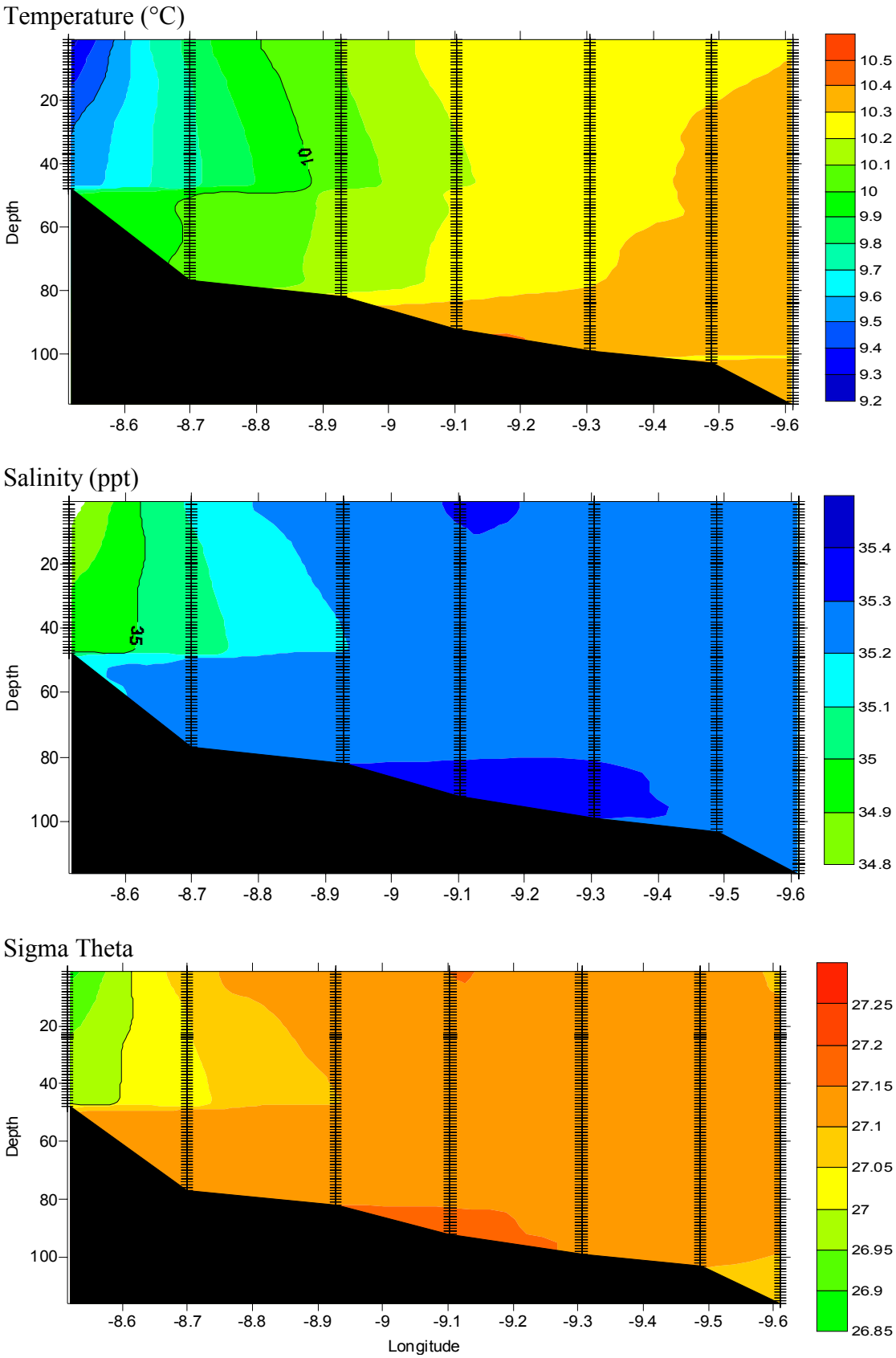
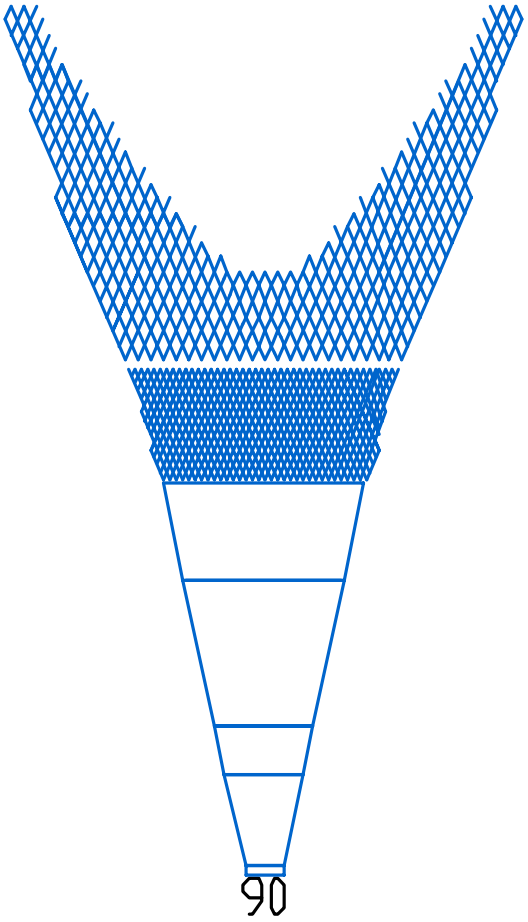


Figure 15. Vertical distribution of temperature (above), salinity (middle) and density (bottom) of transect T9, sites 39-45.

Appendix 1

22 x 12 fm
Herring Midwater Trawl
Fishing Circle 330m



Mesh (mm)	**Twine** (No.)
Belly:	
1600	210/624
1600	210/624
800	210/312
400	210/180
200	210/78
100	210/66
50	210/48
50	2mm braid

Mesh (mm)	**Twine** (No.)
Wings:	
1600	210/624

Brailer:

- 17 fm long made up of 4 x 260 meshes 20mm of No. 210/60 twine with top and middle splitter.
- Codend 20mm No. 210/72 double complete with lifting rings.
- Bottom section of the brailer is fitted with a 60mm No. 3.5mm braided coverbag.

Note: All mesh sizes given in half meshes.