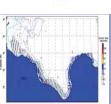


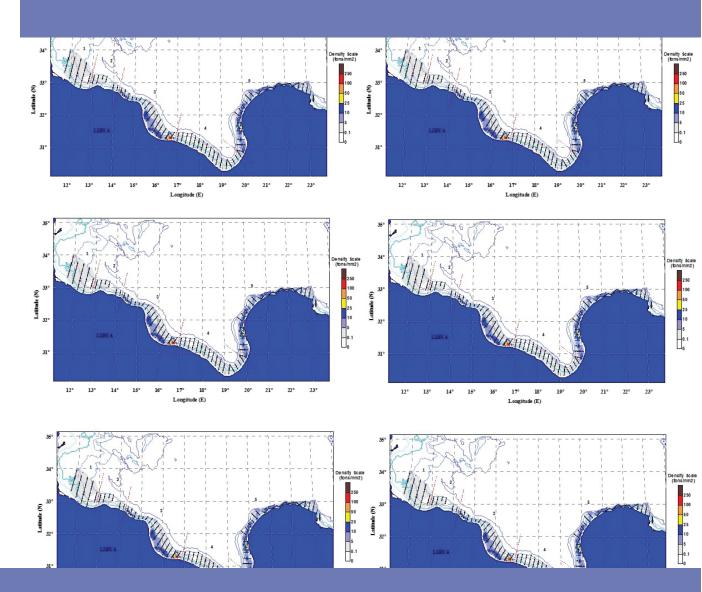
Food and Agriculture Organization of the United Nations





MEDSUDMED - TECHNICAL DOCUMENTS

Report of the MedSudMed acoustic survey: Libyan continental shelf - South central Mediterranean Sea (06 August - 02 September 2010)



REPORT OF THE MEDSUDMED ACOUSTIC SURVEY: LIBYAN CONTINENTAL SHELF - SOUTH-CENTRAL MEDITERRANEAN SEA (06 AUGUST - 02 SEPTEMBER 2010)

The conclusions and recommendations given in this and in other documents in the Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily Project series are those considered appropriate at the time of preparation. They may be modified in the light of further knowledge gained in subsequent stages of the Project.

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Preface

The Regional Project "Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF). The Directorate-General for Maritime Affairs and Fisheries of the European Commission (DG MARE) co- funded the project since October 2012. The Italian Regione Siciliana funded a project aimed at strengthening MedSudMed's effectiveness on issues related to demersal resources, namely crustaceans, for 18 months, starting from May 2011.

MedSudMed promotes scientific cooperation between research institutions of the four participating countries (Italy, Libya, Malta and Tunisia), for the continuous and dynamic assessment and monitoring of the status of the fisheries resources and the ecosystems in this area of the Mediterranean Sea

Research activities and training are supported to increase and use knowledge on fisheries ecology and ecosystems, and to create a regional network of expertise. Particular attention is given to the technical coordination of the research activities between the countries, which should contribute to the implementation of the FAO Code of Conduct for Responsible Fisheries and the Ecosystem Approach to Fisheries. Consideration is also given to the development of an appropriate tool for the management and processing of data related to fisheries and their ecosystems.

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Publications

The MedSudMed Project publications a re issued as s eries of Technical Documents (GCP/RER/010/ITA/MSM-TD-00) and Scientific Reports (GCP/RER/010/ITA/MSM/SR-00) related to meetings, missions and research organized by or conducted within the framework of the Project.

Comments on this document would be welcomed and should be sent to the Project headquarters:

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Preparation of this document

Acoustic surveys are probably the most important source of fisheries independent data to investigate the ecology, abundance and spatial distribution of small pelagic fish species, and to detect possible influence of environmental factors on their abundance and distribution. The experts of the countrie s participating in the FAO MedSudMed Project (Assessment and Monitoring of the fisheries Resources and the Ecosystems in the Straits of Sicily), during the "MedSudMed Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing their A bundance and Distributi on (Tunisia, October 2003)", deemed necessary to expand the area covered by acoustic surveys and investigate areas where little or outdat ed information fish biom ass was available. As fol low up, cooper ative oceanographic and acoustic surveys at sea were organised by the Project in the south-central Mediterranean Sea. Acoustic surveys surveys were organised in Libyan waters in 2008 and 2010. After each survey a document summarising participating instititions, methods used and r esults achieved was prepared and published as MedSudMed Technical Documents.

This document is the final version of the report of the MedSudMed Acoustic Survey carried out in Libyan waters from 06 August to 02 September 2010 on board of the R/V Maria Grazia. The document presents also the results of the processing of the data collected during the survey. The survey was organised in the framework of the MedSudMed Project in cooperation with the Istituto per l'Ambiente Marino Costiero (IAMC-CNR) of Mazara del Vallo/Capo Granitola (Italy) and the Ma rine Biology Research Centre (MBRC) of Taj ura (Libya). The Fi shery Acoustic Laboratory of VNIRO, Moscow, Russia and the Fishing Technology Department of the Istituto di Scienze Marine (ISMAR-CNR) of Ancona, Italy, were also involved in the surve y and/or in the data processing.

This report is one of outcome s of the MedSudMed Project component on "Small Pelagic Fish: Stock Identification and Oceanographic Processes Influencing their abundance and distribution". This report is primarily for scientists of the south-central Mediterranean Sea; it can also be of interest for students and professional of fisheries research and management in the Mediterranean Sea region. It is believe d to be a contribution to better knowledge on the distribution and abundance of small pelagic fish in the south-central Mediterranean Sea.

Acknowledgements

The Libyan Authorities, through the General Authority of Marine Wealth, are gratefully acknowledged for their support. Mr Nurredin E ssarbout (MBRC, Libya) and Mr Salvatore Mazzola (IAMC-CNR, Italy) are warmly thanked for the efforts spent and the support provided in the organization of all activities and for making this work possible. The crew of the R/V Maria Grazia is thanked for its work.

Bonanno, A., Assughayer, M., Barra, M., Basilone, G., Fontana, I., Genovese, S., Nfate, A., Popov, S., Pulizzi, M., Zgozi, S. 2015. Report of the MedSudMed Acoustic Survey: Libyan continental shelf – south-central Mediterranean Sea (06 August – 02 September 2010).

MedSudMed Technical Documents No. 37. GCP/RER/ITA/MSM-TD-30, Rome, 2015: 112 pp.

ABSTRACT

This document is the final version of the report of the MedSudMed Acoustic Survey carried out in Libyan waters from 06 August to 02 September 2010 on board of the R/V Maria Grazia. The document presents also the results of the processing of the data collected during the survey. The survey was carried out under the cooperative framework promoted by the FAO MedSudMed Project (Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily). The main objective of the survey was to gather information on the biomass and spatial distribution of small pelagic fish and on some environmental factors along the Libyan continental shelf. To this extent, acoustic measurements of small pelagic fish were carried out. Sampling of small pelagic fish using a pelagic trawler was carried out as well. During the survey, advantage was also taken to measure some physico-chemical parameters of the water column. The acoustic survey was the second survey for the assessment of small pelag ic fish biomass after the MedSudMed-08 Acoustic survey carried out in 2008 in Libyan waters. Previous surveys were carried out in 1993-1994. An overall description of the sampling scheme, of the area explored and of the methods adopted is provided. The bi omass, abundance, spatial distribution, length frequency distribution and length weight-relationship for the main small pela gic species found in Libyan waters is described: Engraulis encrasicolus, Sardina philcardus, Sardinella aurita, Trachurus mediterraneus, Scomber japonicas, Boops boops, Spicara spp. and Etrumeus teres. Sea water temperature, salinity and oxygen along the water column are also illustrated.

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1. Introduction

The regional assessment of small pelagic fish abundance and spatial distribution in relation to environmental parameters are two of the research activities endorsed by the MedsudMed Coordination Committee. These activities are developed in the framework of the MedSudMed Project component "Small Pelagic Fish: Stock Identification and Oceanographic Processes Influencing their abundance and distribution".

The cooperative MedSudMed acoustic surve y "MSM Libya 2010" was carried out along the Libyan waters on board of "R/V Maria Grazia" from 06th August to 02nd September 2010. It was the second survey for the assessment of small pelagic fish biomass since 1993-1994 in this area, after the MedSudMed a coustic survey 2008 (MedSudMed Technical Documents No 30¹). The survey was executed in cooperation with scientists of the Istituo per l'Ambiente Marino Costiero-Consiglio Nazionale per le Ricerche (IAMC-CNR) of Mazara del Vallo (Italy), the Marine Biology Research Centre (MBRC) of Tajura (Tripoli, Libyan Arab Jamahiriya), the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) of Moscow (Russia) and the FAO MedSudMed Project (Assessment and Mo nitoring of the Fisheries Resources and the Ecosystem in the Straits of Sicily, GCP/RER/010/ITA).

The survey was carried out in the framework of the MedSudMed Component on "Small Pelagic Fish: Stock I dentification and Oceano graphic Processes Influencing their abundance and Distribution". The overall objective of the survey was to assess the biomass and the spatial distribution of small pelagic fish in the Libyan waters by means of acoustic methods. During the survey, CTD data were also collected to study the water-mass circulation and its possible effects on the spatial distribution of small pelagic fish. The area covered during the survey spans along the whole Libyan coasts as shown in Figure 1.

The following activities were carried out during the survey:

- 1) Acoustic data acquisition using a scientific echo-sounder Simrad EK60 with two hull mounted split beam transducers (ES38-12 and ES120-7) and operating at frequencies 38 and 120 kHz. The scientific echo-sounder was calibrated for the 38 kHz at the end of the transects that were covered between Marsala and Siracusa during the "Ancheva 2008" survey. The calibration was performed on 26th July (see Annex 1) in the bay of Siracusa using standard copper spheres with known Traget Strenght, TS (-33.6 dB for 38 kHz). During the acquisition phase, e chogram signals were recorded on hard disk with the acquisition and post-processing software ER60. The total length of the echosurvey was 1280 nautical miles.
- 2) Biological sampling of small pelagic fish using a pelagic trawl net equipped with a Simrad ITI to control the net opening during sampling. The trawl net was a "Volante Monobarca"

¹ Bonanno A., Zgozi S., Rumolo P., El Turki A., Cuttitta A., Hamza M.A., Basilone G., Uheshi O., Placenti F., Bara M., Genovese S., Assugayer M., De Luca B., Leonardi M., Fontana I., Giacalone G., Azzaro F., Patti C., del Core M., Ceriola L. 2015. Report of the MedSudMed-10 Oceanographic Survey, Libyan continental shelf (south-central Mediterranean Sea) 15 – 30 July 2010. GCP/RER/ITA/MSM-TD-38. MedSudMed Technical Documents, 381: 79 pp

type, with the following dimensions: 78 m total length, 22 m sac k with 18 mm mesh opening, max vertical and hor izontal opening of 10 and 13 m respectively, for a total mouth opening of about 130 m^2 . The trawl has a total of 252 meshes ($78 \times 2 + 48 \times 2$) of 600 mm. Steel rope of 16 mm diameter and 50 m length warp. Rectangular boards, $190 \times 115 \text{ cm}$ and 380 kg each.

The sensors of the Simrad ITI were positioned on the upper part of the mouth of net, while the hydrophone used for the transduction of acoustic signals into electric signals was fixed on an iron tube positioned on the right side of the vessel. The speed of the vessel was 3.5-4.5 knots during the biological sampling. For each biological sample, EK60 records were monitored and saved to check the bottom a nd to be used during the acoustic data processing. During the survey 18 trawl hauls were performed.

3) Measurement of physico-chemical parameters of the water column with a multiparametric probe SEABIRD mod. 9/11 plus. The probe was put into the water from the left side of the vessel, using a double drum and an 8 mm steel cable. The sensors that were connected to the CTD measured: pressure, temperature, conductivity, fluorescence, dissolved oxygen and light transmission. Samples were collected along the vessel track trying to collect at least 2 CTD profiles for each transect. During the survey 114 CTD casts have been collected.

2. Participating Institutes

Scientists form the following research institutions participated in the organization and execution of the survey:

- 1. Istituto per l'Ambiente Marino Costiero (IAMC CNR), Capo Granitola and Naples, Italy
- 2. Marine Biology Research Centre (MBRC), Tripoli, Libya
- 3. Fishery Acoustic Laboratory of VNIRO, Moscow, Russia

3. Staff on board

The crew of the Maria Grazia vessel was composed by 10 persons (Table 1). Six scientists and one officer of the Libyan Coast Guard participated in the each leg of the survey: from 06 to 16 August 2010 (Table 2); and from 17 August to 2 September 2010) (Table 3).

Table 1. Crew of the R/V Maria Graziad during the Echosurvey "MSM Libya 2010".

Rank	Name
Master	Gallo Luigi
Boatswain	Pappalardo Francesco
Seaman	Zeffiro Luigi
Seaman	Calvanico Michele
Seaman	Pizzullo Francesco
Chief Eng.	Cozzolino Ciro
Cadet Eng.	Ronca Jean Pierre
Cook	Apicella Biagio
Technician	Patanè Aimone
Technician	Celletti Giovanni

Table 2. Scientific crew who participated in the 1^{st} leg of the "MSM Libya 2010" survey on board the R/V Maria Grazia.

Name	Sex	Nationality	Title	Role on board	Institution
1) Angelo Bonanno	M	Italian	CNR Researcher	Chief scientist	IAMC-CNR Mazara (TP)
2) Tarub Bahri	F	Algerian /French	FAO officer	Misc. measurements	FAO MedSudMed
3) Domenico Tegolo	M	Italian	Associated Prof.	Misc. measurements	University of Palermo
4) Sergey Goncharov	M	Italian	CNR Technician	Acoustics	VNIRO FAL
5) Salem Zgozi	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
6) Sergey Popov	M	Italian	CNR Researcher	Acoustics	VNIRO FAL
7) Mohamed Hamza	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
8) Mohamed Assughayer	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
9) Ahmed Nfate	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
10) Vito Palumbo	M	Italian	CNR Collaborating technician	Fishing operations	IAMC-CNR Mazara (TP)
11) Jamal Salem Rabha	M	Libyan	Coast Guard	Observer	Tripoli

Table 3. List of scientific crew of the 2^{nd} leg of the "MSM Libya 2010" survey on board the R/V Maria Grazia.

Name	Sex	Nationality	Title	Role on board	Institution
1) Angelo Bonanno	M	Italian	CNR Researcher	Chief scientist	IAMC-CNR Capo Granitola (TP)
2) Sergey Popov	M	Russian	CNR Researcher	Acoustics	VNIRO FAL
3) Mohamed Assughayer	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
4) Ahmed Nfate	M	Libyan	MBRC Researcher	Misc. measurements	MBRC Tripoli
5) Vito Palumbo	M	Italian	CNR Collaborating technician	Fishing operations	IAMC-CNR Capo Granitola (TP)
6) Giovanni Giacalone	M	Italian	CNR Collaborating technician	Fishing operations	IAMC-CNR Capo Granitola (TP)
7) Esmail Elbaheri	M	Libyan	Coast Guard	Observer	Tripoli

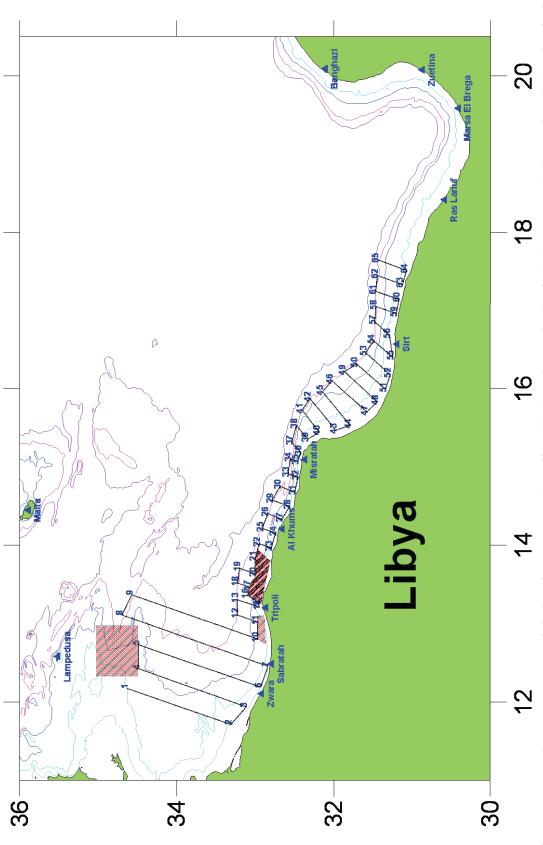


Figure 1. Acoustic transects covered during the survey "MSM Libya 2010", R/V Maria Grazia. 06 August – 02 September 2010. The shadowed zones are forbidden areas for survey.

4. Narrative of the survey

Day 1 and 2: 6-7 August (Friday and Saturday, Mazara del Vallo).

The first two days were used for collecting a new fishing net from Ancona and for waiting good weather conditions. Furthermore, the c ables of ITI system, damaged during the pr evious echosurvey, were repaired and a new metallic protection for the trasducers was installed.

Day 3: 8 August (Sunday, Mazara del Vallo).

The first part of the morning was dedicated to the formalities for embarking the scientific crew. Work shifts were allocated as reported in the following table, which also includes the names of the Libyan scientists who will be embarked in Zwara.

The vessel has left the Mazara del Vallo harbour at 10:28 a.m.

	Working period	Scientific staff
1 st shift Acoustics and CTD	00 – 04 and 12 – 16	Ignazio Fontana
2 nd shift Acoustics and CTD	04 - 08 and $16 - 20$	Sergey Popov
3 rd shift Acoustics and CTD	08 – 12 and 20 – 24	Gianni Celletti
Biological sampling	7.00 – 23.00	Gualtiero Basilone Maurizio Pulizzi Ahmed Nfate Mohamed Assughayer

Day 4: 9 August (Monday, Mazaradel Vallo – Zwara).

At 02:00 a.m. the echosurvey started from the station CTD1 of the first transect (98 nm long), and it was decided to perform a CTD station each 10 miles. Sea conditions are good and operations continued from station CTD1 to CTD 9. Then the vessel followed the transect 2-3 towards Zwara. At 01:00 p.m. the CDT10 was completed and acquisition was interrupted to go to Zwara. At 02:00 p.m. the vessel moored in front of Zwara at about 1 nautical mile from the harbour because not enough depth was inside the harbour (only 4 meter) for the Maria Grazia vessel (draft was 5 meters). At 05:00 p.m. the Libyan customs and some persons of the Agency carried out on board the procedures for embarking the colleagues of MBRC. Formalities were completed with the Port Authority and the Police Station, but the vessel should stay in the anchorage area until 12:00 a.m. of the following day.

Day 5: 10 August (Tuesday, Zwara).

At 00:30 p.m. the vessel received the permission to move and we came back to the vertex n°3. At 14.00 the echosurvey was started on the transect 3-4. At 03:21 p.m. trawl N.1 started at depth 50 and speed 4.4 kn. The trawl was completed at 03:52 p.m. with a catch of 15 kg, mainly small sardinella and two Balistes. The survey continued until the trawl n° 2 at depth 65 m; the catch was 146 kg with several species: sardine, small anchovy, sardinella, trachurus, scomber, spicara,

boops, etc. All the pelagic species were measured for length frequency distribution. The survey continued along the transect 3-4 and until the CTD18.

Day 6: 11 August (Wednesday, Zwara).

At 08:45 a.m. the acquisition was interrupted for carrying out the trawl haul n°3 at depth 100 m. The bottom was inspectioned before making the trawl. The catch was 14 kg, mainly anchovy and *Scomber japonicus*. The survey continued with CTD 20 and 21 until 01:18 p.m. when the trawl n°4 was carried out at depth of 150 m. The catch (13 kg) was mainly composed of anchovy, sardine and scomber. The echosurvey continued until the point 6 with CTD n° 22. At 06:22 p.m. the acquisition of data was interrupted for the trawl haul n° 5 on a depth of 152 m. The net was set on the bottom but the result was not so abundant (2.6 kg); the catch was composed of anchovy and trachurus (as pelagic species). Unfortunately, during the recovering operation of the net one of the two weights of the net was lost. The crew arranged a new weight (200 kg) by means of chain. The survey continued towards the point 6 with CTD stations until n°27.

Day 7: 12 August (Thursday Zwara-Tripoli).

During the night the transect 6-7 and CTD until the n°29 were completed. The data collection along the transect 7-8 was interrupted for carrying out the trawl haul n° 6. The latter started at 09:21 a.m. after having checked the bottom at a depth of 65 m. The echosurvey started again at 10:58 a.m. from the CT D station n°30; then it was interrupted for pe rforming the biological sampling in the haul n°7 at a depth 155 m. In this haul the catch was of 15 kg mainly composed of anchovy, scomber and sardine. Afterwards the survey followed the transect 7-8 with the CTD stations from 33 to 38.

Day 8: 13 August (Friday Zwara-Tripoli).

During the night transects 7-8 and 8-9 were completed with CTD stations until the n°41. At 06:21 a.m. the transect 9-10 started. After the vertex 10 and CTD42 the data acquisition was interrupted for checking the bottom for the haul n°8. At 08:48 a.m. the haul started on a depth of 130 m; the total catch was 27 kg, mainly composed (70%) by big anchovy (15-17.5 cm total length), sardine and trachurus. The survey continued along the transect 9-10 with CTD until n°49. At 09:00 p.m. the bottom depth become useful for trawling (156 m) and, after the inspection along the transect, the trawl was set close t o the bottom. The catch was poor with some anchovy, trachurus and shrimps. At 11:00 p.m. the survey restarted.

Day 9: 14 August (Saturday, Tripoli).

Good weather conditions. Collection of acoustic and CTD data was carried out regularly. Table I reports information on transects covered during the day and Table II includes information on the CTD stations. The first biological sampling started after the inspection of the bottom on a depth of 40 m in the area in front of Tripoli. Unfortunately, the net entangled the bottom and it was lost. The hauls was almost completed when it was noted a strange movement of the cables of the doors, so the vess el was stopped but the inertial speed was yet high for some minutes. Later when the cables were recovered on board it was noticed that the "tie" of the cables were taked off and the net with the weights and several meters of the ropes which link the net to the doors were lost. It was strange because no entangling structure were noted during the inspection or coming back during the trawl.

In the rest of the day the recovering operation were carried out. Firstly it was deployed an anchor with chain on the botto m and it was trawled trough the point where we supposed the net was.

Due to the rocky bottom also the anchor was lost after two attempts. So the Marine Agency was contacted for a diver which would find the net on a bottom of 40m. The agency suggested to wait for the divers until 05:00 p.m. but nobody came. It was decided to continue the acoustic program with CTD until the day after when the divers would be available. The data acquisition was carried out until vertex 20 and CTD61 station. At 12:00 p.m. the increasing wind and waves did not permit to carry out the data collection, so the Captain suggested to stop work until the morning.

Day 10: 15 August (Sunday, Tripoli).

In the morning we came back to the point in front of the Tripoli harbour where the net was lost and contacted the agency for divers. Divers arrived at 04:00 p.m. The last position of the vessel and some information about the net were given to the divers; we also explained them that the first aim would be to recover the transducer of ITI and after the rest of the net. One diver started searching but after 2 hour, about at 07:00 p.m., he come back to the vessel without results. At 07:30 we moved to Zwara, because the day after the disembarking of the Libyan collegues should have taken place. The vessel reached the anchorage area at 11:30 p.m.

Day 11: 16 August (Monday, Zwara).

In the morning the Marine agency (Marine Agency Department – Tel. +218 91 21 25 685; Fax +218 21 33 51 608; E-mail agency@rashilal.com) was contacted and it promised to carry out the procedures within the morning, but the Sta ff from the Marine Agency and local Authorities reached the vessel around 17:00 on a dig boat. After finalization of the administrative formalities, the vessel moved to Lampedusa.

Day 12: 17 August (Tuesday, Lampedusa).

The vessel ar rived at the Lampedusa harbour at about 08:00 a.m. and the procedure for disembarking three personnel of the scientific crew were carried out. In particular, Gualtiero Basilone, Ignazio Fontana and Maurizio Pulizzi were disembarked.

At 09:30 p.m. Angelo Bonanno, Vito Palumbo and Giovanni Giacalone reached the vessel and the procedure for their embarkment were accomplished.

The vessel has left the Lampedusa harbor at about 10 p.m. in order to arrive to Zwara in the next morning. The voyage to Zwara took all the night.

Day 13: 18 August (Wednesday, Zwara – Tripoli).

At 01:00 p.m. the vessel is at the anchorage are a in front of Z wara waiting for the bureaucratic procedures for embarking the colleagues of MBRC and the Officer of the Coast Guard. After completing such steps, at 05:00 p.m. the vessel moved towards the point where the net was lost. At 11:30 the vessel is at the point of the haul N.10 and the c rew started searching the net by means of the ITI system. Good weather conditions.

Day 14: 19 August (Thursday Tripoli).

Excellent weather conditions for all the day. The divers arrived at 11:00 a.m. and started searching the net according to the information acquired in the previous day. Unfortunately such activity did not produce any results. At about 06:00 p.m. the divers went away and the crew started a new procedure to find probable points in which the net could be. After contacting dr. Salem Zgozi, it was decided to continue the echosurvey since the divers could come back only on Saturday 21th August. The vessel moved towards the point 19 of the echosurvey. At 21:25

UTC the acquisition procedure st arted with the planned collection of a coustic and CTD data. Work shifts are as follows:

	Working period	Scientific staff
1 st shift	00 – 04 and 12 – 16	Mohammed Assughayer Giovanni Giacalone
2 nd shift	04 –08 and 16 – 20	Sergey Popov Vito Palumbo
3 rd shift	08 – 12 and 20 – 24	Angelo Bonanno Hammed Nafathi
Biological sampling	6.00-24.00 (*)	Vito Palumbo Mohammed Assughayer Giovanni Giacalone Hammed Nafathi

^(*)In the first part of the second leg of the echosurvey no biological sampling was carried out due to the problems with the pelagic net.

Day 15: 20 August (Friday, Tripoli – Misurata).

Acoustic and CTD data collection continued during all night and during the day until the CTD station N.77. Activities were interrupted to travel towards Tripoli (position of the trawl N.10).

Day 16: 21 August (Saturday, Tripoli).

The vessel arrived at the point of the net (32°58.981N 013°13.279E) at 10:30 a.m. and the crew checked the position of the transducers installed on the net by means of the ITI system. At 11:00 a.m. dr. Salem Zgozi and two divers joined the scientific group on board the Maria Grazia vessel. After having transferred all the acquired information about the position of the net on the bottom, one diver went underwater and finally found the net. The first step was to collect the transducers of the ITI system and, subsequently, the blue rope of the net was b rought on board the vessel. The net was then collected starting from the final part; all the parts of the net were taken from the bottom. The initial part of the net was broken but the most part of the net was in good conditions. Taking into account that supplementary work (new and stronger connections for all ropes) was necessary for installing again the net, it was decided to go to the point N.35 of the echosurvey and continue the acquisition of acoustic and CTD data until the net was ready.

Day 17: 22 August (Sunday, Misurata – Gulf of Sirt)

Good weather conditions even though a small long wave, moving southward, was present. The acquisition procedure started at 03:25 a.m. from the point N.35 while the first CTD station was N.78 at the point N.36. During night time Vito Palumbo, Ciro Cozzolino and some components of the crew reconstructed more reliable connections for all ropes. Since some hauls were present in the first part of the n et, it was decided to install the backup net. During all the day acoustic

transects were acquired from point 35 to point 43, CTD data were collected from station CTD78 to CTD87, and trawls N. 11 and 12 were carried out.

Day 18: 23 August (Monday, Gulf of Sirt)

For all the day a strong wind was present in the work area but not so strong to convince to interrupt the work on board the vessel. At 09:50 am , after checking for the presence of fish on the echogram and the evenness of the bottom, it was decided to interrupt the survey in order to perform the trawl haul N. 13. The survey continued routinely and only at 04:32 p.m. the vessel moved towards the starting point of the trawl N.14. After having checked for irregularities of the bottom the trawl N. 14 was performed. Unfortunately, the trawl haul was interrupted due to an unexpected obstacle on the bottom and the net was lost. All the ropes and the transducers of ITI were recovered; only the net (from the mouth to the end) was lost. It was decided to continue collecting acoustic and CTD data from the station CTD95.

Day 19: 24 August (Tuesday, Gulf of Sirt).

Good weather and sea conditions. During the night transects from point CTD98 to CTD101 were completed. In the morning Vito Palumbo and so me components of the crew reconstructed the previous and last net; in the afternoon the net was installed on the winch in order to be ready for the evening trawl. During the day acoustic data were acquired along transects from vertex 50 to point n. 60. At 08:54 p.m. the trawl n. 15 was completed. During the afternoon we contacted the Agency for making bunker (50 tons of diesel). To this aim, Mr Lamin told us that the vessel Maria Grazia should be in the morning of Wednesday 25th august in Ras Lanuf. Accordingly, after the CTD station n. 108 the echosurve y was interrupted in order to go to Ras L anuf for bunker (about 95 nautical miles far).

Day 20: 25 August (Wednesday, Ras Lanuf).

Calm sea, little wind and veiled sky. At 10:00 a.m. the vessel was at the anchorage area in front of Ras Lanuf. The Captain contacted the Port Control and explained that we were waiting for information from Agency Ras Al Hilal. At 01:00 p.m., not ha ving received still any info, we contacted by phone Mr Lamin that told us that in one hour the authorization from Custom should be ready. On the contrary, Mr Lamin called again and said that the authorization was not given; so he proposed also to reach Bengasi or Misurata to make the bunker. This was a very big mistake since the vessel sailed for about 90 nm without a reason. After a long discussion with the Captain of the vessel, we decided to go to Misurata since the vessel had not enough fuel for arriving in Bengasi and, in case of another reject of authorization, in Italy.

Such event produced a long delay in the work of the vessel and sing led out some limits in the planning of the activities. In particular, we have lost 24 hours of work and we travelled without any reason for about 200 nm.

Day 21: 26 August (Thursday, Misurata).

Good weather and sea conditions. The vessel arrived at 02:00 p.m. at the Misurata harbour. After having contacted the Port Control and the Agency (Mr Lamin), the vessel put the anchor in the anchorage area in fornt of the port waiting instructions from Agency. We contacted many times Mr Lamin and each time he told to wait one or two hours for the bunker. At 06:30 p.m. he said that the bunker will be made the day after eventhough it is Friday (typical holiday for Libya). In the last two days we asked to ourself which kind of problem the Agency could have met since we lost two (and maybe three) days for fuel without enough information.

Day 22: 27 August (Friday, Misurata – Tripoli).

At about 01:00 p.m. Mr Lamin contacted us and said that the supply for gasoline was ready and the Port Control should have called in half a hour. This time this was right and the vessel entered the Misurata harbour at about 02:20 p.m. After having made bunker (about 50 tons of diesel), the vessel has left the harbour to go to the initial point of trawl n. 16. The main idea was to perform three trawls in an area, between Tripoli and Misurata, in which no biological samples have been collected still due to the problems met with the net. The trawl haul was then carried out at 19:22 UTC in a pelagic layer. The vessel moved to the position of the trawl n.17 to be performed the day after in the morning.

Day 23: 28 August (Saturday, Misurata – Tripoli).

At 05.30 a.m. the scientific crew start ed checking the bottom for trawl n. 17. The trawl was completed at 07:45 a.m. and the vessel moved towards the point of trawl n. 18. Such trawl was conducted on a bottom of about 70 m but durin g the haul the TrawlEye sensor did not transmit signal to the vessel probably due to a mistake in deploying the net.

After completing the trawl n. 18, the vessel moved towards the point n. 60 of the echosurvey.

Day 24: 29 August (Sunday, Sirt – Ras Lanuf).

Good weather conditions. At 08:25 the surveystarted with the CDT station n 109. We interrupted data acquisition many times in order to find a possible site for making a trawl haul but with no result. So the acquisition of acoustic and CTD data continued until the station CTD114. At 10:00 p.m. the survey was concluded to go to Misurata for disembarking the colleagues of MBRC and the officer of Coast Guard, since Mr Lamin said to be sure to complete all the bureaucratic procedures in Misurata.

Day 25: 30 August (Monday, Misurata)

The vessel arrived in front of the Misurata harbour early in the morning. After having contacted the Misurata Port control, the Captain positioned the vessel in the anchorage area, even though the weather conditions of the area be came worst and worst. The Agency and Mr Lamin were informed about the a rrival; Mr Lamin suggested to wait for the necessary administrative procedures. At about 00:30 p.m. Mr Lamin was contacted again and he said that in Misurata we were loosing time since the documents for the Maria Grazia vessel were still in Zwara. Again a big mistake of the Agency. In the previous three days we asked by phone to Mr Lamin if problems could arise if we concluded the echosurvey in Misurata and each time he said "no problem". Now he suggested to go as soon as possible to Zwara (170 nm far) to complete the procedures. This was a terrible error since the weather conditions became worst and worst and it was necessary to wait at the anchorage area until 05:00 p.m. Then the Captain and the chief scientist decided to move towards Zwara, even though the sea was rough.

Day 26: 31 August (Tuesday, Zwara – Strait of Sicily)

The vessel sailed durin g the night with bad sea conditions and arrived in front of the Zwara harbour at about 09:00 a.m. We contacted both the Zwara port control and the Agency. All the bureaucratic steps were completed at 03:00 p.m. so at 03:30 p.m. the vessel started sailing towards Messina. The sea state was rough.

Day 27: 1 September (Wednesday, Strait of Sicily)

All the day was used for sailing towards Messina. Sea state very rough.

Day 28: 2 September (Thursday, Messina)

The vessel arrived at the Messina harbour during the night. The day was used for disembarking the scientific crew and all the material and samples of the echosurvey.

5. Materials and Methods

5.1 Acoustic data acquisition

The echosurvey covered the continental shelf with depths in the range 0-200 m; Figure 1 shows the echosurvey design adopted in GSA21 (Libyan waters). The echosurvey was conducted along parallel transects perpendicular to the coastline. The mean distance between transect was chosen equal to 10 nautical miles. Only in the largest continental shelf on the western part of the study area, due to the long transects, the distance between transects was chosen equal to 15 nautical miles. Mainly due to bad weather conditions, the survey did not covered the eastern part of the Libyan waters (Figure 1). In total, the distance traveled along transects and between parallel transects was about 1280 nm.

Acoustic sampling was performed at boat speed of 8-9 knots, using a scientific echo-sounder Simrad EK60 with one split beam transducer (ES38B) fixed on the hull (3.5 m from the sea surface) and operating at 38 kHz.

In relation to the available vessel time it was decided to acquire acoustic data 24 hours a day (both during day and night time), even though the acoustic prospecting is suggested to be performed during the day only.

The scientific echo-sounder was calibrated according to the me thodology described by Johannesson and Mitson (1983) at the end of the transects that were covered between Marsala and Siracusa during the "Ancheva 2010" survey. The calibration was mcarried out on 26th July in the bay of Siracusa using standard copper spheres with known TS (-33.6 dB for 38 kHz). During the acquisition phase, echogram signals were recorded on hard disk with the acquisition and post-processing software ER60. In Annex 1 the results of the calibr ation procedure are reported.

5.2 Analysis of the Echograms

The analysis of acoust ic data (post-processing) was performed by means of the SonarData EchoView (V. 3.30) software package. Minimum resolution of the echo-integration interval was agreed to be 1 nm. After having set the calibration parameters, the values of the Nautical Area Scattering Coefficient (NASC; MacLennan et al., 2002) for each nautical mile of the survey (EDSU) were estimated. In particular, Total NASC, due to the total backscattering signal in the water column, and NASC Fish per EDSU were evaluated.

5.3 Biological sampling

The acoustic evaluation of fish biomass foresees the sampling of fish at the same time of the acoustic data recording according to a precise protocol (McLennan and Simmonds, 2005). Accordingly, the acquisition of acoustic data during the survey was interrupted to carry out the experimental control catches by a pelagic/mid-water trawl net. The trawls position is shown in Figure 2. The boat speed during the trawling was 3.5-4.5 knots and the net was monitored continuously by using a netsonde, in order to control the opening of the mouth and the position respect to the bottom.

The structure of the equipment used for the biological sampling is the following:

- pelagic trawl net 78 m long, initial mesh size 182x800 mm and lateral mesh size 400 mm, and code end 22 m long with 18 mm mesh size. The max vertical and horizontal opening were 10 m and 13 m respectively but during the trawl operations the vertical opening was about 7 m;
- 50 m steel cable with a diameter of 16 mm, doors 190 x 115 cm of 380 kg each;
- Kongsberg Simrad ITI monitoring trawl net system.

For using the Simrad ITI system, the sensors were installed on the upper part of the mouth of the net while the hydrophone was installed on a tow body put into the sea only during trawl hauls. The vessel speed was 3.5-4.5 knots and the S imrad EK60 echosounder a cquired acoustic data useful for the next stage of data processing.

It was necessary to use the scientific echosounder in order to inspect the bottom structure before performing the catch with the net; such procedure was adopted for avoiding dangerous structures on the bottom (rocks, rel icts, bottom roughness, etc.) since during the trawl hauls the net was installed very close to the bottom due to the escaping behavior of small pelagic species.

The catched samples were weighed and measured according to the following:

- all catch was sorted, except for unusually large catches for which a sub-sample of the catch was sorted;
- total length was measured using ½ cm size classes;
- the whole size class was weighted.

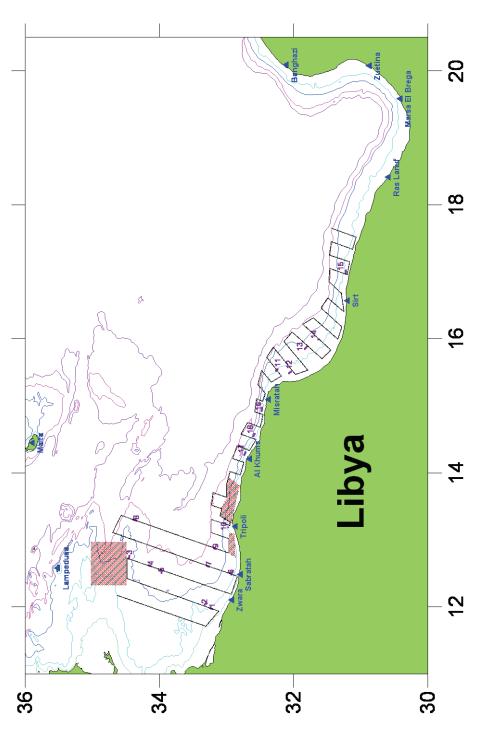


Figure 2. Position of the trawl hauls made (numbers) and acoustic transects covered during the survey "MSM Libya 2010", R/V Maria Grazia. The shadowed zones are forbidden areas for the survey.

5.4 Estimation of fish density

The next step was to divide the estimated values of NASC Fish in relation to the results of the control catches. Usually, this procedure depends on the fish species caught, the bottom features, water masses circulation, etc.

During the "MSM Libya 2010" a coustic survey 18 trawl hauls were carried out. In order to objectively assign (as much as possible) at each EDSU the corresponding reference trawl, a nearest neighbour search, based on kd-tre e (Bentley J.L., 1975) data st ructure, was applied. Considered dimensions for the analysis were geographical coordinates (latitude and longitude) and depth. Because the neighbours were defined on the basis of Euclidean distance, geographic coordinates and depth were standardized for obtaining similar range values for each dimension. The Kd-tree represents a kind of geometric data structure, us eful for o rganizing geometric features like points in d- dimensional space allowing a faster processing in near est neighbour search. The tree is defined by means of a recursive binary partitioning method. In this context a set of points (in our case the trawls) can be organized in a tree-like structure by recursively cutting the d-dimension space starting from the dimension having the widest spread. Once the tree was defined, a nearest neighbour search, based on the relative position of the EDSU with respect to the trawls, was carried out. The goodness of the association was visually evaluated considering the bathymetry as well as the 2d partitioning of the space e performed by means of Voronoi polygons (Figure 3).

A first run evidenced the need to weight the influence of depth with respect to geographical coordinates. Indeed, the study area presents two well defined sub-areas in term of bath ymetric gradient. The westernmost part is characterized by a large plateau with bathymetric gradient much lower than the eastern part, being the latter characterized by narrower continental shelf. The analysis of CTD data, collected during the echosurvey, gave the possibility to highlight different environmental conditions in the two sectors. Such differences may likely lead to differences in fish assemblage (e.g. in Bonanno *et al.*, 2015), so further justifying the separation in two sub-areas. The weight for the depth variable was chosen by multiplying in each area the standardized depth by a constant factor. Particularly, in the eastern sector, where the bathymetric gradient is higher, the factor was set to 0.5, so avoiding the association between EDSU and trawls very far among them but characterized by comparable depths. Conversely, in the western part of the study area, the factor was set to 1.1 slightly increasing the weight of depth over the geographic distance.

The obtained association (Figure 4) evidenced a good agreement with the Voronoi tessellation, except in some sectors (especially in the western part) where the Kd-tree nearest neighbour search performed a better association with respect to the bathymetric gradient.

Kd-tree nearest neighbour search was performed in R statistical environment (http://www.r-project.org/) using FNN package (http://cran.r-project.org/web/packages/FNN).

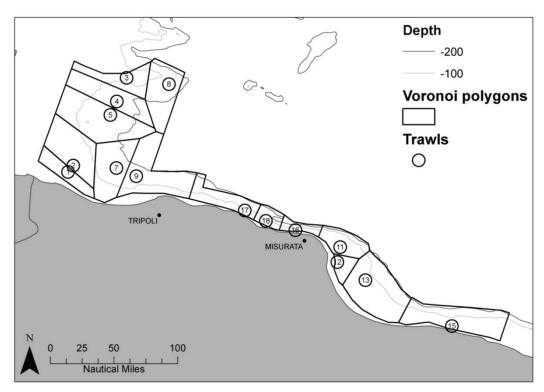


Figure 3. Voronoi tessellation of the study area. In this case the Trawls-EDSU association is based on the position of the trawls and the geometry of the study area only. This approach (not accounting for depth) lead to some inconsistency in the association. Indeed Trawls 5 (150m depth) is associated to EDSU having very different depth with respect to the mean trawl depth.

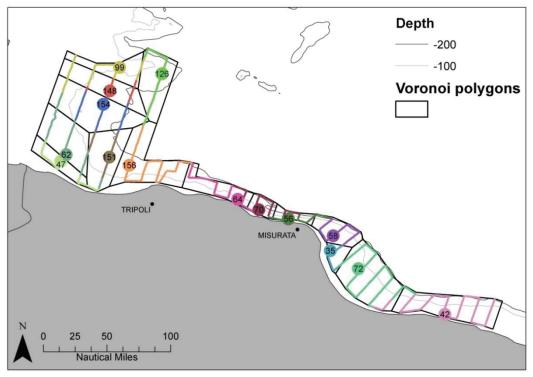


Figure 4. Trawls-EDSU association based on Kd-tree neighbour search overlaying the Voronoi polygons. Some correction with respect to bathymetry are particularly evident in the westernmost sector of the study area. Large points represents the trawls position reporting the trawls depth as point label. The colours indicate the association between EDSU and trawls.

The analysis of the biological sample allowed to evaluate the number of species (n) and the number of specimens for each of the m size classes. The proportion of each species $(v_j; j = 1, ..., n)$ in each trawl haul and the proportion for each length class k (k = 1, ..., m) and for each species f_{jk} are:

$$\sum_{j=1}^{n} v_j = 1$$

$$\sum_{k=1}^{m} f_{jk} = 1$$
where
$$v_j = \frac{n_j}{N}$$
and
$$f_{jk} = \frac{n_{jk}}{n_j}$$

and

 n_i = total number of specimens of species j in the sample,

 n_{jk} = total number of specimens of species j in the length class k in the sample,

N = total number of specimens in the sample.

For the species *j* and the length class *k* the back-scattering coefficient is

$$NASC_{ajk} = \rho_{ajk} * \sigma_{spjk}$$

where

 ρ_{ajk} = fish surface density of and species j in the length class k [n° of fishes/NM²], σ_{spjk} = back-scattering cross section of length class k and species j given by

$$\sigma_{spjk} = 4\pi * 10^{\frac{TS_{jk}}{10}}$$
 and $TS_{jk} = a_j Log_{10}(L_k) + b_j$

where L_k is the length of the size class k in cm. For each nautical mile the back-scattering coefficient for the species j is

$$NASC_{aj} = \sum_{k=1}^{m} \rho_{ajk} * \sigma_{spjk}$$

and the back-scattering coefficient for all the species is

$$NASC_a = \sum_{j=1}^n \sum_{k=1}^m \rho_{ajk} * \sigma_{spjk}$$

On the other hand, surface density of the size class k for the species $j [n^{\circ} \text{ of fishes/mn}^{2}]$ is

$$\rho_{ajk} = \rho_a * \nu_j * f_{jk}$$

where ρ_a [n° of fishes/mn²] is the density of pelagic fish species. From the above equations the back-scattering coefficient for all the species is given by

$$NASC_a = \rho_a \sum_{j=1}^n \sum_{k=1}^m v_j * f_{jk} * \sigma_{spjk}$$

For each EDSU the NASC_a may also be given by

NASC_a =
$$\frac{\rho_{ajk}}{\nu_j * f_{jk}} * \sum_{j=1}^n \sum_{k=1}^m \nu_j * f_{jk} * \sigma_{spjk}$$

and substituting v_j and f_{jk} , the density for each species and each size class is

$$\rho_{ajk} = \frac{\text{NASC}_a * n_{jk}}{\sum_{i=1}^n \sum_{k=1}^m n_{jk} * \sigma_{spjk}} \quad \text{n° of fishes/mn}^2$$

or

$$\rho_{ajk} = \frac{NASC_a * n_{jk} * w_{jk} * 10^{-6}}{\sum_{i=1}^{n} \sum_{k=1}^{m} n_{jk} * \sigma_{spjk}} t/mn^2$$

where w_{jk} is the mean weight (g) of the size class k for the species j. In the last equation the term $n_{jk}*w_{jk}$ is the total weight of the size class k for the species j (W_{jk} in g). Consequently ρ_{ajk} may be

$$\rho_{ajk} = \frac{NASC_a * W_{jk} * 10^{-6}}{\sum_{i=1}^{n} \sum_{k=1}^{m} n_{jk} * \sigma_{spjk}}$$
t/mn²

The surface density for the species *j* is

$$\rho_{aj} = \sum_{k=1}^{m} \rho_{ajk} = \frac{NASC_a * 10^{-6} * \sum_{k=1}^{m} W_{jk}}{\sum_{j=1}^{n} \sum_{k=1}^{m} n_{jk} * \sigma_{jk}} = \frac{NASC_a * 10^{-6} * W_J}{\sum_{j=1}^{n} \sum_{k=1}^{m} n_{jk} * \sigma_{jk}}$$
 t/mn²

where W_j is the total weight of the fish species j in the sample. The total fish surface density is

$$\rho_a = \sum_{j=1}^n \rho_{aj} = \frac{NASC_a * 10^{-6} * \sum_{j=1}^n W_j}{\sum_{i=1}^n \sum_{k=1}^m n_{jk} * \sigma_{jk}} = \frac{NASC_a * 10^{-6} * W}{\sum_{j=1}^n \sum_{k=1}^m n_{jk} * \sigma_{jk}}$$
t/mn²

where W is the total weight (g) of the sample.

The used Target strength (TS) -Length equations for all the pelagic species caught during the survey "MSM Libya 2010" are reported in Annex 2.

The estimated fish surface density per species and size class were used to obtain the spatial distribution pattern by means of the Kriging interpolation method. To this aim, the SURFER© (Ver. 8.0 – Golden Software) software package was used.

5.5 Evaluation fish biomass

To increase precision, the biomass estimation was obtained by applying a post-sampling (density based) stratification (Johannesson and Mitson, 1983).

For each considered species three density classes were identified by means of Natural Breaks Jenks classification method (Jenks, 1967). Using an iterative procedure, the Natural Breaks Jenks method finds k (number of classes) "optimal" classes minimizing intra class deviation from the class mean and maximizing each class's deviation from the means of the other classes. In this way the following density strata were defined for each considered fish species:

Stratum	1	2	3
Al	Low density	Medium density	High density
Abundance description	(t/NM ²)	(t/NM ²)	(t/NM^2)
Engraulis encrasicolus	0.1-10	10-50	50-240
Sardina pilchardus	0.1-15	15-55	55-224
Sardinella aurita	0.1-25	25-100	100-244
Etrumeus teres	0.1-5	5-20	20-53
Spicara maena	0.1-5	5-25	25-136
Spicara smaris	0.1-5	5-10	10-23
Spicara flexuosa	0.1-5	5-10	10-23
Boops boops	0.1-5	5-20	20-42
Scomber scombrus	0.1-5	5-10	10-25
Scomber japonicus	0.1-15	15-60	60-132
Trachurus mediterraneus	0.1-15	15-45	45-132

The total biomass W is evaluated by the formula

$$W = \sum_{i=1}^{n} W_i = \sum_{i=1}^{n} \rho_i * S_i$$

where in each i stratum W_i is the biomass (t), ρ_i is the mean biomass density (t/NM²) and S_i is the stratum area (NM²), defined by density isolines computed over IDW interpolated density surface. Variance of density values in the *i-th* stratum is espressed by

$$D_{i}^{2} = \frac{\sum_{j=1}^{m_{i}} (\rho_{ij} - \overline{\rho}_{i})^{2}}{m_{i} - 1} \qquad [t/NM^{2}]^{2}$$

where ρ_{ij} $(j = 1, ..., m_i)$ are density values in the *i-th* stratum, $\overline{\rho}_i$ is the mean density in the *i-th* stratum and m_i is the number of density values in the *i-th* stratum. Biomass precision is estimated with

$$\omega_{w} = \sqrt{\sum_{i=1}^{n} \omega_{i}^{2}} = \sqrt{\sum_{i=1}^{n} \frac{D_{i}^{2} \bullet S_{i}^{2}}{m_{i}}}$$
 [t]

where ω_i is the precision of the biomass estimate in the *i-th* stratum and *n* is the number of strata. The confidence intervals of the biomass estimate are

$$I = W \pm t(m) \bullet \omega_w \qquad [t]$$

 $I = W \pm t(m) \bullet \omega_w \qquad [t]$ where $m = \sum_{i=1}^{n} m_i$ is the total number of density values of the area and t(m) is the Student T-test with $m \operatorname{degr}_{\overline{e}}$ of freedom.

The cartographical projection used for the biomass computation was UTM 33N W GS84 (EPSG:32633).

5.6 Acquisition and processing of oceanographic data

The sampling plan of oceanographic data, adopted during the "MSM Libya 2010" echosurvey, was designed to ensure compatibility between the procedure for the estimation of pelagic biomass and the study of water masses characteristics in the Libyan waters. To this aim, the sampling plan with CTD probe has focused on the sea area over the continental shelf, up to 200 m depth (Figure 5).

Hydrological data were acquired at each station through the multiparametric CTD probe SBE 9 plus (Underwater Unit) and the SB E 11plus module (De ck Unit) of the SEA- BIRD ELECTRONICS, Inc. At each station, a hydraulic winch has shifted the CTD probe from the surface to the bottom with a constant speed of 50 m/min.

The SEASAVE program (sampling frequency of 24 Hz) was used for collecting and saving data; raw data were saved in hexadecimal format in the HD linked to the SEA-BIRD system.

In each station three different files were saved:

- namefile.con (configuration file for the parameters of all the installed sensors)
- namefile.hex (raw data file in hexadecimal format)
- namefile.hdr (station info file)

The multiparametric probe was equipped with sensors to me asure pressure, temperature, conductivity, fluorescence, light transmission, dissolved ox ygen concentration and photosynthetically active radiation (PAR).

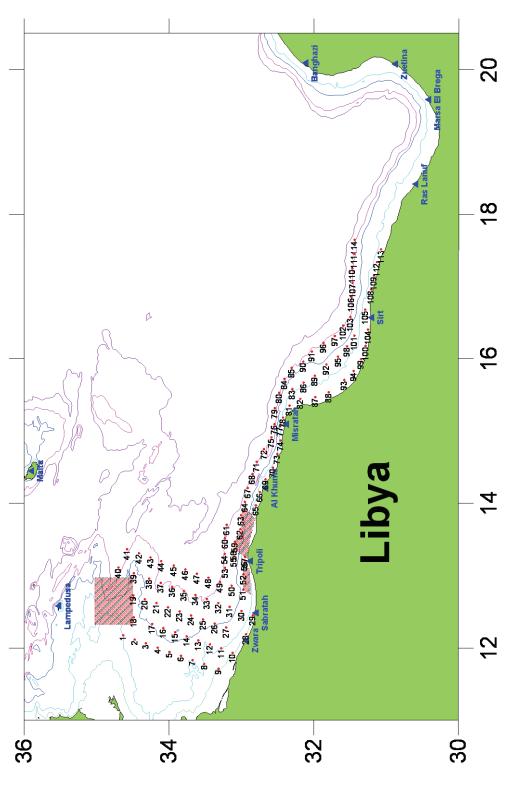


Figure 5. Position of CTD stations covered during the survey "MSM Libya 2010", R/V Maria Grazia. The shadowed zones are forbidden areas for the survey.

Data acquired only during downcast were submitted to an appropriate post-processing procedure using the software package "SEASOFT-Win32 (SBE Data Processing - CTD Data Processing and Plotting Software). Such procedure uses an *ad hoc* processing and includes the following steps:

datcnv.exe	it converts the acquired data (raw data) from hexadecimal format to a text file
	format (namefile.cnv);
alignctd.exe	it corrects the error due to the position of various sensors installed on the CTD
	frame;
wildedit.exe	it finds unusual values and delete them if required;
celltm.exe	it use a recursive filter to remove the effects of thermal inertia of the water
	mass inside the measuring cell on the conductivity values;
filter.exe	it uses a low-pass recursive filter to eliminate unexpected changes from the
	physical point of view;
loopedit.exe	it finds the values along the profiles corresponding to a speed of down cast
	less than a pre-established one;
binavg.exe	it evaluates variable values along the profile for a chosen sampling step (depth
	in m or pressure in db);
derive.exe	it derives salinity, density and other oceanographic parameters;

The interpolation of processed data and the subsequent presentation of the different fields at different depths was performed by means of the Ocean Data View software package (Schlitzer, 2007).

6. Results

One of the final results of acoustic data processing is the distribution map of the whole backscattering biomass in the water column. In this case each organism present in the column, characterised by an acoustic impedance different from the sea water one, may reflect part of the acoustic signal transmitted by the transducers. For the study area the Total NASC estimated for each nautical mile is presented in the following Figure 6.

The backscattering produced only by pelagic fishes is shown in the F igure 7. As it can be observed most of the pelagic community is distributed close to the Libyan coasts in the shallower part, characterized by depth less than 100 m.

Further interpretation of results is linked to the biological information from the pelagic control hauls.

In the following sections the biomass estimation and the spatial distribution pattern are presented for Anchovy (*Engraulis encrasicolus*), Sardine (*Sardina philcardus*), Round sardinella (*Sardinella aurita*), Mediterranean horse mackerel (*Trachurus mediterraneus*), Chub mackerel (*Scomber Japonicus*), Bogue (*Boops boops*), Round herring (*Etrumeus* teres), and three *Spicara* species (*S. smaris*, *S. maena* and *S. flexuosa*).

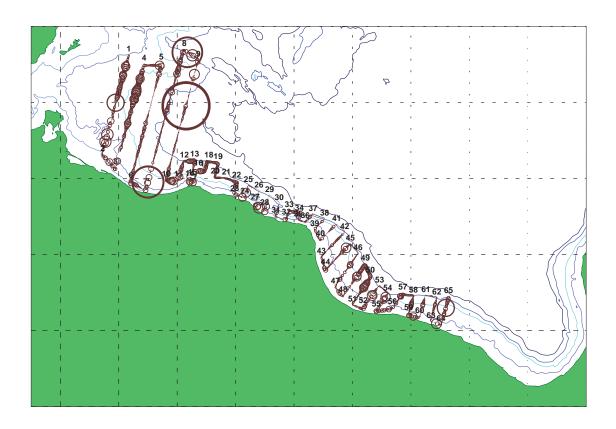


Figure 6. Total NASC distribution during the MSM Libya 2010 echosurvey.

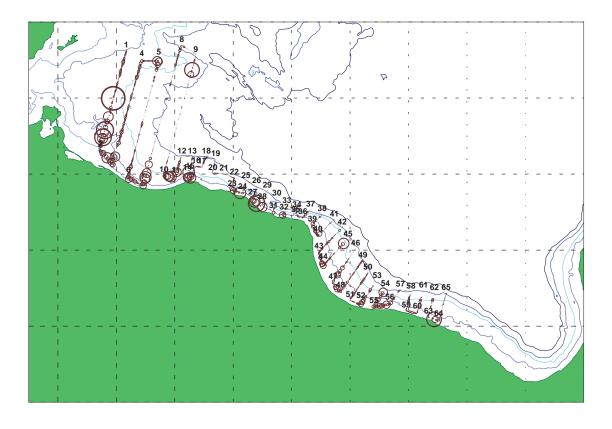


Figure 7. NASC Fish distribution during the MSM Libya 2010 echosurvey.

Anchovy (Engraulis encrasicolus)

Total anchovy biomass in the whole survey area was 28904 t with its higher proportion in the density stratum 10-50 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-10	10-50	50-240
Sample dimension (Num.)	455	53	4
Mean surface density (t/NM²)	2.22	18.5	149.5
Standard deviation (t/NM²)	2.5	8.61	62.95
Biomass in the density interval (t)	11533.98	11838.79	5531.5
Area (NM²)	6607	913	8

Total Biomass (t)	28904.27
Standard deviation (t/NM²)	1352.257
CI - (t/NM²)	26253.85
CI+ (t/NM²)	31554.69
cv	4.68
Total area (NM²)	10232.90

Anchovy density (t/NM²) spatial distribution, shown in Figure 8, is mainly concentrated in the western part of the surveyed area, even though a small abundance was also recorded in the Gulf of Sirt.

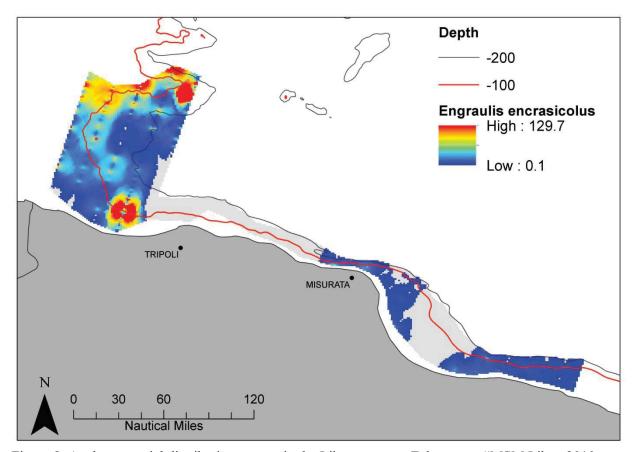


Figure 8. Anchovy spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Anchovy specimens were found in the trawls n. 2, 3, 4, 5, 7, 8, 11, 12, 1 5 and 16 (Figure 2). Three well distinct modes were found in the frequency distribution: juveniles around 6.5 cm total length (TL) and adults around 9.5 and 14.5 cm TL. Other minor modes (11.5 and 15.5 cm TL) could represent different cohorts. The full size range was between 5.5 and 17.5 cm TL (Figure 9). Anchovie uveniles were collected in the trawls n. 15 and 16. In the trawl n. 2 almost all the

specimens were between 7.5 and 11.5 cm. The trawls n. 3, 4, 7 and 8 p resented only one mode with specimens of bi gger sizes. This spatial segregation among size classes suggests that probably the stock is not full y mixed and different life stages probably inhabit different habitat and environmental condition. Unfortunately no age data are available to support this hypothesis.

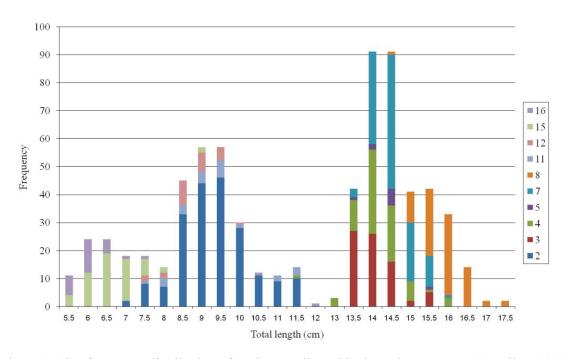


Figure 9. Size frequency distribution of anchovy collected in the Echosurvey "MSM Libya 2010".

The different size classes recorded permitted to obta in a representative length vs. weight relationship for a wide size range (Figure 10). The length-weight relationship parameters are shown in the same figure.

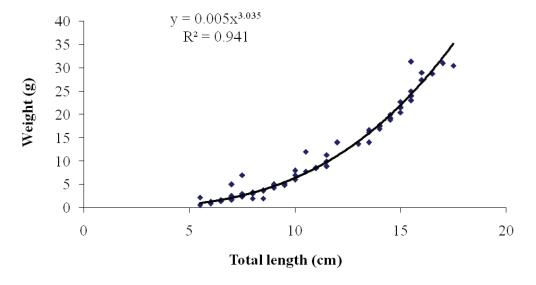


Figure 10. Length-weight relationship for anchovy collected in the Echosurvey "MSM Libya 2010".

Sardine (Sardina philcardus)

Total sardine biomass in the whole survey area was 47248 t with its higher portion in the density strata 15-55 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-15	15-55	55-224
Sample dimension (Num.)	223	71	9
Mean surface density (t/NM²)	4.24	27.99	119.27
Standard deviation (t/NM²)	4.43	11.22	47.58
Biomass in the density interval (t)	11509.51	22619.45	13119.33
Area (NM²)	3960	1106	13

Total Biomass (t)	47248.29
Standard deviation (t/NM²)	1894.988
Ci - (t/NM²)	43534.11
CI + (t/NM²)	50962.47
cv	4.01
Total area (NM²)	10232.90

Sardine spatial distribution (Figure 11) shows that the species is only present in the western area. No sardine specimen was collected west of Tripoli area.

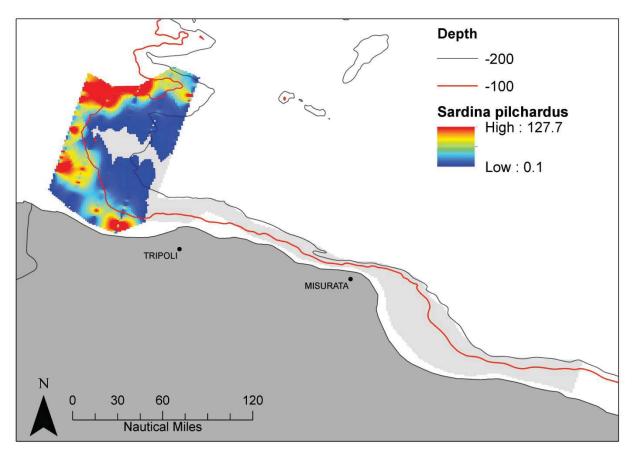


Figure 11. Sardine spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Sardine were found in five trawls and only one mode was present in the frequency distribution around 15.5 cm TL (Figure 12). No juvenile specimen was found in the catches, probably because the survey was carried out after the recruitment period for sardine, or because during postlarval and juvenile stages sardine are very close to the coast, or because the nursery grounds for sardine are out of the surveyed area.

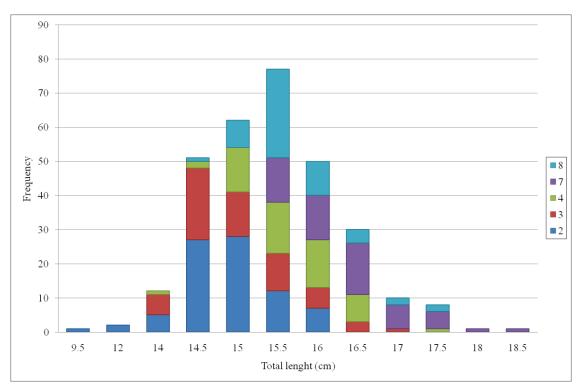


Figure 12. Size frequency distribution of sardine collected in the Echosurvey "MSM Libya 2010".

In the following the relationship between size and weight for sardine is estimated in the size range between 9.5 and 18.5 cm TL (Figure 13).

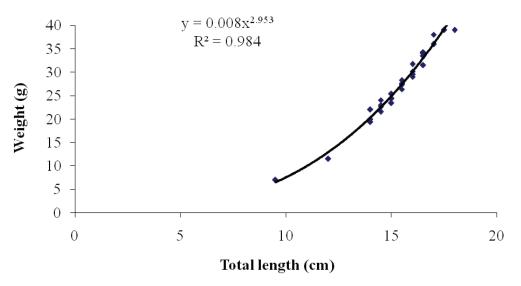


Figure 13. Length-weight relationship for sardine collected in the Echosurvey "MSM Libya 2010".

Round sardinella (Sardinella aurita)

Round sardinella biomass in the whole surve y area was 57670 t with its higher portion in the stratum 25-100 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-25	25-100	100-244
Sample dimension (Num.)	278	59	6
Mean surface density (t/NM²)	6.44	43.59	168.87
Standard deviation (t/NM²)	6.69	17.92	58.49
Biomass in the density interval (t)	19504.46	26852.38	11314.07
Area (NM²)	4059	722	8

Total Biomass (t)	57670.91
Standard deviation (t/NM²)	2350.804
Ci - (t/NM²)	53063.34
Ci + (t/NM²)	62278.48
cv	4.08
Total area (NM²)	10232.90

Round sardinella spatial distribution, shown in F igure 14, was more extended if compared to anchovy or sardine. Higher density was recorded both in the westernmost area and in the Gulf of Sirt. It is worth noting that no sardinella specimen was collected in the most offshore trawl hauls.

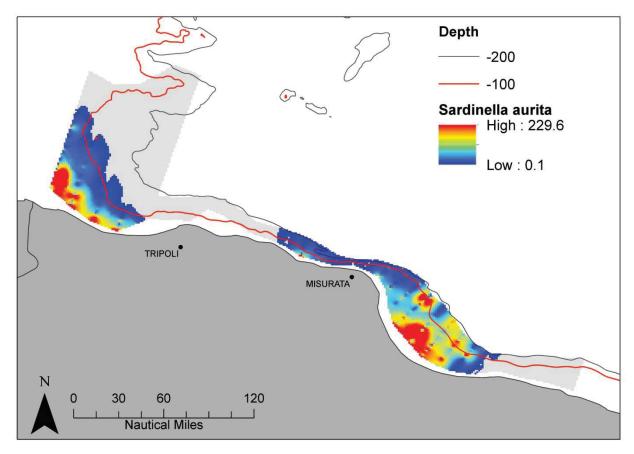


Figure 14. Round sardinella spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Round sardinella was found in the trawls n. 1, 2, 11, 12, and 18 (Figure 2). Three well distinct modes were present in the frequency distribution: the juveniles around 8.5 cm TL, and adults at around 11 and 17.5 cm TL (Figure 15). The full size range was between 5.5 and 21 cm TL. The juveniles were caught only in the trawls n. 2 and 12, while in the trawl n. 13 almost all the specimens were between 16.5 and 21 cm TL.

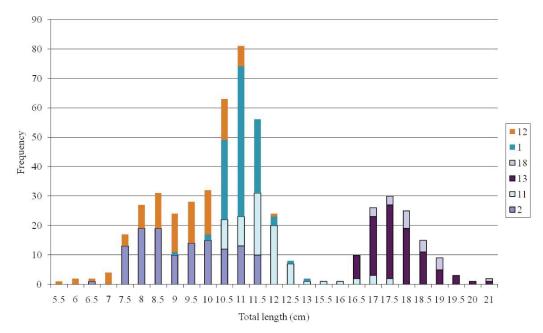


Figure 15. Size frequency distribution of Round sardinella collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

The different size classes collected permitted to obta in a r epresentative length-weitgh relationship for a wide size range (Figure 16).

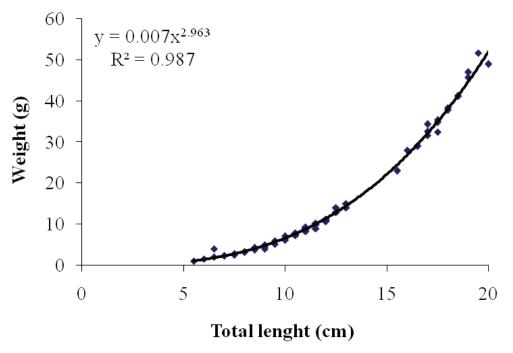


Figure 16. Length-weight relationship for Round sardinella collected in the Echosurvey "MSM Libya 2010".

Mediterranean horse mackerel (Trachurus mediterraneus)

Total Mediterranean horse mackerel biomass in the whole survey area was 15584 t with its higher portion in the acoustic density stratum 0-15 (t/NM²); the following table summarizes the estimated biomass in each stratum.

Density strata (t/NM²)	0-15	15-45	45-132
Sample dimension (Num.)	314	13	7
Mean surface density (t/NM²)	2.35	24.95	86.66
Standard deviation (t/NM²)	3.1	7.96	33.81
Biomass in the density interval (t)	8636.15	3568.4	3379.63
Area (NM²)	5204	157	12

Total Biomass (t)	15584.18
Standard deviation (t/NM²)	985.708
CI - (t/NM²)	13652.19
CI + (t/NM²)	17516.17
cv	6.33
Total area (NM ²)	10232.90

T. mediterraneus spatial distribution, shown in Figure 17, singles out an higher concentration in the coastal waters close to Tripoli, even though other small fish aggregations were also recorded in offshore waters in the western part of the study area.

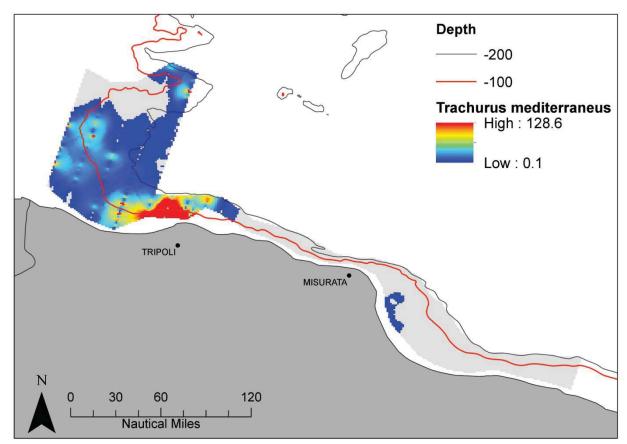


Figure 17. Mediterranean horse mackerel spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

T. mediterraneus was found in several trawls: n. 2, 7, 8, 9 and 12 (F igure 2). Despite its wider distribution among trawls, a relative small number of specimens were found in the samples. Three well distinct modes were present in the frequency distribution (Figure 18): the juveniles

around 13.5 cm TL and the others around 16 cm and 22.5 cm TL. Other size frequency minor modes could be present but the low number of specimens does not a llow to extract such information. The full size range was between 10 and 27 cm TL. The juveniles were collected mainly in the trawls 2 and 9. The spatial segregation among size classes and trawls appear much less pronounced than for anchovy suggesting that the stock is mixed even if different life stages inhabit different habitat and environmental condition. The length weight relationship for the size range 6.5-27 cm TL was estimated and shown in Figure 19.

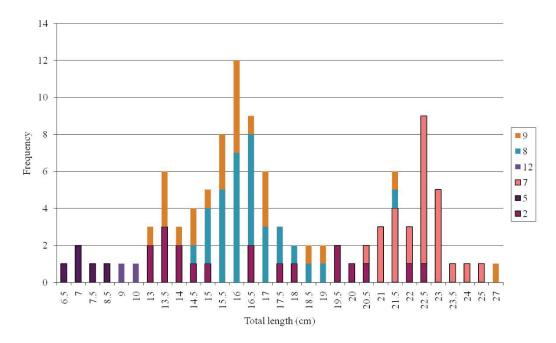


Figure 18. Size frequency distribution of Mediterranean horse mackerel collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

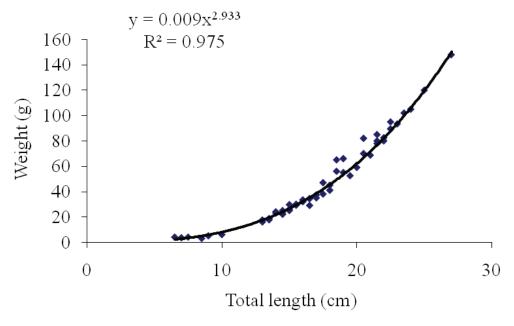


Figure 19. Length-weight relationship for Mediterranean horse mackerel collected in the Echosurvey "MSM Libya 2010".

Chub mackerel (Scomber japonicus)

Chub mackerel biomass in the whole survey area was 17414 t with its higher portion in the stratum $0-15 \text{ (t/NM}^2)$; the following table summ arizes the estimated bio mass in each d ensity stratum.

Density strata (t/NM²)	0-15	15-60	60-132
Sample dimension (Num.)	170	15	3
Mean surface density (t/NM²)	1.27	10.57	30.83
Standard deviation (t/NM²)	1.22	4.27	10.7
Biomass in the density interval (t)	2486.78	1596.57	832.5
Area (NM²)	3963	97	2

Total Biomass (t)	17414.86
Standard deviation (t/NM²)	1131.486
Ci - (t/NM²)	15197.15
CI+ (t/NM²)	19632.57
cv	6.50
Total area (NM²)	10232.90

Chub mackerel was found in two main areas: the western part of the Libyan continental shelf and the coastal area between Tripoli and Misurata (Figure. 20). The greatest density was recorded in this latter area.

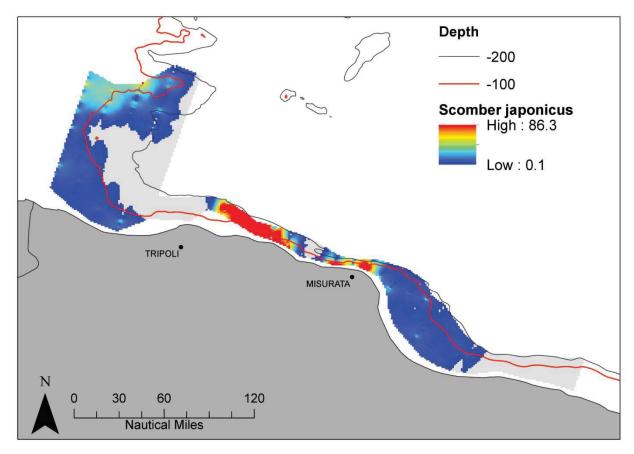


Figure 20. Chub mackerel spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Chub mackerel species was found in the trawls n. 1, 2, 3, 4, 11, 12, 13, 16 and 17 (Figure 2). Two distinct modes were present in the frequency distribution: the juveniles around 12 cm TL and the other around 15.5 cm TL (Figure 21). The full size range was between 5 and 27.5 cm TL. Smaller specimens were mainly collected in the trawl n. 12, while in the trawl n. 4 almost all the specimens were between 11 and 13 cm TL. The spatial segregation among size classes and trawls appear to exists, suggesting that the stock is not fully mixed and different life stages probably inhabit different habitat and environmental condition.

The length-weight relationship for the size range 5-27.5 cm TL is shown in Figure 22.

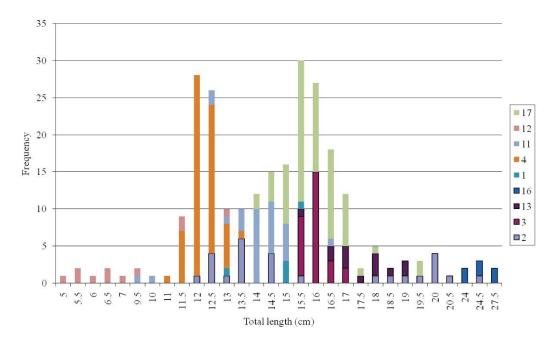


Figure 21. Size frequency distribution of Chub mackerel collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

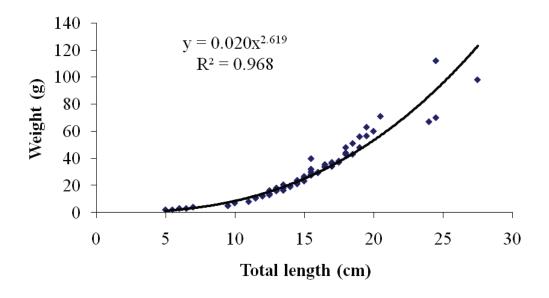


Figure 22. Length-weight relationship for Chub mackerel collected in the Echosurvey "MSM Libya 2010".

Bogue (Boops boops)

Total bogue biomass in the whole survey area was 4915 t with its higher portion in the stratum 0-5 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-5	5-20	20-42
Sample dimension (Num.)	170	15	3
Mean surface density (t/NM²)	1.27	10.57	30.83
Standard deviation (t/NM²)	1.22	4.27	10.7
Biomass in the density interval (t)	2486.78	1596.57	832.5
Area (NM²)	3963	97	2

Total Biomass (t)	4915.85
Standard deviation (t/NM²)	385.1438
Ci - (t/NM²)	4160.97
CI + (t/NM²)	5670.73
cv	7.83
Total area (NM²)	10232.90

Bogue spatial distribution, shown in F igure 23, is mainly concentrated in the western a rea; relatively high densities are also present in the coastal waters close to Misurata.

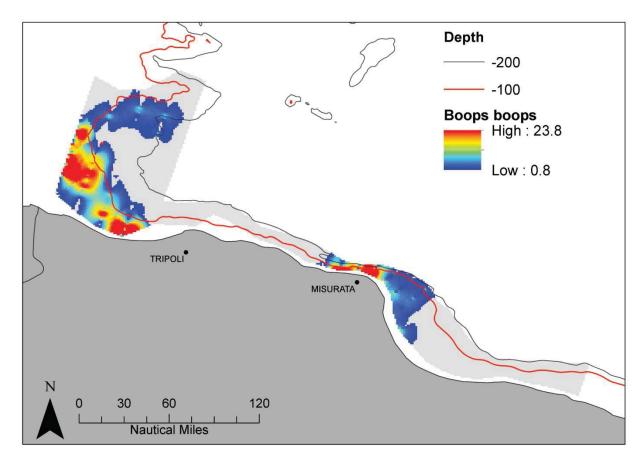


Figure 23. Bogue spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Bogue was found in several trawls (n. 2, 4, 7, 11, 12, 16 and 18; F igure 2). Two well distinct modes were present in the frequency distribution (Figure 24): the juveniles around 9.5 cm TL and the other around 14 cm TL. The full size range was between 7 and 18.5 cm. The juveniles were collected only in the trawls n. 11, 12 and 16 and presents the most part of specimens in the range between 7 and 11 cm TL. In the trawl n. 2 almost all the specimens were between 13 and 16 cm TL. Trawl n. 18 presents the widest size range among the others. The spatial segregation among size classes and trawls appears relevant and suggests that the stock is not fully mixed and different life stages probably inhabit different habitat and environmental condition.

The length weight relationship for the size range 7-18.5 cm TL is shown in Figure 25.

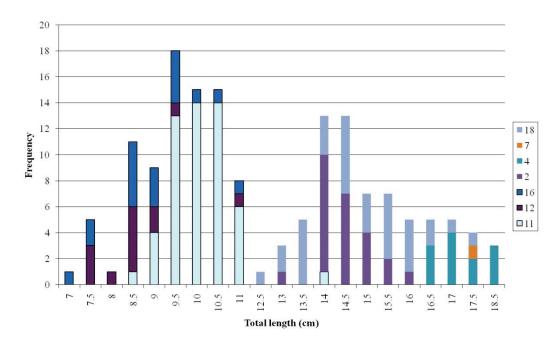


Figure 24. Size frequency distribution of Bogue collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

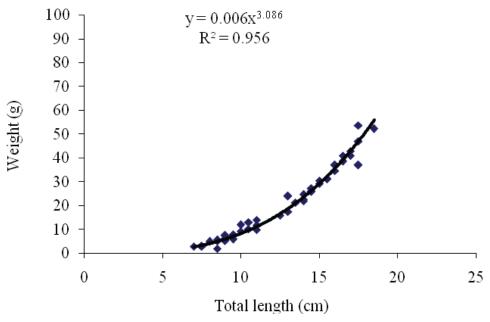


Figure 25. Length-weight relationship for Bogue collected in the Echosurvey "MSM Libya 2010".

Picarel (Spicara flexuosa)

Total Spicara flexuosa biomass in the whole survey area was 1975.86 t with its higher portion in the stratum 0-5 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-5	5-10	10-23
Sample dimension (Num.)	86	3	3
Mean surface density (t/NM²)	1.25	8.67	16.6
Standard deviation (t/NM²)	1.09	0.85	5.8
Biomass in the density interval (t)	1302.33	225.33	448.2
Area (NM²)	1896	10	2

Total Biomass (t)	1975.86
Standard deviation (t/NM²)	223.184
Ci - (t/NM²)	1538.42
CI + (t/NM²)	2413.30
cv	11.30
Total area (NM²)	10232.90

The spatial distribution of this species (Figure 26) showed a main area located in the westernmost part of the study area characterized by depths lower than 100 m.

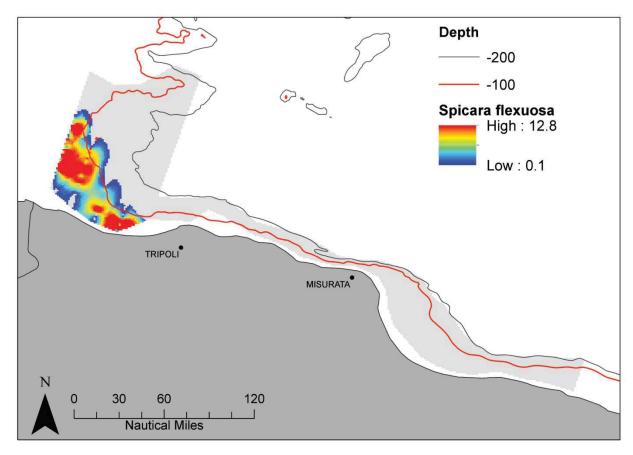


Figure 26. Spicara flexuosa spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

The size range of *S. flexuosa* was between 11.5 and 14 cm TL (Figure 27). The species was caught only in the trawl haul n. 2 (Figure 2).

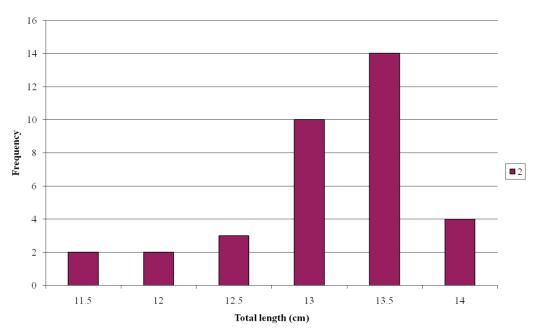


Figure 27. Size frequency distribution of *Spicara flexuosa* collected in the Echosurvey "MSM Libya 2010".

The length weight relationship for the size range 11.5-14 cm is shown in Figure 28.

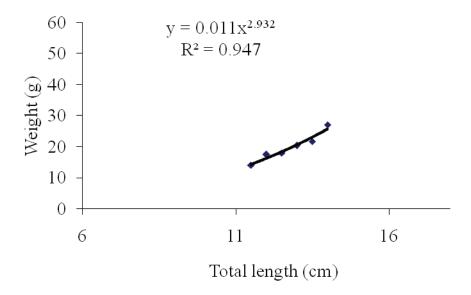


Figure 28. Length-weight relationship for *Spicara flexuosa* collected in the Echosurvey "MSM Libya 2010".

Picarel (Spicara smarris)

Total *Spicara smaris* biomass in the whole survey area was 2062.19 t with its higher portion in the stratum 0-5 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-5	5-10	10-23
Sample dimension (Num.)	124	6	3
Mean surface density (t/NM²)	0.8	7.38	17.13
Standard deviation (t/NM²)	0.94	1	6.05
Biomass in the density interval (t)	1129.99	383.93	548.27
Area (NM²)	2352	37	4

Total Biomass (t)	2062.19
Standard deviation (t/NM²)	199.2087
Ci - (t/NM²)	1671.74
CI + (t/NM²)	2452.64
CV	9.66
Total area (NM²)	10232.90

The species was mainly located in two different areas (Figure 29): one in the westernmost part of the study area, and the second one in the coastal waters east of Misurata.

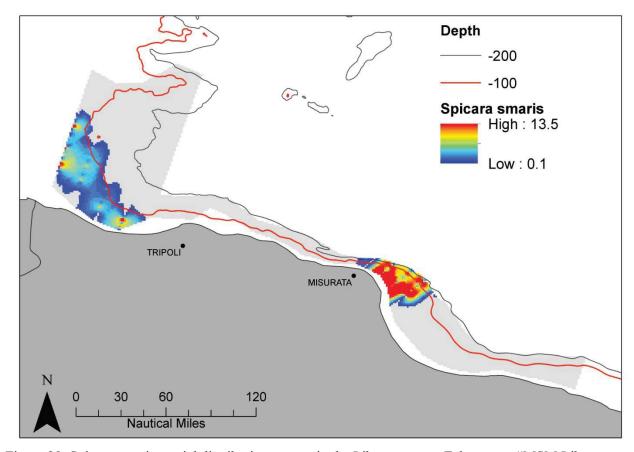


Figure 29. Spicara smaris spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

The recorded size range for *S. smaris* was between 8.5 and 14 cm T L (Figure 30), wider than what observed for *S. flexuosa*. The size distribution among trawls appears partially overlapping; even bigger and smaller specimens were collected in two different trawls (2 and 11). Also for of *S. smaris* the spatial distribution among sizes suggests a certain degree of mixing among different areas.

The length-weight relationship for the size range 8.5-14 cm TL is shown in Figure 31.

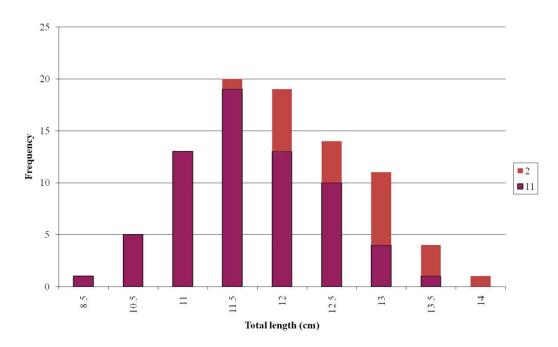


Figure 30. Size frequency distribution of *Spicara smaris* collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

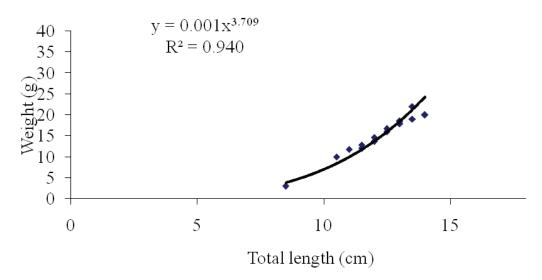


Figure 31. Length-weight relationship for *Spicara smaris* collected in the Echosurvey "MSM Libya 2010".

Blotched picarel (Spicara maena)

Total *Spicara maena* biomass in the whole survey area was 1894.55 t with its higher portion in the stratum 25-136 (t/NM ²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-5	5-25	25-136
Sample dimension (Num.)	25	3	2
Mean surface density (t/NM²)	1.2	10.93	81.4
Standard deviation (t/NM²)	1.2	8.06	76.65
Biomass in the density interval (t)	275.08	317.07	1302.4
Area (NM²)	376	93	8

Total Biomass (t)	1894.55
Standard deviation (t/NM²)	619.3593
Ci - (t/NM²)	680.61
CI + (t/NM²)	3108.49
cv	32.69
Total area (NM²)	10232.90

The species was mainly located in the coastal waters west of Misurata (Figure 32).

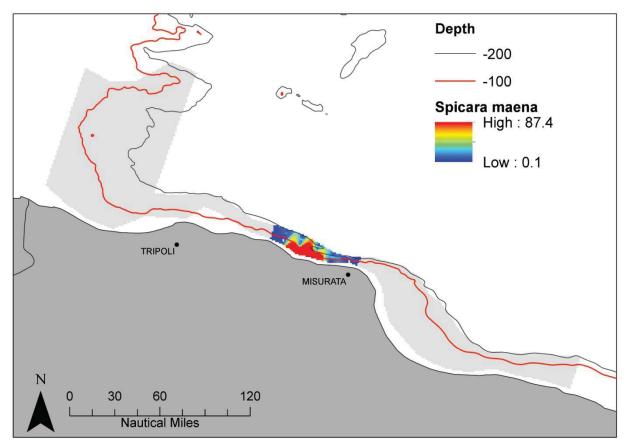


Figure 32. *Spicara maena* spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

Only few specimens of *S. maena* were recorded in two trawls (n. 2 and n. 17; Figure 2). Based on these low numbers no significant results could be outlined on the size distribution in different areas (Figure 33).

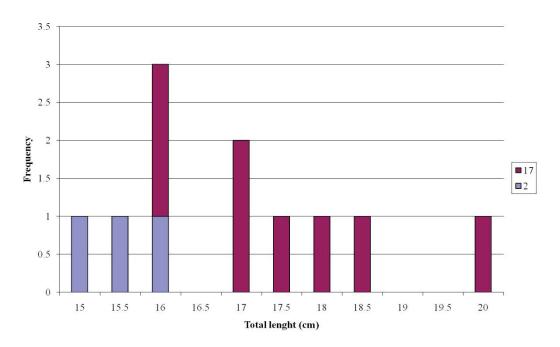


Figure 33. Size frequency distribution of *Spicara maena* collected in the Echosurvey "MSM Libya 2010". Different colors correspond to different trawl hauls.

The length-weight relationship for the size range 12.5-18.5 cm TL of *S. maena* is shown in Figure 34.

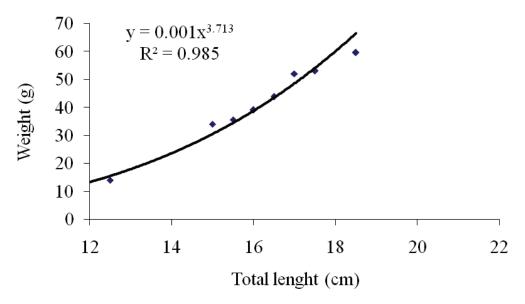


Figure 34. Length-weight relationship for *Spicara maena* collected in the Echosurvey "MSM Libya 2010".

Red-eye round herring (Etrumeus teres)

Total Round herring biomass in the whole survey area was 6914 t with its higher portion in the density strata 5-20 (t/NM²); the following table summarizes the estimated biomass in each density stratum.

Density strata (t/NM²)	0-5	5-20	20-53
Sample dimension (Num.)	120	33	9
Mean surface density (t/NM²)	1.07	10.38	27.79
Standard deviation (t/NM²)	1.32	4.03	9.85
Biomass in the density interval (t)	1180.35	3372.12	2362.06
Area (NM²)	1409	474	13

Total Biomass (t)	6914.53	
Standard deviation (t/NM²)	376.3141	
Ci - (t/NM²)	6176.95	
Ci + (t/NM²)	7652.11	
CV	5.44	
Total area (NM²)	10232.90	

Round herring was mainly found in the eastern part of the surveyed area, even though a small nucleus was also recorded close to Misurata (Figure 35).

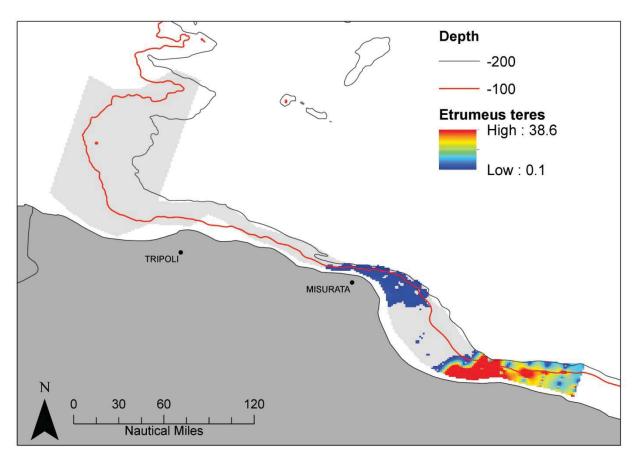


Figure 35. Round herring spatial distribution pattern in the Libyan waters. Echosurvey "MSM Libya 2010".

The Round herring specimens were collected in the trawls n. 11, 13, 15 and 16 (Figure 2). Two well distinct juveniles modes were present in the frequency distribution around 5.5 and 9.5 cm TL (Figure 36). The full size range was between 4.5 and 13.5 cm TL. It is worth noting that the two modes were caught in two different trawl hauls positioned in the Gulf of Sirt. This spatial

segregation among size classes suggests that probably the stock is not fully mixed and different life stages probably inhabit different areas with different environmental conditions.

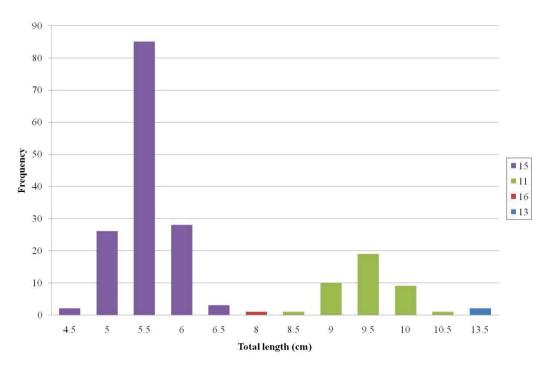


Figure 36. Size frequency distribution of Round Herring specimens collected in the Echosurvey "MSM Libya 2010".

The different size classes recorded permitted to obtain the length vs. weight relationship (Figure 37). The relationship parameters are shown in Figure 37 as well.

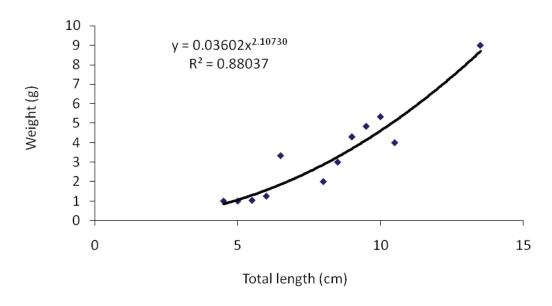


Figure 37. Length-weight relationship for Round Herring estimated in the Echosurvey "MSM Libya 2010".

Water masses characteristics

Among the recorded oceanographic parameters (temperature, salinity oxygen, fluorescence, water transparency, etc.) in this section only temperature, salinity and oxygen were selected and discussed. They were chosen as the most representative to characterize the water masses along the Libyan coast during the echosurvey. Examples of CTD profiles are reported in Figure 38. All CTD profiles are reported in Annex 3.

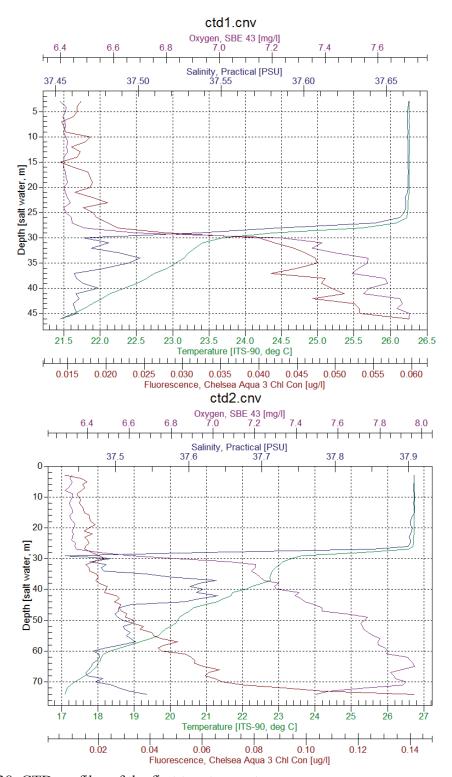


Figure 38. CTD profiles of the first two transects.

Vertical sections of the whole area

In Figure 39 the temperature (a), salinity (b) and oxigen (c) patterns are shown along an offshore coastal section. A well thermally stratified column is evident, whit the uppermixed layer showing an almost constant thickness and the thermocline positioned in the layer 20-40 m.

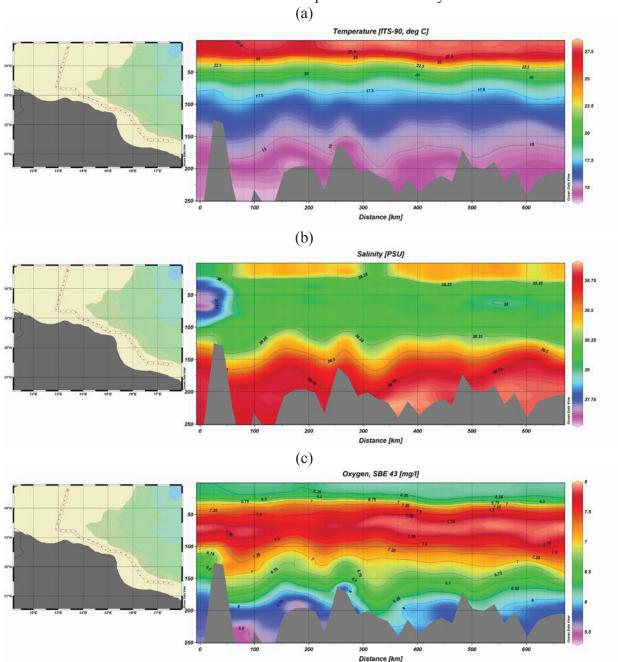


Figure 39. a) Temperature, b) Salinity and c) Oxigen sections recorded in the offshore stations

Both salinity and oxigen sections (Figure 39 b and c) show the position of MAW core located around 50-60 m. Clea r differences are evident in this layer between the western area and the eastern one. The signature of the MAW, characterized by a salinity minimum, shows lowe r values (37.7 ‰) in the western part of the Libyan waters, while in the eastern higher salinity values were recorded (38 ‰).

The oxygen pattern shows a clear low density in the upper mixed layer, with an increase of the value from 7.5 to 7.9 mg/l in the MAW layer.

Surface plots of the whole area

The temperature surface plot (Figure 40) showed a certain degree of dissimilarity between the eastern and the western areas, with relatively lower temperature in the latter.

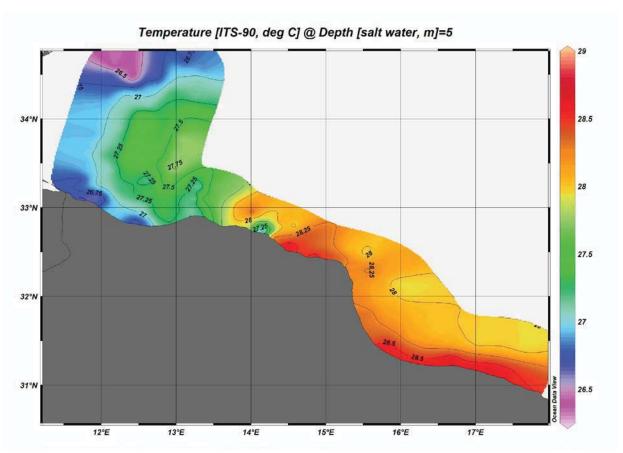


Figure 40. Surface temperature pattern over the whole study area at 5 m depth.

Salinity surface plot (Figure 41) shows similar trend between the two areas, highlighting a positive longitudinal gradient. An opposite gradient is evident in the oxigen pattern (Figure 42).

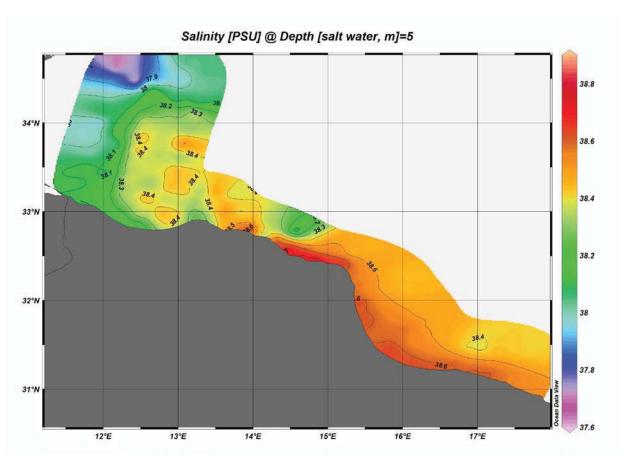


Figure 41. Surface salinity pattern over the whole study area at 5 m depth.

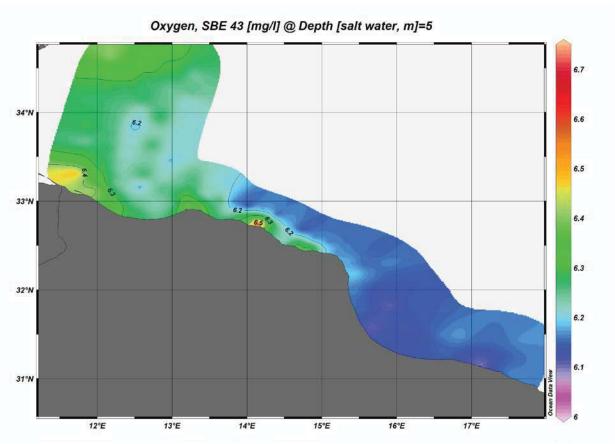


Figure 42. Surface oxigen pattern over the whole study area at 5 m depth.

The T-S scatter-plot for all the CTD stations shown in Figure 43 was obtained by superimposing stations of the two main subareas: red dots for eastern area and blue for the wastern one. Western stations show a large salinity range in the MAW layer, while in the eastern sations surface waters are saltier.

Even though the maximum depth (300 m) was investigated only in few offshore stations, the T-S plot shows the differences also for LIW (Levantine Intermediate Water), which is saltier in the eastern area than in the western one.

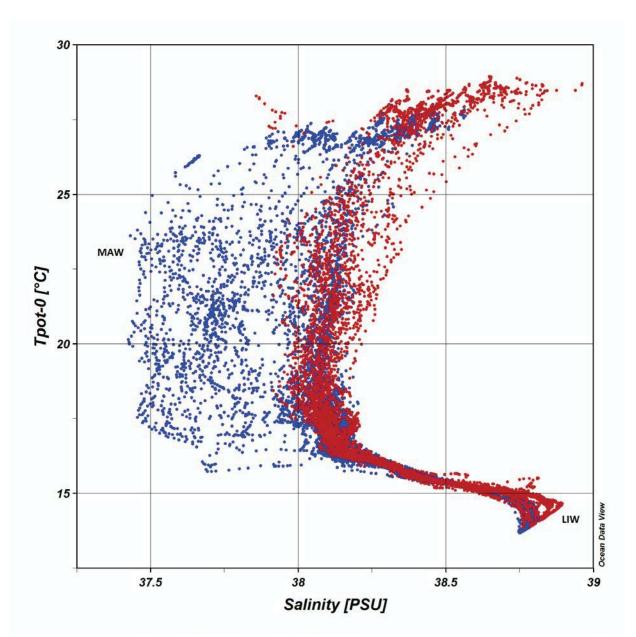


Figure 43. TS scatter-plot for all the CTD stations. Red stations are located in the eastern part (longitude > 13.4°) of the study area while blue stations are located in the western area.

The vertical profiles of temperature, salinity and fluorescence single out the main differences in the oceanographic parameters between the two sub-areas (Figure 44).

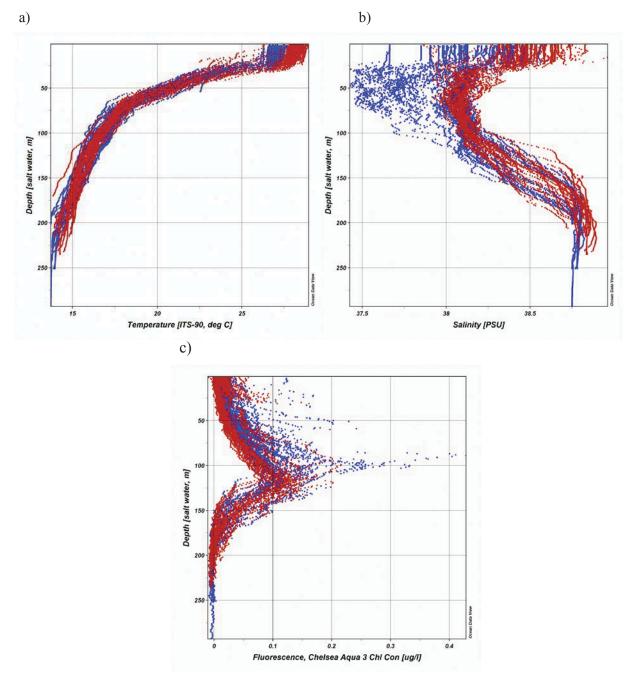


Figure 44. Vertical profiles of temperature (a), salinity (b) and fluorescence (c). Red stations are located in the eastern part (longitude $> 13.4^{\circ}$) of the study area while blue stations are located in the western area.

7. Discussions

The oceanographic conditions in the whole area showed a clear pattern similar to the one observed during the surve y carried out in summer 2008. In particular, the collected oceanographic data singled out, also by means the TS scatter-plot, two different physical environments in the western and in the eastern parts of the surveyed area. It is likely to hypothesize that diffe rent oceanographic conditions may drive fish species association in different sub-areas, as it was evidenced in Bonanno et al. (2015). Also during this second echosurvey in Libyan waters the cumulative biomass of small pelagic species was higher in the western part than in the other parts of the survey area. Moreover, pelagic fish association in the western area is completely different compared to the other areas. In particular, the western area presents exclusive association of small pelagic species, such as Sardina pilcardus, Spicara flexuosa and Trachurus mediterraneus, which were not met in the other sub-areas. Similar consideration could be outlined for the other fish association and oceanographic condition.

A more accurate data analysis is to be performed to confirm such preliminary observations.

The most relevant information, on the basis of the collected acoustic data and biological samples (trawls), is that the pelagic species constitute a relevant fishing resource. Ten commercially important fish species were estimated in the Libyan waters. Sardina pilchardus biomass was quite abundant but only in the western area. Engraulis encrasicolus showed a higher presence, compared to sardine, and its presence was recorded in several trawl hauls. Its biomass could be relevant for fisheries activity even though the Libyan fishery prefer other small pelagic resources like round sardinella or sardine. The most abundant pelagic species was the Sardinella aurita which was also widely distributed along the Libyan coasts. Among the mentioned species only Sardinella aurita represents an important target species for Libyan fishery. The chub mackerel also constitutes an important target species for Libyan fishery and the acoustic evaluation, even though limited to the we stern and part of the central Libyan areas, supported the presence of a biomass above 15000 t. Other species as Boops boops and Spicara sp. are economically less important but their role in the ecosystem is relevant, based mainly on their distribution and abundance, which seem to suggest a relevant role in the pelagic food web.

More detailed studies should be necessary to apply the ecosystem approach to the fishery and to reconstruct the linkage among all these components. Also from the result s here obtained, the Libyan ecosystem seems to represent the more preserved Mediterranean habitat, which permits comparative studies with other areas much more exploited. This opportunity should be kept by Libyan scientists to increase the scientific knowledge on the ecosystem dynamics, also taking advantage of the ongoing research activities in the framework of the MedSudMed Project.

8. Notes, recommendations and acknowledgments

The total echosurvey track along the Libyan coasts was not completed due to bad weather conditions and limited vessel time.

The timing of the survey was mainly affected by bad weather, which delayed the beginning of the work, and by the relative small size of the vessel and its limited autonomy. Moreover, the second half of the survey was carried out in an area known for its unevenness bottom where trawling is rather difficult. The work-plan covered about 70 % of the L ibyan continental shelf and the data collected will allow updating information on the status of small pelagic fish stocks along the Libyan coast (from Tunisian border to middle part of the Sirt Gulf).

Even though the echosurvey did not cover the whole Libyan continental shelf, the results of this survey are of big interest since the survey covered the most important area for small pelagic in Libyan waters, as singled out by the previous echosurvey performed in summer 2008.

Taking into account the results of biomass evaluation, even though the echosurvey did not cover to the whole Libyan waters, the high fish density estimated in some area requires much more detailed information on species composition and size distribution. To this aim a lon ger survey time is needed for p erforming additional trawls and, finall y, for obtaining a more detailed description of species composition in the area.

Some areas, due to the roughness of the bottom or the presence of relicts, seem to be used by fish schools as shelter sites; in this areas it was not p ossible to perform any trawl, despite the big amount of fish detected by the echosounder. In order to obtain a much more precise results on species composition and their size distribution, it would be necessary in future echosurveys to have an additional fi shing vessel equipped with purse seine net (*Lampara* vessel) much more efficient than the pelagic trawls used routinely in the acoustic surveys, to achieve fish samples in rough bottom areas.

The amount of small pelagic fish biomass estimated and the existing of a professional fisheries exploiting these resources, suggest the need of a contiue (i.e. annual) monitoritoring of standing stocks by means of echosurvey and by collecting information on commercial fishery through a landing survey. In this way it will be possible to obtain data on the total amount of pelagic species landed during the year and to take biological samples to study the fundamental parameters of population dynamics and the population structure (age composition, length at first maturity, etc.).

Results on the *Sardinella aurita* biomass distribution showed the presence this species very close to the coast, but unfortunately, due to the forbidden access to the area close to the coastline it is likely to hypothesize that its total biomass was underestimated during this survey; so it is strongly recommended for the next survey to be allowed the navigation also near the coast until the depth of 10 m.

The Libyan Authorities are gratefully acknowledged for having authorized the survey.

Thanks are expressed to all crew members of the M/N Maria Grazia for their availability and attention singled out during the whole period of the survey.

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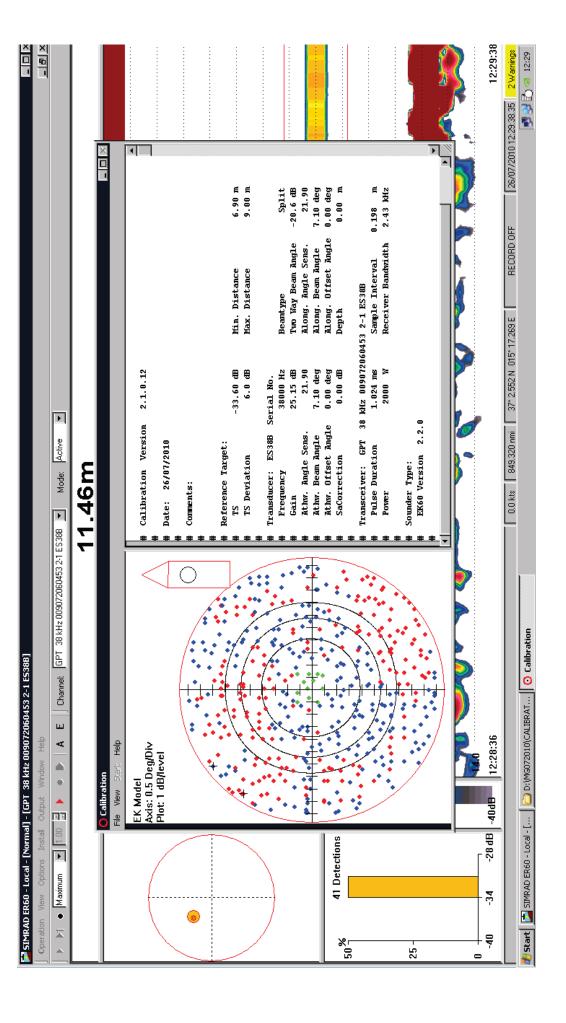
Calibration reports

GPT38kHz, ES38B: 1024mks, 2000W

Date 26/07/2010

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Calibration EK60 in Siracusa waters (37°02.642′N; 15°17.540′E)
Depth = 13.6m; Sphere depth = 10.2m
# Calibration Version 2.1.0.12 # Date: 26/07/2010 # Comments: #
#
# Reference Target:
   TS
                 -33.60 dB
                                Min. Distance
                                                    6.90 m
   TS Deviation
                        6.0 \, \mathrm{dB}
                                   Max. Distance
                                                        9.00 m
# Transducer: ES38B Serial No.
#
   Frequency
                     38000 Hz
                                    Beamtype
                                                        Split
#
   Gain
                   25 15 dB
                                 Two Way Beam Angle -20.6 dB
   Athw. Angle Sens.
                                     Along. Angle Sens.
                          21.90
                                                            21.90
                                       Along. Beam Angle 7.10 deg
   Athw. Beam Angle
                        7.10 deg
                                      Along. Offset Angle 0.00 deg
   Athw. Offset Angle 0.00 deg
   SaCorrection
                       0.00 \, \mathrm{dB}
                                   Depth
                                                    0.00 \, \text{m}
# Transceiver: GPT 38 kHz 009072060453 2-1 ES38B
#
   Pulse Duration
                       1.024 ms
                                    Sample Interval 0.198 m
#
   Power
                    2000 W
                                 Receiver Bandwidth 2.43 kHz
#
# Sounder Type:
   EK60 Version 2.2.0
# TS Detection:
                      -40.0 dB
                                                        100 %
   Min. Value
                                   Min. Spacing
                                       Min. Echolength
#
   Max. Beam Comp.
                           6.0 \, \mathrm{dB}
                                                              60 %
#
   Max. Phase Dev.
                           8.0
                                   Max. Echolength
                                                          160 %
#
# Environment:
  Absorption Coeff. 7.1 dB/km
                                      Sound Velocity
                                                         1544.4 m/s
#
# Beam Model results:
   Transducer Gain = 24.78 \text{ dB}
                                      SaCorrection
                                                        = -0.60 \text{ dB}
   Athw. Beam Angle = 6.88 \text{ deg}
                                        Along. Beam Angle = 6.90 \text{ deg}
#
#
   Athw. Offset Angle = 0.08 \text{ deg}
                                       Along. Offset Angle= 0.05 deg
#
# Data deviation from beam model:
  RMS = 0.16 dB
   Max = 1.06 \text{ dB No.} = 338 \text{ Athw.} = -4.2 \text{ deg Along} = 2.8 \text{ deg}
  Min = -0.87 \text{ dB No.} = 342 \text{ Athw.} = -3.1 \text{ deg Along} = 4.0 \text{ deg}
# Data deviation from polynomial model:
# RMS = 0.13 \text{ dB}
  Max = 0.96 \text{ dB No.} = 338 \text{ Athw.} = -4.2 \text{ deg Along} = 2.8 \text{ deg}
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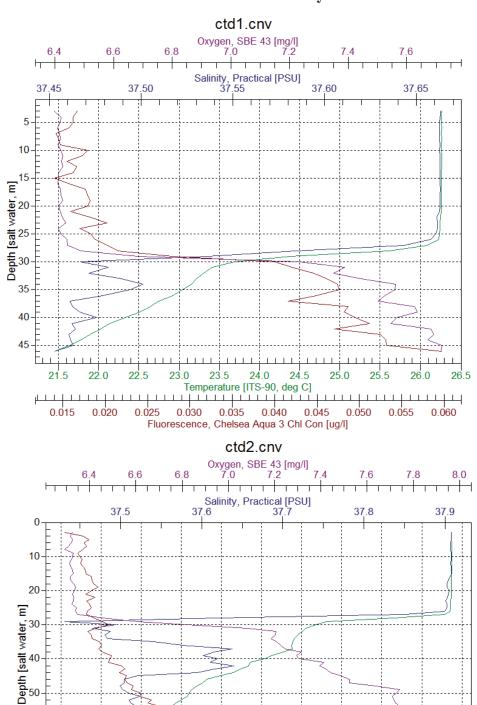
Min = -0.90 dB No. = 337 Athw. = -2.4 deg Along = 2.7 deg



Annex 2
Target Strength (TS)-Length relationships

Species	TS equation	References
Engraulis encrasicolus	$TS = 20 \log TL - 75.29$	Barange et al., 1996
Sardina pilchardus	$TS = 20 \log TL - 72.6$	MEDIAS Group
Sardinella aurita	$TS = 20 \log TL - 72.6$	Debnol et al., 1985
Trachurus trachurus	$TS = 20 \log TL - 68.7$	Lillo et al., 1996
Trachurus mediterraneus	$TS = 20 \log TL - 68.7$	Lillo et al., 1996
Trachurus picturatus	$TS = 20 \log TL - 68.7$	Lillo et al., 1996
Spicara smaris	$TS = 20 \log TL - 71.2$	Ona, 1999
Spicara maena	$TS = 20 \log TL - 71.2$	Ona, 1999
Spicara flexuosa	$TS = 20 \log TL - 71.2$	Ona, 1999
Boops boops	$TS = 20 \log TL - 71.2$	Ona, 1999
Etrumeus teres	$TS = 20 \log TL - 71.2$	Ona, 1999
Scomber scombrus	$TS = 20 \log TL - 84.9$	Edwards et al., 1984
Scomber japonicus	$TS = 20 \log TL - 73.8$	Svellingen et al., 2008

CTD Profiles for each station of the "MSM Libya 2010" Acoustic Survey



21

0.06

0.04

Temperature [ITS-90, deg C]

Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]

0.08

0.10

60

70-

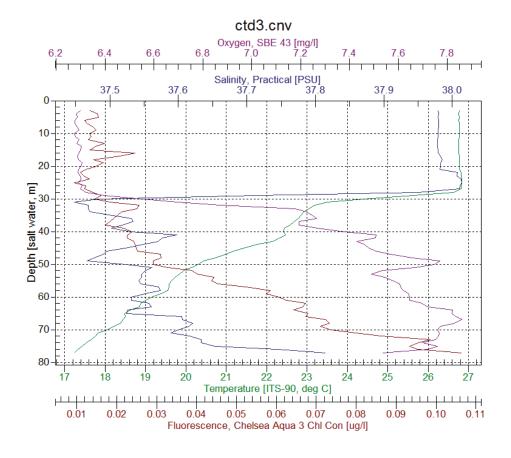
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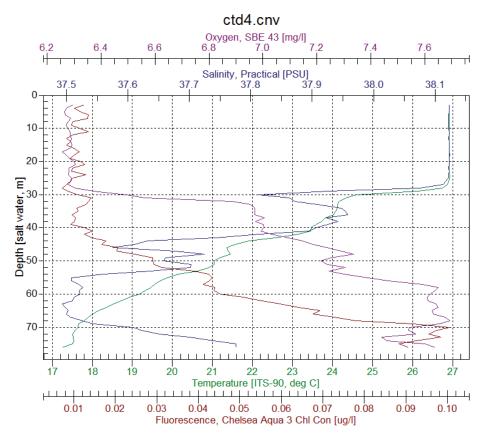
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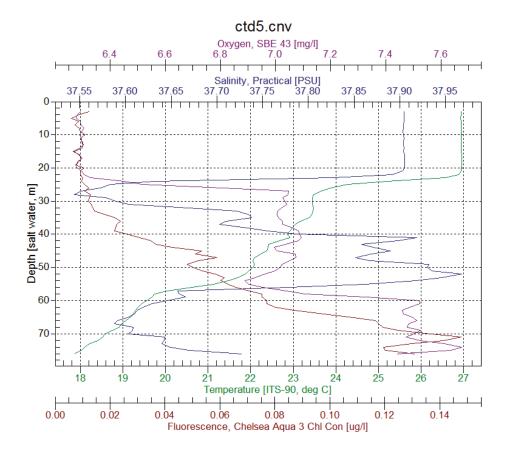
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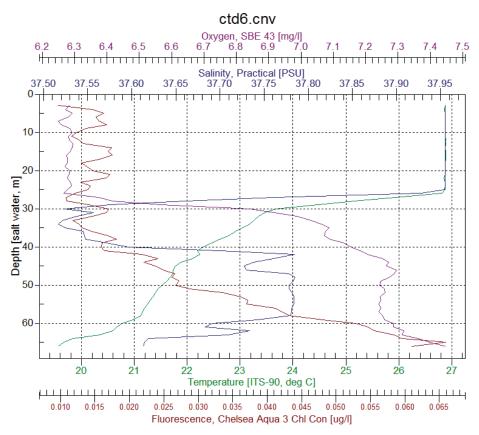
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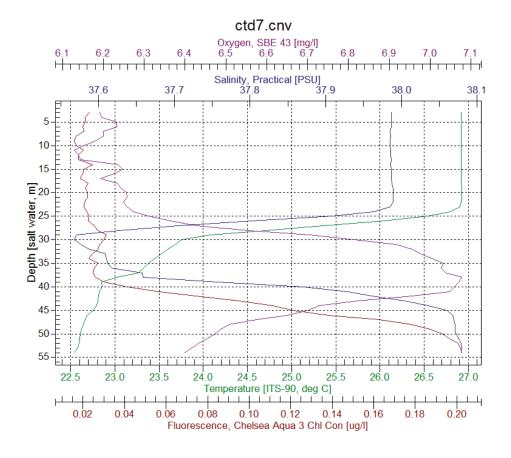
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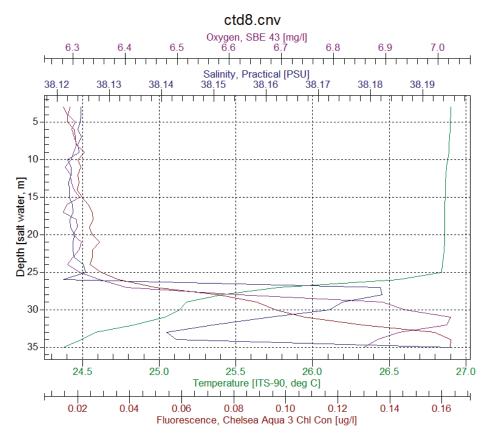


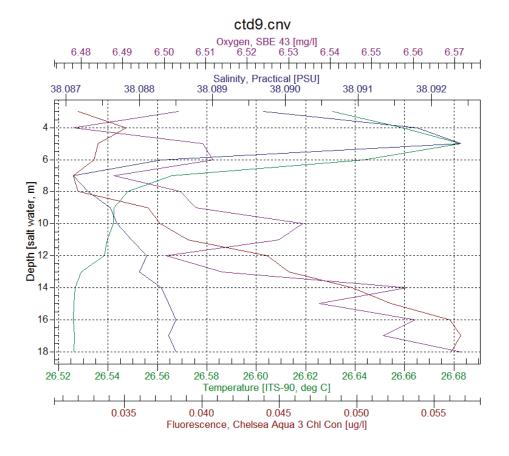


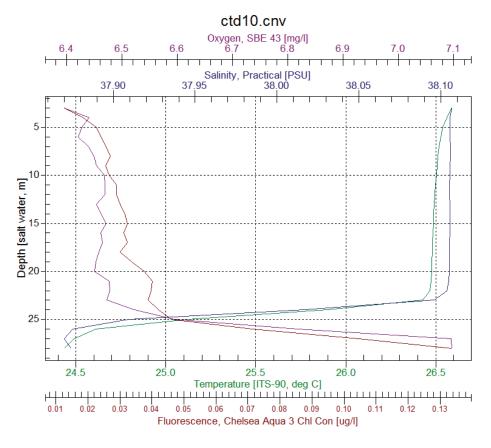


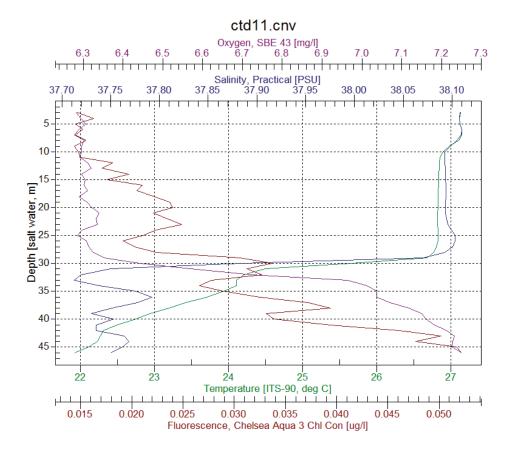


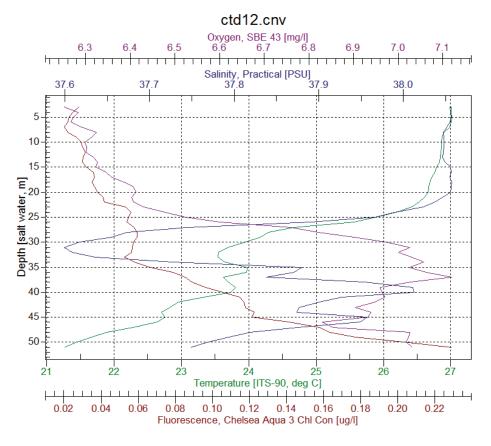


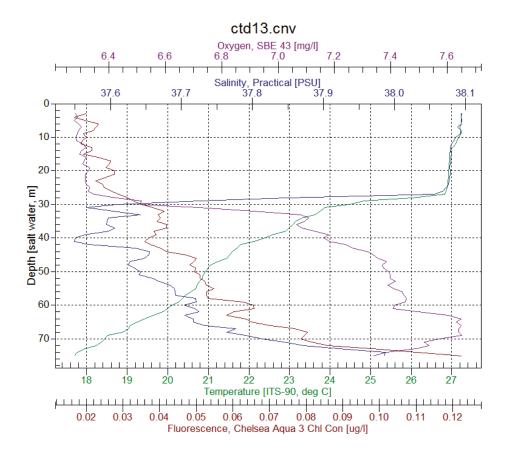


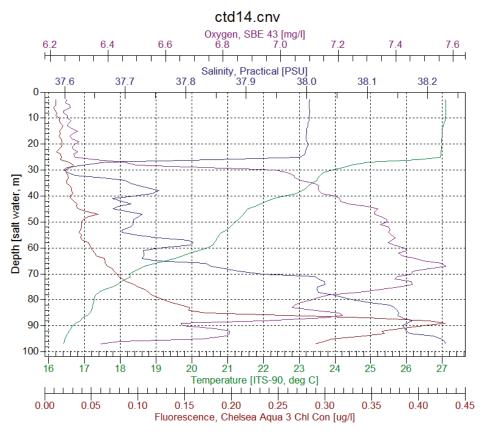


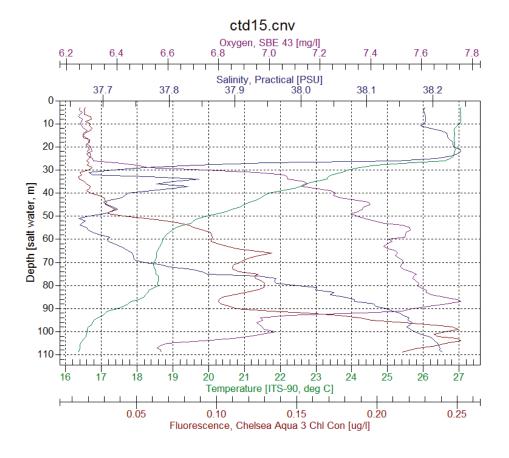


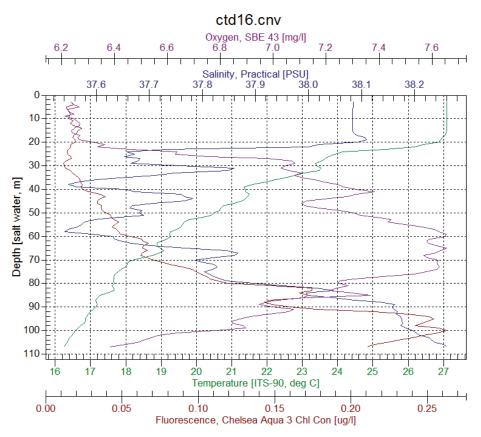


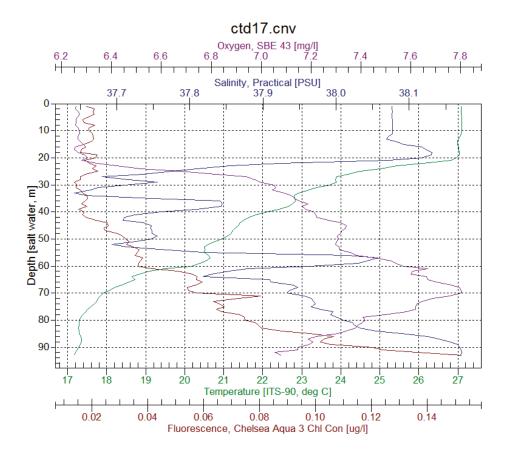


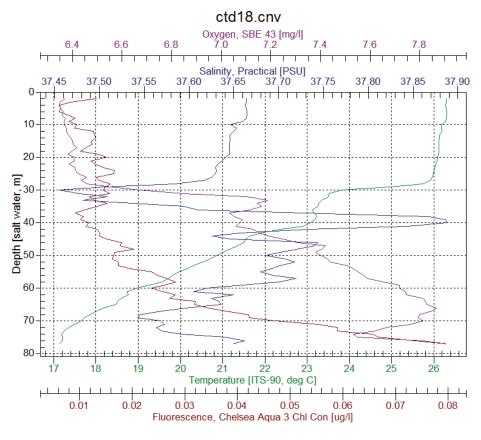


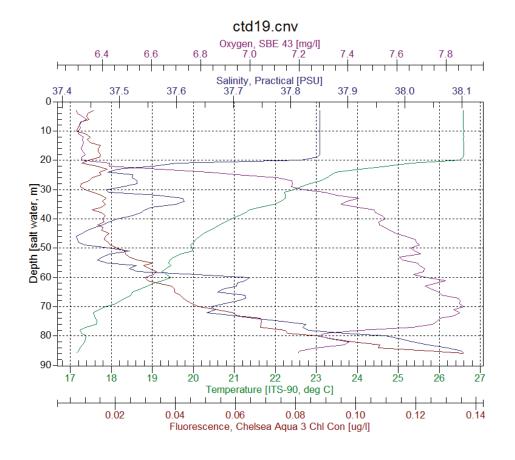


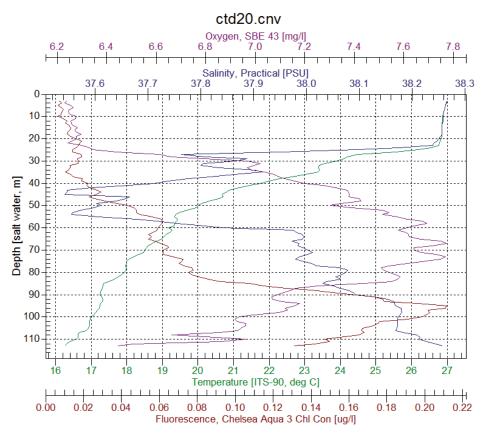


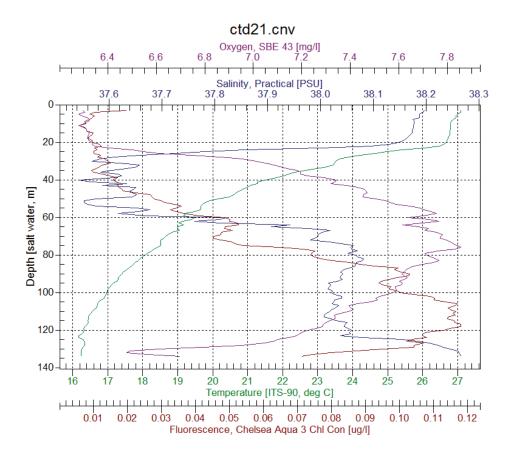


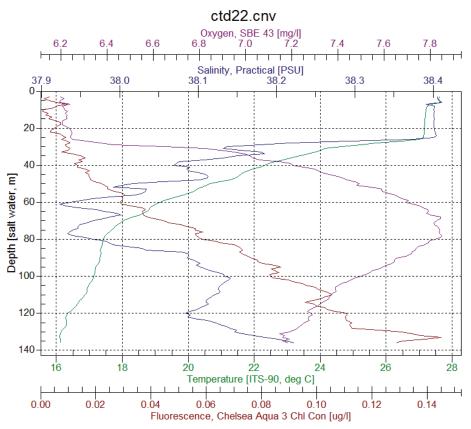


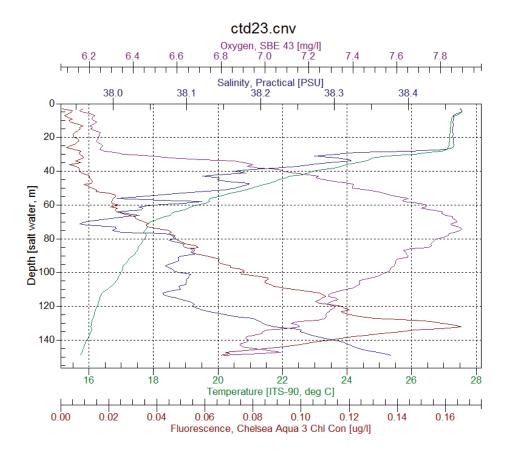


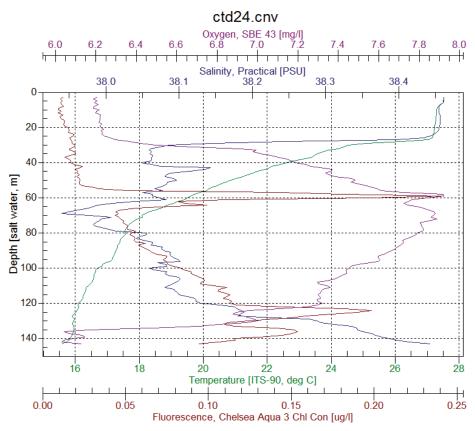


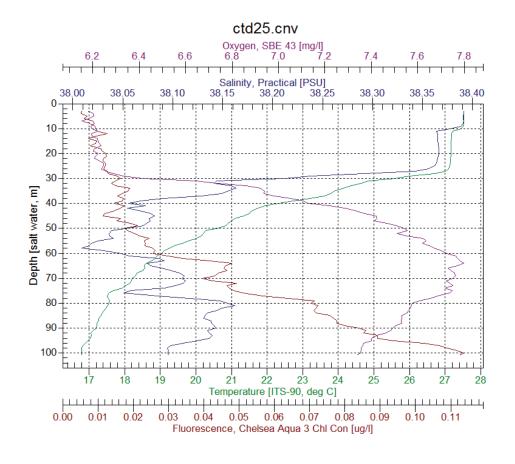


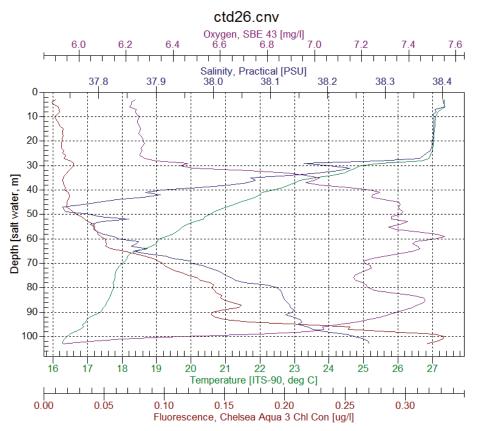


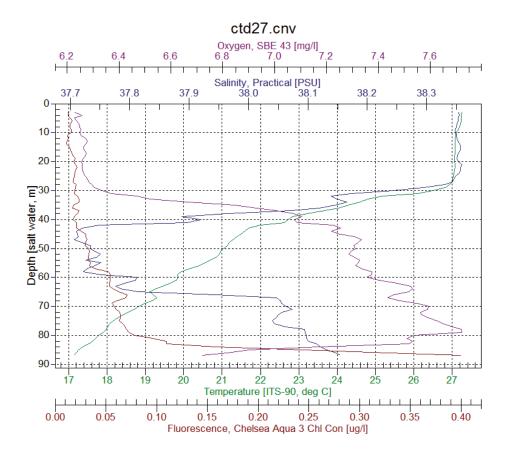


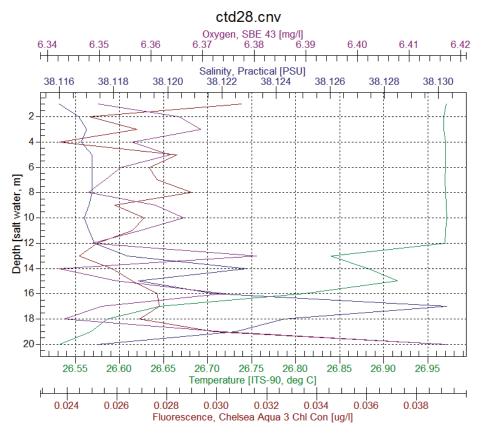


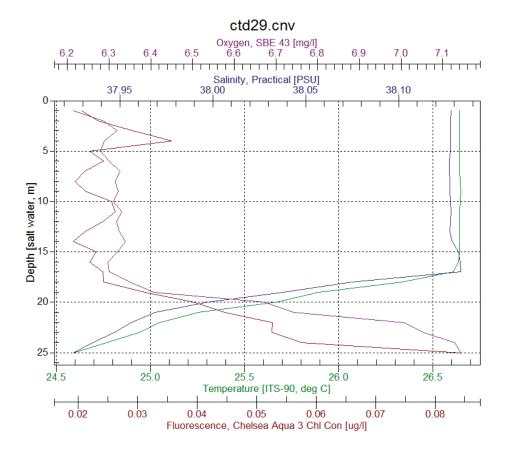


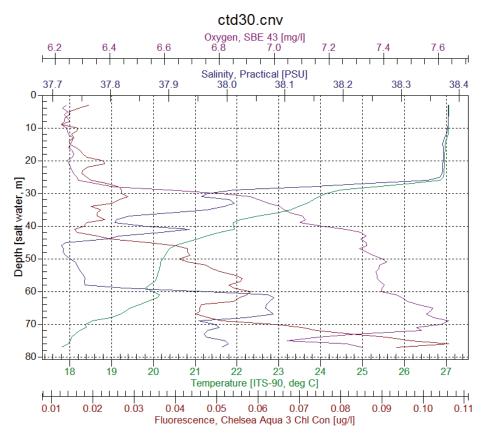


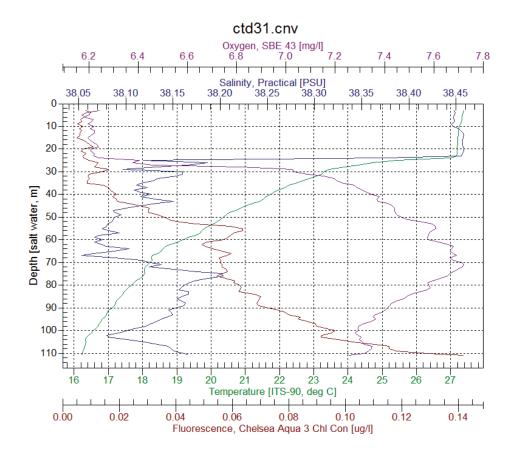


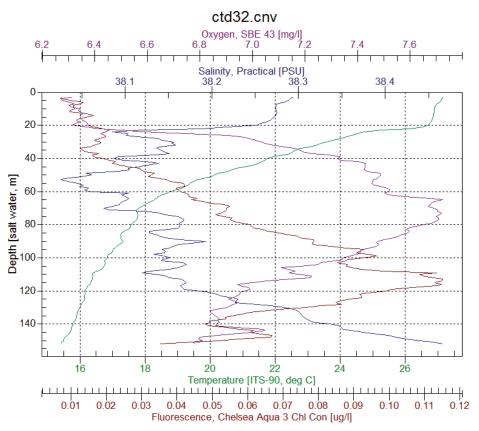


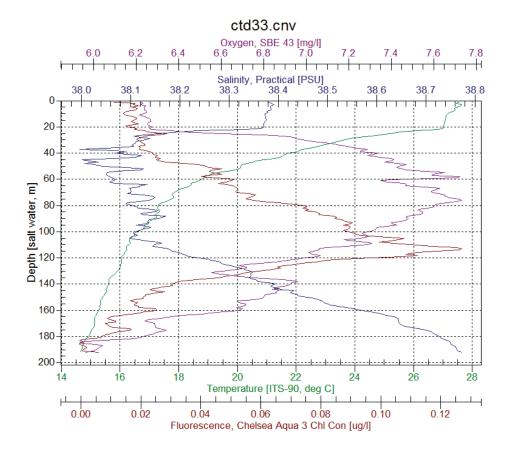


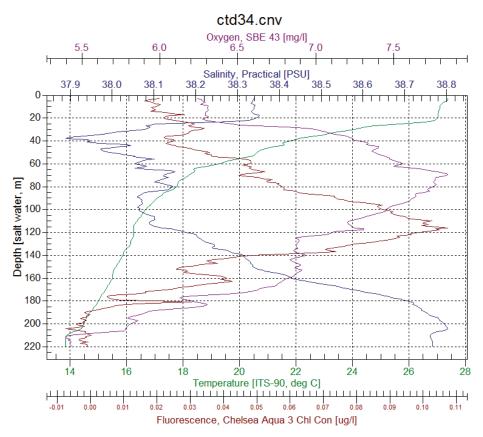


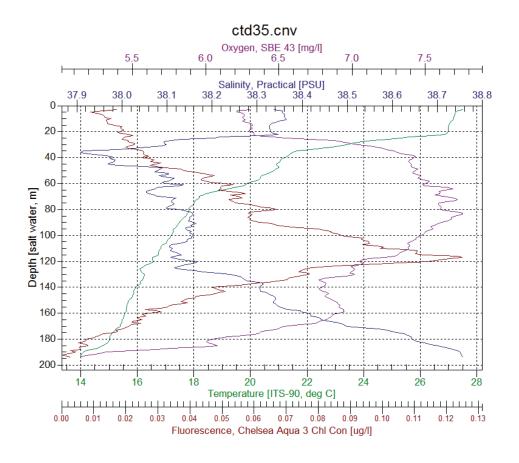


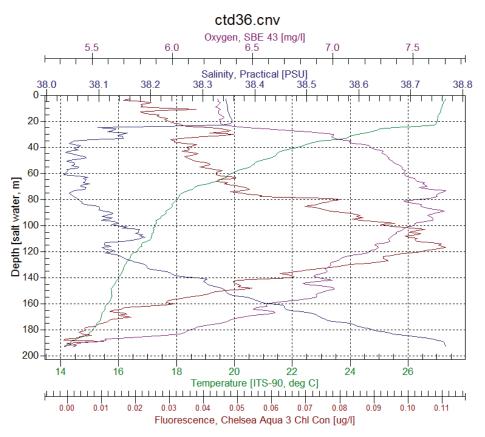


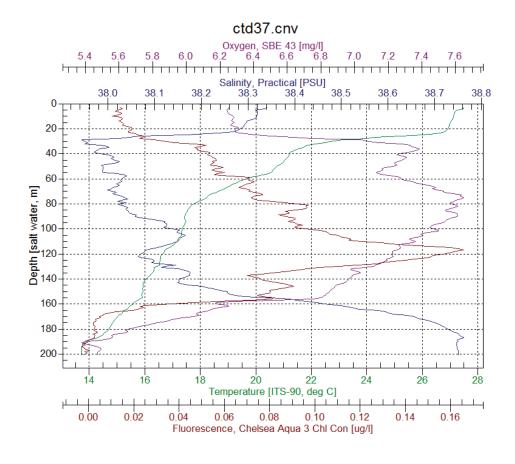


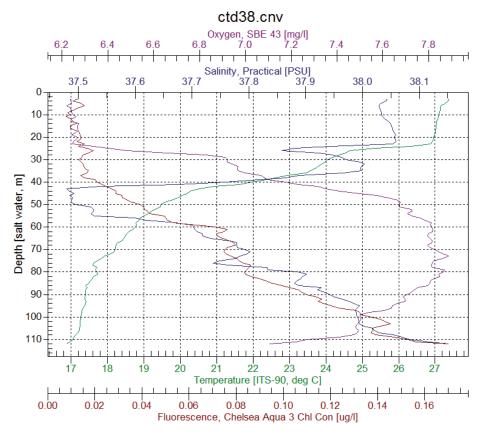


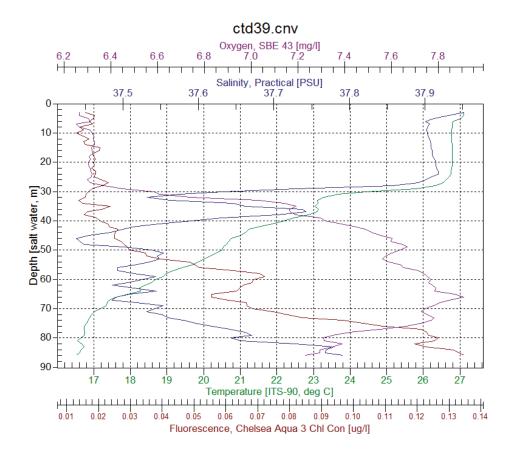


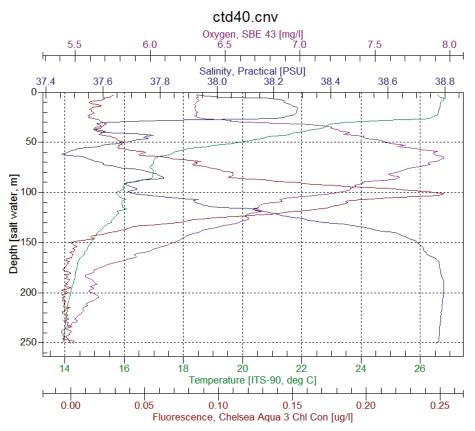


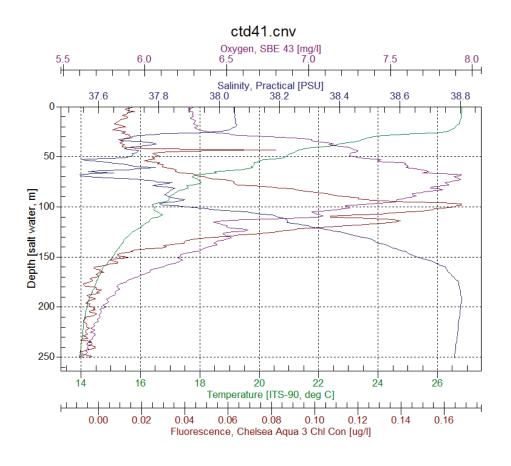


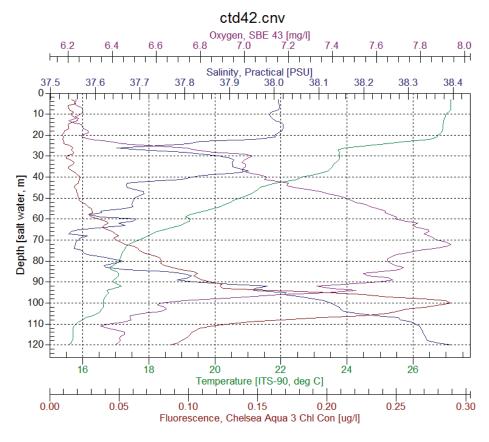


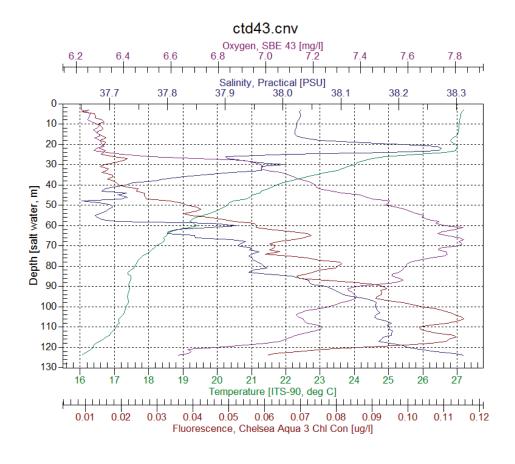


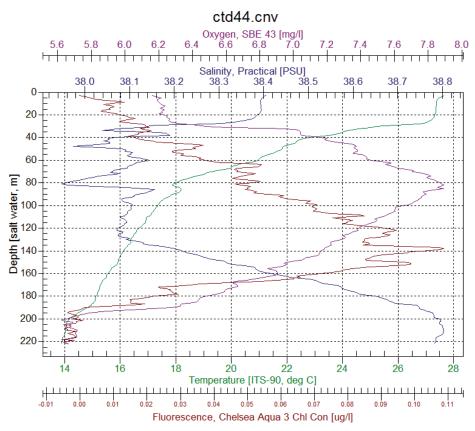


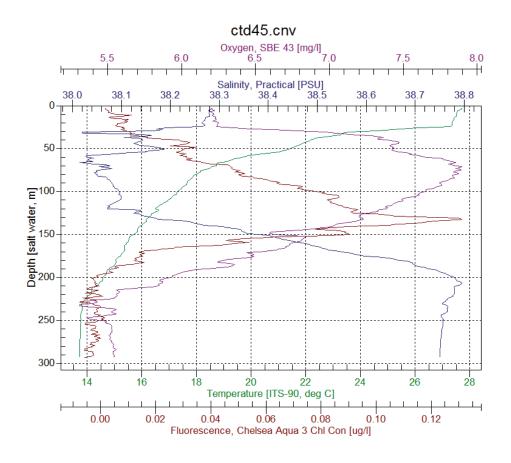


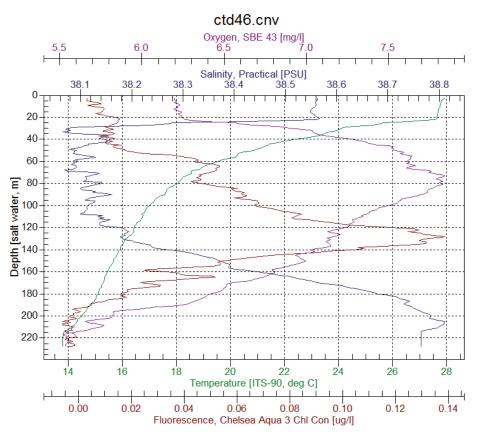


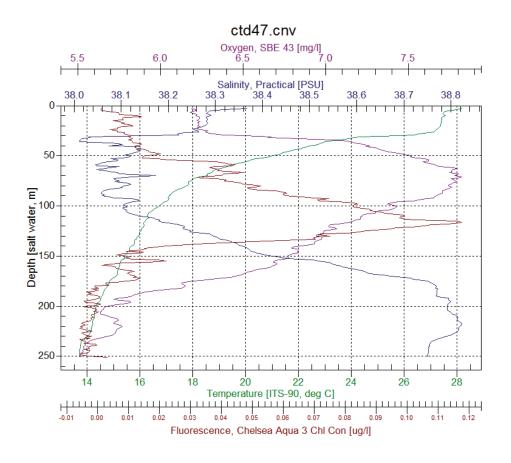


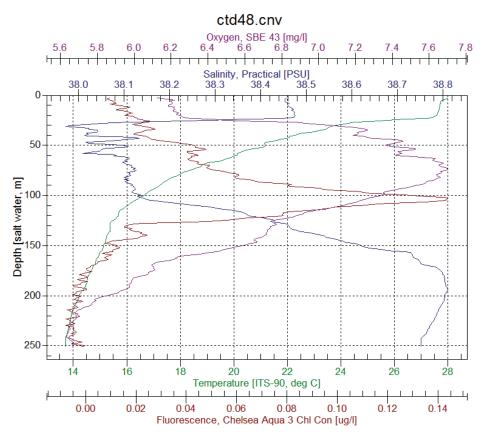


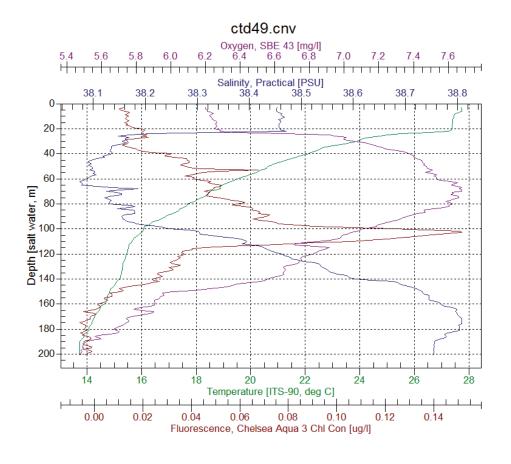


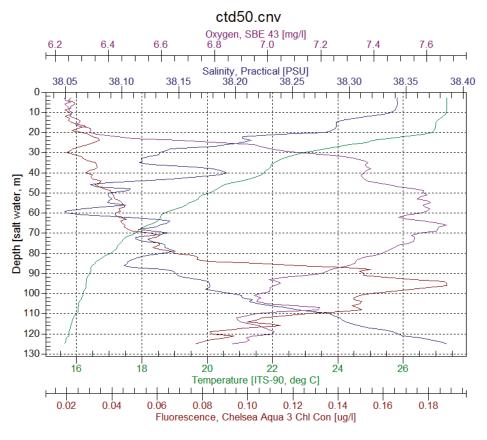


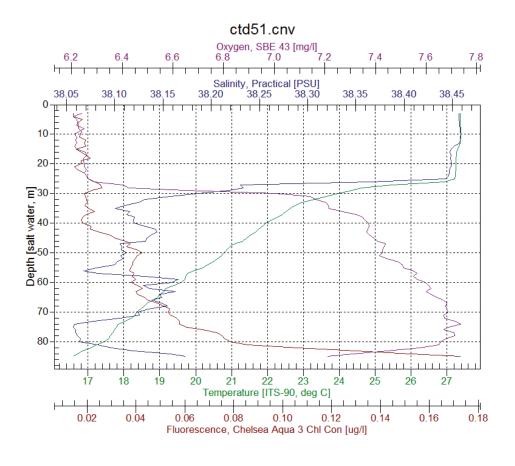


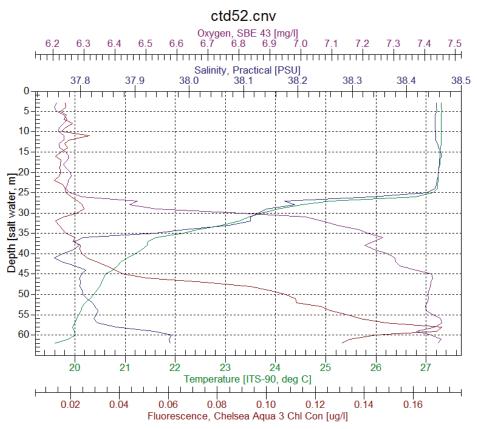


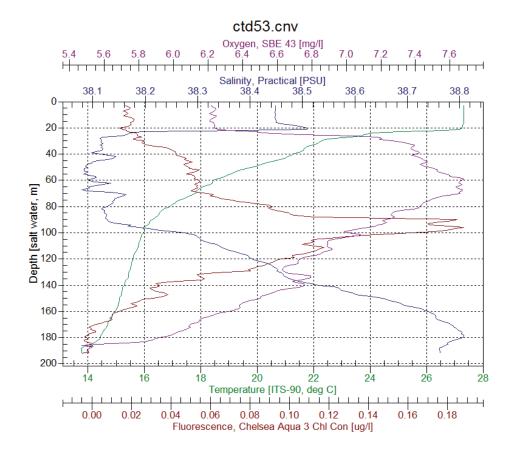


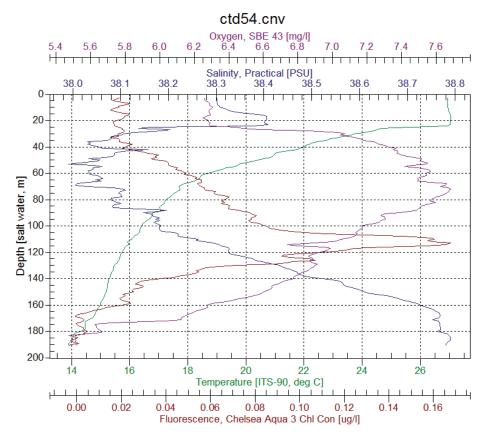


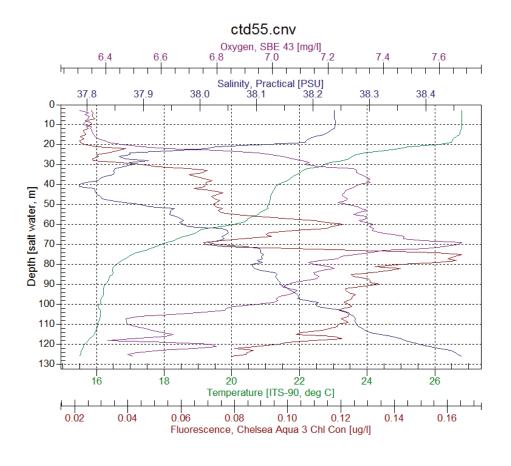


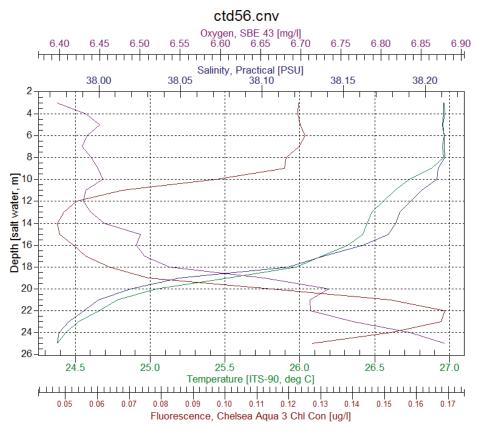


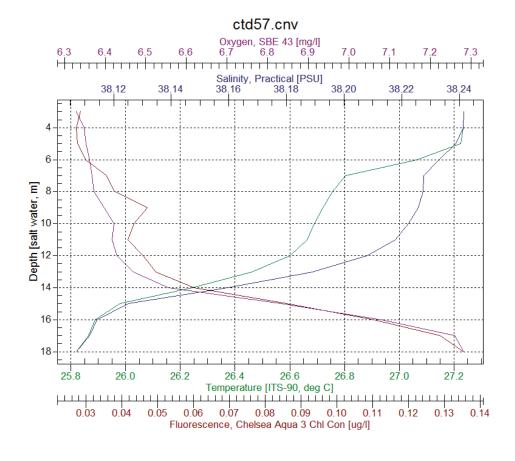


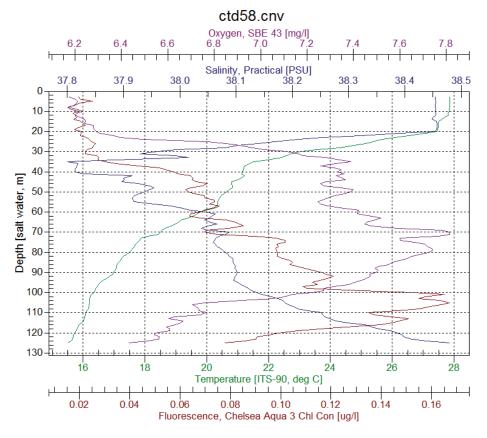


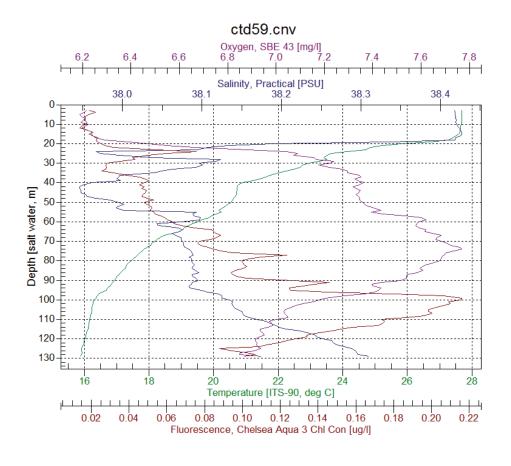


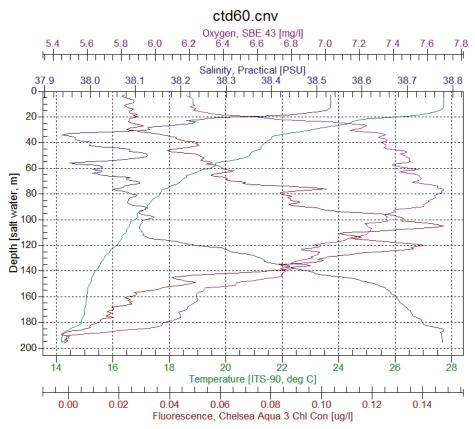


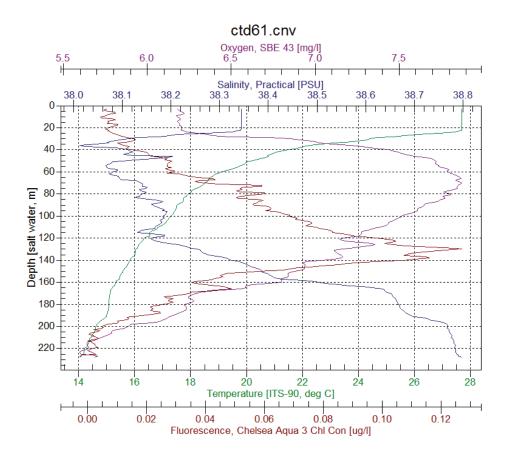


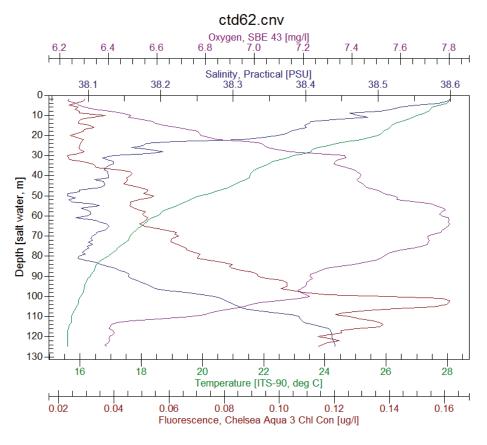


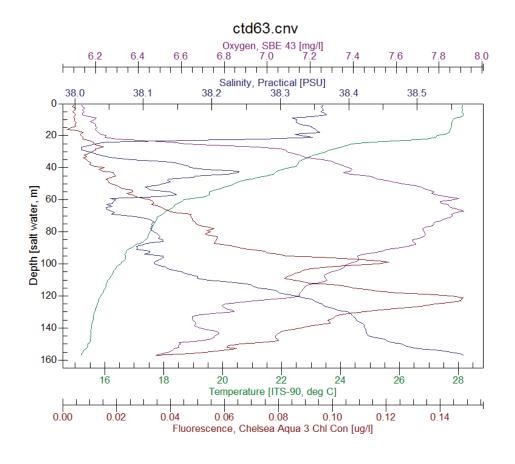


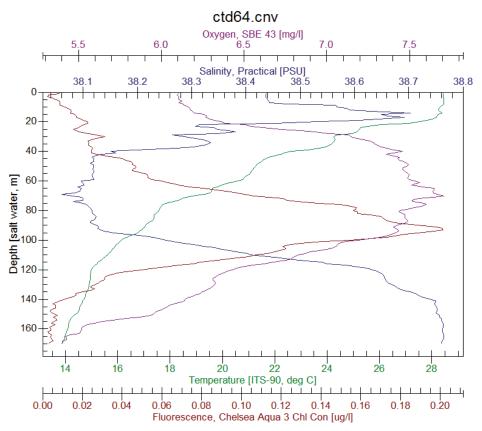




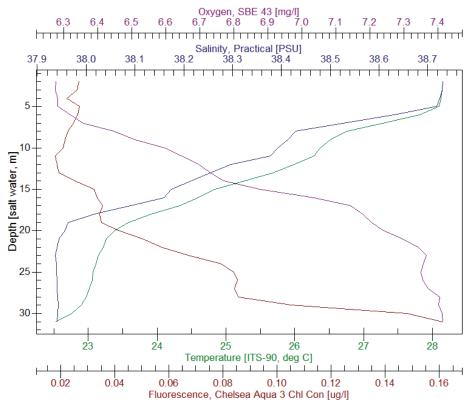


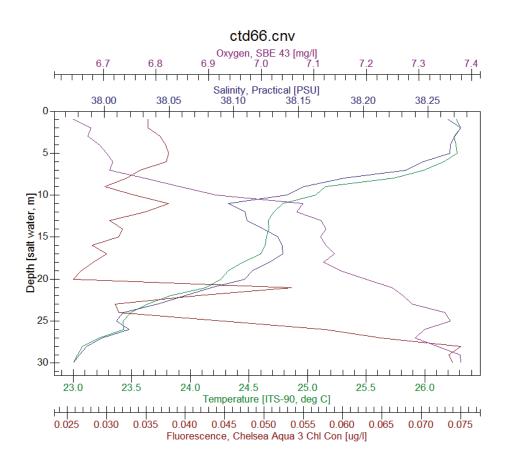


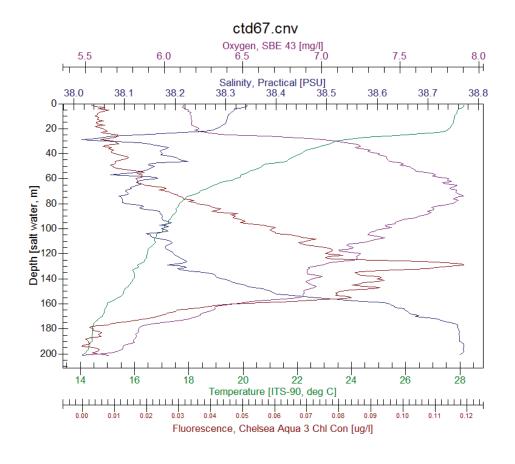


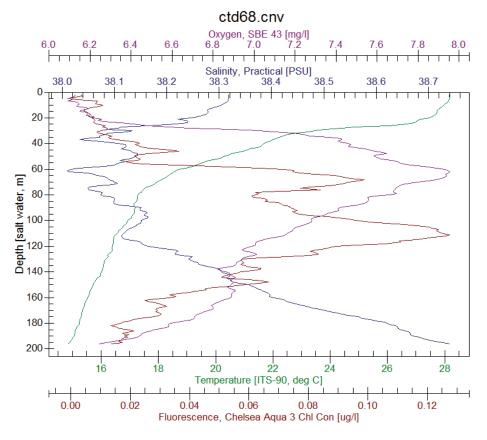




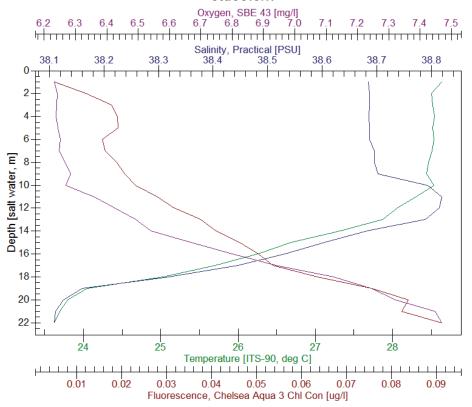




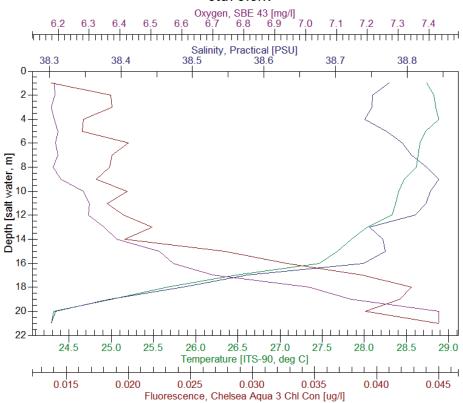


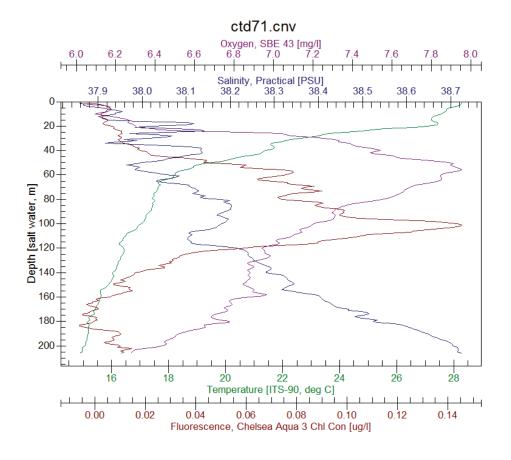


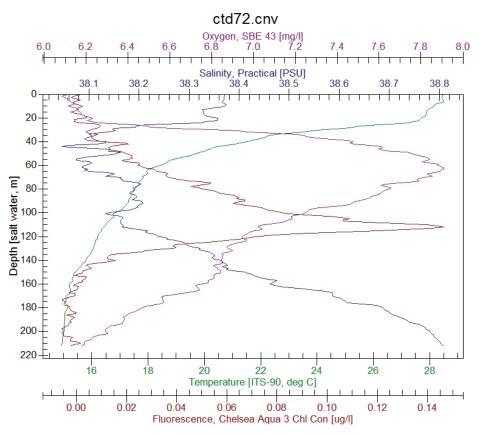
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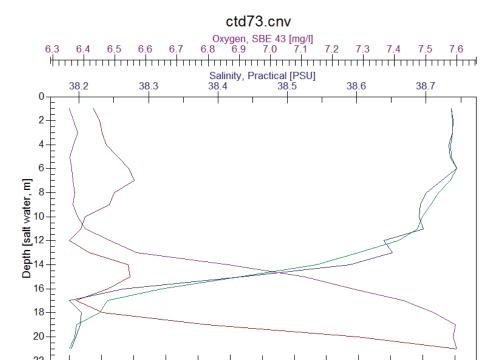


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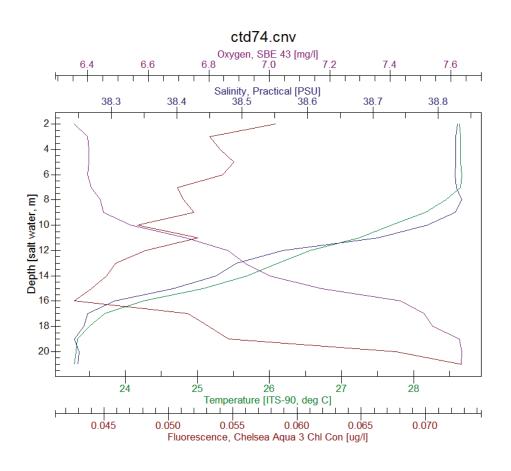


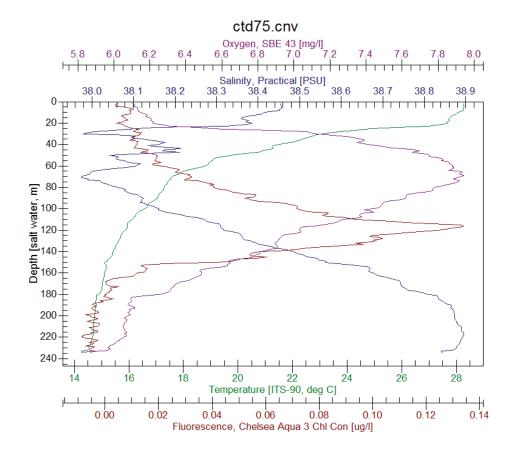


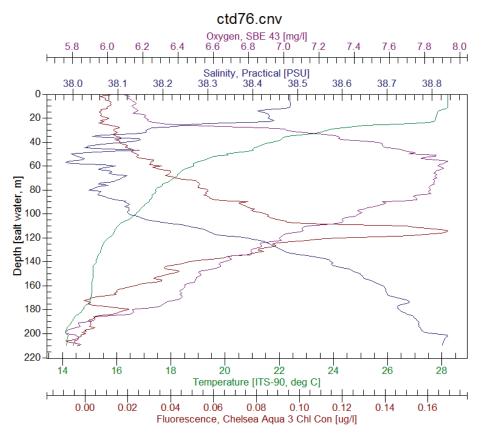


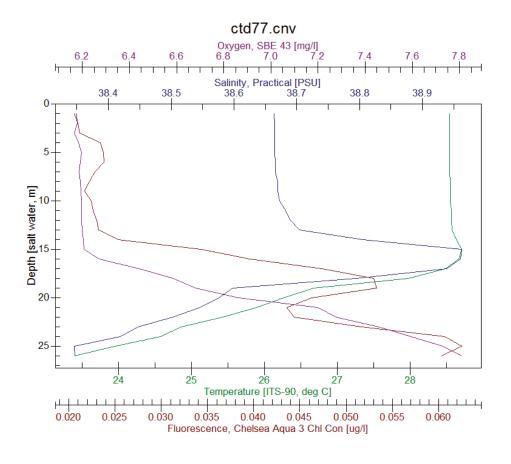
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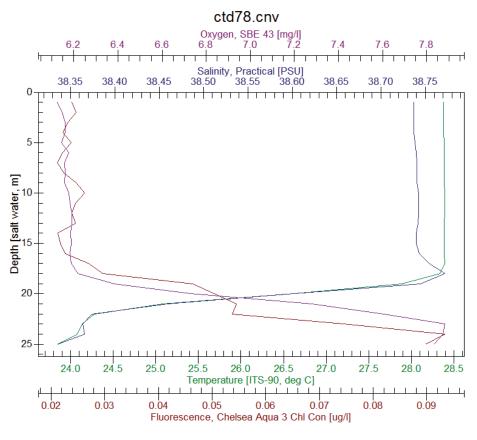
0.04 0.05 0.06 0.07 0.08 0.09 0.10 0.11 Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]

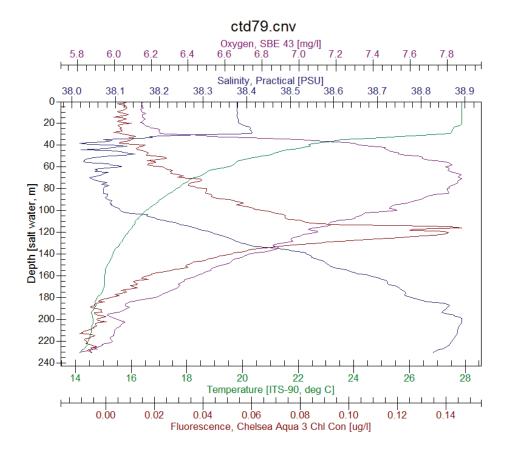


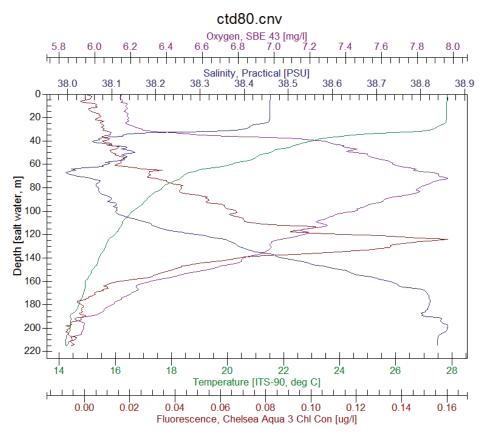




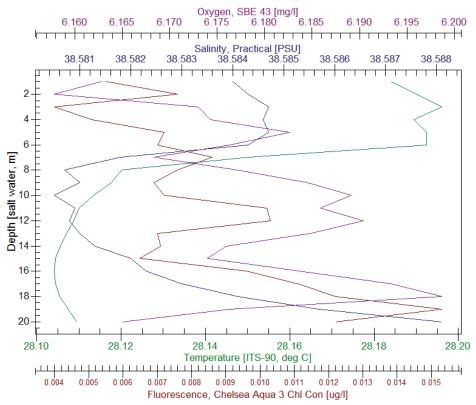




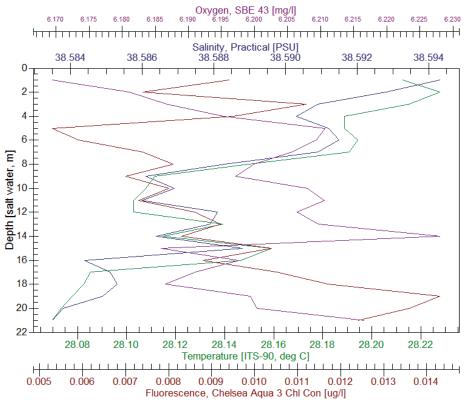


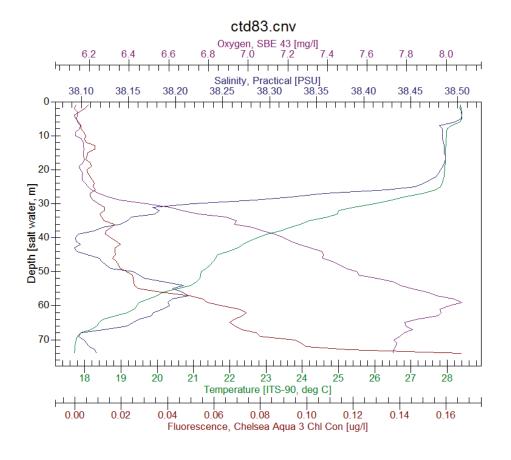


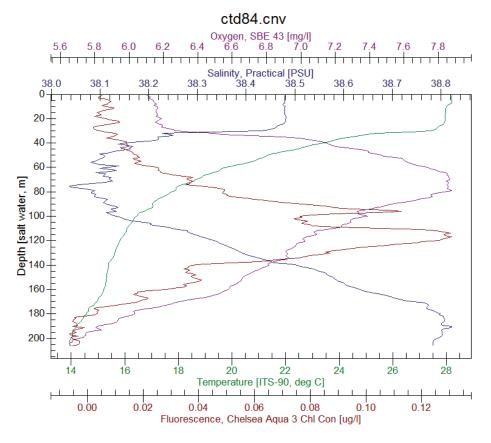


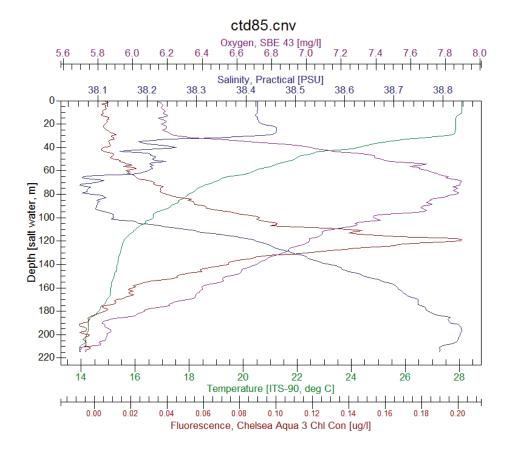


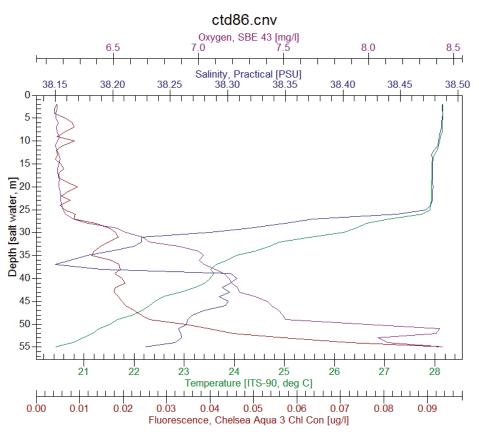
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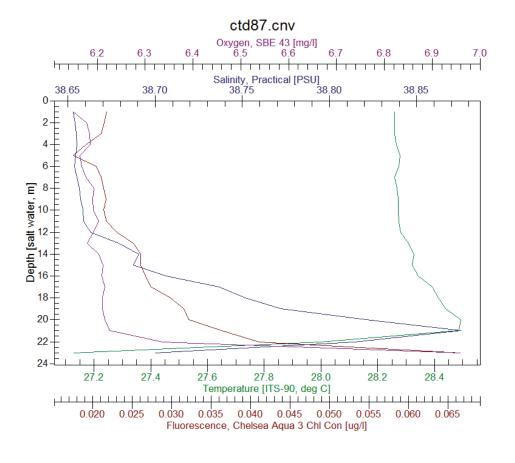


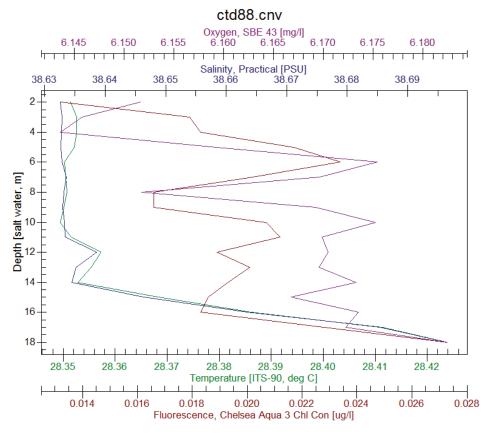


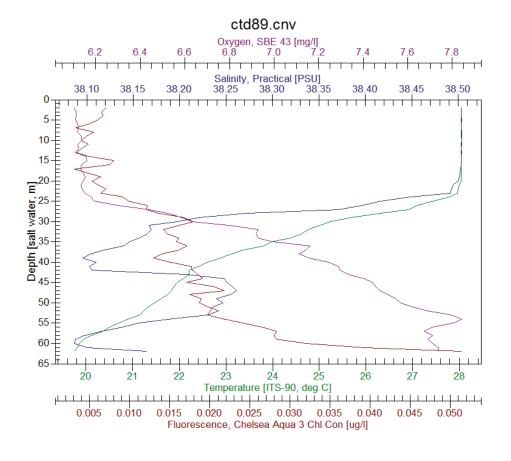


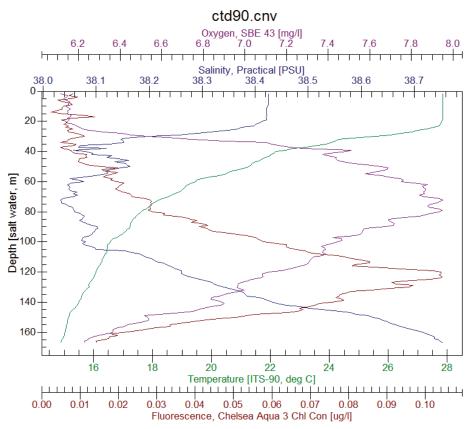


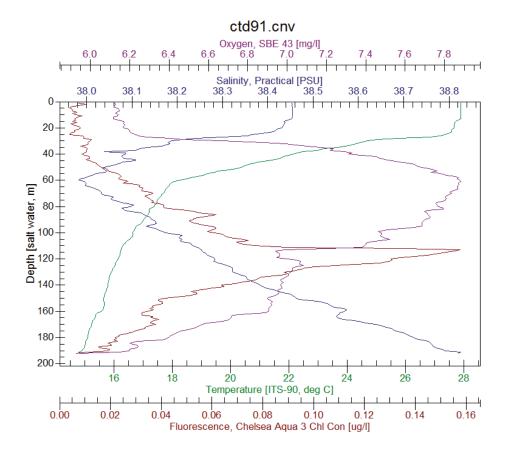


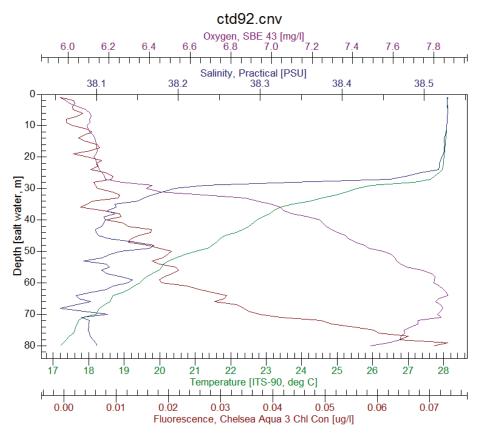


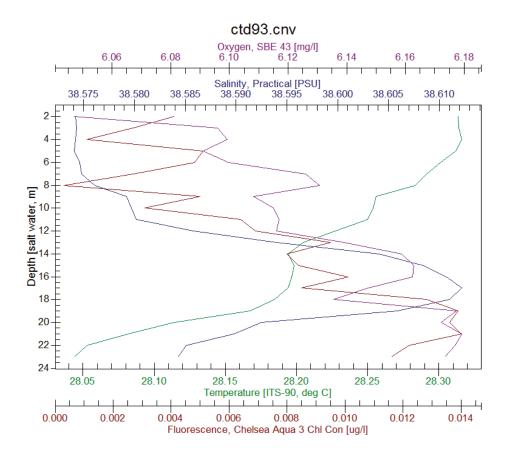


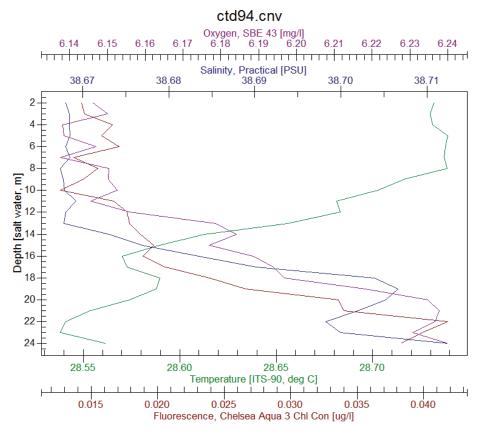


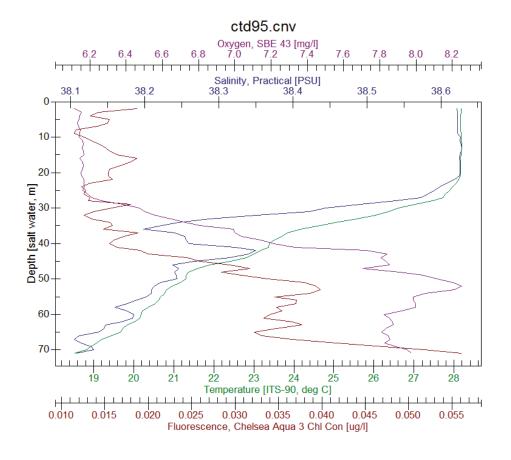


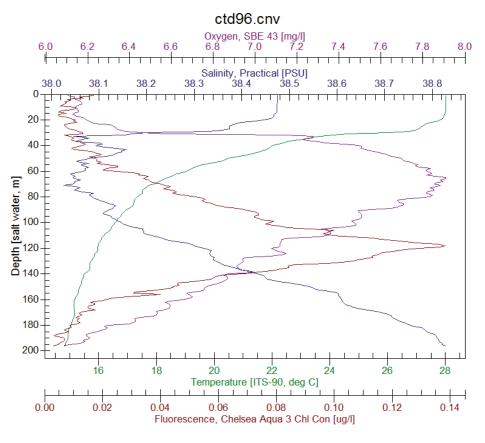


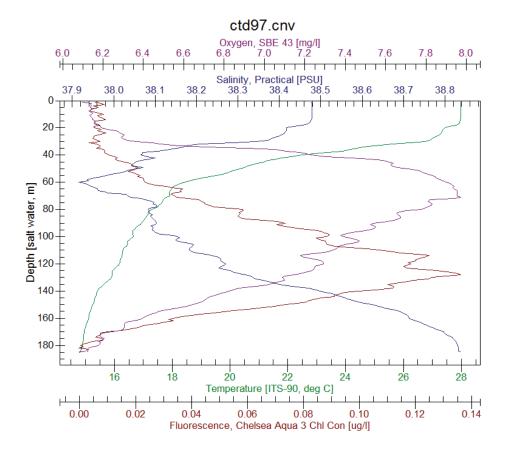


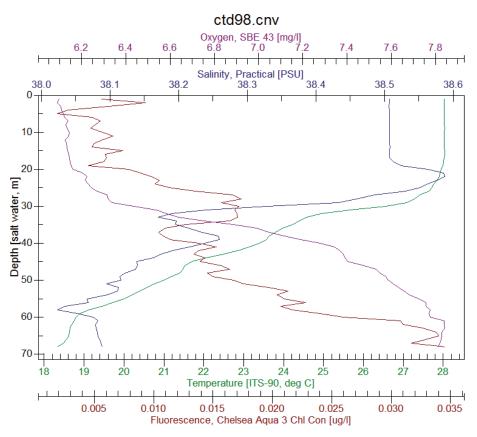


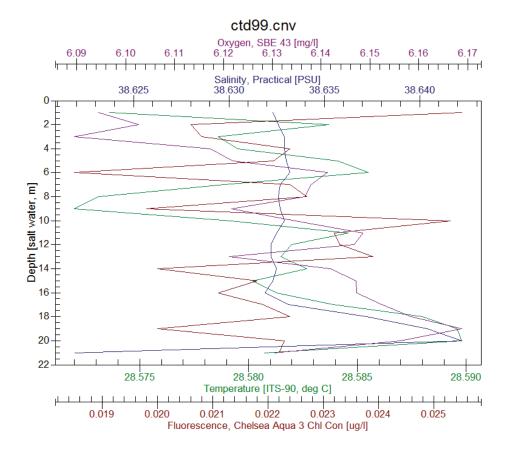


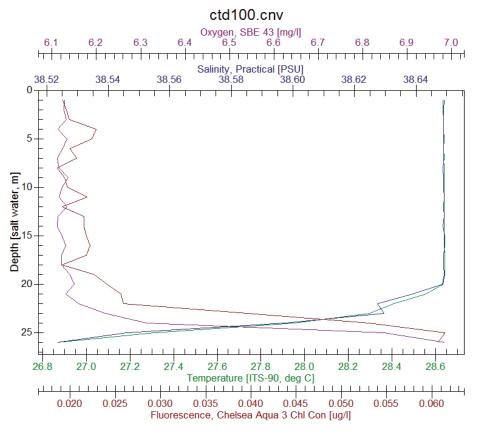


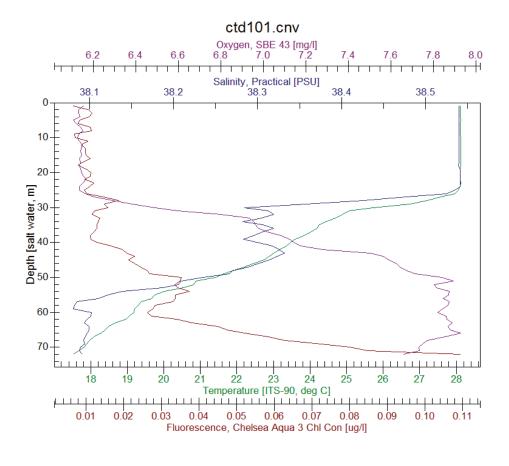


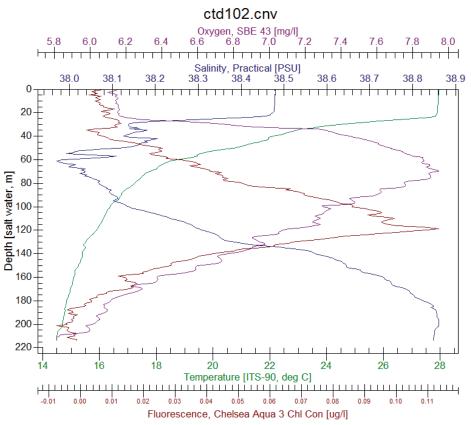


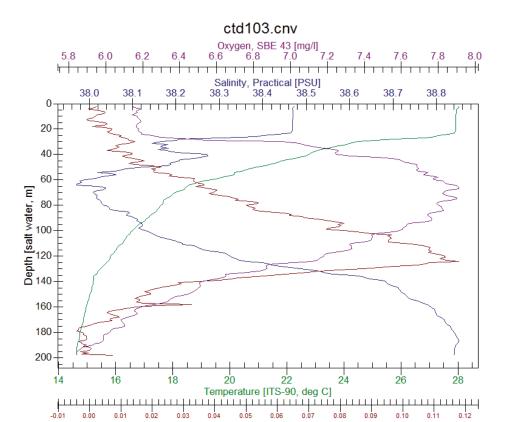




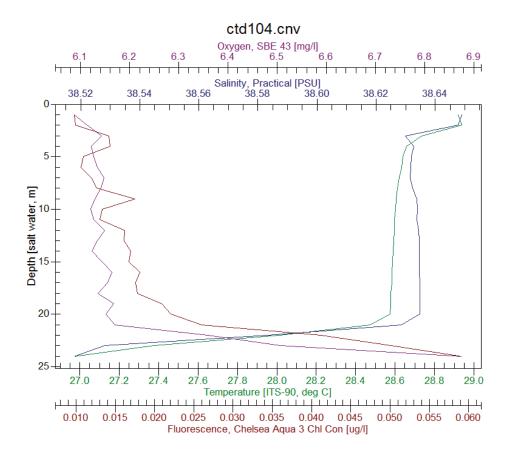


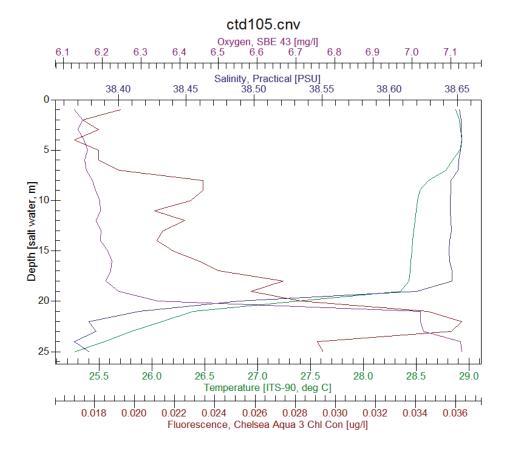


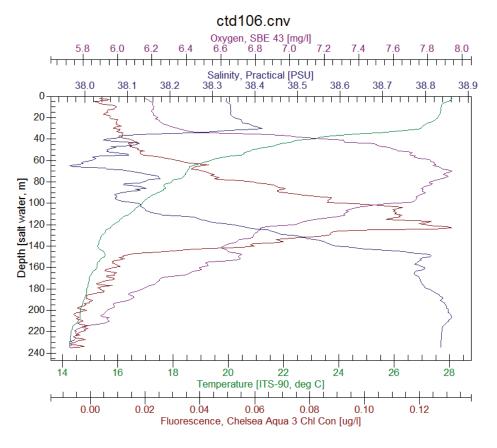


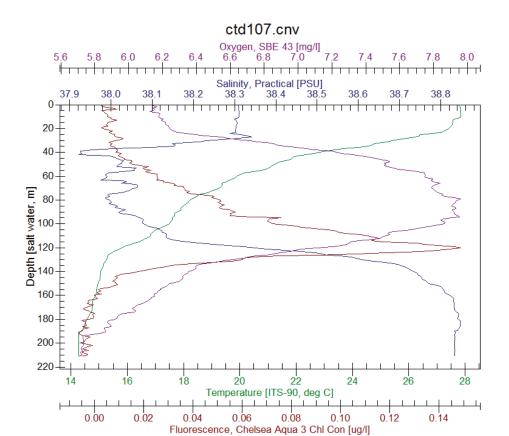


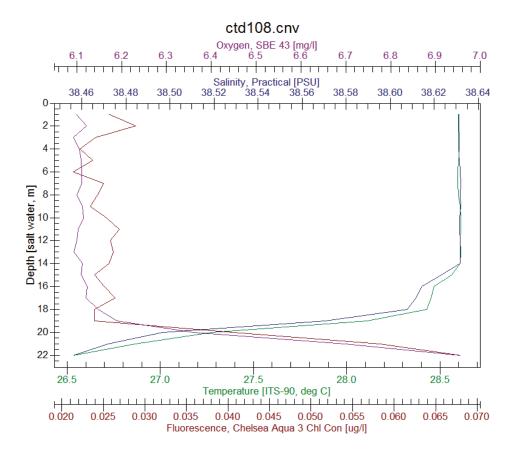
Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]

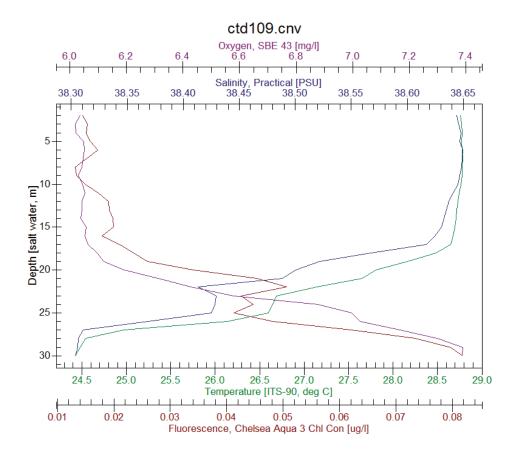


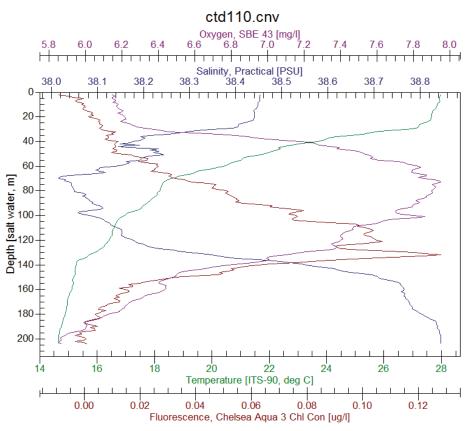




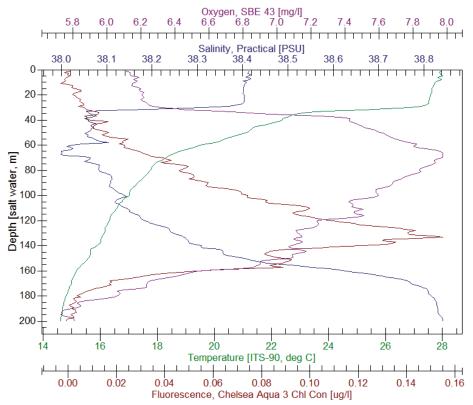


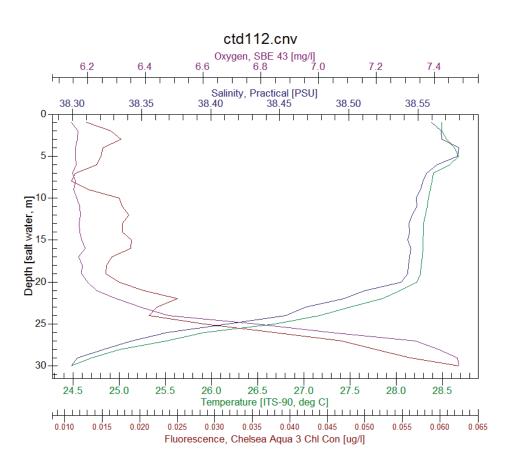


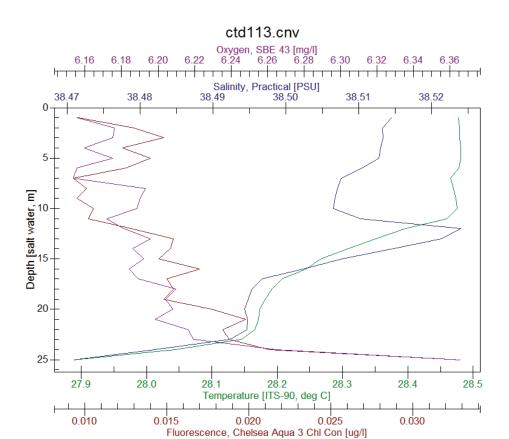


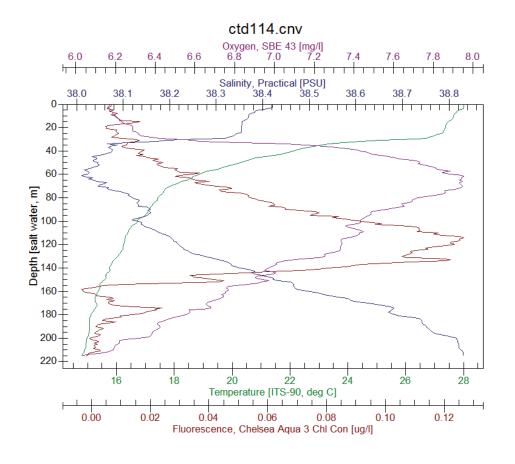












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