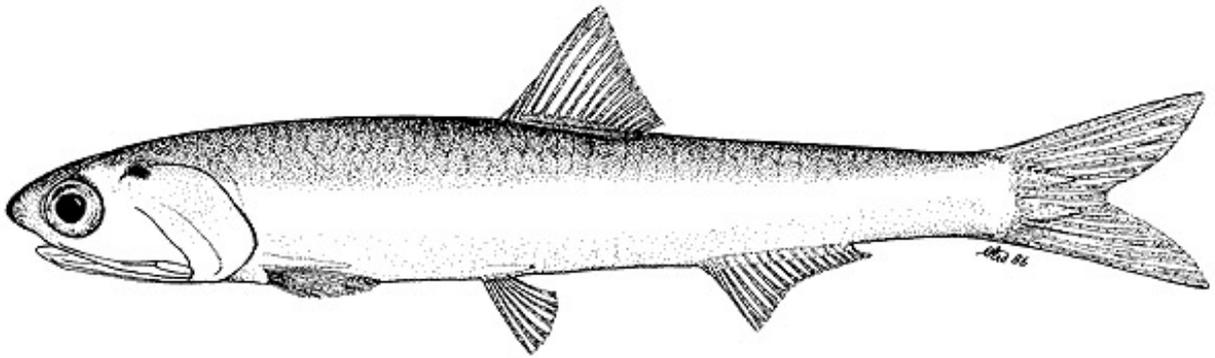


Manual for the Turkish Acoustic Survey (TAS)



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Project TR07-AG-01 / Turkey
Introduction of Stock Assessment to the Fisheries
Management System of Turkey - TIFSA -

A Preface

Within the frame of the EU-Turkey Twinning project TR07-AG-01 "Introduction of Stock Assessment to the Fisheries Management System of Turkey - TIFSA –", a workshop was held from 4.-8.1.2010 in Trabzon, Turkey. This event was attended by participants from Turkey and Germany:

Eberhard Götze, vTI-SF, Hamburg, Germany

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Yaşar Genç, SUMAE, Trabzon, Turkey

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The overall aim of the workshop was to develop guidelines for the implementation of acoustic surveys on small pelagic species in the Turkish part of the Black Sea, especially Anchovy. To achieve this goal, a review on the relative importance of pelagic fish species in this area, the distribution (temporal and spatial) and the behaviour of these species was done (Annex, see chapter J). The manual for Turkish Acoustic Surveys (TAS) was developed based on this information.

As survey planning and hydroacoustic investigations are technically and logistically rather complex, it was not the aim to present a final solution covering the most advanced techniques and procedures (which are often not implemented in areas with very long hydroacoustic experience). Moreover, a simple and practicable solution should be proposed, which can be further developed and improved according to the results of practical exercises. The manual should therefore be seen as a first but robust step toward the implementation of a Turkish acoustic survey in the Black Sea. Amongst others, required human, time and financial resources can be estimated based on the procedure described in this manual.

B Survey Design

B.1 Area of observation

The area of the acoustic survey directed to the investigation of abundance and population structure of Black Sea anchovy should cover the Turkish economic zone with focus on those areas, where anchovy is concentrated. Following the review of the distribution and migration of Black Sea anchovy (Annex, see chapter J), the near coast areas are most important and the abundance rapidly decreases with distance from coast. Toward the coast, the area is limited by the 15m depth line.

B.2 Stratification

The geographic stratification used for the Turkish Acoustic Survey - TAS is based on the official Turkish fishery statistical rectangles (Fig. 1). Due to their large expansion (up to 2700nmi²), those rectangles are divided into 4 smaller rectangles (Fig. 2). The TAS-stratification has a spacing of 0.5°Latitude and 0.5°Longitude (30nmi north-south, approximately 22nmi east-west), resulting in a maximum area per rectangle of 680nmi².

The area for all strata with a water depth deeper than 15m has to be calculated and stored in the database. These areas has to be used for the calculation of total biomass (see chapter G)

Within these 0.5°x0.5° strata, all required parameters of the acoustic investigations and catch composition and length distribution from fishing hauls are determined and recorded. The estimation of the abundances is then carried out separately in each stratum.

Following information found in literature, anchovy concentrates within few miles off the coast. Therefore, only near shore rectangles will be sampled intensively (see orange rectangles in Fig. 2). Nevertheless, it is advisable to check the

assumption of very low numbers offshore with transects in yellow rectangles, especially in such cases where significant numbers of anchovy are found at the northern part of the transect.

In addition to rectangle based explorations, investigation about the population structure of pelagic species (individual weight, sex, age) has to be conducted on a broader scale to reduce work load. For that purpose 4 larger areas, called divisions, are defined (Fig. 2).

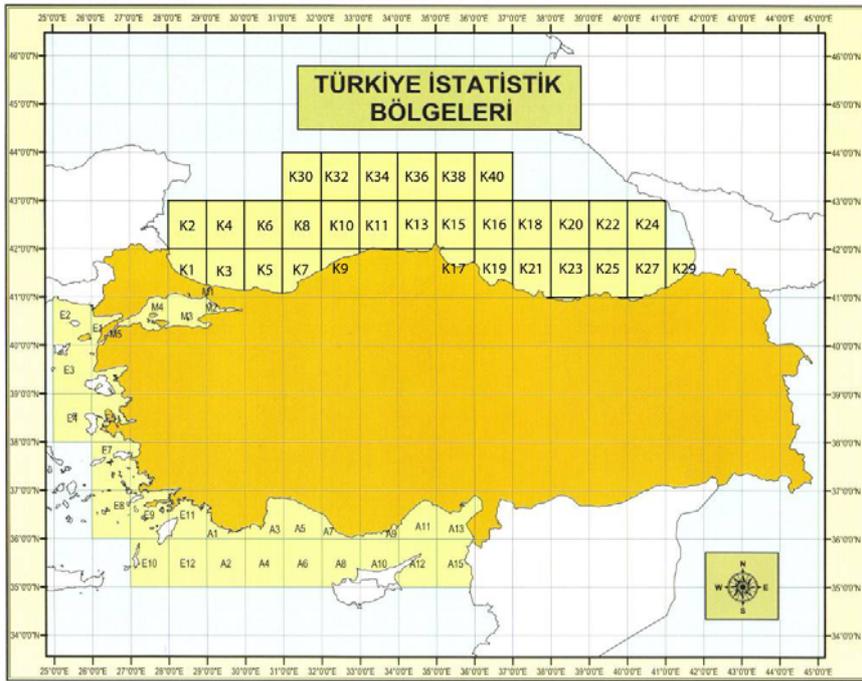


Fig. 1: Map of the Black Sea with official Turkish statistical rectangles

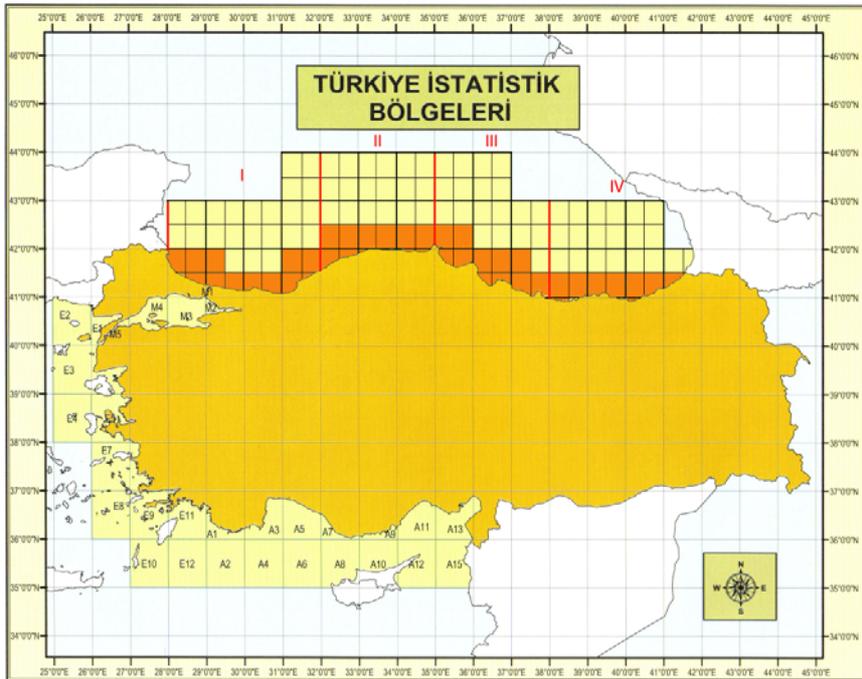


Fig. 2: Map of the Black Sea including stratification of the area used for acoustic survey targeting Black Sea anchovy. Black lines indicate the borders of the rectangles used for acoustic survey; Bold black lines indicate the borders of the official Turkish statistical rectangles; Red lines indicate the borders of divisions (I to IV); orange rectangles indicate areas, which have to be sampled with high intensity

Proposal for a systematic naming/numbering of 0.5°x0.5° strata

It is useful to have a systematic naming of strata, which allows a simple calculation of the rectangle for any given geographical position. Here, we propose a system, which covers entire Turkish waters (Fig. 3):

The numbering of rectangles starts at 35°00'N and 25°00'E. The name of each rectangles is composed of the count of rectangles in South-North-direction (starting at 35°00'N, i.e. "rows" of rectangles) and the count of rectangles in West-East-direction (starting at 25°00'E, i.e. "columns" of rectangles).

Therefore, the calculation for a given position is very simple:

with

Lat = Latitude of the given position in decimal degrees

XX = "row" of rectangles (two digits)

Lon = Longitude of the given position in decimal degrees

YY = "column" of rectangles (two digits)

XXYY = rectangle name

XX = round up $((\text{Lat}-35)/0.5)$

YY = round up $((\text{Lon}-25)/0.5)$

Example: $42^{\circ}42.0'N$ $29^{\circ}15.0'E$ = $42.7^{\circ}N$ $29.25^{\circ}E$ → rectangle 1609

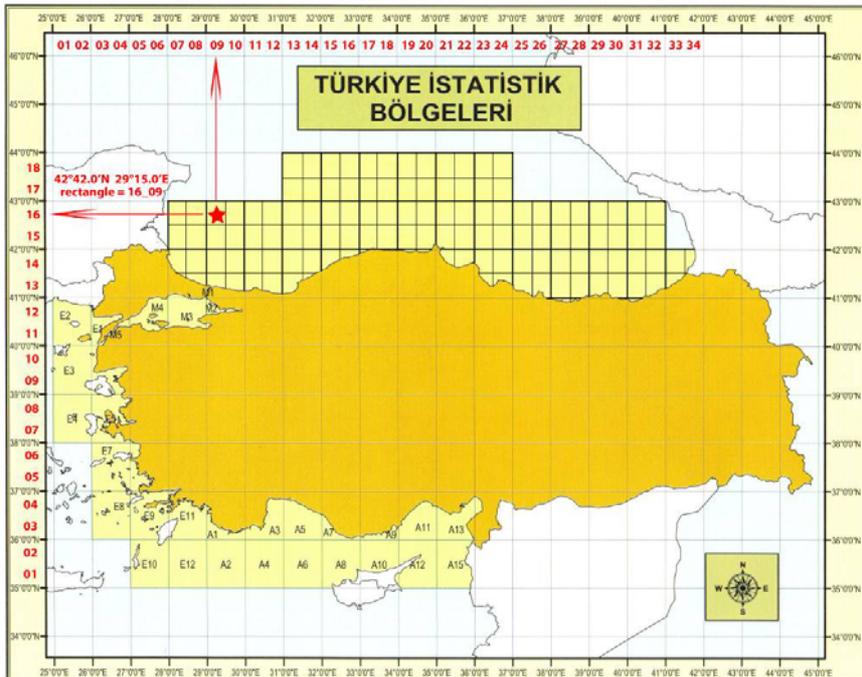


Fig. 3: proposal for the numbering of 0.5°x0.5° rectangles in Turkish Waters, including an example. Small rectangles in the Mediterranean and the Marmara Sea are not shown.

B.3 Transects

All investigations are carried out along a predetermined transects. It is advisable to run transects perpendicular to the strongest gradient in fish density. In the present case, these are tracks in NS direction from the coast into deep water.

For near shore rectangles, the distance between transects should be not more than 15 nmi, recommended is an equal spacing of 15' Longitude, approx. 11nmi (Fig. 4).

In offshore areas, a strong decrease in fish density is expected. In these regions a reduction of sampling intensity is advisable. Here, a spacing of 30'Longitude could be possible, whereby the transect should be placed in the middle of the stratum.

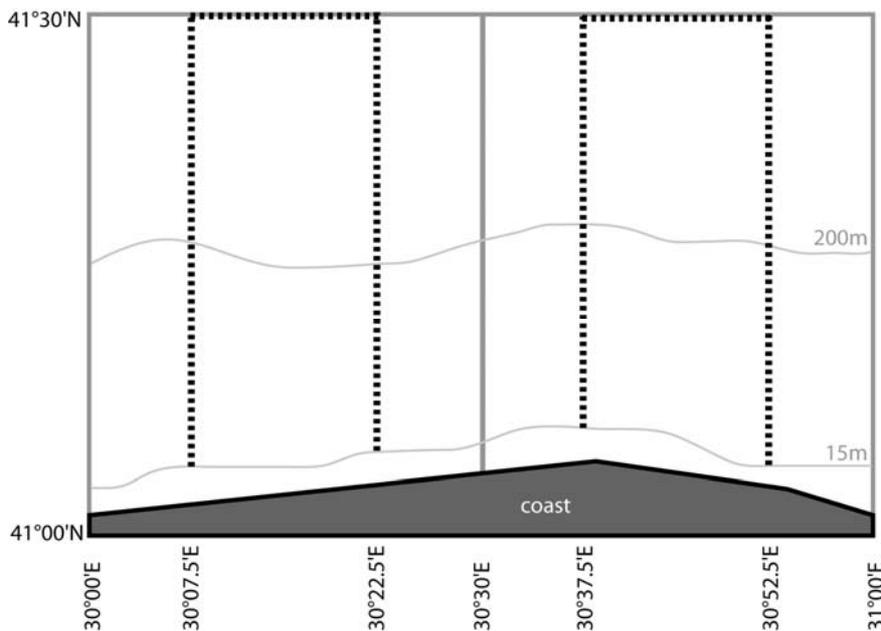


Fig. 4: Example for a design of hydroacoustic transects within two rectangles with a spacing of approximately 22nmi (15' Longitude). Coast line and depth contour are schematic and not related to reality in the shown rectangle. Black dotted line: hydroacoustic transect. Grey lines: depth contours.

B.4 Observation time

Season:

Following information from literature and from commercial sampling, Anchovy arrives at the Turkish coast during October and can be found in high abundances along the coast (few miles off the coast), whereby a movement from west to east along the coast is typical. Highest catches are typically conducted in November and December, before anchovy reaches the Georgian coast during January/February.

Therefore, the November and December (preferable mid November until mid December) are suitable to cover a large fraction of anchovy in a rather limited area.

Unfortunately, this period is the main fishing season for anchovy in the Black Sea, resulting in a potential problem for abundance estimation. This problem and a possible solution are discussed in chapter H.

Daytime:

Anchovy is forming schools during daytime in mid to deeper water layers. Therefore, investigations should be conducted during daytime (which is approx. 10 hours in November/December).

Transect sequence:

It is known, that a large fraction of anchovy migrates towards the Turkish coast following an eastward migration along the coast. The consequences of migration on acoustic survey design were investigated by Rivoirard et al. (2000).

Consequently, following aspects have to be taken into account:

- the transects in the east should be carried out before anchovy migrates into Georgian waters
- the transects in the middle and western parts of the Turkish coast should be sampled after all/most anchovy arrived at the Turkish coast

Therefore, it is proposed to start transect work in the east and go the west.

B.5 Survey speed

During acoustic measurements, ships speed should be around 10kn. At higher speeds, problems with engine noise and propeller cavitation are expected. Rough weather conditions may require a reduction of vessel speed to avoid bias (e.g. air bubbles below vessel, can be reduced by a dropped keel).

C Acoustic measurements

C.1 Nomenclature

The nomenclature used in this manual follows the nomenclature used in MacLennan et al. (2002).

Relevant units are:

nmi	.....	nautical mile
S_A	.....	nautical area backscattering coefficient (NASC) in m^2/nmi^2
TS	.....	target strength
σ_s	.....	back scattering cross section

C.2 Equipment

It is assumed that the echo sounder SIMRAD EK 60 with a main frequency of 38kHz will be used for quantitative acoustic investigations.

During the last years, the usage of multi-frequency acoustics became popular. Such acoustic set up could help to improve species recognition of echo-scatters, whereby much information and experience is required to conduct a multi-frequency analysis. This information is not available for Black Sea conditions. Nevertheless, the use of other frequencies (e.g. 120kHz and 200kHz) is highly recommended. If preconditions are met in the future, results from previous surveys with multifrequency-data-recordings can be recalculated.

C.3 Calibration

Prior to each acoustic survey, the sonar system must be calibrated. The necessity of calibration and the calibration procedure are described in Foote et al. (1987) and in the manual of the echo sounder. Some important points are mentioned below.

A sheltered bay with a minimum water depth of 20 m would be optimal for these measurements. In calm weather, the calibration can be also carried out in the open sea. Strong and turbulent water currents and ship movement are problematic during calibration. Therefore, a suitable place must be selected carefully in advance and the ship must be moored with anchors both the bow and the stern of the ship, to reduce ships motions.

For the measurements, the program "Calibrate" must be started, which is part of the EK60-software. This program supports the complete calibration procedure. During calibration, a standard sphere (usually made from copper) with known acoustic properties is positioned in at least 10 m distance (recommended 20m) in the acoustic axis of the transducer by three thin lines. The use of remote-controlled winches is very suitable. Using these winches, the sphere has to be moved through the entire sound beam. This movement can be controlled by the program display. When all indicated areas are covered, the necessary parameters are estimated and directly transferred into the sonar. It is advisable to prepare a protocol for the calibration.

C.4 Settings

Some instrument settings will significantly influence the acoustic measurement. Most of these settings of the echo sounder are determined by the calibration procedure and are certified in the calibration protocol. Other relevant parameter settings are:

- pulse rate: at least 1s to prevent disturbing bottom echoes
- pulse length: usually 1ms for 38kHz

It should be noted that these parameters are also set during the calibration.

These parameters should be checked regularly during the survey to prevent inconsistencies in estimations.

C.5 Sampling interval

For further analysis, echo-signals have to be summarized over a defined distance along the transect. The averaging interval is known as the ESDU (Elementary Sampling Distance Unit). Normally, this ESDU is 1nmi.

D Postprocessing of echo recordings

D.1 Postprocessing software

The acoustic signals are stored as digital samples by the echosounder. Once a file from the echo signal is stored, the data processing can be carried out by a specific software system. In marine acoustic surveys, „Echoview“ (<http://www.echoview.com>) is the most frequently used postprocessing system. Different modules can be obtained for this software. For the planned tasks of simple echointegration a minimum set of three modules is required:

- Base module
- Bathymetric module
- Analysis export module

Additional modules are useful for further tasks, such as the school detection module and the multifrequency module. They are not covered in the following descriptions, but it might be useful to obtain these modules, as well.

D.2 Removal of unwanted signals

Beside echo signals from target species, frequently echo signals from unwanted sources are recorded, such as scattering layers, plankton, bottom, air bubbles near the surface etc.. Such signals should not be used to calculate the abundance of target species. Therefore, echo recordings have to be scrutinized in a first processing step:

In the vertical direction, the echo signal should be bordered by a surface and a bottom line. The surface line indicates the upper limit of the undisturbed targets. This line will be adjusted below the end of the transmitting pulse and the indications of air-bubbles. In the case of a hull-mounted transducer the surface line is chosen to about 10 m. The bottom line is usually generated by the sonar automatically. You can even add an offset to have a certain safety distance to

the ground. Sometimes, the automatic bottom detection algorithm fails and parts of the seabed are interpreted as target signals. This can lead to very large errors, because the ground is a good reflector compared to the fish body resulting in very strong echoes. The bottom line should therefore be studied very carefully and suspicious sites must be corrected manually using the postprocessing software.

Even between surface and bottom line, we can find a number of disturbing signals.

Frequent sources of disturbance are scattering layers, usually associated with halo- or thermoclines. EchoView provides several tools to highlight such regions. These regions are marked as "bad region" and are hidden from further analysis and integration.

D.3 Allocation of targets

Anchovy is the most abundant fish species in Turkish Black Sea waters during observation time. Low proportions of other pelagic species (mostly horse mackerel, sprat, whiting) can be expected. Especially, a fishery targeting horse mackerel is conducted in the same time and area. Therefore, species recognition might be an essential task/challenge.

Several methods can be used to assign echoes to different species, e.g.:

a) No assignment of echoes directly to different species. All fish echoes are integrated together (after the removal of noise) and total fish abundance is calculated. Calculated fish abundance will be splitted into different species based on the fish species composition derived from fishery hauls.

b) Separate integration of different echo groups. This separation is based on knowledge about, e.g.

- the composition of different echo groups (such as layers etc.)
- their school parameters (length, height, shape and intensity of schools etc.)
- the variable response of different echo targets (species) to different frequencies, i.e. multifrequency analysis.

With respect to the rather poor knowledge about acoustic properties and schooling behaviour of different species in the Black Sea, following description of a procedure is restricted to option a). Nevertheless, it is highly recommended to conduct investigations regarding species recognition based on school identification and multifrequency analysis. If the essential knowledge is available, the recorded data can be reanalyzed based on these methods.

An illustration of species separation based on properties of echoes is given in Fig. 5.

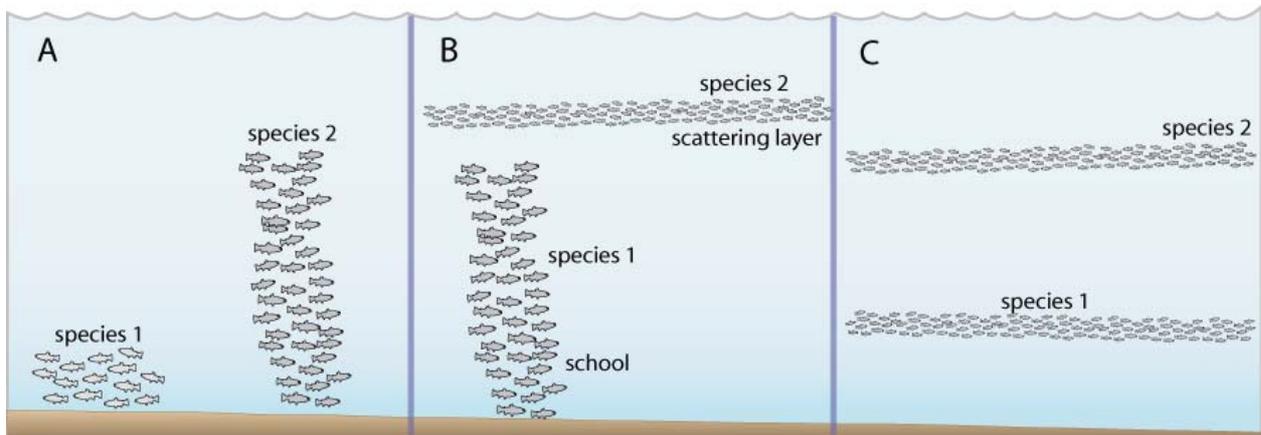


Fig. 5: Example for species recognition based on different shape, size and distribution of echoes. A) schools with different size, shape, echo intensity; B) school and echo scattering layer; C) scattering layers with distinct characteristics, such as vertical distribution.

D.4 Data storage

If the echogram is sufficiently cleaned, the echoes can be integrated as nautical area backscattering coefficient (NASC) for each sampling interval.

If not using school detection algorithms, the option "Export" → "Analysis by Cells" → "Integration" of Echoview can be used. This cell is bounded by the surface and bottom line and the limits of each ESDU (normally 1 n.mi.) The NASC and all other parameters that have been previously selected are stored in a database. This process is repeated for all sampling intervals and transects. The resulting tables are stored in the database.

The final layout of echo database and its connection to the fishery database cannot be given here, since the fishery database will be developed in one of the next workshops within the framework of the Twinning project.

E Fishery Samples

The acoustic parameters of fish depend on species and length (MacLennan und Simmonds 1992). Therefore, detailed information about species composition and length distribution are necessary for abundance estimation.

In general,

- the number of hauls should be as high as possible, especially when species identification based on echo recordings is difficult.
- a sample should be obtained from schools and echo layers, appearing in the echo sounder
- fishing gear and trawl speed has to be suitable to get a representative sample of the species assemblage in the area

E.1 Fishing gear

The preferred fishing method is trawling, whereby the trawl should

- be usable for fishing in midwater and at the bottom
- be small and handy to allow fast and accurate control of the fishing gear
- have a vertical opening of approximately 10m
- have a cod end mesh size of 10mm (bar length) or less

Similar trawl designs are used e.g. in Baltic and North Sea Acoustic surveys and can be requested e.g. by Germany.

E.2 Fishing

At least, two hauls should be carried out per 0.5°x0.5° rectangle.

The trawl speed must be high enough to even catch fast swimming pelagic species (3 to 4.5kn). Standard trawl duration is 30 minutes, whereby in cases of very high concentrations, trawl duration might be reduced slightly. Catch results must be standardized to standard haul duration (catch/30min, catch per unit effort, CPUE)

It is very important, that all types of fish concentration are sampled to identify species assemblage. In the case of two or more layers in one area, all layers should be sampled by separate hauls. In the same way, schools and echo layers should be sampled separately.

The behaviour of the trawl has to be controlled by a netsounder (e.g. Scanmar).

Information about the trawl has to be registered.

E.3 Biological Sampling

E.3.1 Species composition

The catch has to be sorted into all species. The weight per species has to be registered.

If it is not possible to sort the entire catch, sufficient subsamples can be sorted, whereby following options occur:

a) Large homogeneous catch of small fish: a subsample of at least 50kg (randomly taken) should be sorted. The total weight of the catch, the weight of the subsample and the total weight per species in the subsample should be registered.

b) Large heterogeneous catch of small fish with few larger fish: large and small fish should be separated. Large fish has to be sorted and total weight per species should be registered. From the mixture of the small fish, at least 50kg should be sorted and treated as a).

If subsamples were taken, the weight in total catch of that given species can be calculated

$$W_i = \frac{w_i}{w_s} * W_c$$

W_c weight of the fraction of catch where the subsample is taken from

W_i weight of species in total catch

w_s total weight of subsample

w_i weight of species in subsample

E.3.2 Length distribution

For all species, the distribution of total length has to be recorded. Total length (TL) refers to the length from the tip of the snout to the tip of the longer lobe of the caudal fin, usually measured with the lobes compressed along the midline. It is a straight-line measure, not measured over the curve of the body.

Length is measured 0.5cm below for all small species and 1cm below for larger species, such as rays.

To get a reasonable length distribution, the sample size for length measurements of a given species depends on the size spectrum.

In case of a narrow size spectrum for anchovy, horse mackerel and whiting, a subsample should be taken containing at least 200 specimens per species. In cases of wide size spectrum of these species, a subsample of at least 400 specimens should be measured.

At least 50 specimens per species of other species should be measured.

E.3.3 Weight distribution

For anchovy, horse mackerel and whiting, the weight distribution should be registered. Depending on the available resources, weight distribution can be registered per haul, per Turkish statistical rectangle or division. If weight distribution is not recorded, it is recommended to cover the larger stratum homogeneously.

Weight sampling is rather effective, if fish are sorted in to boxes per length group and groups weighted afterwards.

E.3.4 Age distribution

At least for anchovy, the age distribution has to be registered. Depending on the available resources, age distribution can be registered per haul, per Turkish statistical rectangle or division. If age distribution is not recorded, it is recommended to cover the larger stratum homogeneously.

For anchovy, at least 10 otoliths per 0.5cm-length class and per stratum should be analysed.

E.4 Physical sampling

The distribution of pelagic fish is usually related to physical parameters of the water. Therefore, temperature, salinity and oxygen should be recorded regularly along the transect and after every haul using a vertical CTD. The vertical resolution should be at least 1m.

Additional information might be helpful to understand the ecology of pelagic fish species. With respect to the aim of an implementation of an ecosystem based management and to enhance the understanding of anchovy ecology, it is reasonable to register additional parameters, such as Chlorophyll-a concentration, particle concentration and others.

F Handling of biological data

For all acceptable hauls in each stratum the mean relative species distribution and the mean relative length and age distribution for each relevant species has to be calculated as basis for abundance estimation (chapter G).

In acoustic surveys targeting pelagic fish assemblages, catch rates are typically poorly related to abundance. Therefore, each trawl catch in each stratum is given equal weight. Very small samples are considered as non representative and excluded from further analysis.

F.1 Species composition

Trawl catches in each stratum has to be combined to give a mean relative species distribution. The species frequency f_i of species i can be estimated by

$$f_i = \frac{1}{M} \sum_{k=1}^M \frac{n_{ik}}{N_k} \quad (\text{F.1})$$

f_i	.....	frequency of species i in the total catch in stratum
n_{ik}	.....	the number of fish of species i in haul k
N_k	.....	the total number of all fish species in this particular haul
M	.....	the number of acceptable hauls in this stratum

For simplicity reasons, species with a relative catch proportion less than one percent can be excluded from further analysis.

F.2 Length distribution

For each species i , the mean length distribution has to be calculated

$$f_{ij} = \frac{1}{M_i} \sum_{k=1}^{M_i} \frac{n_{ijk}}{N_{ik}} \quad (\text{F.2})$$

- f_{ij} frequency of length class j and species i
- n_{ijk} the number of fish of species i in length class j and in haul k
- N_{ik} the total number of species i in this particular haul k
- M_i the number of acceptable hauls containing species i

F.3 Age distribution

Common stock assessment models are age based. Consequently, survey results have to be calculated for individual age classes. For each spatial stratum used for age sampling (see chapter E.3.4) an age distribution has to be calculated. The age distribution for each chosen stratum is estimated as unweighted mean of all samples, i.e.

$$f_{ia} = \frac{1}{M} \sum_k f_{ak} \quad (\text{F.3})$$

G Abundance estimation

G.1 General principle

It is assumed that the mean area scattering cross section s_A is proportional to the number of fish in the stratum. This mean s_A is the arithmetic mean of all individual s_{An} in the stratum, which have been determined for each ESDU with EchoView under Chapter D.

$$s_A = \frac{1}{n} \sum_n s_{An} \quad (\text{G.1})$$

G.2 Estimation of total numbers

The basic equation for estimating the abundance N from the s_A in a stratum of area A is

$$N = \frac{s_A}{\langle \sigma \rangle} * A \quad (\text{G.2})$$

The proportionality factor $\langle \sigma \rangle$ is the mean acoustic scattering cross section. In dense concentrations of fish this value can not be measured directly by acoustic means. The value must be estimated from the results of the biological samples. From experiments the scattering cross sections of species i was found as an approximation

$$\sigma_i = \sum_j f_{ij} * d_i * L_j^2 \quad (\text{G.3})$$

f_{ij} frequency of length class j and species i
 L_j midpoint of length class j
 d_i species dependent factor

For the coefficient d the following values can be temporarily used which are common in other marine regions:

species	d
Anchovy	9,533E-07
Sprat	9,533E-07
Horse mackerel	2,235E-06

It is recommended to find better approximations by experiments from the Black Sea.

The mean backscattering cross section $\langle \sigma \rangle$ in the stratum is estimated as the weighted mean of all Individual σ_i

$$\langle \sigma \rangle = \sum_i f_i * \sigma_i \quad (G.4)$$

f_i frequency of species i in the total catch in stratum

σ_i mean scattering cross section of species i

These two equations together give the final relation

$$\langle \sigma \rangle = \sum_i f_i * d_i \sum_j f_{ij} * L_j^2 \quad (G.5)$$

The conversion factor σ must be calculated according to this relationship for each stratum. With this factor, the total abundance N in this stratum can be obtained by equation G.2.

G.3 Species and age distribution

The total abundance of targets in the stratum N can be divided in partial numbers N_i of all species i contributing to the NASC.

$$N_i = f_i * N \quad (\text{G.6})$$

Additionally the abundance of the species N_i can be splitted into numbers by age class N_{ia}

$$N_{ia} = f_{ia} * N_i \quad (\text{6.7})$$

H Potential pitfalls and possible solution

H.1 Effect of aggregation and migration

As mentioned in Annex, see chapter J, during main fishing season from October to February, anchovy conduct intensive migration along the Turkish coast. The main migration direction is from West to East. This migration has to be taken into account during survey planning.

It is proposed to choose a transect sequence from East to West.

H.2 Effect of high fishing pressure during survey season

As mentioned in Annex, see chapter J, Anchovy aggregate along the Turkish coast of the Black Sea in winter. Therefore, this season is best suitable to cover a large fraction of Anchovy within an acoustic survey. At the same time, very high fishing targeting anchovy is established in Turkish waters with estimated gross outtakes of approx. 200.000-300.000 tonnes per year, which corresponds to a very high fraction of the entire stock abundance.

(Bingel et al. 1996) stated "In a fishery of high fishing intensity where each individuals recruiting from each batch depleted just after its arrivals in the fishing ground the biomass estimation with acoustical technique is only an instantaneous censusing."

Nevertheless, a correction of the survey result is necessary and possible. The abundance estimated from the Turkish Acoustic Survey (TAS) heavily depends on the relative timing of fishing season and TAS (Fig. 6 left). Consequently, an optimal setup would be to conduct the acoustic survey prior to the beginning or after the end of the fishing season. This is not practicable, since fishing season covers the entire period when anchovy is aggregated along the Turkish coast.

A possible way to calculate a steady abundance (e.g. abundance prior or after the fishing season) is to take into account the catches from the official catch statistic prior or after the survey (Fig. 6 right). Due to the relative long duration of the survey compared to the fishing season, it might be necessary to correct the abundance for each survey sub-regions separately (e.g. Turkish official rectangles or divisions).

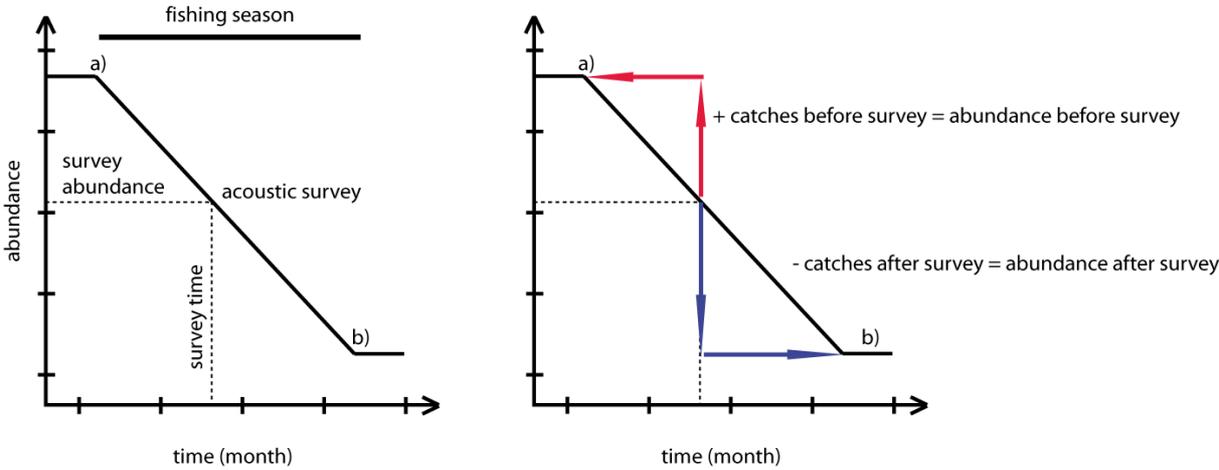


Fig. 6: Schematic development of anchovy abundance during high fishing season in the black Sea and its impact on the result of the Turkish Acoustic Survey (TAS).

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