INVESTIGATIONS ON THE FISH STOCKS IN ATATÜRK DAM LAKE BY USING CLASSICAL AND ACOUSTICAL TECHNIQUES

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submitted by **Ekin AKOĞLU** in partial fulfillment of the requirements for the degree of **Master of Science in Graduate School of Marine Sciences, Middle East Technical University** by,

Prof. Dr. Ferit Bingel
Director, **Graduate School of Marine Sciences** ....

Prof. Dr. Ferit Bingel
Head of Department, **Marine Biology and Fisheries** ....

Prof. Dr. Ferit Bingel
Supervisor, **Graduate School of Marine Sciences, METU** ....

Assoc. Prof. Dr. Ali Cemal Gücü
Co-Supervisor, **Graduate School of Marine Sciences, METU** ....

Examining Committee Members:

Prof. Dr. Özden Baştürk
Faculty of Fisheries., Mersin University ....

Prof. Dr. Ferit Bingel
Graduate School of Marine Sciences., METU ....

Assoc. Prof. Dr. Ali Cemal Gücü
Graduate School of Marine Sciences, METU ....

Prof. Dr. Nilgün Kubilay
Graduate School of Marine Sciences, METU ....

Assoc. Prof. Dr. Zahit Uysal
Graduate School of Marine Sciences, METU ....

Date: February 8, 2008

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Ekin AKOĞLU

Signature :

ABSTRACT

INVESTIGATIONS ON THE FISH STOCKS IN ATATÜRK DAM LAKE BY USING CLASSICAL AND ACOUSTICAL TECHNIQUES

AKOĞLU, Ekin
M.S., Institute of Marine Sciences
Supervisor: Prof. Dr. Ferit Bingel
Co-Supervisor: Assoc. Prof. Dr. Ali Cemal Gücü
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The Atatürk Dam Lake is located in the southeastern part of Turkey and was formed after the construction of the Atatürk Dam on the Fırat River in 1990. Initially, the dam lake was planned to serve as a reservoir for irrigation and to supply water for domestic and industrial usage. In contrast to its initial functions, the dam lake in time has gained a special character that best suits for fishery. Following the construction of the dam, the natural fish species of the Fırat River became the permanent inhabitants of the lake. Over the years, apart from these species, the State Hydraulic Works has carried out biomanipulation researches in the lake to increase the "population" of the lake by its natural fish species and to introduce commercially important but not native species like Mirror Carp so that the lake would have an alternative source of income for the local people via fisheries. The changing economical situation of the lake for the local people has reinforced research from the fisheries point of view to discover the present situation of the fish stocks present in the lake and to ensure the sustainable utilization of these stocks through successful management of fisheries. This study aimed to answer and propose solutions to fishery related issues of the lake.

The fish stocks in the lake were investigated by using fisheries acoustics and classical techniques. As part of the acoustical research, the entire lake was surveyed with a scientific ecosounder to collect data on size classes and the distribution of the fishes in the water column. To support the acoustical findings and to estimate the fish stock sizes in the lake, gill-net samplings were carried out simultaneously with the acoustical sampling at various stations across the lake. Afterwards, acoustical data and gill-net samplings' results were combined to find out the available fish biomass. In addition, the gill-net data were processed with conventional (classical) methods to calculate the growth constants for the fishes that will further assist in estimation of the available stocks present in the lake for fisheries. Based on the findings of this study, some management measurements were proposed for the sustainable utilization of the fish stocks in the lake by the fisheries.

During two different cruises carried out in April and September, 2005, the fish biomass in the lake was estimated to be 34 kg/ha in April and 10 kg/ha in September, respectively. Both the small pelagic fish species *Acanthobrama marmid* and relatively bigger *Chalcalburnus mossulensis* had dominated the lake in terms of biomass. These species were also the most frequently observed species in the gill-net catches. The major part of the fish populations was found within upper 20 meters depth in April and September. Abundance distributions of the fishes were similar to the biomass distribution values. The likely underfished fish species *Acanthobrama marmid*, *Chalcalburnus mossulensis*, *Carasobarbus luteus* and *Mugil abu* were abundant enough to apply growth and yield analysis.

Keywords: Atatürk Dam, underwater acoustics, fisheries, fisheries acoustics

ÖZ

ATATÜRK BARAJ GÖLÜ'NDEKİ BALIK STOKLARININ KLASİK VE AKUSTİK TEKNİKLER KULLANILARAK ARAŞTIRILMASI

AKOĞLU, Ekin
Yüksek Lisans, Deniz Bilimleri Enstitüsü
Tez Yöneticisi: Prof. Dr. Ferit Bingel
Ortak Tez Yöneticisi: Assoc. Prof. Dr. Ali Cemal Gücü
Şubat 2008, 133 sayfa

Türkiye'nin güneydoğusunda yer alan Atatürk Baraj Gölü, 1990 yılında yapımı tamamlanan Atatürk Barajı'ndan sonra oluşmuştur. Baraj gölü öncelikli olarak sulama ve yerel ve endüstriyel kullanım için su sağlamak üzere planlanmıştır. Gölün öncelikli amaçlarına paralel olarak göl, zaman içerisinde balıkçılığa son derece uygun bir karakter kazanmıştır. Barajın inşaatının tamamlanmasından sonra, Fırat Nehri'nde doğal olarak bulunan balık türleri oluşan baraj gölünün daimi balık faunasını oluşturmuşlardır. Yıllar içerisinde, Devlet Su İşleri, yerel halk için yeni bir geçim kaynağı oluşturabilmek ve gölde doğal olarak bulunan balıkların miktarını arttırmak ve ekonomik açıdan önemi olan aynalı sazan gibi balık türlerini de göle aşılamak için biyomanipulasyon çalışmaları gerçekleştirmiştir. Gölün yerel halk açısından değişen önemi ile birlikte, göldeki balık stoklarının durumunun ortaya çıkarılması ve balıkçılık yönetiminin başarılı bir şekilde sağlanarak bu stokların sürdürülebilir bir biçimde kullanımı için bir balıkçılık araştırmasının yapılması zorunlu hale gelmiştir. Bu çalışmada bu sorulara yanıtlar sunmak ve balıkçılıkla ilgili konularda çözümler üretmek amaçlanmıştır.

Gölde bulunan balık stokları balıkçılık akustiği ve klasik yöntemler kullanılarak araştırılmıştır. Akustik araştırmanın bir parçası olarak, su kolonundaki balıkların dağılımı ve boy grupları hakkında veri elde etmek için bütün göl alanı bilimsel bir eko-sounder ile akustik sefer dahilinde taranmıştır. Akustik verileri desteklemek ve göldeki balık stoklarının büyüklüğü hakkında bilgi toplamak için, akustik araştırmalara paralel olarak pek çok farklı istasyonda solungaç ağı örneklemesi gerçekleştirilmiştir. Bunu takiben, gölde halihazırdaki balık biyokütlesini hesaplamak üzere solungaç ağı orneklemesi sonucunda elde edilen veriler akustik verilerle birleştirilmiştir. Buna ek olarak, solungaç ağı verileri, gölde bulunan balık stoklarının tahminine katkı sağlayacak olan balıkların büyüme sabitlerinin belirlenmesi için klasik metodlarla analiz edilmiştir. Böylelikle gölde bulunan toplam ürün miktari hesaplanmıştır. Bu çalışmada elde edilen sonuçlar doğrultusunda, göldeki balık stoklarının balıkçılık tarafından sürdürülebilir bir şekilde kullanılabilmesi için uygulanması gereken ölçütler hakkında önerilerde bulunulmuştur.

2005 yılının Nisan ve Eylül aylarında gerçekleştirilen iki seferde, göldeki balık biyokütlesinin Nisan ayında 30 kg/ha ve Eylül ayında 10 kg/ha olduğu tahmin edilmiştir. Bu biyokütlenin büyük bir kısmının küçük bir balık türü olan *Acanthobrama marmid* ve nispeten daha büyük boylu *Chalcalburnus mossulensis* tarafından oluşturulduğu ortaya çıkarılmıştır. Bu iki tür, solungaç ağı örneklemesinde en çok gözlenen türler olmuştur. Nisan ve Eylül aylarında balıkların önemli bir kısmının yüzeyden 20 metre derinliğe kadar dağılım gösterdiği saptanmıştır. Balıkların bolluk açısından dağılımları biyokütle dağımları ile benzerlik göstermiştir. Balıkçılık tarafından az avlanan balık türleri olan *Acanthobrama marmid*, *Chalcalburnus mossulensis*, *Carasobarbus luteus* ve *Mugil abu* büyüme ve ürün analizlerinin uygulanabilmesine olanak verecek kadar yeterli sayıda örneklenmiştir.

Anahtar Kelimeler: Atatürk Barajı, sualtı akustiği, balıkçılık, balıkçılık akustiği

To My Dearest Mum and Dad,

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1 INTRODUCTION

Atatürk Dam is one of the 21 dams of the Southeastern Anatolia Project of Turkey. It is built on the Fırat River and completed in 1990. It is one of largest earth-and-rock fill dams in the world, with the embankment 184 m high and 1820 m long. The Atatürk Dam Lake has a surface area of 817 km^2 (URL 1, 2007). Reservoir capacity is 48.7 km^3 (Şafak et al., 1994). Atatürk Dam Lake is utilized for hydro-power energy, irrigation and domestic and industrial water supply.

1.1 General Properties of the Atatürk Dam Lake Region

The Fırat river basin lies in three countries; Turkey, Syria and Iraq. Fırat river is born in Turkey and flows south-eastwards crossing Syria into Iraq. The main stream of the Fırat in Turkey has four major tributaries; the Karasu, the Murat, the Munzur, and the Peril. The length of the main stream is 2,330 km. The hydrographic and hydrological characteristics show great variation over the basin (Murakami, 1995).

1.1.1 Hydrology of the River

The Fırat has almost a regular regime, characterized by two months, April and May, of very high average flow. It has a dry period of eight months from July to February. The annual average flow is 635 m^3/sec and may show considerable annual variations. The average winter flows vary between 200 and 300 m^3/sec and increase in February when early spring rains occur at lower elevations. The increase in flow rate continues during March, when the snow begins to melt. In April and May monthly average flows reach 2,000 m^3/sec or higher, with maximum floods occurring between mid-April and early May with the combined effect of melting snow and rainfall. The flow diminishes after June and reaches its minimum values in September and sometimes October (Murakami, 1995). The climate conditions of the lake are mostly terrestrial. The surrounding environment is made up of barren lands.

1.1.2 Fishes of the Atatürk Dam Lake

Unlike Keban and Karakaya Dam Lakes, Atatürk Dam Lake is one of the least studied dam lakes on the river Fırat in terms of hydrology and limnology. Since data are limited, only the fish species found in the scope of this thesis research were introduced.

Although 28 different species were reported to be present in the lake by Kuru (1975), in this study 16 fish species belonging to 5 families and 13 genera were observed in the catch composition of the gill-net sampling. The taxons of these species as compiled from a report by European Network for Biodiversity Information (ENBI) (2005) were:

Phylum: Chordata
- **Classis:** Actinopterygii
  - **Ordo:** Cypriniformes
    - **Familia:** Cyprinidae (12 species)
      - **Genus:** Cyprinus
        - **Species:** *Cyprinus carpio*
      - **Genus:** Capoeta (2 species)
        - **Species:** *Capoeta trutta*
        - **Species:** *Capoeta capoeta umbla*
      - **Genus:** Carassius
        - **Species:** *Carassius auratus*
      - **Genus:** Barbus (3 species)
        - **Species:** *Barbus grypus*
        - **Species:** *Barbus luteus*
        - **Species:** *Barbus rajanorum mystaceus*
      - **Genus:** Leuciscus
        - **Species:** *Leuciscus leuciscus*
      - **Genus:** Cyprinion
        - **Species:** *Cyprinion macrostomus*
      - **Genus:** Acanthobrama
        - **Species:** *Acanthobrama marmid*
      - **Genus:** Chalcalburnus
        - **Species:** *Chalcalburnus mossulensis*
      - **Genus:** Chondrostoma
        - **Species:** *Chondrostoma regium*
    - **Familia:** Balitoridae
      - **Genus:** Orthrias
        - **Species:** *Orthrias spp.*
  - **Ordo:** Siluriformes
    - **Familia:** Siluridae

Genus: Silurus
Species: *Silurus triostegus*
Ordo: Synbranchiformes
Familia: Mastacembelidae
Genus: Mastacembelus
Species: *Mastacembelus simack*
Ordo: Perciformes
Familia: Mugilidae
Genus: Liza
Species: *Liza abu*

Therefore, the species observed were mentioned in this subsection.

1.1.2.1 *Liza abu* (Heckel, 1846)

This species is sometimes referred as *Mugil abu*, and found under the family of Mugilidae.

Morphology: It bears 2 dorsal fins, first is spiny and bears generally 4 spines and the latter bears soft rays after 1 or 2 spines. The anal fin spines are 3 and followed by generally 8 soft rays. The pelvic fins contain 1 spine. The pectoral fins are long and reach to 75 -80 % of the head length. The general color of the body is silvery with a light brown or grayish color in the back and a yellowish-silver color in the belly (URL 2, 2007).

Habitat: It is actually a freshwater species and found in rivers, channels, lakes, ponds, reservoirs and drains. It occasionally enters estuaries.

Distribution: This species is found in Tigris (Dicle) - Euphrates (Fırat) and Orontes (Asi) river basins; south-eastern part of Turkey, in Iraq, Iran, the rivers draining to the Persian Gulf and in Pakistan (URL 2, 2007).

Size: It attains a maximum size of 26 centimeters with 150 grams weight (URL 2, 2007).

Food: This species consumes aquatic plant parts, organic debris and phytoplankton followed by zooplankton and aquatic insects (URL 2, 2007).

Growth: It reaches a maximum age of 7 years (Al-Yamour et al., 1988). In the Turkish Tigris River, there were 4 age groups reported (Ünlü et al., 2000).

Reproduction: This species spawns twice each year in the Zohreh River in Iran, which drains to the northern Persian Gulf in Iran (Marammazi, 1994). The spawning season in Iraq is from end of February to mid-March (van den Eelaart, 1954, c.f. URL 2, 2007).

1.1.2.2 *Carassius auratus* (Linneaus, 1758)

This species is a member of the Cyprinidae family. The genus is characterized by a compressed body. Last unbranched dorsal and anal fin rays are serrated. The dorsal fin is single and long, the anal fin is short. The mouth is small and terminal and lips are thick and fleshy with no barbels (URL 2, 2007).

Morphology: It has one dorsal fin with 3-4 unbranched rays followed by 12-20 branched rays. Anal fin contains 2-4 unbranched rays followed by 5-6 branched rays, pectoral fins have branched rays of 11-18, and pelvic fins bear 6-9 branched rays. The dorsal and anal fins' spine denticles are about 10-15. The golden or orange color of artificially bred aquarium variety is obvious. However, populations in the wild gradually revert to a wild-type of color (URL 2, 2007).

Habitat: This species is a freshwater species and usually found in lakes and reservoir. They are found in ponds or pools in streams with aquatic vegetation but are often introduced into small bodies of water as an ornamental fish (URL 2, 2007).

Distribution: The native distribution is in northern Asia and China, reaching northern drainages of the Caspian Sea in the western limits of its distribution (Libosvarsky, 1962, c.f. URL 2, 2007). The species has been widely introduced to garden ponds and released from aquaria in temperate to warm waters world-wide (URL 2, 2007).

Size: This species attains 52 centimeters and weighs about 5 kg (URL 2, 2007).

Food: Food is predominantly zooplankton but also includes aquatic insects, crustaceans, mollusks, worms, detritus, filamentous algae, macrophytes and young fish (URL 2, 2007)

Growth: Maturity is attained at 3-4 years in the Volga Delta. Life span is 13 years with most growth in the first 2-4 years to a size of 15-20 centimeters (Gudkov, 1985, c.f. URL 2, 2007; Kizina, 1986, c.f. URL 2, 2007).

Reproduction: Spawning is in late April to mid-May in the Volga Delta and occurs in May-June in the Anzali Mordab, Iran (Sayad Borani et al., 2001). Eggs are laid in 2-5 batches over a spawning period extending into July.

1.1.2.3 *Cyprinus carpio* (Linnaeus, 1758)

This species has been widely introduced as a food fish and is found in the Cyprinidae family. The aquaculture of this species is wide in Europe and the most famous variety is mirror carp, which is utilized and farmed as a source of food. This genus is characterized by a compressed but heavy body, large size, rounded snout and 2 pairs of barbels. The members of this genus have a very long dorsal fin and the last unbranched ray is spine-like and serrated. The anal fin is short. The last unbranched ray of anal fin is spine-like and serrated (URL 2, 2007).

Morphology: This species is easily identified by the long dorsal fin, the spines in both the dorsal and anal fins, and the two pairs of barbels. The dorsal fin contains 2-5 unbranched rays followed by 14-23 branched rays; anal fin comprises 2-4 unbranched rays followed by 3-7 branched rays. Pectoral fins have 13-19 branched rays and pelvic fins have 5-9 rays. The dorsal fin's last unbranched ray has developed as a toothed spine and the anal fin has a similar spine (URL 2, 2007).

Habitat: This species prefers soft vegetation in shallow waters, necessary for successful reproduction. Still waters are the preferred habitat but they are found in the lower courses of lowland rivers with moderately flowing water and occasionally in water exceeding 2 m/sec discharge (URL 2, 2007).

Distribution: The species has been introduced in the Middle East, Europe and Asia for aquaculture.

Size: Carp resident in fresh waters are smaller than semi-diadromous carp. Maximum size exceeds 1.2 m and 68 kg (URL 2, 2007).

Food: Food includes aquatic insects, crustaceans, worms and mollusks, and more rarely, fish. Feeding almost completely stops in winter and the fish enters a phase of hibernation (URL 2, 2007).

Growth: Females are larger and mature a year later than male. Sexual maturity is attained in the second year of life and in a few individuals even by the end of the first year, in the southeastern Caspian Sea; but in the southwestern Caspian Sea this occurs in the third and fourth years (Kuliyev and Agayarova, 1984, c.f. URL 2, 2007). Resident carps in Dagestan mature in their third year at about 30 centimeters and have an average life span of 6 years whereas the semi-anadromous or semi-diadromous forms mature in their fourth year at 35-36 centimeters and have an average life span of 8 years (Shikhshabekov, 1969, c.f. URL 2, 2007).

Reproduction: Spawning time variations are governed by temperature and the most favorable temperature is 18-20 ˚C (URL 2, 2007).

1.1.2.4 ***Barbus grypus*** (Heckel, 1843)

Barbus grypus is also known as *Tor grypus*. It belongs to the Cyprinidae family.

Morphology: This species is identified by having two pairs of barbels and a strong and smooth spine in the dorsal fin. The dorsal fin has 4 unbranched rays and 7-9 branched rays. Anal fin has 3 unbranched and 5 branched rays. Pectoral fins contain 14-18 branched rays and pelvic fins have 7-8 branched rays. Overall color has a pale rose to light orange effect. The back is a dark olive-brown to blackish-green with the flanks pale rose, light orange to yellowish to silvery and belly silvery to milk-white. Lips are pale red. The operculum is golden (URL 2, 2007).

Habitat: The habitat for this species in the Tigris River was described as distributed throughout the river and its tributaries. This species may enter marshes on floods, favoring areas where there is fresh river water, but returns to rivers as it requires a higher oxygen concentration than most marsh residents (van den Eelaart, 1954, c.f. URL 2, 2007; Al-Hamed, 1966b, c.f. URL 2, 2007; Al-Hamed, 1972, c.f. URL 2, 2007).

Distribution: This species is found in the Tigris-Euphrates basin and the Orontes River basin (URL 2, 2007).

Size: It attains 96 centimeters and 9.7 kg in Dukan Reservoir, Iraq (Al-Hakim et. al., 1981, c.f. URL 2, 2007). 1.5 m length and 30 kg weight was reported for Syria (Gruvel, 1931, c.f. URL 2, 2007).

Food: The species was found to be a herbivore taking filamentous algae and higher plant parts (Al-Hamed, 1965, c.f. URL 2, 2007). It may also take some small fishes.

Growth: Males are longer than females before maturation and shorter thereafter. Females reach 13 years and males 8 years of age and fish mature at 45-48 centimeters total length in their fifth year. Males mature earlier than females (Al-Hakim et. al., 1976, c.f. URL 2, 2007). Life span is 17 years for females and 11 years for males in the Dukan Reservoir, Iraq (Al-Hakim et. al., 1981, c.f. URL 2, 2007). It was found that this species matures at 3-5 years of age in 40-50 centimeters length in the Al-Therthar Reservoir (about 65 km northwest of Baghdad) and the Tigris River (Kut Dam) in Iraq (Ali et. al., 1981, c.f. URL 2, 2007). About the Tigris River populations in Iraq, it was found that males mature at about 45 centimeters and females at about 50 centimeters, with most fish mature in their fourth year and start spawning at the beginning of their fifth year of life. Maximum age observed was 12 years (Al-Hamed, 1966a, c.f. URL 2, 2007; Al-Hamed, 1966b, c.f. URL 2 2007, Al-Hamed, 1972, c.f. URL 2, 2007).

Reproduction: The spawning season in the Tigris River between Beled and Tigrit in Iraq is late May to late June after an upriver migration in April (URL 2,2007).

1.1.2.5 *Leuciscus leuciscus* (Linnaeus, 1758)

This species is a member of the Cyprinidae family.

Morphology: It has a narrow, small and pointed head, large eyes and a small inferior mouth. It has a grayish blue back, silvery sides, its belly is white and its paired fins are yellowish. Anal and dorsal fins are both concave (URL 3, 2007).

Habitat: This species natively lives in a temperate climate and prefers waters with a 6.0 to 8.0 pH and an ideal temperature range of 4 to 22 °C. It prefers clear streams flowing over a gravelly bottom, and deep, still waters, keeping close to the bottom in winter but disporting itself near the surface, in the sunshine of summer (URL 4, 2007).

Distribution: It is an inhabitant of the rivers and streams of Europe; north of the Alps as well as in Asia, but it is most abundant in France and Germany, as well as having spread to Ireland where it is used as a bait fish (URL 4, 2007).

Size: It grows to a maximum length of 40 centimeters, a maximum weight of 1 kg, and may live for up to 16 years (URL 4, 2007).

Food: It feeds on worms, insects, insect larvae, snails, and also rarely on vegetable matter (URL 4, 2007).

Growth: It grows slowly and has an average life span of seven to ten years (URL 3, 2007).

Reproduction: Most individuals become sexually mature when two years old. The males develop spawning tubercles on their bodies and on their paired fins during the spawning season. It spawns once a year, between March and May, laying eggs on a sandy or stony bed or on aquatic plants. The young hatch after 25 days at a temperature of 13 °C (URL 3, 2007).

1.1.2.6 ***Barbus luteus*** (Heckel, 1843)

This species belongs to the family Cyprinidae and also known as *Carasobarbus luteus.*

Morphology: Dorsal fin has 4 unbranched rays followed by 9-11 branched rays. The last unbranched dorsal fin ray is smooth, thickened, sharp-edged and spine-like. Anal fin comprises 3 unbranched rays followed by 5-7 branched rays. Pectoral fins have 13-17 branched rays and pelvic fins contain 7-9 branched rays. There is a pelvic axillary scale. The mouth is terminal to subterminal and lips are weakly developed. There is one pair of short barbels at the corner of the mouth. The back and upper flank is greenish black or grey-green fading to a whitish or silvery belly. There is a dark stripe along the mid-line of the back and a dark mid-lateral stripe exists. Fins are grayish to lime-green. The lips are orange. The eye rim is yellow-green (URL 2, 2007).

Habitat: This species in Iraq is a resident in still waters and the slower sections of rivers and is the main fish in canals (van den Eelaart, 1954, c.f. URL 2, 2007). In summer it goes to the deeper basins of marshes and remains in the shade of plants. It tolerates warm water but does not go into open waters (URL 2, 2007).

Distribution: This species is found in the Orontes and Quwayq rivers (Syria) and in the Tigris-Euphrates basin (URL 2, 2007).

Size: It attains a 38 centimeters calculated maximum length and 501 grams (Ahmed, 1982, c.f. URL 2, 2007) or 750 grams (Borkenhagen, 2005).

Food: Food is mainly detritus, aquatic plants, and algae are taken throughout the night and day (URL 2, 2007).

Growth: Maturity is attained at a minimum of 11.2 centimeters for females and 12.2 centimeters for males, at age 1+. The largest fish are 26.0 centimeters and age 6 in the Hawr al Hammar in southern Iraq (Ahmed et. al., 1984, c.f. URL 2, 2007). It was also found 6 age groups for fish from the Garma Marshes, Iraq (Barak and Mohamed, 1983, c.f. URL 2, 2007). 7 age groups were present in Tharthar Reservoir in Iraq (Ahmed, 1982, c.f. URL 2, 2007). Fish up to age group 8+ were observed in the Diyala River, Iraq (Biro et. al., 1988, c.f. URL 2, 2007).

Reproduction: The spawning season for the lower Euphrates River was found as May-July (peak June-July) (Bhatti and Al-Daham, 1978, c.f. URL 2, 2007; Al-Daham and Bhatti, 1979, c.f. URL 2, 2007).

1.1.2.7 *Cyprinion macrostomus* (Heckel, 1843)

This species is under the Cyprinidae family.

Morphology: The dorsal fin has 4 unbranched and 12-17 branched rays. The dorsal fin's last unbranched ray is strong and serrated to the tip. The anal fin has 3 unbranched and 6-7 branched rays. Pectoral fins have 12-17 branched rays and pelvic fins contain 7-9 branched rays. The back is bluish-grey to bluish-black or brown, flanks are silvery or silvery-yellow and the belly is white with silvery tints. The upper head is light brown. Scales are outlined with dark pigment and the anterior exposed scale base is darkened. The cleithrum area is pink or orange in some fish with pink or orange spots on up to 5 rows of flank scales but mostly along the anterior lateral line (URL 2, 2007).

Habitat: It is known to live in a variety of habitats such as rivers, streams, reservoirs and ponds, as well as canals and gravel pits (URL 2, 2007).

Distribution: This species is found in the Orontes, Quwayq and Tigris-Euphrates basins (URL 2, 2007).

Size: Reaches 19.3 centimeters standard length (Krupp, 1985c; c.f. URL 2, 2007).

Food: Major food items are of plant origin with occasionally some chironomid larvae, copepods and cladocerans (URL 2, 2007).

Growth: Maximum age is 7 years. Growth is slow and there is no difference in growth between males and females (URL 2, 2007).

Reproduction: Spawning occurs principally in May and June, with some in early July, but by July most fish are spent (URL 2, 2007).

1.1.2.8 *Acanthobrama marmid* (Heckel, 1843)

This species belongs the Cyprinidae family.

Morphology: The last unbranched dorsal fin ray is a thickened, stiff and smooth spine, the rigid part varying from 15 to 26 % of standard length. Some small fish lack an enlarged dorsal fin spine. Dorsal fin has 3 unbranched rays and 7-9 branched rays. Anal fin contains 3 unbranched and 13-22 branched rays. Pectoral fins have 12-18; pelvic fins have 7-9 branched rays. The overall color is silvery to whitish with the head and back reddish-brown (URL 2, 2007).

Habitat: It usually lives in large rivers and its tributaries and in dam lakes (URL 2, 2007).

Distribution: This species is found in the Tigris-Euphrates basin of Turkey, Syria, Iraq and Iran, the Quwayq and Orontes Rivers, and possibly the Amik Lake and the Bardan stream near Tarsus (Ladiges, 1960, c.f. URL 2, 2007; Krupp, 1985c, c.f. URL 2, 2007).

Size: This species reaches 20.8 centimeters (Berg, 1949, c.f. URL 2, 2007).

Food: In Shatt al Arab, Iraq, these fish were found to be detritivores, having organic detritus as the dominant gut content, followed by phytoplankton (blue-green algae and diatoms), small crustaceans (ostracods, cyclopoids, cladocerans), and aquatic plants, with dominance varying by month (Younis et. al., 2001a, c.f. URL 2, 2007; Younis et al., 2001b, c.f. URL 2, 2007).

Growth: In Tigris River, Turkey, females grow faster and are larger in size than males at the same age, particularly for age groups III and IV. Condition factor for males was 1.554 and for females 1.550. It was found that 5 age groups with age group III was dominant for both sexes (Ünlü et al., 1994).

Reproduction: It was reported that spawning takes place in May to late June for Tigris River, for Turkey population. It was also cited that in a Keban Dam population (on the Euphrates River in Turkey) the spawning season is extended and runs from April to August (Ünlü et al., 1994).

1.1.2.9 *Chalcalburnus mossulensis* (Heckel, 1843)

This species is a member of Cyprinidae family.

Morphology: Dorsal fin has 3 unbranched and 7-9 branched rays, anal fin comprises 3 unbranched and 10-14 branched rays. Pectoral fins have 14-16 branched rays, pelvic fins 8-9 branched rays. Overall color is silvery. The back is a bluish-brown or reddish-brown, bluish-black or blackish. A dark, lead-colored stripe runs along and above the mid-flank and has a width about the same as the eye diameter. The stripe may only be evident posteriorly (URL 2, 2007).

Habitat: This species is found in streams, rivers, lakes, reservoirs and marshes (URL 2, 2007)

Distribution: It is found in the Tigris-Euphrates basin and adjacent basins (URL 2, 2007).

Size: The length reaches about 22 centimeters (Ergene, 1993).

Food: In Shatt al Arab, Iraq, the species feeds on phytoplankton (algae and diatoms) at 44 %, followed by organic detritus at 36.7 % and arthropods at 3.1 % (Younis et. al., 2001b, c.f. URL 2, 2007).

Growth: In the Karasu of Turkey, it was found that 4 age groups exist and it was mentioned that there were 5 age groups present for another Turkish study (Ergene, 1993). In another study in the Karasu River, it was found that age groups 1 to 6 are present with age group 3 being the most abundant (Türkmen and Akyurt, 2000).

Reproduction: A female of 15.5 centimeters long with mature eggs was reported (Berg, 1949, c.f. URL 2, 2007). In Qarmat Ali River, Iraq, fish had a fecundity of 1926-11779 eggs (Saud, 1997, c.f. URL 2, 2007).

1.1.2.10 *Barbus rajanorum mystaceus* (Heckel, 1843)

This species is found under the family of Cyprinidae. *B. rajanorum mystaceus* is a little known species (Duman, 2002). It is very common in Euphrates and Tigris Rivers (Kuru, 1975).

Size: This species reaches up to 60 centimeters length.

Growth: The age distribution of *B. rajanorum mystaceus* was found between 1-9 years in males and females (Duman, 2002).

1.1.2.11 *Orthrias spp.*

The members of this genus belong to the family Balitoridae. There are at least 18 species found mainly in western Asia with a few in Europe. The body is elongate, thick, and rounded or slightly compressed. The head is slightly depressed or compressed. Eyes are small and widely spaced. There are no nasal barbels. The lower lips are moderately furrowed. The dorsal fin has 7-9 branched rays. The pelvic fins are inserted slightly behind the dorsal fin origin. The caudal fin is slightly emarginated to deeply forked. There is no dorsal crest on the caudal peduncle. Color is brownish, being barred, striped, bearing irregular spots and blotches, or more or less regular rows of spots. The pectoral fins of males are broadened and thickened, and covered by tubercles in the spawning season. Tubercles also develop on the sides of the head (URL 2, 2007).

1.1.2.12 *Chondrostoma regium* (Heckel, 1843)

This species is a member of Cyprinidae family.

Morphology: Dorsal fin has 8-11 branched rays; anal fin has 9-12 branched rays. Pectoral fins contain 14-18 rays and pelvic fins comprise 6-9 rays. The back is olive-brown with bluish tinges and the flanks and belly are silvery-white. The dorsal and caudal fins are grayish and the other fins are hyaline. Some fish have bright orange fins, the pectorals are paler, the pelvic and anal fins are fringed by white (URL 2, 2007).

Habitat: This species is found in rivers, lakes and reservoirs. This species prefers stone grounds and still waters in rivers and lakes in Turkey (Ünlü, 2006).

Distribution: It is found in the Tigris-Euphrates basin and the Mediterranean basins of southeastern Turkey and the northern Levant (URL 2, 2007).

Size: It reaches up to 40 centimeters length and 1 kg weight (URL 2, 2007).

Food: This species is omnivorous taking insect larvae and eggs and fry of other fishes. Gut contents also include diatoms and algae as well as large quantities of sand (URL 2, 2007). However, in the Suat Uğurlu Dam, Turkey it was found that Navicula, Cymbella and Synedra were the most frequently consumed organisms (Gümüş et al., 2002).

Growth: In a study in the Bafra Altınkaya Dam lake in Turkey using vertebrae, otoliths, scales, opercle and subopercle it was found that age reaches 5, perhaps 6 years and scales were found to be the best structure to use for age determination (Polat and Gümüş, 1995). Growth characteristics of this species in the Atatürk Dam on the Turkish Euphrates River were examined. Eight age groups were found (Oymak, 2000).

Reproduction: The breeding season at Al Kadhmia in the Tigris River near Baghdad was March to May (Daoud and Qasim, 1999, c.f. URL 2, 2007). It was stated that this species probably spawns in May or June in Syria (Beckman, 1962, c.f. URL 2, 2007) and it was found that condition factors were highest in April and May in the Atatürk Dam, Turkey (Oymak, 2000).

1.1.2.13 ***Mastacembelus simack*** (Banks and Solander, 1794)

This species is a member of Mastacembelidae family.

Morphology: It has 68-90 soft dorsal rays and 70-90 soft anal rays after 3 spines. Pectoral fins have 19-24 rays. The penultimate spine in the dorsal fin and the central anal spine are the longest spines. The back is blackish to brown, the lower flank is spotted yellow and the belly is white to yellowish. A series of about 20-24 black to blackish-brown, oval spots ringed with a lighter brown follow a dark, broad but irregular stripe on the head and anterior back in the mid-line. Dorsal, anal and caudal fins are yellowish. The dorsal and caudal fins are barred. The anal fin may be almost immaculate. The pectoral fins are yellowish and are finely barred (URL 2, 2007).

Habitat: This species is known from both lotic and lentic environments (Pazira et. al., 2005, c.f. URL 2, 2007).

Distribution: This species is distributed in the Quwayq, Orontes and Tigris-Euphrates basins (URL 2, 2007).

Size: It reaches 58.4 centimeters total length, probably larger to almost 1 m (URL 2, 2007).

Food: Food is assumed to include invertebrates but two fish from Iran contained fish scales and fish skeletal remains. Other species of this genus are known to eat fish eggs and fry (URL 2, 2007). Gut content in the Hawr al Hawizah, Iraq in 2005-2006 was 55.0 % shrimps and 45.0 % fish and in the Al Kaba'ish Marsh was entirely fish (Hussain et. al., 2006, c.f. URL 2, 2007).

Growth: Life span was up to 6 years although most fish were 3 years or younger. Females grew rapidly to age 3, after which annual growth decreased (URL 2, 2007).

Reproduction: Fish taken on November, 26th have small but developing eggs, suggestive of spring spawning (URL 2, 2007).

1.1.2.14 *Silurus triostegus* (Heckel, 1843)

This species belongs to the family Siluridae. This genus is characterized by an elongate body, rounded anteriorly but compressed posteriorly; a depressed head and 2-3 pairs of barbels. The maxillary barbels are well-developed. They are often as long as the head. The mouth is large and terminal. Nostrils are well separated and the eyes are small and not visible from the underside of the head. They have a very short and spineless dorsal fin. Anal fin is very long and united to the rounded caudal fin; pectoral fins bear a strong serrated spine (URL 2, 2007).

Morphology: Bears 4 barbels in some specimens as opposed to the usual 6 in *Silurus glanis* but there is evidence that the four-barbelled Silurus have 6 barbels when young and one pair of mandibular barbels is reabsorbed (Haig, 1952, c.f. URL 2, 2007). Specimens with one pair and with two pairs of mandibular barbels have been reported (Kobayakawa, 1989, c.f. URL 2, 2007). 4 mandibular barbels (2 pairs) in 3 specimens, 3 barbels in 1 specimen and 1 pair in another specimen were recorded for Turkish Euphrates River fish (Ünlü and Bozkurt, 1996). In *Silurus triostegus*, the adults apparently lose one pair of barbels (Krupp, 1992, c.f. URL 2, 2007). In another study, *S. glanis* had 4 mandibular barbels (2 pairs) while in *S. triostegus* 11 fish had 4 mandibular barbels and 12 fish lacked the posterior mandibular pair. There was no apparent trend in barbel loss associated with increase in body size (Coad et al., 2000).

The pectoral fin spine is strongly serrated on its inner surface and smooth on its outer surface. The maxillary barbel reaches only to the end of the head, not much longer as in *S. glanis*. However, it was reported that maxillary barbels are longer than the head and later that they reach the end of the head (Ünlü and Bozkurt, 1996). The lower jaw is longer than the upper jaw (URL 2, 2007). Dorsal fin has 3-4 branched rays, pectoral fins have 11-14 branched rays with 1 spine, pelvic fins bear 8-13 branched rays after 1 unbranched ray, and anal fin rays are 77-94. The upper body is mottled pale yellow-brown and black. Overall color may appear dark or light and yellowish. The belly and lower head are white with the belly having black spots. Maxillary barbels and margin of the lower jaw are very dark brown (URL 2, 2007).

Habitat: It was established that this species is found in open and vegetated lakes and marshes and rivers in Iraq. (van den Eelaart, 1954, c.f. URL 2, 2007). The larger fish are mostly confined to rivers, entering marshes and lakes only on floods (URL 2, 2007).

Distribution: This species is found in the Tigris-Euphrates basin including its Iranian portion in Khuzestan and such rivers as the Arvand, Bahmanshir, and Jarrahi, and the lower Karun, Karkheh and Dez (Marammazi, 1995; Abdoli, 2000).

Size: The weight reaches 4.5 kg in Iraq (van den Eelaart, 1954, c.f. URL 2, 2007; Herzog, 1967, c.f. URL 2, 2007); length reaches 1.5 m in the Syrian Euphrates (Gruvel, 1931, c.f. URL 2, 2007) and to more than 2 m (Krupp, 1992, c.f. URL 2, 2007).

Food: Fish are important food of this species including *Liza abu* and *Acanthobrama marmid* (Al-Shamma'a and Jasim, 1993, c.f. URL 2, 2007; Ünlü et. al., 1996). Aquatic insects are also taken but fish predominate (URL 2, 2007).

Growth: Age groups from 2 to 7 years were found for fish from a marsh area north of Basrah, Iraq in 6 weight groups from 300 to 3900 g (Al-Abood, 1989, c.f. URL 2, 2007). 600 specimens from the Al-Hammar Marsh north of Basrah, Iraq were examined for age using vertebrae and eye lens diameter and 6 age groups were found (Al-Hassan and Al-Sayab, 1994, c.f. URL 2, 2007). In Atatürk Dam Lake 11 age groups were found (Oymak et al., 2001).

Reproduction: Spawning takes place in March in Iraq (van den Eelaart, 1954, c.f. URL 2, 2007; Al-Hassan et. al., 1990, c.f. URL 2, 2007) and to May and June in Turkey (Oymak et al., 2001). The highest condition factors were found in April in Atatürk Dam Lake, Turkey.

1.1.2.15 *Capoeta trutta* (Heckel, 1843)

This species belongs to the family Cyprinidae. This genus Capoeta is characterized by a compressed to rounded and moderately elongate body and an inferior and transverse mouth. The lower jaw has a sharp, horny sheath. The barbels are absent or in 1 or 2 pairs, dorsal fin is short usually, with 7-9 branched rays, with the last unbranched ray thickened and bearing serrations. Anal fin is short usually with 5 branched rays. The color is mostly uniform (URL 2, 2007).

Morphology: The combination of small scales, transverse mouth, the very strong last unbranched dorsal fin ray and the color pattern identify this species. Dorsal fin has 3-5 unbranched rays followed by 7-9 branched rays; anal fin has 2-3 unbranched rays followed by 5 branched rays. Pectoral fins contain 14-18 branched rays and pelvic fins have 5 branched rays. The head and body and the dorsal fin and sometimes the caudal fin are covered with small, distinctive black spots, often c or x-shaped. Spots are apparent through the silver flank color. Color is brownish to yellowish or olive-green on the back with silvery white flanks and the belly is lighter, white with silvery tints. Some fish are very pale almost whitish (URL 2, 2007).

Habitat: This species is considered to be stenohaline (Marammazi, 1994).

Distribution: It is found in the Quwayq, Orontes and Tigris-Euphrates basins including the Iranian portion of the latter (Berg, 1949, c.f. URL 2; Marammazi, 1995) and the Gulf basin in the Zohreh River in Iran.

Size: It attains at least 45.8 centimeters total length (URL 2, 2007).

Food: Gut contents include diatoms, green algae and large amounts of sand (URL 2, 2007).

Growth: The majority of the population studied by Ünlü (1991) in the Tigris River in Turkey are in age groups 2 and 3 although males live up to age 7 and females up to age 10 (Ünlü, 1991). In a stream in the Euphrates River drainage of Turkey, it was found that fish live for 8 years with 60-90 % of the fish in age groups 1 to 3 (Gül et al., 1996).

Reproduction: Spawning in the Tigris River in Turkey took place in May-June. Males mature at age 2 and females at age 3 (URL 2, 2007).

1.1.2.16 *Capoeta capoeta umbla* (Heckel, 1846)

Capoeta capoeta umbla is another fish species found under the family Cyprinidae.

Morphology: It has a cylindrical body compressed laterally. The body is covered with very small scales. The mouth is wide, and the snout is blunt. The lips are covered with a corneous skin. It has a pair of small barbels. The last spine in the dorsal fin is serrated in the posterior part. The dorsal fin has 3-4 spines followed by 9-10 soft rays. The anal fin contains 3 spines followed by 5 soft rays (Geldiay and Balık, 1988).

Distribution: It is distributed throughout the upper zones of Tigris-Euphrates River basin (Geldiay and Balık, 1988).

Size: This species may attain a maximum length of 45 centimeters (Geldiay and Balık, 1988).

1.1.3 Previous Studies Carried Out in the Lake

Since the establishment of Atatürk Dam in 1990, there have been some studies carried out in its reservoir, especially on fisheries. According to a study carried out in Bozova district of the lake, 12 fish species were found to be present in the area (Duman and Çelik, 2001). These species were *Mugil abu, Cyprinus carpio, Capoeta trutta, Carasobarbus luteus, Chondrostoma regium, Tor grypus, Aspius vorax, Chalcalburnus mossulensis, Leuciscus cephalus orientalis, Barbus rajanorum mystaceus, Silurus triostegus* and *Mastacembelus simack*.

In 1993, the State Hydraulic Works carried out a study leaded by Şafak et al. (1994) on the fish stocks present in the lake to determine stock sizes. The study was carried out by 1460-meter-long gill-nets. Differently from the Duman et al.'s findings in 2001, there were 14 species observed in the catches. Most of the species were the same species as stated by Duman et. al. (2001) but some new species, namely *Vimba vimba*, *Cyprinion tanuiradius* and *Alburnus alburnus* were found to be present. The study of Şafak et al. (1994) revealed that the fisheries' catches in the lake was 850 tonnes and the major constituents of the catch was *Carasobarbus luteus, Barbus rajanorum mystaceus, Alburnus alburnus, Leuciscus cephalus, Silurus triostegus, Aspius vorax* and *Cyprinus carpio*.

The fishing pressure in the lake has been consistent since the establishment of the reservoir. The fishing fleet was investigated in the reservoir and the number of fishermen and the power of the fishing fleet are summarized in Table 1 (Şafak et al., 1994).

Table 1.1: Fisheries power in the lake in 1994 (Şafak et al., 1994).

Region	Number of Fishermen	Number of Boats	Average Catch (kg/day)
Urfa	244	47	280
Adıyaman	333	50	1100
Gerger	70	13	320
Samsat	45	6	90
Hilvan	45	14	100
Kahta	165	23	500
Total	**902**	**153**	**2390**

1.2 Acoustical Methods in Fisheries Studies

Remote detection of fish is possible by using sound waves. After Sund (1935), acoustics has had a great impact on fishing (MacLennan, 1990). In commercial fisheries, echolocation of fish by underwater acoustics has become an important tool (Misund, 1997). Over the years, acoustical techniques have also played an important role not only in commercial fisheries but also in fisheries research. Sampling a great volume of water in reasonably shorter time periods is possible with today's underwater acoustical devices. Alternative sampling methods like conventional fishing methods such as trawling are very time consuming when compared to acoustics. Observations with acoustics have cleared out how fish are distributed in the water column. Furthermore, fish behavior can be observed by sonar to discover how fish avoid from fishing gears and how they are caught. Acoustic tags can be used to observe fish behavior (MacLennan, 1990).

During the years following Second World War, underwater acoustics became an important tool in fisheries science (Devold, 1950), and various acoustical properties of fish began to be investigated (Midttun and Hoff, 1962; Shibata, 1971).

The need for a more quantitative and precise method gave way to the invention of the echo integrator (Dragesund and Olsen, 1965), in which the voltage generated by the backscattered echo signals is squared and summed over intervals of depth and distance traveled. By calibrating the echo integrator using metal spheres with known backscattering strength (Foote et al., 1987), the recording properties of the instruments can be measured. If the backscattering strength (TS: Target Strength) of the recorded fish is known, the echo integrator output can be converted to units of fish density in the sampled volume of water and thus area (MacLennan and Simmonds, 1992). These principles are applied in acoustic surveys for estimating abundance of fish stocks (Misund, 1997).

Acoustic fish detection equipment has enabled fishermen to locate and catch fish far beyond the sustainability of most commercially interesting fish stocks in the world. On the other hand, by scientific application of acoustic equipment, the distribution and abundance of fish stocks can be mapped and estimated independent of commercial fishing activity. These scientific estimates are becoming increasingly important in the management of many commercially important fish stocks (Misund, 1997).

1.3 The Aim of the Study

Since its establishment, Atatürk Dam Reservoir has not been studied in terms of fish stock sizes. There are previous studies on fish species concerning biometrics. However, these studies either only covered a small area of the lake, or limited to a couple of fish species. For this reason, to discover the fisheries potential and fish stocks of the reservoir, a study covering most of the reservoir area as a whole was necessary. Using the results of the estimation of the fishable biomass, it is possible to apply suitable fisheries management measures to reach and attain more or less a sustainable utilization of fish species.

2 MATERIAL AND METHOD

In order to study the fish stocks in the Atatürk Dam Lake, two acoustical surveys with simultaneous gill-net samplings and two separate gill-net surveys were conducted. A scientific echo-sounder and two sets of gill-nets were used for sampling fish stocks. The acoustical surveys with gill-net samplings were carried out between April 21st - 27th, 2005 and September 20th - 27th, 2005 and the gill-net surveys were conducted between November 29th - 30th, 2005 and December 22nd - 23rd, 2005 respectively.

2.1 Acoustical Sampling

The acoustical data were collected on board with a SIMRAD EY500 single beam echo-sounder with 120 kHz frequency. Before each survey the echo-sounder was calibrated by using a copper sphere. The calibration sheet of the echo-sounder and the calibration parameters are shown in Table 2.1. The "Transducer Depth" is the installation depth of the transducer relative to the water surface. This depth is taken into account when calculating the depth of the water column and added to the sounder detected depth. "Absorption Coefficient" is the absorption of sound in the water. Since study area was a freshwater lake, it was set to 4 dBkm, which is equal to the absorption coefficient of sound in freshwater. The "2-Way Beam Angle" is the two-way beam opening solid angle and it was set to -20.5 dB. "Sv Transducer Gain" and "TS Transducer Gain" are the peak transducer gains assumed during the computation of volume backscattering strength (echo received from a unit volume of water body) and target strength (the intensity of reflected echo at 1 meter distance from a target) respectively. "Angle Sensitivity Alongship", "Angle Sensitivity Athwartship", "3dB Beamwidth Alongship", "3dB Beamwidth Athwartship", "Alongship Offset" and "Athwartship Offset" calibration parameters are not available in single beam echo-sounders. Water temperature was set to the mean surface water temperature of the lake according to the in situ measurements. This parameter affects the speed of sound in water. Therefore, "Sound Speed" was calculated referencing from the water temperature and salinity, which is zero in freshwater lakes, and found to be 1482 m/s.

Table 2.1: EY500 transducer calibration sheet.

Parameter	**Value**
Transducer Type	120-25
Transducer Sequence	O
Mode	Active
Transducer Beam Type	Single
Transducer Depth (m)	1
Absorption Coefficient (dBkm)	4
Pulse Length	Medium
Frequency (kHz)	119.047
Bandwidth	Wide
Maximum Power (W)	63
2-Way Beam Angle (dB)	-20.5
Sv Transducer Gain (dB)	32.4
TS Transducer Gain (dB)	32.4
Angle Sensitivity Alongship	-
Angle Sensitivity Athwartship	-
3dB Beamwidth Alongship (dg)	-
3dB Beamwidth Athwartship (dg)	-
Alongship Offset (dg)	-
Athwartship Offset (dg)	-
Water Temperature (Celsius)	20
Salinity	0
Sound Speed (m/s)	1482

The EY500 sounder system used in the study comprised a transducer, a transceiver, a portable PC, a power supply and a GARMIN GPS for logging navigational data. The transceiver parameters are shown in Table 2.2.

Table 2.2: Transceiver parameters of the SIMRAD EY500 echosounder.

Frequency (kHz)	**Beam Type**	**Power (W)**	**Pulse Duration (ms)**			**Bandwidth (kHz)**		**Resolution (cm)**
						Narrow	**Wide**	
119.047	Single	60	0.1	0.3	1	1.2	12	3

The transducer receiver was bow mounted on DSI-1; a small vessel belonged to the General Directorate of State Hydraulic Works. Each day the acoustical data collection started in the morning at around 9 a.m. and continued till dusk. The in situ data were recorded simultaneously to the hard disk of a portable computer in binary file format.

Before post-processing, the acoustical data stored in 296 binary files, each 10 MB in size, were first converted into ASCII file format for ease of examination by using SHOW software supplied by SIMRAD.

2.1.1 Cruise Tracks

The cruise tracks traveled in April and September cruises were designed to cover as much area as possible throughout the lake (Figure 2.1). Conventional methods like parallel design and zigzag design of the tracks were not applied since the morphological structure of the lake area was very irregular and included many small bays. The bathymetric structure of the basin did not allow predetermining any tracking strategy for cruises since there were sudden and great changes in depths while cruising across the lake.

The distribution of the fish in similar reservoir lakes in the area such as Keban Dam Lake are more confined to layers where bottom depth does not exceed 50 meters and fishes were generally found to be close to the bottom (Gücü, 2000). The bottom depths at the central part of the lake exceed 50 meters. Hence, less emphasis were given to the tracks on central part to optimize the cruise time.

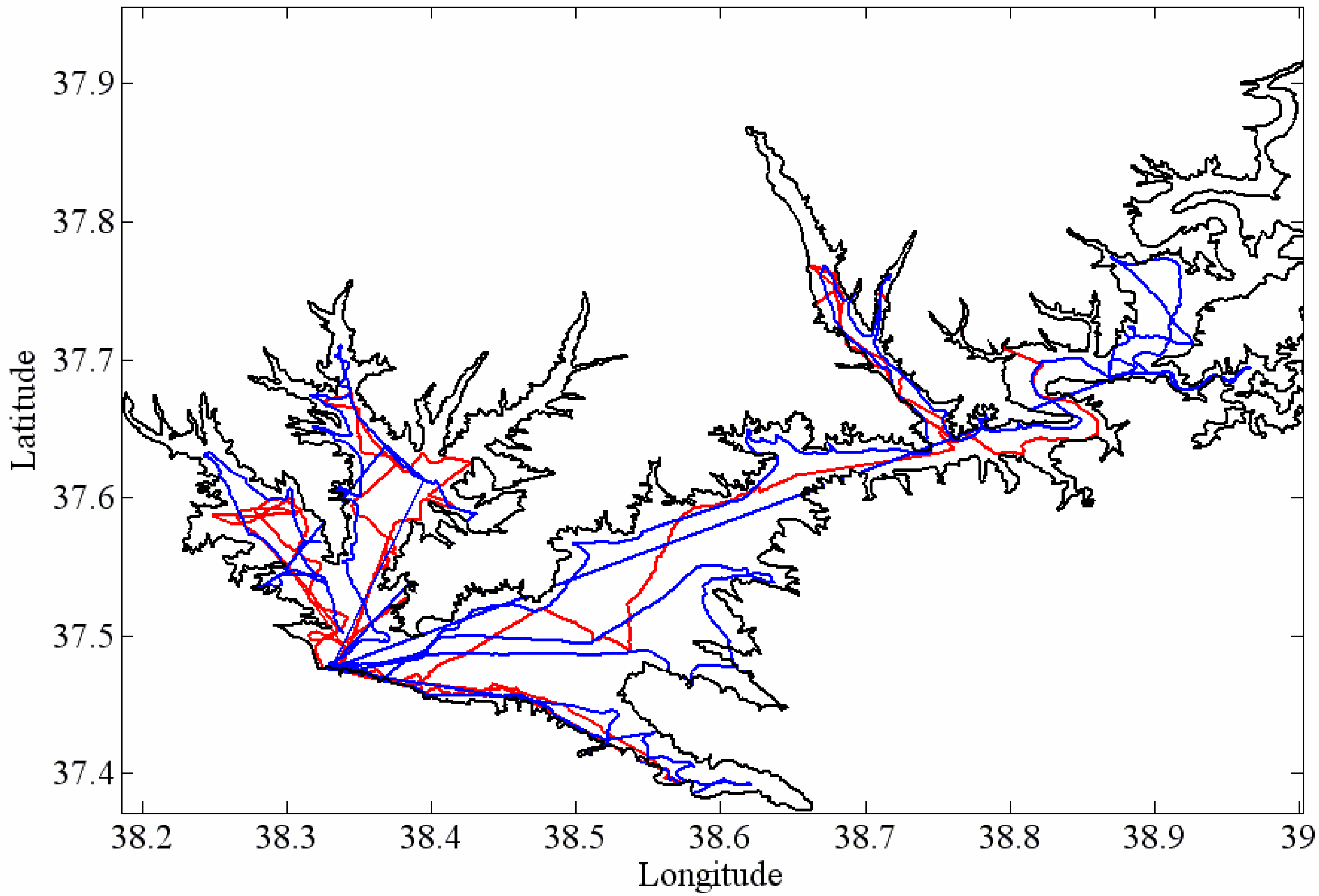

Figure 2.1: Cruise tracks in April (red) and September (blue).

2.1.2 Bathymetry

A MATLAB script was written to obtain bathymetric chart of the lake (Appendix A). Each geographic coordinate, logged by the GARMIN GPS into the data files, was extracted with its corresponding depth calculated by the echo-sounder, and written into an ASCII file. Since there were 4 months between the acoustic cruises, the water level in the dam lake changed. This effect was also taken into account and according to the differences of water levels between April and September; necessary adjustments were made in depth calculation based on the water level change data obtained from the State Hydraulic Works.

Since the data points were not geographically uniform, interpolation of the values at evenly spaced points were necessary in order to create a grid of the data points. After the interpolation, construction of the surface plot by connecting neighboring matrix elements to form a mesh of quadrilaterals was made and the partial bathymetry of the lake was mapped.

2.1.3 Acoustical Data Processing

The raw data files, converted from binary telegrams into ASCII telegrams, contained matrices made up of pelagic and bottom echo values in decibels (dB). An example of a simple telegram is shown in Figure 2.2.

The GL tag in ASCII telegrams contains navigational data, namely the longitude and latitude. D1 contains the detected depth in meters. Q1 contains main and bottom echogram values in dB as ASCII text with comma separated values. Before the main and bottom echogram matrices there stand pelagic and bottom information lines. The first value in the pelagic line indicates that the representation of the water column starts from 0 meter depth (Pelagic Range Start) and the second value indicates that the representation of echogram end at 150 meters depth (Pelagic Range Stop). The last value shows that there are 250 Pelagic Echogram Values for the whole water column.

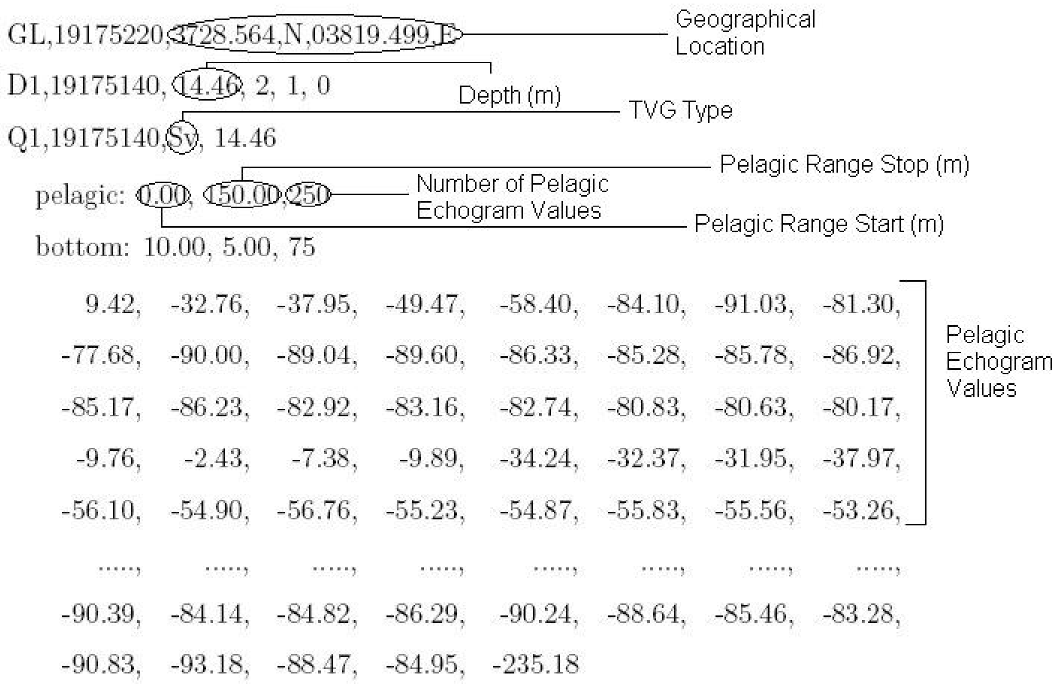

Figure 2.2: An Example of a SIMRAD EY500 Telegram (SIMRAD, 1998).

2.1.3.1 Processing Algorithm

Processing algorithm is shown in a flowchart represented in Figure 2.3. The processing algorithm can be summarized as follows:

Step 1: Open ASCII file for reading.

Step 2: Find first GL tag in file and get navigational data; find related D1 tag and get Depth.

Step 3: Read Pelagic Range Start (PRStart) and Pelagic Range Stop (PRStop) values: These two values set the information range in the Pelagic Echogram Values section. If PRStart and PRStop are 0 and 150 respectively it means that the Pelagic Echogram Values comprise information from surface to 150 meter depth even if the current Depth is shallower or deeper than 150 meters.

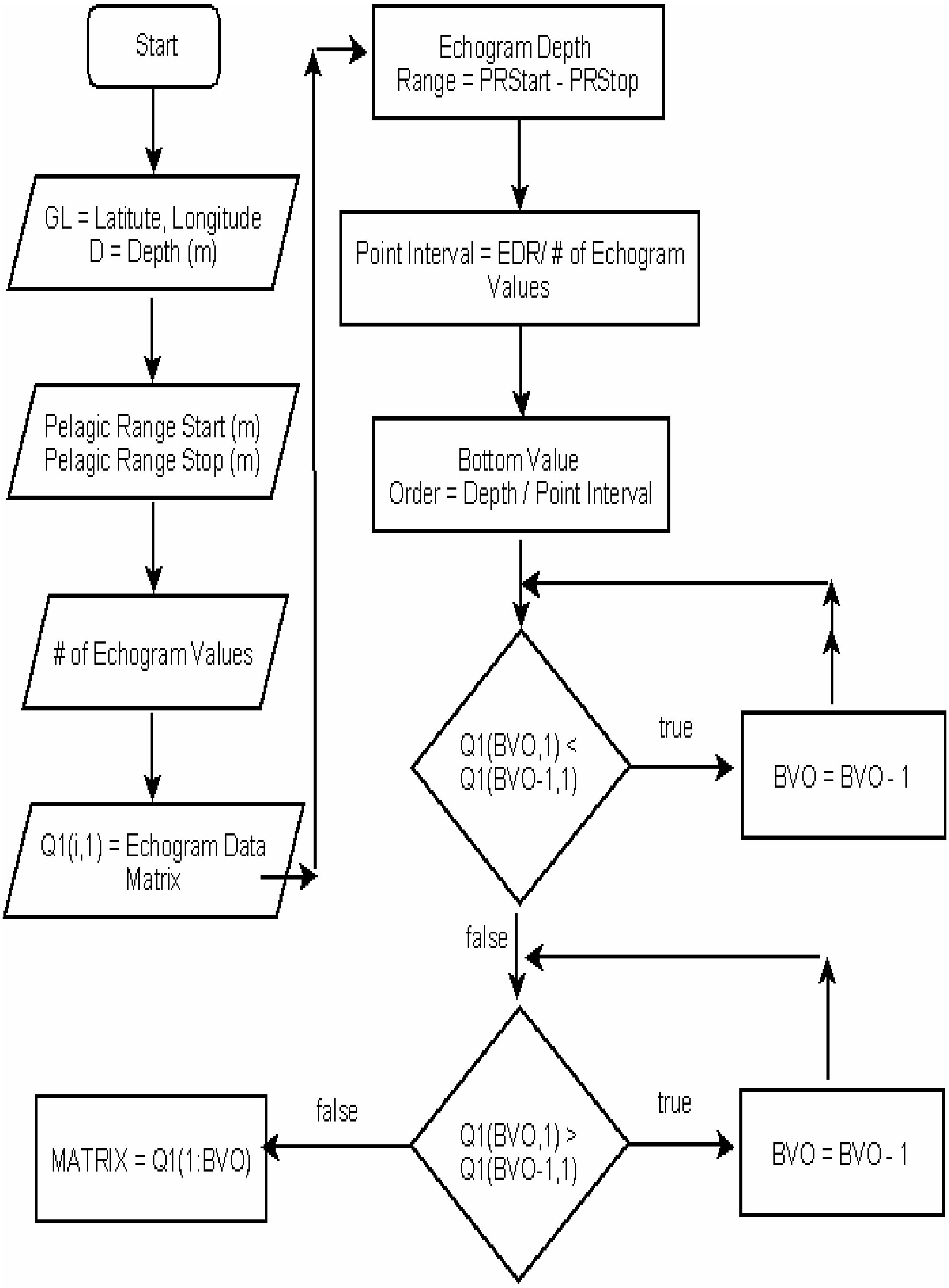

Figure 2.3: Flowchart of the MATLAB script (Appendix B) written for postprocessing of SIMRAD EY500 telegrams.

Step 4: Read the Number of Echogram Values: This number shows the information on how many values there are in the Pelagic Echogram Values' matrix.

Step 5: Read Pelagic Echogram Values into a column matrix under the name Q1.

Step 6: Find Echogram Depth Range (EDR) by EDR = PRStop - PRStart.

Step 7: Find Point Interval (PI) by PI = EDR / Number of Echogram Values: This is the distance between each element of Q1 Pelagic Echogram Values' matrix.

Step 8: Find Bottom Value Order (BVO) by BOV = Depth/PI: BottomValueOrder is the i^{th} element of the Q1 matrix, which is the bottom.

Step 9: This step includes a decision mechanism that checks a condition and a loop that shifts backwards unless the condition is met.

Step 10: Similar to Step 9 but this time with a different condition. This step with Step 9, the bottom echo is successfully removed from the pelagic echoes, including the false bottom detections caused by side-loop effects. Side-loop effects are side effects of the beam pattern of the transferred beam when it encountered a very steep slope on the bottom or the beam faces the bottom with an angle different from 90°.

Step 11: Finally, the new truncated matrix is set to another variable.

Completing the aforementioned steps, the new S_v (volume backscattering strength in dB) values' matrix was converted into s_a (area backscattering coefficient) values' matrix using equation 2.1 (SIMRAD, 2000). The volume backscattering strength (S_v) is the magnitude of echoes received from a unit volume sampled by the echo-sounder. The area backscattering coefficient (s_a) is similar to S_v but this time the unit is area covered by the echo-sounder (m^2 /$hectare^2$). In the equation 2.1, r_0 is the reference distance, which is equal to 1 m, r_1 is the starting depth, which is usually equal to 0, r_2 is the target range of the transducer and r is the distance between r_1 and r_2.

$$s_a = 4\pi r_0^2 * mean[\int_{r1}^{r2} S_v dr] * 100^2 (m^2/ha^2) \quad 2.1$$

Later, the converted echo values were averaged. And the geographic location data with its corresponding depth and averaged s_a values were recorded into an ASCII file. This process was repeated for all the geographical location data recorded during the surveys. Afterwards, s_a - depth frequencies were plotted with corresponding standard deviations (s) in order to see the depthwise distribution of the values and for the determination of the depth strata.

The mean s_a values where depth is deeper than 80 meters were omitted since the fishery in the lake is not applicable below 80 meters depth. The area backscattering coefficients were sorted out to 8 subdivisions of the lake. These subareas were determined on the basis of the lake's geographical structure and water circulation (see Figure 2.4). The areas 1, 2, 3, 5 and 7 are five relatively shallow semi-enclosed areas where each might have their own characteristics due to the limited water circulation and their isolated structures. The areas 4 and 6 are open water areas and cover the deepest areas of the lake. Finally, area 8 is the less surveyed area both by gill-net and acoustical sampling; therefore it was treated as another separate distinct subarea (Figure 2.4).

2.1.3.2 Bottom Tracking

For bottom tracking and successful separation of bottom echoes from the fish echoes, the steps 9 and 10, which were mentioned in the subsection 2.1.3.1, were applied to the echo values starting from the maximum detected echo intensity in the echo matrix to the surface until the criteria stated in the loops are matched.

Firstly, the program seeks for the bottom value stated in the telegram file. The value, which is considered as bottom by the sounder, is the i^{th} value and derived by dividing the sounder detected depth with the range between the each data points (see steps 2, 7 and 8 in subsection 2.1.3.1). Afterwards, the program enters 2 loops followed by each other. In the first loop, the program checks whether the echo value just before

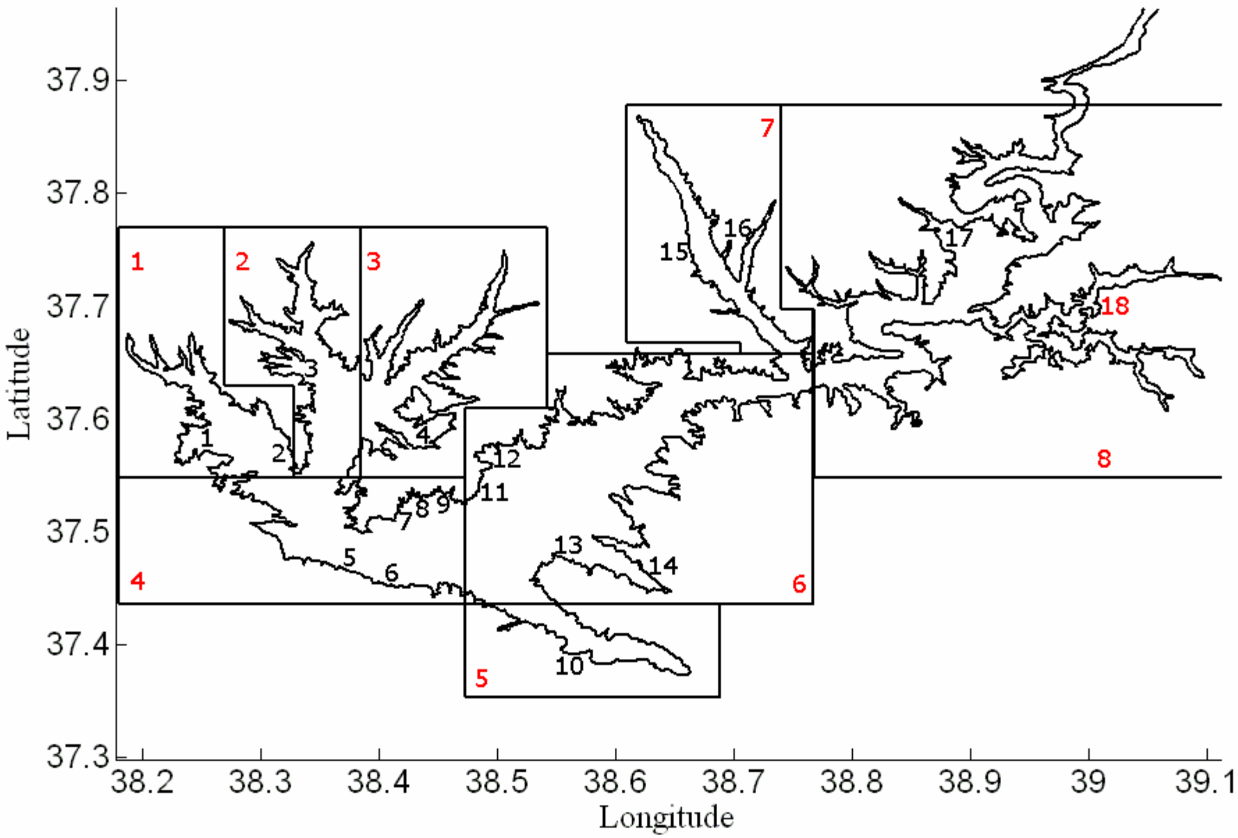

Figure 2.4: Subareas of the lake and gill-net stations (1 Akpınar, 2 Bağpınar, 3 Yazlık, 4 Gölpınar, 5 Dutluca, 6 Yaşlıca, 7 Kumluca1, 8 Kumluca2, 9 Samsat, 10 Bozova, 11 Balcılar, 12 Yarımbağ, 13 Kasımkuyu, 14 Tekağaç, 15 Şeyhbaba, 16 Oluklu, 17 Geldibuldu, and 18 Çaylarbaşı).

the bottom value is smaller than the magnitude of the bottom echo. If the value is smaller, than the smaller value is considered to be the first bottom echo and again the loop is executed checking if the new bottom echo value is smaller than the preceding echo value. Repeating the aforementioned steps, the execution of the loop continues until the echo just before the bottom echo value is bigger. Then control of the program passes to the execution of the second loop.

In the second loop, the inverse condition of the first loop is tested. This time the program controls whether the bottom echo value, which was found by the execution of the first loop, is bigger than the preceding value. The loop continues until the condition is not met, and the first echo value disproving the statement of second loop (see Figure 2.3) is considered to be the real first bottom echo.

Figure 2.5 shows an echogram formed by plotting of sounder detected values. In the figure, the distorted areas just above the bottom are the noise caused by side-loop effects. In Figure 2.6, another echogram is shown for the same ping interval and region after the bottom tracking algorithm was applied to the sounder detected data. By applying the bottom tracking algorithm, the false bottom echoes were removed.

2.1.4 Target Strength (TS) Distributions

In order to calculate the abundance of fish per a unit area in the lake, the TS (target strength) distribution of the fishes in the lake must be known. Therefore, the TS frequency distribution of the fishes was calculated from binary SIMRAD EY500 files using acoustical post-processing software called EP500, supplied by SIMRAD. The obtained TS frequency distributions were sorted out to pre-determined subareas. In each subarea of the lake, the mean s_a values in each depth stratum were calculated. The obtained TS frequency distributions were used to build TS distribution tables for each subarea of the lake. The mean s_a values were then divided by the mean TS values so that the number of fishes in each subarea was determined.

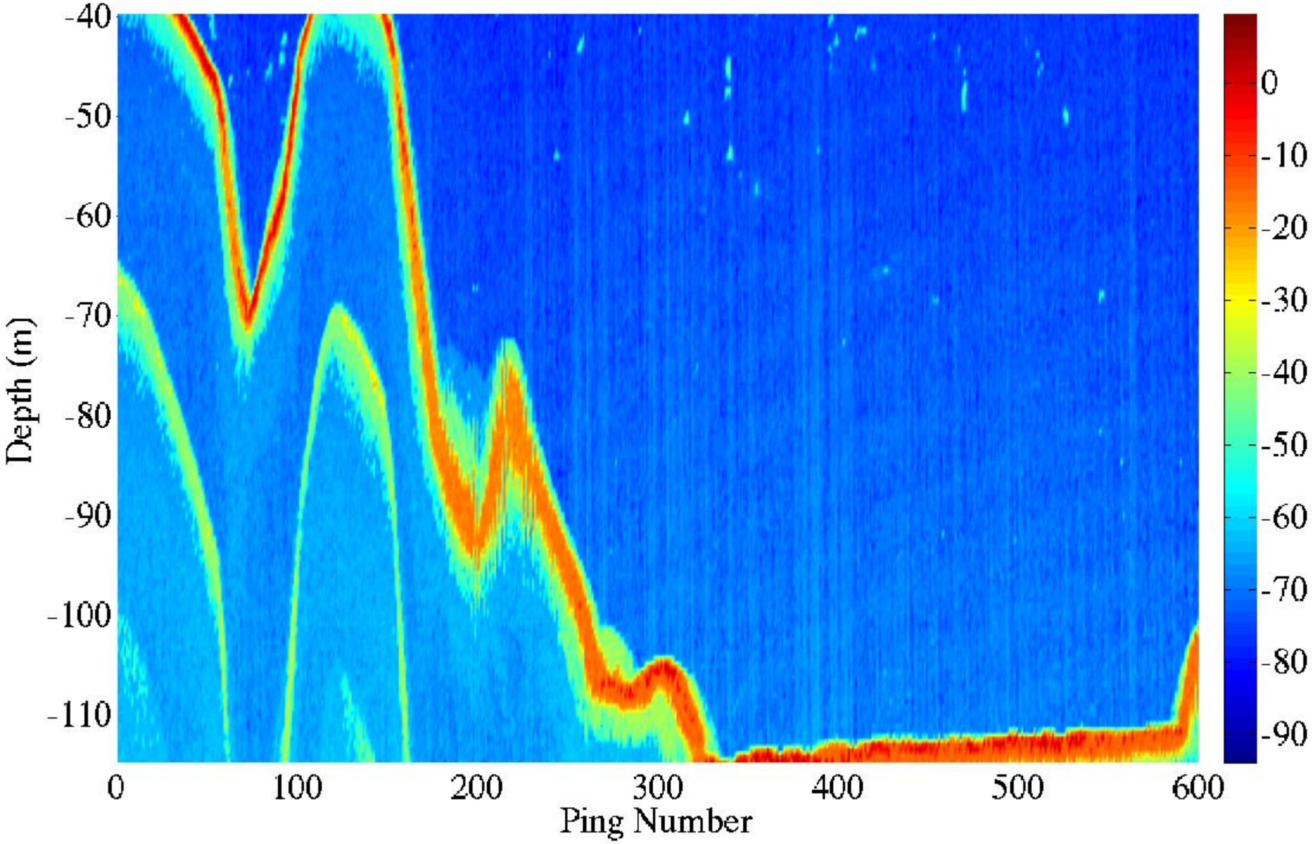

Figure 2.5: A sample echogram without bottom tracking.

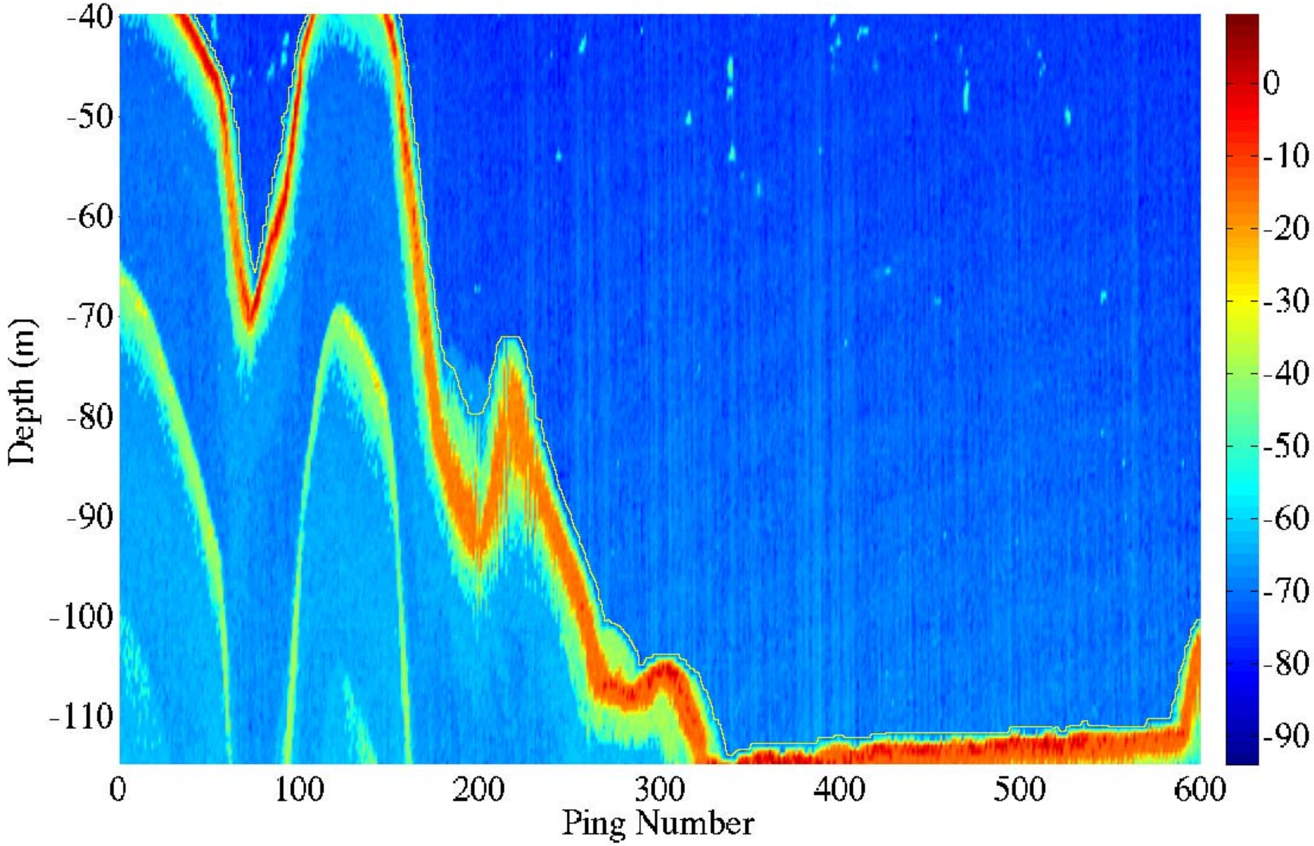

Figure 2.6: A sample echogram with bottom tracking applied (yellow line indicates the redefined bottom).

There is a known relationship between Target Strength (TS) of fish and fish length. Hydro-acoustic methods can only estimate the abundance (number of fish/ha) of fish in their habitats. However, the size of the fish (in length) can be converted from decibel (dB) into length using decibel-length relationship formulas such as Love's empirical equation (Viravong et al., 2004). The general relationship between TS and length is shown in Figure 2.7.

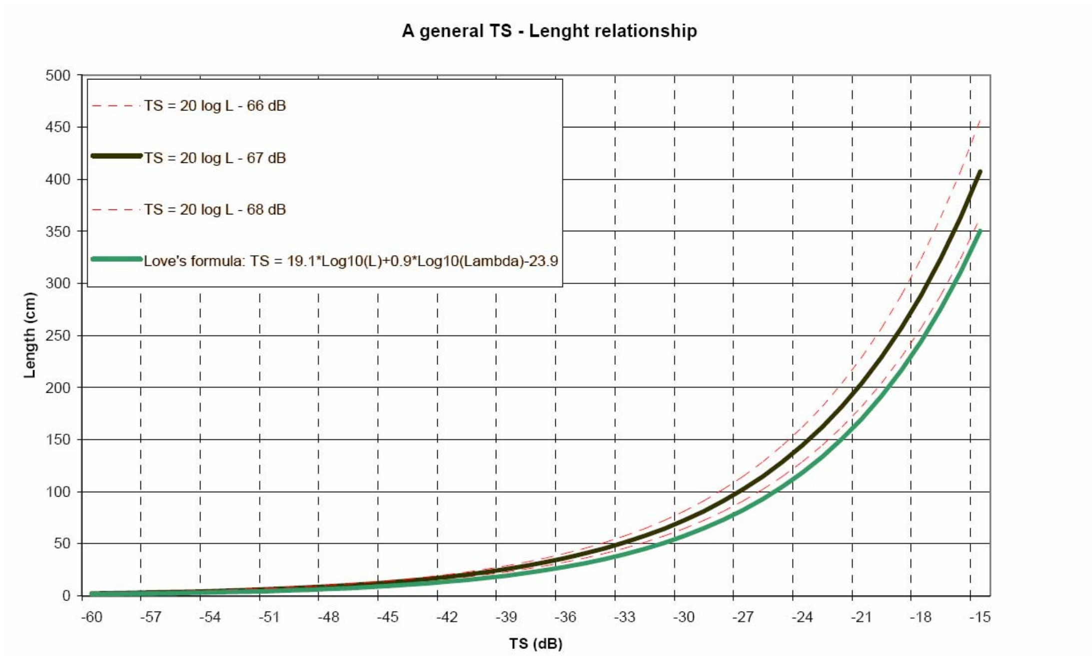

Figure 2.7: Relationship between target strength and fish size (Viravong et. al., 2004).

The established Target Strength (TS) distributions were formed into TS classes with 3 dB intervals. The classes were plotted against depth strata which were constituted with 5 meter intervals starting from 4 meters depth down to 40 meters. Below 40 meters to 80 meters the whole water columns was treated as one stratum. Below 80 meters depth the results were not shown since they were not considered in stock calculations.

Length classes were calculated via Love's (1975) empirical equation (equation 2.2), where TS is the target strength, L is the total length of fish, λ is the wavelength of the sound wave. The length classes are approximate values.

$$TS = 19.1 * \log_{10} L + 0.9 * \log_{10} \lambda - 23.9 \quad 2.2$$

The total length (L) of fish was derived by redesigning the Love's equation (see equation 2.3). The sound speed was assumed to be 1482 m/s in freshwater. The frequency of the transducer was 119.047 kHz (see Table 2.1).

$$L = 10^{\frac{TS+23.9-(0.9*\log 10\lambda)}{19.1}} \quad 2.3$$

2.2 Temperature Profiles

Vertical temperature measurements were made in 6 different stations in April and 4 different stations in September. The stations are shown in Figure 2.8. For temperature measurements an YSI 6920 V2 sensor was used. The profiles were recorded starting from surface down to the bottom.

2.3 Gill-net Sampling

Gill-net sampling was carried out simultaneously with the acoustical surveys. Following the acoustical data collection, two sets of gill-nets were deployed in the stations within the regions covered by the acoustical investigation (Figure 2.4). The gill-net sampling stations and dates are shown in Table 2.3. Nets were set approximately around noon and collected the next day in the morning. Each set contained nets in variable lengths with 9, 11, 22, 30, 40 50 and 60 millimeters knot to knot mesh sizes. Nets were 1.5 meters in height and 10 meters in length for 9, 11 and 22 millimeter-mesh-sized nets and 100 meters for the remaining. The gill-nets were deployed in areas which were sampled by acoustics just after the acoustical sampling. The gill-net haul was landed and sorted out to species. The fish were measured in total length and weight and the measurements were recorded for later analysis of weight-length relationships.

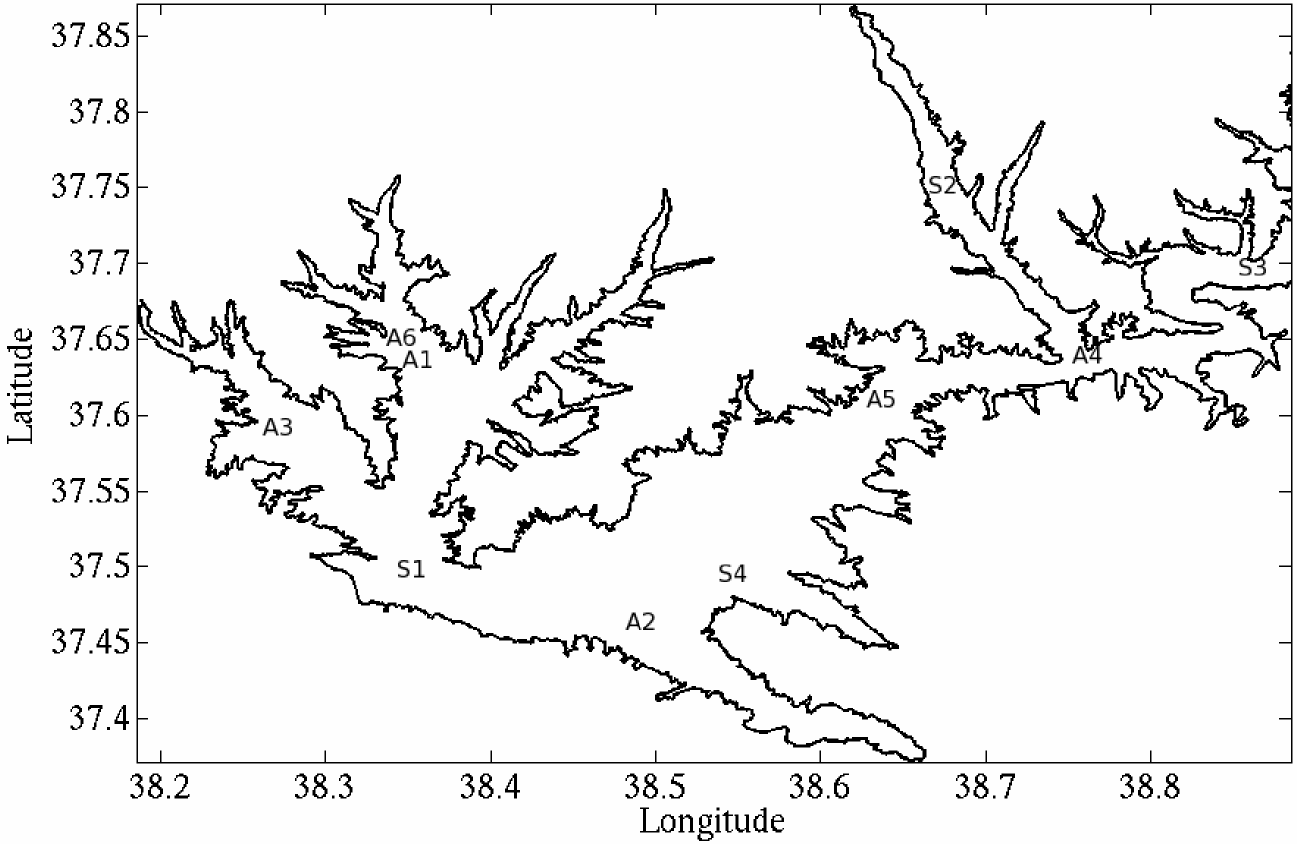

Figure 2.8: Stations of temperature profiles (S = September, A = April).

Table 2.3: Gill-net stations and sampling dates.

Sampling Date	**Station Name**	
20 April 2005	Set 1: Dutluca	Set 2: Yaşlıca
21 April 2005	Set 1: Akpınar	Set 2: Bağpınar
22 April 2005	Set 1: Gölpınar	Set 2: Yazlık
23 April 2005	Set 1: Dutluca	Set 2: Yaşlıca
24 April 2005	Set 1: Balcılar	Set 2: Yarımbağ
25 April 2005	Set 1: Kumluca 1	Set 2: Kumluca 2
20 Sep 2005	Set 1: Dutluca	Set 2: Yaşlıca
21 Sep 2005	Set 1: Akpınar	Set 2: Bağpınar
22 Sep 2005	Set 1: Yazlık	Set 2: Gölpınar
23 Sep 2005	Set 1: Dutluca	Set 2: Yaşlıca
24 Sep 2005	Set 1: Kasımkuyu	Set 2: Tekağaç
25 Sep 2005	Set 1: Şeyhbaba	Set 2: Oluklu
26 Sep 2005	Set 1: Geldibuldu	Set 2: Çaylarbaşı
27 Sep 2005	Set 1: Balcılar	Set 2: Yarımbağ
29 Nov 2005	Set 1: Akpınar	Set 2: Samsat
30 Nov 2005	Set 1: Bağpınar	Set 2: Bozova
22 Dec 2005	Set 1: Akpınar	Set 2: Bağpınar
23 Dec 2005	Set 1: Samsat	Set 2: Bozova

The gill-net catch frequencies of the species in the 4 sampling seasons are summarized in Tables 2.4 2.5, 2.6 and 2.7. The species were sorted into length classes with 1 centimeter intervals. The numbers show the abundance (number of fish) of each species for the given length class.

Table 2.4: Length distributions of species caught by gillnet sampling in April, 2005.

Length intervals (cm)	Species															
	M. simack	***M. abu***	***C. auratus***	***C. carpio (mirror)***	***C. carpio (common)***	***T. grypus***	***L. leuciscus***	***C. luteus***	***C. macrostomus***	***A. marmid***	***C. mossulensis***	***B.rajanorummystaceus***	***Orthrias spp.***	***C. regium***	***S. triostegus***	***C. trutta***	***C. umbla***
5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	20	26	27	1	0	0	2	0	0	0
8	0	1	0	0	0	0	0	64	47	234	4	0	1	1	0	1	1
9	0	0	0	0	0	0	0	29	21	518	8	0	2	0	0	0	0
10	0	0	0	0	0	0	0	4	3	435	53	0	1	0	0	1	0
11	0	0	0	0	0	0	0	0	0	135	104	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	2	10	118	0	0	0	0	0	0
13	0	1	0	0	0	0	0	0	0	5	23	0	0	1	0	0	0
14	0	3	0	0	0	0	0	3	0	7	6	0	0	2	0	0	0
15	0	22	0	0	0	0	0	2	0	47	7	0	0	10	0	0	0
16	0	23	0	0	0	0	0	4	0	67	21	0	0	9	0	0	0
17	0	7	0	0	0	0	0	1	0	35	24	0	0	2	0	0	0
18	0	2	0	0	0	0	0	0	0	14	31	0	0	0	0	0	0
19	0	1	0	0	0	0	0	8	0	13	66	0	0	1	0	0	0
20	0	1	0	0	0	0	0	10	0	31	62	0	0	0	0	1	0
21	0	0	0	0	3	0	0	11	0	38	25	0	0	0	0	1	0
22	0	0	0	0	3	0	0	9	0	11	6	0	0	0	0	6	0
23	0	0	0	0	1	0	0	6	0	3	4	0	0	1	0	11	0
24	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	18	1
25	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	17	1
26	0	0	0	0	1	0	0	3	0	0	1	0	0	4	0	10	1
27	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	15	1
28	0	0	0	0	0	0	0	4	0	0	1	0	0	3	0	23	0
29	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	15	1
30	0	0	0	0	2	0	0	1	0	0	1	0	0	1	0	14	1
31	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	15	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
33	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	7	0
34	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8	0
35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
37	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0
38	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0
39	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0

Table 2.4: continued.

41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
42	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
∑	1	61	0	1	15	2	0	189	99	163 3	567	0	4	42	0	195	7

Table 2.5: Length distribution of species caught by gill-net sampling in September, 2005.

Length intervals (cm)	**Species**																
	M. simack	***M. abu***	***C. auratus***	***C. carpio (mirror)***	***C. carpio (common)***	***T. grypus***	***L. leuciscus***	***C. luteus***	***C. macrostomus***	***A. marmid***	***C. mossulensis***	***B.rajanorummystaceus***	***Orthrias spp.***	***C. regium***	***S. triostegus***	***C. trutta***	***C. umbla***
5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	3	0	0	0	0	0	50	21	16	0	0	3	0	0	0	0
8	0	34	0	0	0	0	0	61	31	374	1	0	22	0	0	0	0
9	0	58	0	0	0	0	0	14	34	914	0	0	42	0	0	0	0
10	0	30	0	0	0	0	0	2	19	794	5	0	16	0	0	0	0
11	0	3	0	0	0	0	0	0	4	331	18	0	3	0	0	1	0
12	0	1	0	0	0	0	0	1	5	64	27	0	1	2	0	0	0
13	0	0	0	0	1	0	0	0	0	10	14	0	0	2	0	0	0
14	0	3	0	0	0	0	0	5	3	4	36	0	0	1	0	0	0

Table 2.5: continued.

15	0	26	0	0	0	0	0	18	7	6	15	0	0	3	0	1	0
16	0	45	0	1	0	0	0	14	0	57	18	0	0	1	0	1	0
17	0	46	0	1	0	0	0	8	1	56	3	0	0	3	0	1	0
18	0	14	0	1	0	0	0	3	2	30	0	0	0	0	1	0	0
19	0	4	0	2	2	0	0	1	2	11	0	0	0	1	0	0	0
20	0	2	0	0	0	0	0	6	3	4	0	0	0	0	1	1	0
21	0	1	0	3	2	0	0	19	2	4	1	0	0	0	0	0	0
22	1	0	0	0	3	0	0	22	0	1	1	0	0	2	0	0	0
23	0	0	0	1	0	0	0	21	0	2	0	0	0	0	0	2	0
24	0	0	0	1	0	0	0	13	0	0	0	0	0	0	0	5	0
25	1	0	0	1	0	1	0	19	0	0	0	0	0	0	0	5	0
26	0	0	0	0	1	0	0	20	0	0	0	0	0	1	0	16	1
27	0	0	0	0	0	0	0	21	0	0	0	0	0	1	0	11	0
28	0	0	0	0	0	0	0	5	0	0	0	1	0	1	1	15	1
29	0	0	0	0	1	0	0	6	0	0	0	1	0	0	0	17	0
30	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	18	0
31	0	0	0	0	0	0	1	6	0	0	0	0	0	1	0	27	0
32	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	21	1
33	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	24	0
34	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	18	0
35	0	0	0	1	0	0	0	5	0	0	0	0	0	0	1	8	2
36	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	13	0
37	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	16	1
38	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	13	1
39	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	10	0
40	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
43	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
∑	3	270	0	14	11	5	2	359	134	2679	139	3	87	17	9	260	7

Table 2.6: Length distribution of species caught by gillnet sampling in November, 2005.

Length intervals (cm)	**Species**																
	M. simack	***M. abu***	***C. auratus***	***C. carpio (mirror)***	***C. carpio (common)***	***T. grypus***	***L. leuciscus***	***C. luteus***	***C. macrostomus***	***A. marmid***	***C. mossulensis***	***B.rajanorummystaceus***	***Orthrias spp.***	***C. regium***	***S. triostegus***	***C. trutta***	***C. umbla***
5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	14	0	0	0	0	0	5	10	9	0	0	0	0	0	0	0
8	0	42	0	0	0	0	0	4	46	127	1	0	0	0	0	0	0
9	0	10	0	0	0	0	0	0	38	493	0	0	2	0	0	0	0
10	0	0	0	0	0	0	0	0	12	458	5	0	2	0	0	0	0
11	0	2	0	0	0	0	0	0	2	181	34	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	17	14	0	0	0	0	0	0
13	0	3	0	0	0	0	0	0	0	5	9	0	0	0	0	0	0
14	0	1	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0
15	0	4	0	0	0	0	0	9	0	4	2	0	0	0	0	0	0
16	0	18	0	0	1	0	0	5	0	6	7	0	0	0	0	0	0
17	0	14	0	0	0	0	0	2	0	4	2	0	0	0	0	0	0
18	0	2	0	0	1	0	0	1	0	2	0	1	0	0	0	0	0
19	0	0	1	0	1	0	0	2	0	2	2	0	0	0	0	1	0
20	0	0	0	0	0	0	0	6	0	1	4	0	0	0	0	0	0
21	0	1	0	0	1	0	0	12	0	0	2	0	0	0	0	2	0
22	0	0	0	0	0	1	0	27	0	0	3	0	0	0	0	0	0
23	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	3	0
24	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	1	0
25	0	0	0	1	0	0	0	6	0	0	0	0	0	0	0	4	0
26	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	9	0
27	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	5	0
28	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	3	0
29	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
31	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
32	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
33	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
∑	0	111	1	1	4	6	0	109	108	1310	87	4	4	0	0	33	0

Table 2.7: Length distribution of species caught by gillnet sampling in December, 2005.

Length intervals (cm)	Species																
	M. simack	***M. abu***	***C. auratus***	***C. carpio (mirror)***	***C. carpio (common)***	***T. grypus***	***L. leuciscus***	***C. luteus***	***C. macrostomus***	***A. marmid***	***C. mossulensis***	***B.rajanorummystaceus***	***Orthrias spp.***	***C. regium***	***S. triostegus***	***C. trutta***	***C. umbla***
5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7	0	4	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
8	0	21	0	0	0	0	0	24	8	51	2	0	1	0	0	0	0
9	0	5	0	0	0	0	0	38	14	92	0	0	0	0	0	0	0
10	0	1	0	0	0	0	0	17	7	56	24	0	0	0	0	0	0
11	0	0	0	0	0	0	0	8	0	19	80	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	2	67	0	0	0	0	0	0
13	0	1	0	0	0	0	0	0	0	0	17	0	0	0	0	1	0
14	0	1	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0
15	0	19	0	0	0	0	0	2	0	4	6	0	0	0	0	0	0
16	0	35	0	0	2	0	0	4	0	3	6	0	0	0	0	0	0
17	0	9	0	0	2	0	0	2	1	7	6	0	0	0	0	0	0
18	0	3	0	0	0	0	0	1	0	2	3	0	0	0	0	0	0
19	0	0	0	0	0	0	0	1	0	2	6	0	0	0	0	0	0
20	0	0	0	0	0	0	0	2	0	2	5	0	0	0	0	0	0
21	0	3	0	0	0	0	0	5	0	0	6	0	0	0	0	0	0
22	0	0	1	0	0	0	0	8	0	2	0	0	0	0	0	0	0
23	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
24	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	2	0
25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
28	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	3	0
29	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	5	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
31	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	4	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
∑	0	103	2	0	5	2	0	121	36	242	231	4	1	0	1	42	0

2.3.1 Catch per Unit Effort (CPUE)

Considering the total amount of catch in weight, catch per unit of effort values were calculated. Since gill-nets were used as sampling gear in this study, the average catch in weight per unit time (1 hour) and per unit area of net (m^2) was computed.

2.3.2 Gill-net Selectivity

In order to overcome selectivity problem over the length groups, corrections were made to the length frequency distributions of species according to Holt's model for two mesh sizes (Holt, 1980). Firstly, length frequencies were grouped according to mesh sizes for each species. Later, the frequencies were compared in pairs, each mesh size "ma" (smaller mesh size) to one successor "mb" (larger mesh size). Logarithmic ratios were calculated for each length group and only the ratios where the frequencies overlap were used. Afterwards, a regression analysis was applied to the logarithmic ratios of length frequencies against the length classes for fish length (x = L) and slope (b), intercept (a) and selection factor (SF) was calculated (see equation 2.4).

$$SF = \frac{-2 * a}{b * (ma + mb)} \qquad 2.4$$

The optimum fish lengths for being caught (Lm) by the small and large mesh sizes were Lma = SF * ma and Lmb = SF * mb, respectively. The standard deviation (s) was calculated via equation 2.5.

$$s = \sqrt{\frac{-2 * ma * (mb - ma)}{b^2 * (mb + ma)}} \qquad 2.5$$

Points on selection curves were found by using the equations 2.6 and 2.7 where, Sa(L) and Sb(L) are the probability values for the corresponding "L" length interval of mesh size "ma" and mesh size "mb" respectively (Holt, 1980).

$$Sa(L) = exp(-\frac{(L - Lma)^2}{2 * s^2}) \quad 2.6$$

$$Sb(L) = exp(-\frac{(L - Lmb)^2}{2 * s^2}) \quad 2.7$$

An index of the numbers in the population was calculated for each mesh size by using the equations 2.8 and 2.9, where Na(L) and Nb(L) are the reconstructed length frequencies for the corresponding length interval "L" of mesh sizes "ma" and "mb" respectively.

$$Na(L) = \frac{Ca(L)}{Sa(L)} \quad 2.8$$

$$Nb(L) = \frac{Cb(L)}{Sb(L)} \quad 2.9$$

The above mentioned steps were applied to all gill-net samples independently for each month. After all these aforementioned steps completed, a corrected length-frequency distribution was obtained for each species representing the real population length distribution better than before.

2.4 Merging Gill-net and Acoustical Data

Firstly, the number of fishes in each subarea, determined by the acoustical sampling and gill-net data, was needed to be merged in order to calculate the fish biomass distribution across the lake. The s_a values were sorted into subareas and mean sa value for each depth strata was calculated. Afterwards, the TS frequency distributions were sorted into subareas and tabulated for every depth stratum. The mean s_a values were then divided by the TS frequencies stratum by stratum, thus, giving the number of fish per hectare in each stratum.

In the second step, the selectivity analysis applied to the length frequency distributions of fish species in each subarea of the lake. Having the length-weight relationships of every fish species from gill-net samplings, the frequencies in each length classes for each species were converted to biomass in weight. These weights were summed and then proportioned to the acoustical abundance in order to obtain the final biomass contribution of each species. In Figure 2.9, the process of merging gill-net and acoustical data was summarized.

2.5 Fish Growth

In this study, length and weight of each individual fish caught by the gill-net sampling were recorded. In order to estimate the growth and length-weight relationships of the species, the data obtained were processed in a couple of analysis such as length-weight analysis, direct fit of length frequency data, estimation of mortality rates of the stock through the analysis of growth parameters. These analyses are described in detail below.

2.5.1 Length-weight Analysis

It has been found that, within any stanza of a fish's life, weight varies as some power of length (Ricker, 1975). This relationship between fish length and its weight is shown in equations 2.10 and 2.11, where "w" is weight, "l" is length, "a" is the Fulton factor and "b" is the slope.

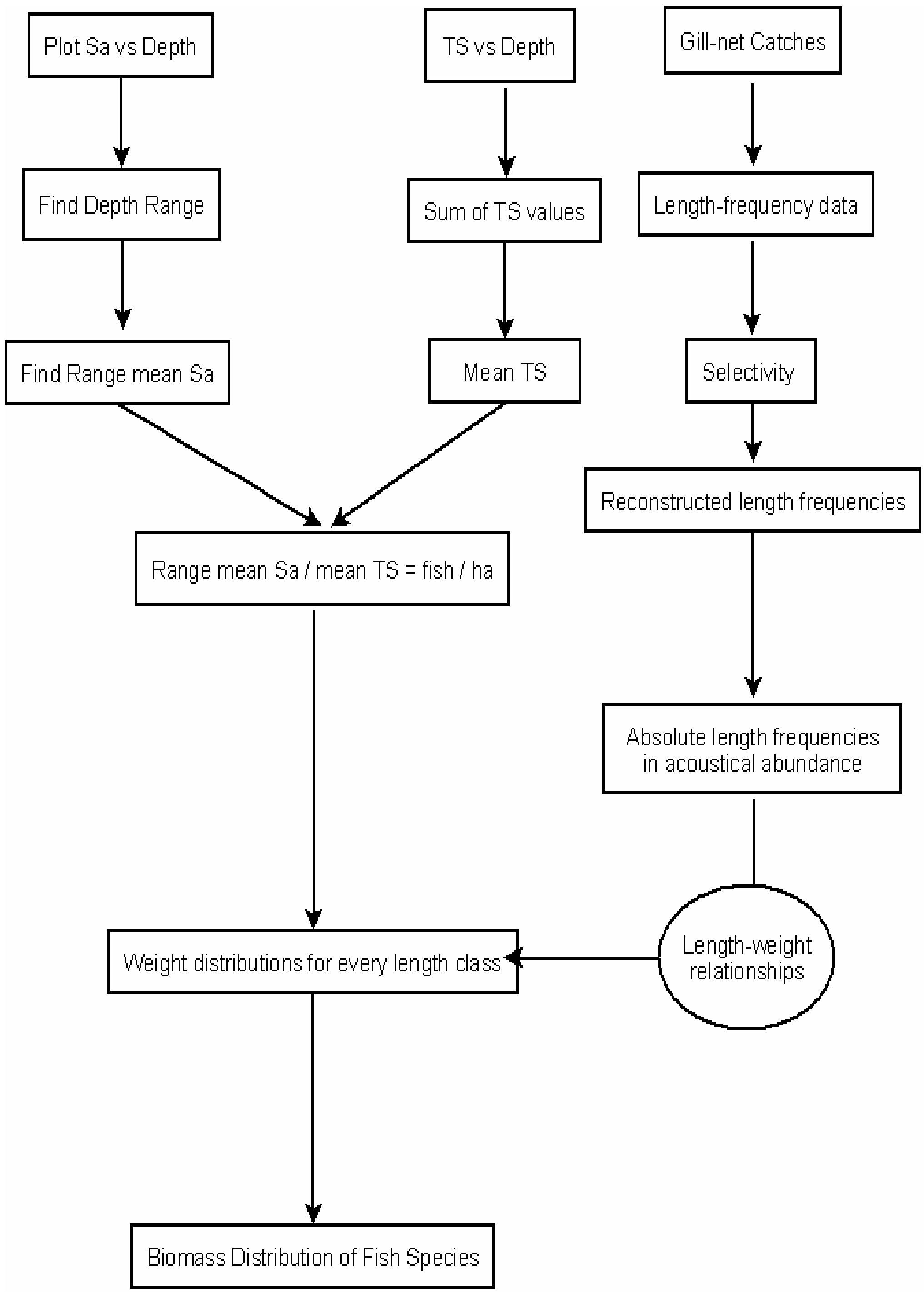

Figure 2.9: Flowchart of merging gill-net and acoustics data.

$$w = a * l^b \qquad (2.10)$$

$$log(w) = log(a) + b * log(l) \qquad (2.11)$$

The value of “b” is determined by plotting the logarithm of weight against the logarithm of length for a large number of fish of different sizes (Ricker, 1975). The “a” value is the inverse logarithm of the value at which the plotted line crossing the x axis.

The length-weight analysis was carried out according to the regression methodology. The lengths and corresponding weights of fish species were recorded in two columns and logarithms of the values were taken in base 10. Then, linear regression analysis was applied to the new values and slope (b), intercept (a) and regression coefficients were calculated.

In order to investigate that whether individuals of the same species from different stations were from the same unit or not, the linear regression equations were compared to each other in terms of elevations and slopes according to Zar’s algorithm (Zar, 1984). This methodology is shown in Figure 2.10.

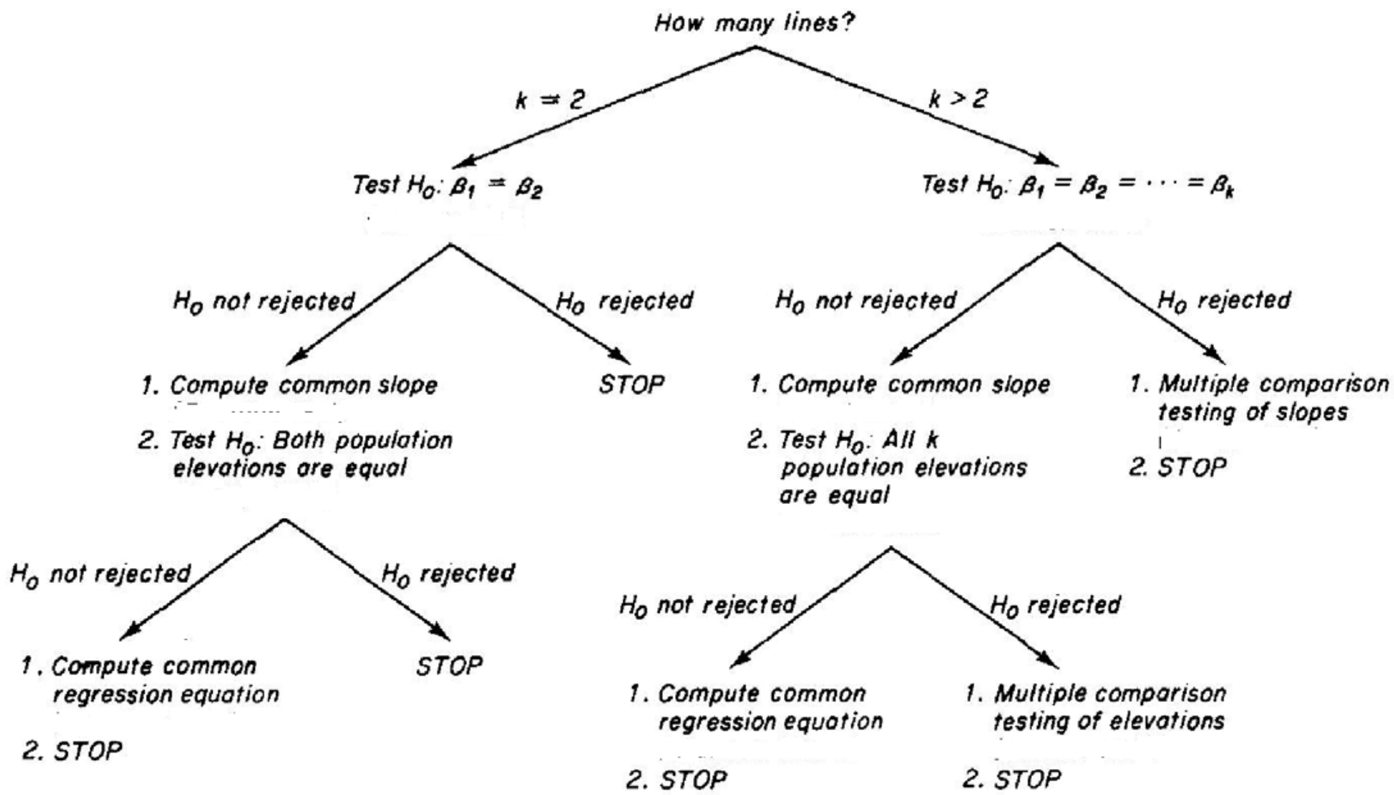

Figure 2.10: Flowchart for the comparison of regression lines (Zar, 1984).

Firstly, according to the number of length-weight relationships, in other words, regression lines (k) that is going to be compared, the suitable branch of routines is selected. Since there were more than 2 regression lines for all of the species sampled in this study, the k value which is bigger than 2 was selected and the H_0 hypothesis, which means all the regression lines have similar slope (b), was tested. Whether H_0 hypothesis is proven to be true or false, the suitable routine is chosen from the Figure 2.10. In this study, the H_0 hypothesis was proven to be true for all species and a common slope for all of the regression lines for each species were calculated. Then another hypothesis assuming that all of the elevations of the population lines are equal was tested. In this study, the second hypothesis was also proven to be true for all of the species and finally a common regression equation was calculated for all of the regressions of each species. In practice, sometimes it is not necessary to compute a common regression equation for all the lines since this test of routines is applied to determine whether all the groups of samples of the same species come from the same population or not. If H_0 is not rejected, one can be sure that all the sampled groups of the same species belong to the same population.

In order to compare length-weight relationships of samples obtained from a population, the condition factor should be calculated. The most commonly used condition factor is Fulton's condition factor (Bingel, 2002). Apart from the comparison of regression lines, Fulton's factor was calculated in order to estimate the differences in terms of nutritional conditions between various samples of fish species from the same population. The heavier a fish is at given length, the larger the factor and thus the better the condition it is in (Ricker, 1975).

2.5.2 The von Bertalanffy Growth Function (VBGF) and ELEFAN I analysis

For population analysis it is important to express the growth of fish in time in a mathematical expression. The basic requirement is an expression which will give the size (in terms of length or weight) at any given age (Gulland, 1975). The most commonly used expression for fish growth is the von Bertalanffy Growth Function (VBGF), which is shown in equation 2.12 as given by Beverton and Holt (2004).

$$l_t = L_\infty[1 - e^{-K*(t-t_0)}] \qquad 2.12$$

where l_t is the length of fish at age t, L_∞ is the average asymptotic length of fish, K is the Brody growth coefficient, t_0 is the hypothetical age at which fish would have been zero length, t is age in years (Ricker, 1975).

There are various methods that can be used to estimate the VBGF parameters such as Bhattacharya analysis, modal progression analysis and direct fit of length frequency data. Since the length distributions of sampled species were constructed, in this study ELEFAN I analysis, which is one of the methods involving the direct fit of length frequency data such as Shepherd's method and Powell-Wetherall plot, was used.

ELEFAN I is a computer program originally written by Gayanilo, Soriano and Pauly (1988) in BASIC programming language. This program is now included in FAO (Food and Agriculture Organization of the United Nations)-ICLARM (International Center for Living Aquatic Resources Management)'s FISAT (Fish Stock Assessment Tools) computer program. ELEFAN I is a routine that can be used to identify the (seasonally oscillating) growth curve that "best" fits a set of length-frequency data, using the value of Rn (the goodness of fit index) as a criterion (Gayanilo et al., 2005).

In ELEFAN I, the length frequency data are reconstructed to generate "peaks" and "troughs", and the goodness of fit index (Rn) is defined by equation 2.13:

$$Rn = 10 * ESP/ASP/10 \qquad 2.13$$

where the ASP ("Available Sum of Peaks") is computed by adding the 'best' values of the available 'peaks' and the ESP ("Explained Sum of Peaks") is computed by summing all the peaks and troughs "hit" by a growth curve of the form (Gayanilo et al., 2005).

$$L_t = L_\infty * (1 - e^{(-K*(t-t_0)} + S_{t_s} + S_{t0}) \quad 2.14$$

where L_t, L_∞, K , t and t_0 are VBGF parameters. S_{ts} and S_{t0} are

$$S_{t_s} = (C * K/2\pi * sin(2\pi(t - t_s)) \quad 2.15$$

$$S_{t_0} = (C * K/2\pi * sin(2\pi(t_0 - t_s)) \quad 2.16$$

where C is the amplitude of oscillation in growth rate over one year due to seasonal effects (Gayanilo et. al. 2005).

The analysis' steps described by Pauly and David (1981) are as follows:

Step 1: restructure the length-frequency samples such that small but clearly identifiable peaks are attributed a number of points similar to that of peaks based on a larger number of fishes.

Step 2: calculate the maximum sum of points available in a set of length-frequency samples. This sum is termed as 'unexplained sum of peaks' (USP).

Step 3: trace through the set of length frequency samples sequentially arranged in time, for any arbitrary seed input of L_∞ and K, a series of growth curves started from the base of each of the peaks, and projected backward and forward in time to meet all other samples of the sample set and/or the same sample repeated again and again.

Step 4: accumulate the points obtained by each growth curve when passing through peaks (positive points) or through the troughs separating peaks (negative points).

Step 5: select the curve which, by passing through most of the peaks and avoiding most troughs, best explains the peaks in the set of samples and therefore accumulates the largest number of points. This new sum is called 'explained sum of peaks' (ESP).

Step 6: decrement or increment, the seeded values of L_∞ and K until the ratio ESP/USP reaches a maximum, and gives the growth parameters corresponding to this optimum ratio.

The length frequencies data were used to fit a growth curve using ELEFAN I package in FAO FISAT II software. The estimation of gill-net selections in the data was not used since the catch frequencies were not plenty enough to deploy that kind of analysis. Therefore, the frequencies derived from gill-net catches were used without prior gill-net selection analysis. The L_∞ is calculated theoretically using the empirical equation from Froese and Binohlan (2000) which is shown in equation 2.17. The L_{max} in the equation is the maximum length of fish observed in the catches.

$$\log L_\infty = 0.044 + 0.9841 * \log(L_{max}) \qquad 2.17$$

In the analysis, L_∞ was kept constant and K-scan module was used to calculate K value by using variable starting points. Before the K-scan routine the C (Amplitude of Oscillation) was set to 1 and according to the spawning period of the species which was derived from previously conducted researches on that species the starting point were altered. Winter point (WP) designates the period of the year (expressed as a fraction of a year) when the growth is slowest (Ama-Abasi et al., 2004). The W P was set to 0 assuming that in winter period the growth rate is so weak and the growth almost stops. Also altering the K and L_∞ values the fit of the growth curve to the data was adjusted.

Due to the selection of the selected fishing gear and the appliance of the gear in inshore has led to insufficient number of individuals for the majority of species sampled. Therefore, it was not possible to deploy ELEFAN I analysis for every length frequency distribution. The species which were taken through the ELEFAN I routine was *Acanthobrama marmid, Carasobarbus luteus, Chalcalburnus mossulensis* and *Mugil abu*.

2.6 Mortality

In fisheries biology, the analytical way to express decrease through time of a fish group born at the same time (cohort) is using instantaneous rates. These rates are defined in equation 2.18 (Gulland, 1975).

$$N_t = N_0 * exp(-Z_t) \qquad 2.18$$

N_0 is the initial number of fish at time zero, N_t is the number of remaining fish at the end of time t and Z is the instantaneous rate of total mortality. Mortality in fishes is as diverse as in terrestrial animals. Although there are several factors acting to decrease the fish stock size in the analytical model developed by Beverton and Holt (2004), the total mortality (Z) has two components (F and M) as shown in equation 2.19 (Gulland, 1975).

$$Z = M + F \qquad 2.19$$

where M is the instantaneous rate of natural mortality and F is the instantaneous rate of fishing mortality.

Knowing two of these entities the third can easily be calculated and hence an independent estimation of Z is important. It is also an important tool in fish stock investigations.

Total mortality (Z) can be estimated in various ways (see Pauly (1984), section 5 for various methods). However, in this study only the length-frequency data set was available from the gill-net catches as well as length-weight relationships of the species present in the lake. Therefore, an equation proposed by Beverton and Holt (1956) was used to estimate Z from the data available. It is shown in equation 2.20:

$$Z = \frac{K * D(L_\infty - \overline{L}^D)}{\overline{L}^D - L'^D} \qquad 2.20$$

where L is the mean length of all fish ≥ L′, L′ is the smallest length of fish fully represented in the length-frequency data. D is surface factor and D = b - a, where “a” is intercept and “b” is the slope of the regression equation. When weight growth is isometric this would correspond to a = 2 and b = 3 (Pauly, 1984).

Another empirical equation from Hoenig (1984) was also applied to calculate total mortality (see equation 2.21). Hoenig’s equation was derived from data on a large number of aquatic animals (mollusks, fish and cetaceans) (Pauly, 1984).

$$\ln(Z) = 1.44 - 0.984 * \ln(t_{max}) \qquad 2.21$$

In equation 2.22, t_{max} is the maximum age observed for the species.

The last equation which was used to calculate total mortality was taken from Beverton and Holt (1956). This equation is based on the principle of estimating mortality rate from mean length (equation 2.22). In this equation, l is the mean length of all fishes observed in the catch and l_c is the length of first capture, K is the Brody growth coefficient and Z is the total mortality rate.

$$Z = K * \frac{L\infty - \overline{l}}{\overline{l} - l_c} \qquad 2.22$$

The natural mortality rate (M) was calculated via equation 2.23. This formula is based on the theory that natural mortality in fish is correlated to mean environmental temperature and inversely correlated with the longevity of fish in the wild (Pauly, 1980). The T is the annual mean temperature of the water in Celsius, L_∞ and K are the VBGF parameters.

$$\log(M) = -0.0066 - 0.279 * \log(L_{\infty}) + 0.6543 * \log(K) + 0.463 * \log(\overline{T}) \quad 2.23$$

2.7 von Bertalanffy Growth Curves

After obtaining the VBGF parameters via aforementioned methods, growth curves of the fishes were drawn. These growth curves were constituted by plotting the total length (L_t) against (t) age in years. The VBGF equation (see equation 2.12) was used to calculate the length values corresponding to age in years.

2.8 Yield Isopleth Diagrams

The yield equation was originally developed by Beverton and Holt (2004). This model is a steady state model describing the state of the stock and the yield in a situation where fishing pattern has been the same for a long period of time and all the fish have been exposed to it since they recruited (Sparre et al., 1989). There are some assumptions underlying this approach:

Recruitment is constant,

All fish of a cohort are hatched on the same date,

Recruitment and selection are knife-edge (Knife-edge selection is the curve of which selection is 0),

The fishing and natural mortalities are constant,

There is complete mixing within the stock (Sparre et al., 1989).

The solution of original equation proposed by Beverton and Holt (2004) is not a simple task. Therefore in this study, yield per recruit curves were constructed via the equation proposed by Ricker (1975).

$$Y = F * N_0 * e^{-M*r} * W_\infty * (\frac{1}{Z} - \frac{3*e^{-Kr}}{Z+K} + \frac{3*e^{-2Kr}}{Z+2K} - \frac{e^{-3Kr}}{Z+3K}) \quad 2.24$$

The symbols are defined as follows:

t_0; the hypothetical age at which fish would have been zero length t_c fish age at first capture

r; t_c - t_0

N_0; hypothetical numbers of fish that reach the age t_0 F mortality caused by fishing

M; natural mortality caused by events such as diseases, predation etc.

Z; total mortality

K; Brody growth coefficient

Y; yield in weight

W_∞; asymptotic weight of fish.

This model can be used for fisheries management if the equation of yield is solved for variable values of F and t_c or l_c. The isopleth curves indicate the isoyield regions where corresponding length or age and fisheries effort coincide. Based on the diagram, tangents of curves, which are perpendicular to the x axis, define the points of best fishing for each curve. Connection of these points results in a curve, which is assumed as eumetric curve, indicating area of best fishing (Beverton and Holt, 2004). Area above and below the eumetric curve is defined as under-fishing and over-fishing zones respectively. According to the graph, one can predict either F or t_c or l_c so that the resulting yield is in the eumetric fishing zone or what precautions should be taken in order to ensure the stock's sustainability and prevent over or under-fishing.

3 RESULTS

In the forthcoming pages firstly the results of fishery acoustical investigations are presented. These are followed by catch and catch composition. Finally yield per recruit analysis' findings are given.

3.1 Acoustics

3.1.1 The Bathymetry

The bathymetric structure of the Atatürk Dam Lake's basin was constituted with the sounder detected depths. The average and maximum depths of the lake were found to be 50 and 152 meters, respectively. The bathymetry of the lake estimated by soundings is shown in Figure 3.1.

3.1.2 Fish Echograms

After all the geographic and acoustic data were extracted from the telegrams for each ping, echograms of the water column were drawn. Single Echo Detections and determination of TS distributions from the lake were based on these plotted echograms by visual examination. In Figure 3.2, a sample echogram is shown. Some of the echoes were surrounded by circles in order to show the detected echoes of fishes and fish schools.

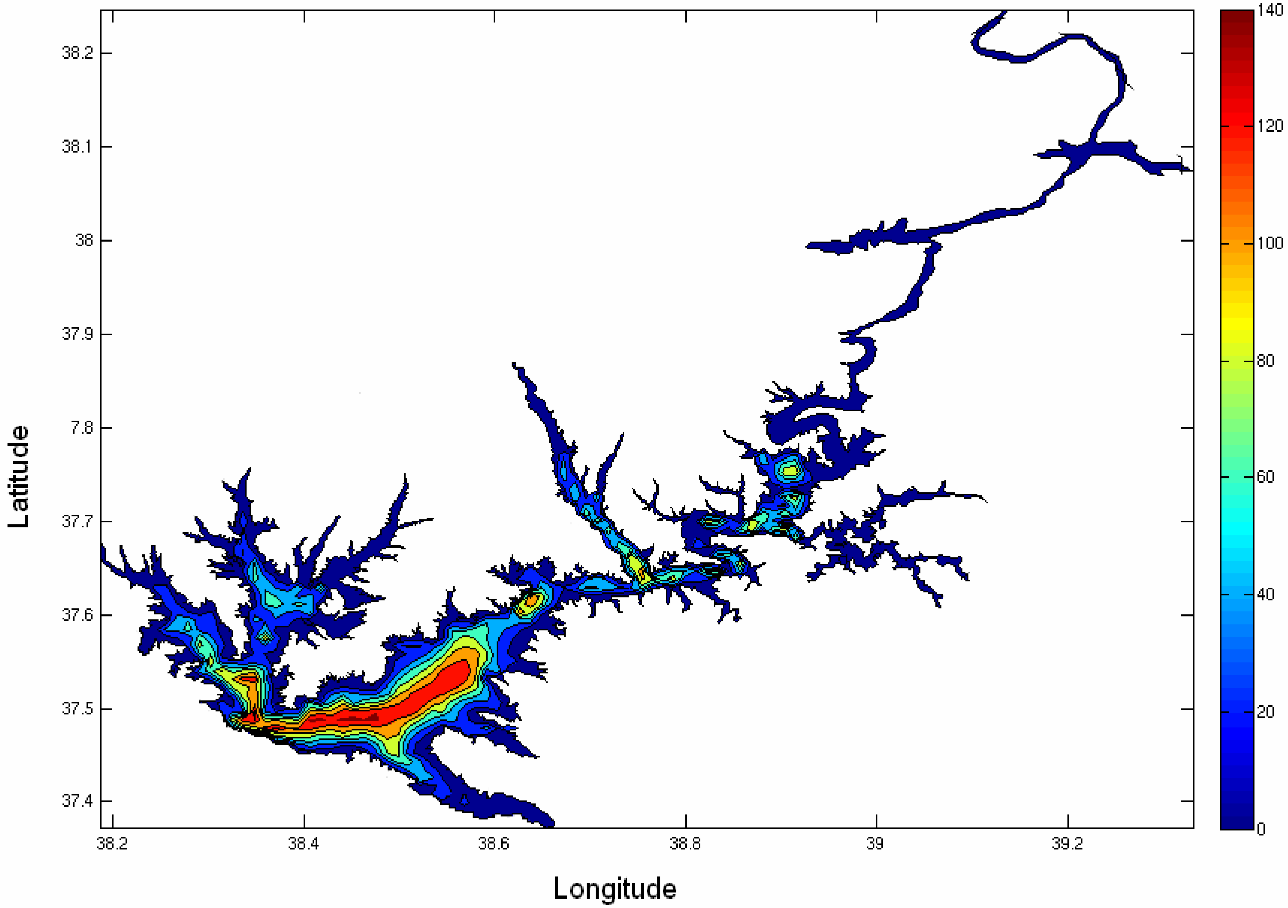

Figure 3.1: The bathymetric map of the Atatürk Dam Lake (colorbar unit is in meters).

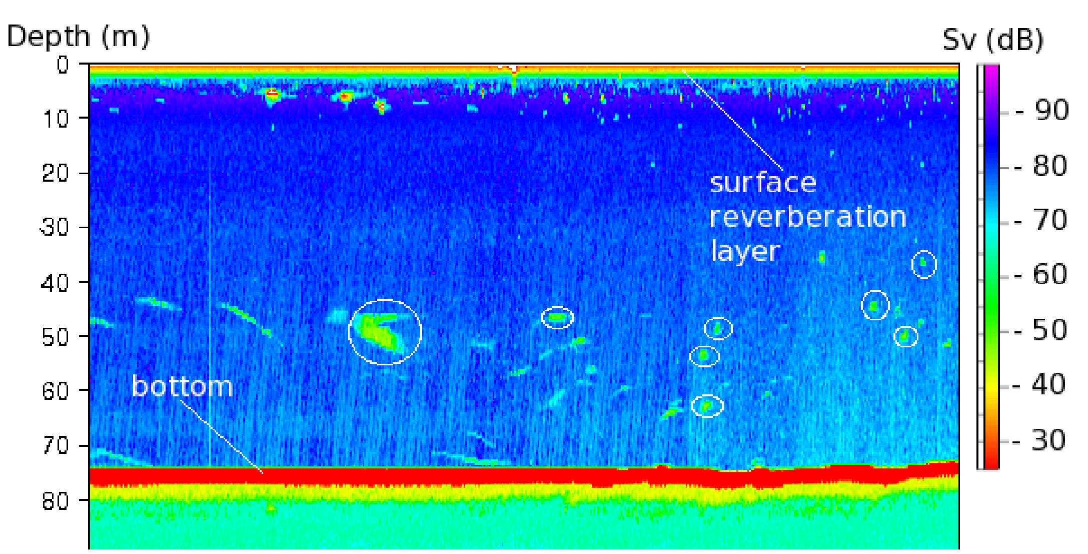

Figure 3.2: A sample acoustic echogram (encircled areas indicate fish echoes).

3.1.3 Echo-Integration

The mean s_a values versus depth and corresponding standard deviations are shown in Figures 3.3 and 3.4.

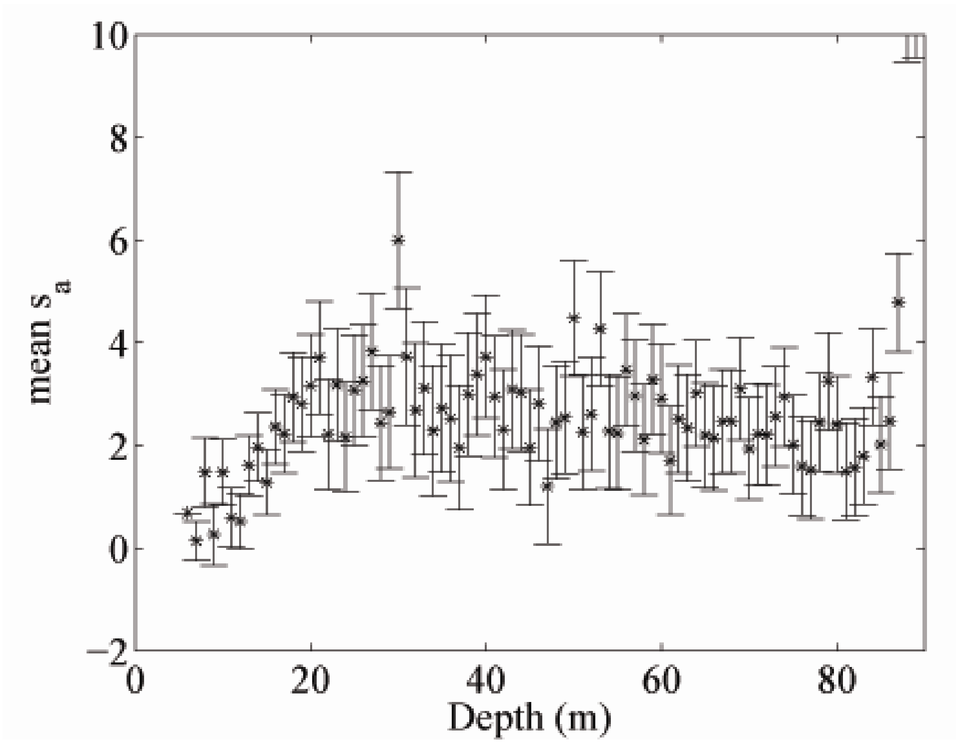

Figure 3.3: Mean s_a distribution versus depth in April, errorbars showing standard deviations (s).

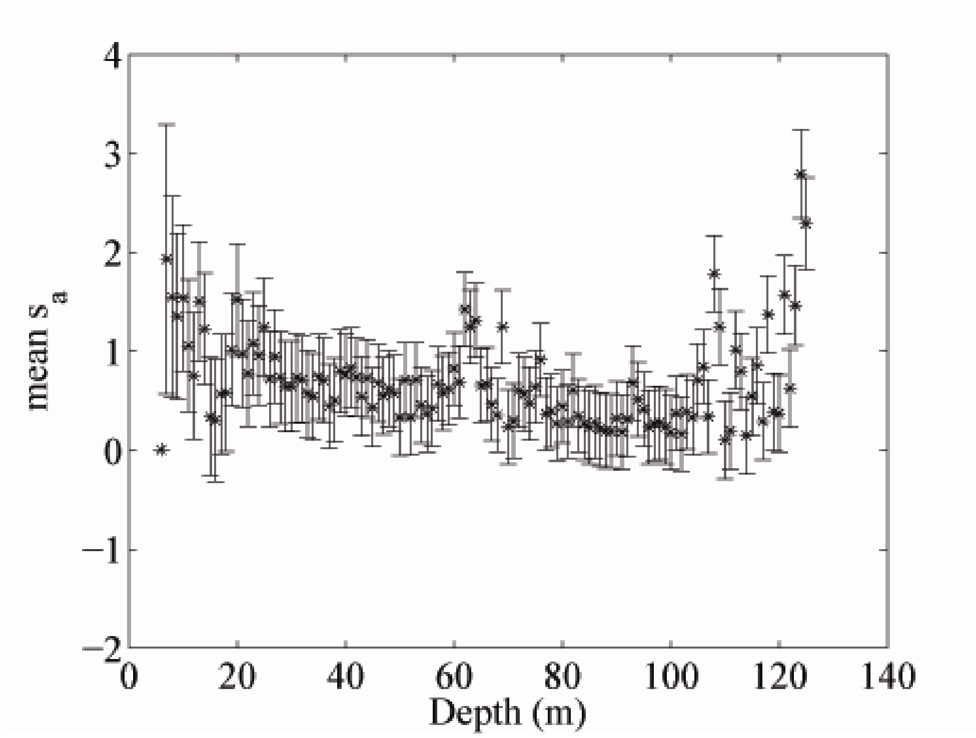

Figure 3.4: Mean s_a distribution versus depth in September, errorbars showing standard deviations (s).

The calculated mean s_a values for each ping in each subarea of the lake and constituted vertical distributions of mean s_a values with corresponding confidence limits for each depth strata are shown in Figures 3.5, 3.6, 3.7 and 3.8.

The mean s_a values were not diverse in subareas 1, 2, 3 and 4 in April and did not exceed 10 $m^2/hectare^2$ whereas their relative standard deviations (s) showed great diversity and high variance (Figure 3.5). In subareas 5, 6, 7 and 8, the s_a values' distribution limits were similar to the ones in the first 4 subareas. However, the standard deviations showed differences. In subarea 5, the standard deviation showed an increasing trend from 15 meters down to 30 meters depth whereas above 15 meters and regions deeper than 30 meters it remained relatively low. In subarea 6, the standard deviation was relatively high only for the deepest depth stratum, 40-80 meters depth. In subarea 7, the standard deviations showed high intervals whereas in subarea 8 this was not the case.

In September, in subarea 1 the standard deviations were low except from the depth strata of 5-10 and 10-15 meters. In subarea 2 the s values were low in all depth strata. In subarea 3 almost none of the depth layers showed high deviations from mean s_a value. Compared to April, the s values in subareas 2, 3 and 4 were very low. Also in subareas 5, 6, 7 and 8 the standard deviations were lower than their corresponding values in April.

These differences in standard deviation values between regions occurred as a result of the number of pings available for each subarea. The more the area is covered by the acoustical survey, the higher will be the number of available pings thus the number of available s_a values will be high, therefore, giving a lower "s" value.

The differences in deviations between depth layers within an area were caused by the distribution of fish assemblages. If the composition of fish assemblages were heterogeneous, i.e. small fish schools are sampled together with other bigger sized fishes, then the echo magnitudes received by the echosounder will be more diverse, including echoes with less intensity together with higher intensities. Therefore, the variance, hence the standard deviation will be high.

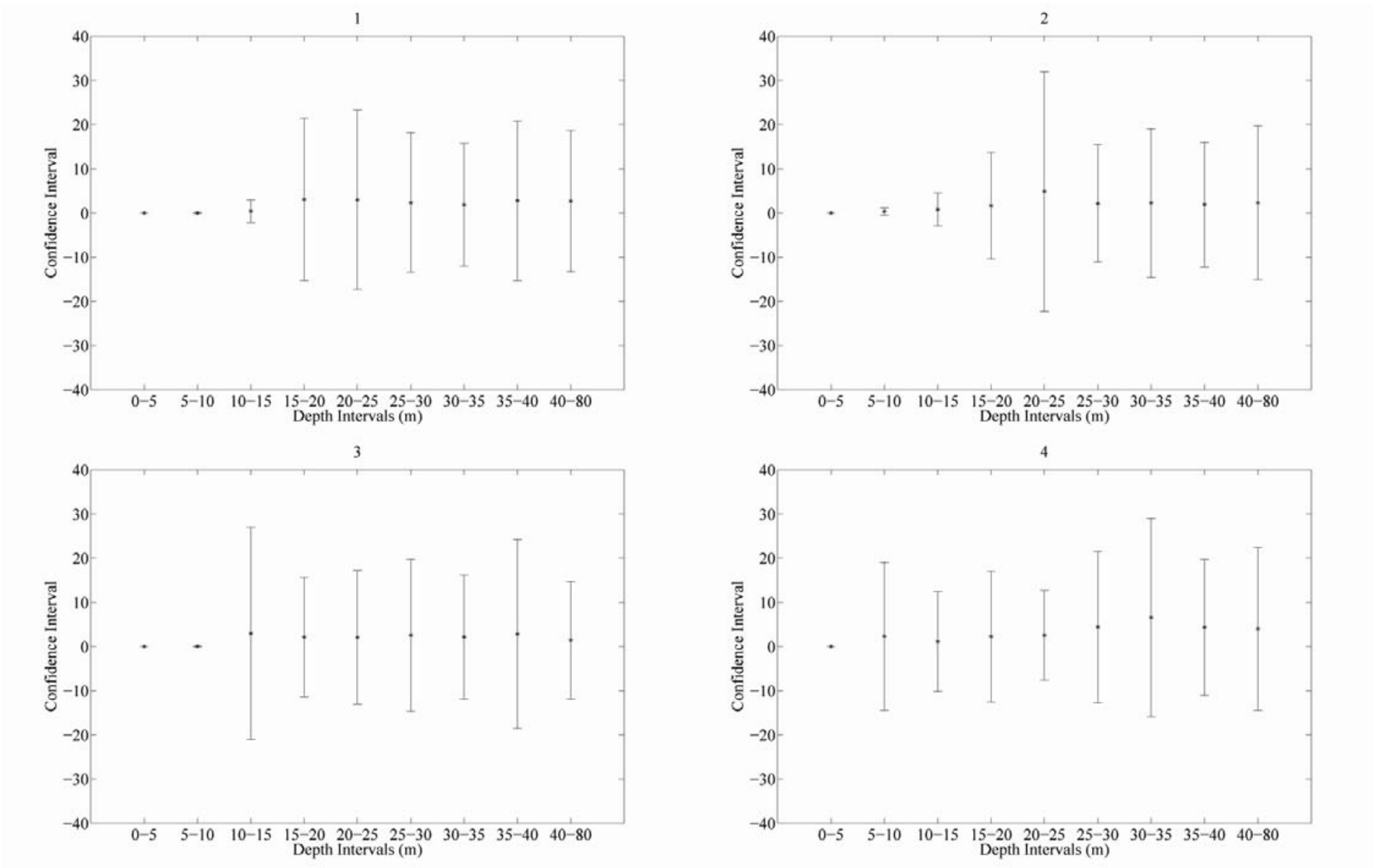

Figure 3.5: The mean s_a values and corresponding confidence intervals at p = 0.05 in subareas 1,2,3 and 4 of the lake (Figure 2.4) in April 2005.

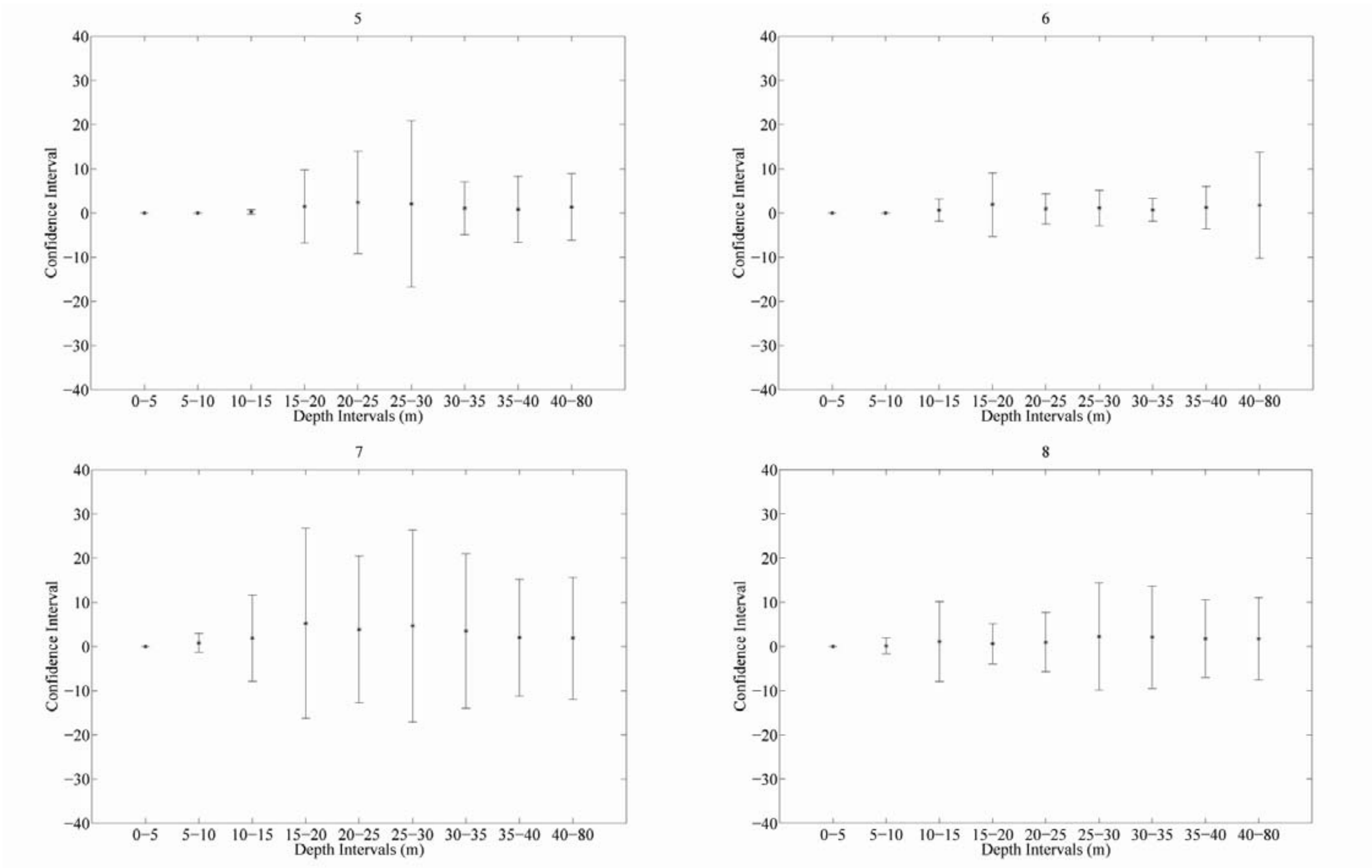

Figure 3.6: The mean s_a values and corresponding confidence intervals at $p = 0.05$ in subareas 5,6,7 and 8 of the lake (Figure 2.4) in April 2005.

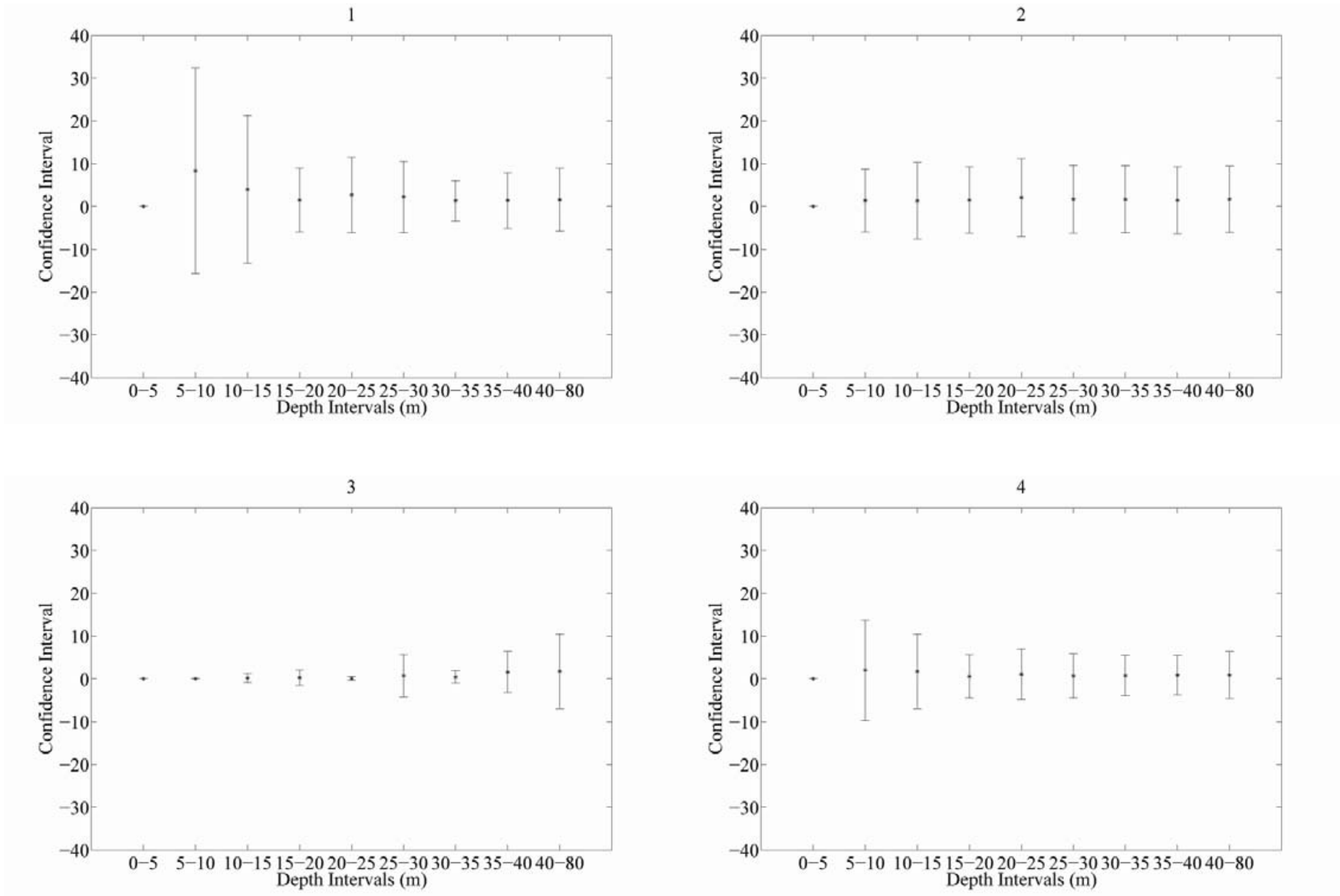

Figure 3.7: The mean s_a values and corresponding confidence intervals at p = 0.05 in subareas 1,2,3 and 4 of the lake (Figure 2.4) in September 2005.

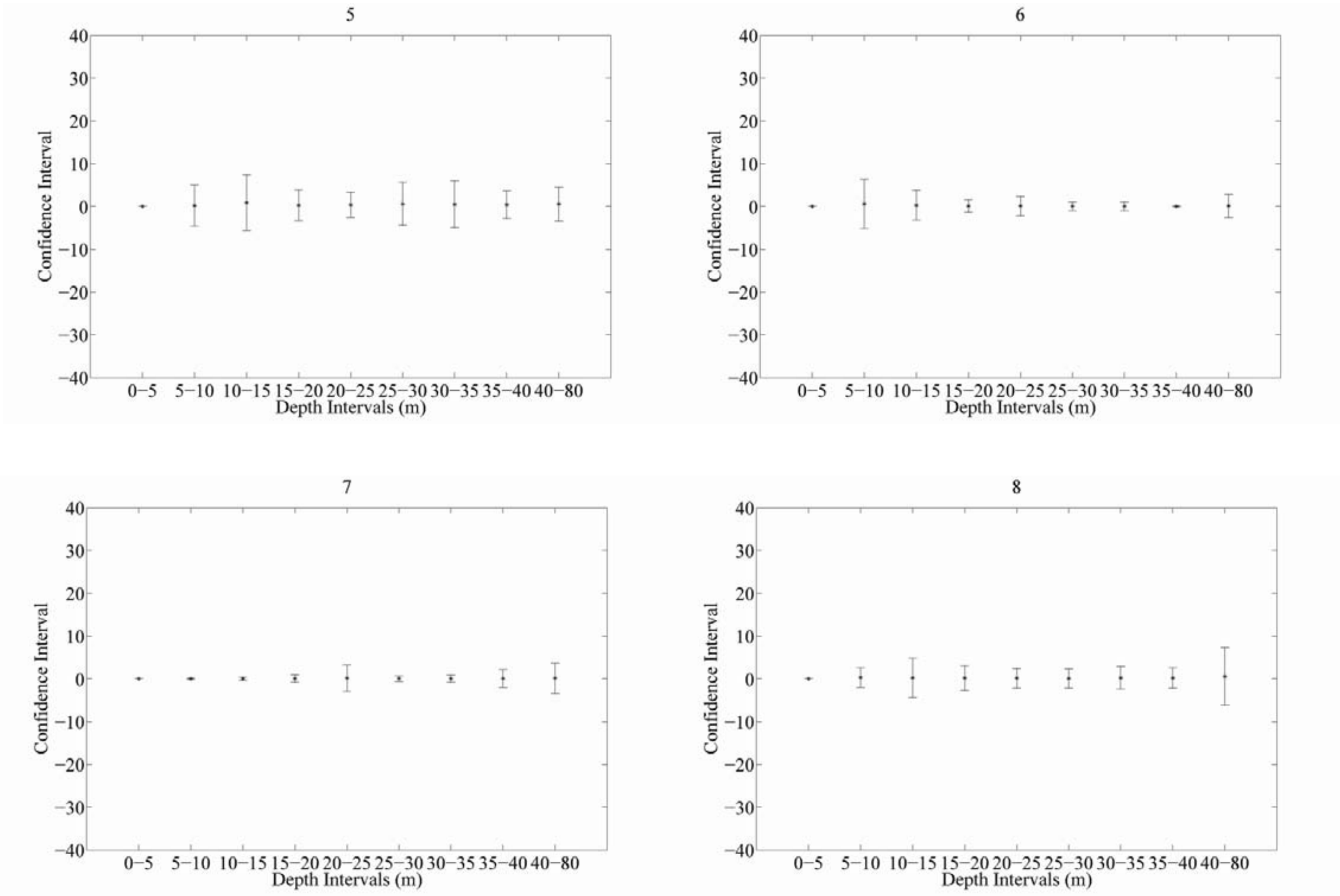

Figure 3.8: The mean s_a values and corresponding confidence intervals at $p = 0.05$ in subareas 5, 6, 7 and 8 of the lake (Figure 2.4) in September 2005.

3.1.4 Target Strength Distribution of Fishes

TS distributions of depth strata for every subarea in the lake were shown in Figures 3.9 and 3.10. The TS values as low as -54 dB to - 60 dB constituted a significant portion of the echoes in all subareas except from the subareas 7 and 8. In subarea 3, relatively high TS values were observed especially between -42 dB to -33 dB. In subareas 7 and 8 the TS values between -51 dB and - 39 dB, which are relatively high as compared to the TS distribution observed in other areas, were dominant in distribution.

Target strength intervals' corresponding length classes are shown in Figures 3.11 and 3.12. The length distribution tables show that a major part of the fish assemblages in the lake is below 20 centimeters length. In Figure 3.12, in the subareas 7 and 8, there was a dense fish accumulation of small sized individuals near the surface. Relatively bigger sized individuals formed a confined layer between 10 and 15 meters depth. In Figure 3.11, there was a heterogeneous fish composition comprised of small and large sized fishes just below the surface layer in subarea 3. In subarea 5, it was found that a small sized fish assemblage existed between 5 and 15 meters depth layer (Figure 3.12). In Figures 3.9 and 3.10, it can be seen that the fish assemblages were generally confined to the depth layers near the surface down to 20 meters depth.

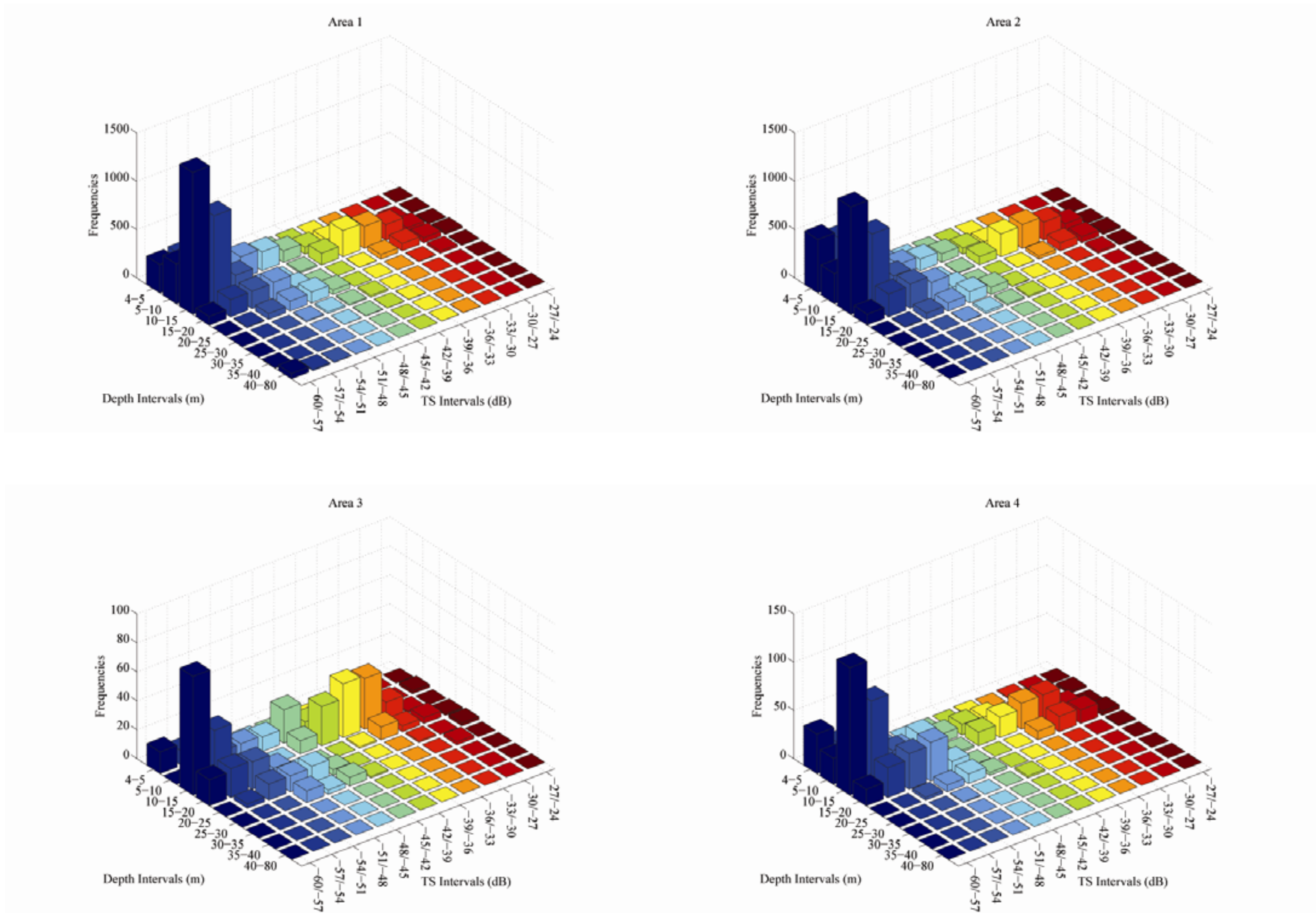

Figure 3.9: TS distributions in subareas 1, 2, 3 and 4 (Figure 2.4) of the lake.

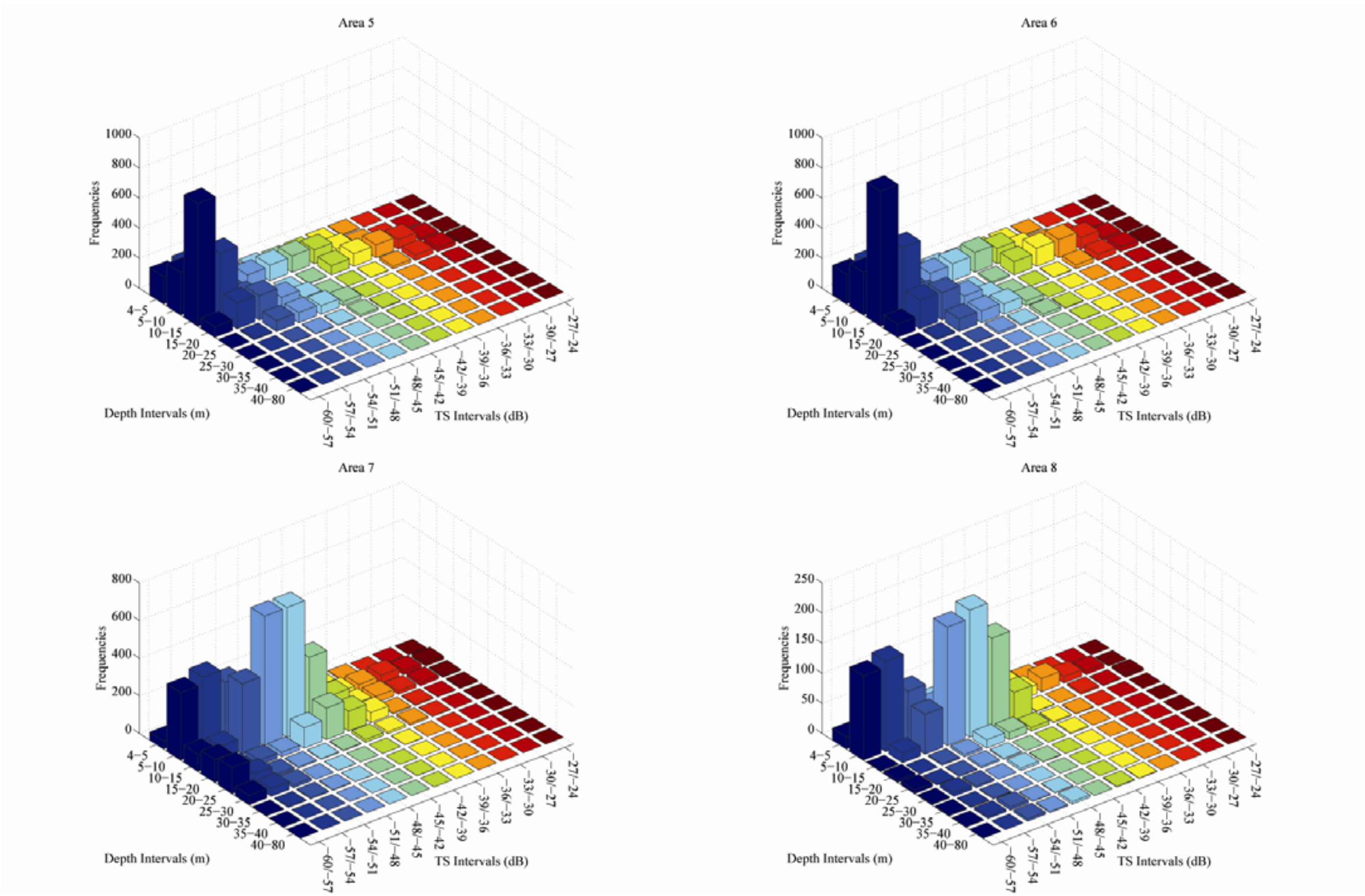

Figure 3.10: TS distributions in subareas 5, 6, 7 and 8 (Figure 2.4) of the lake.

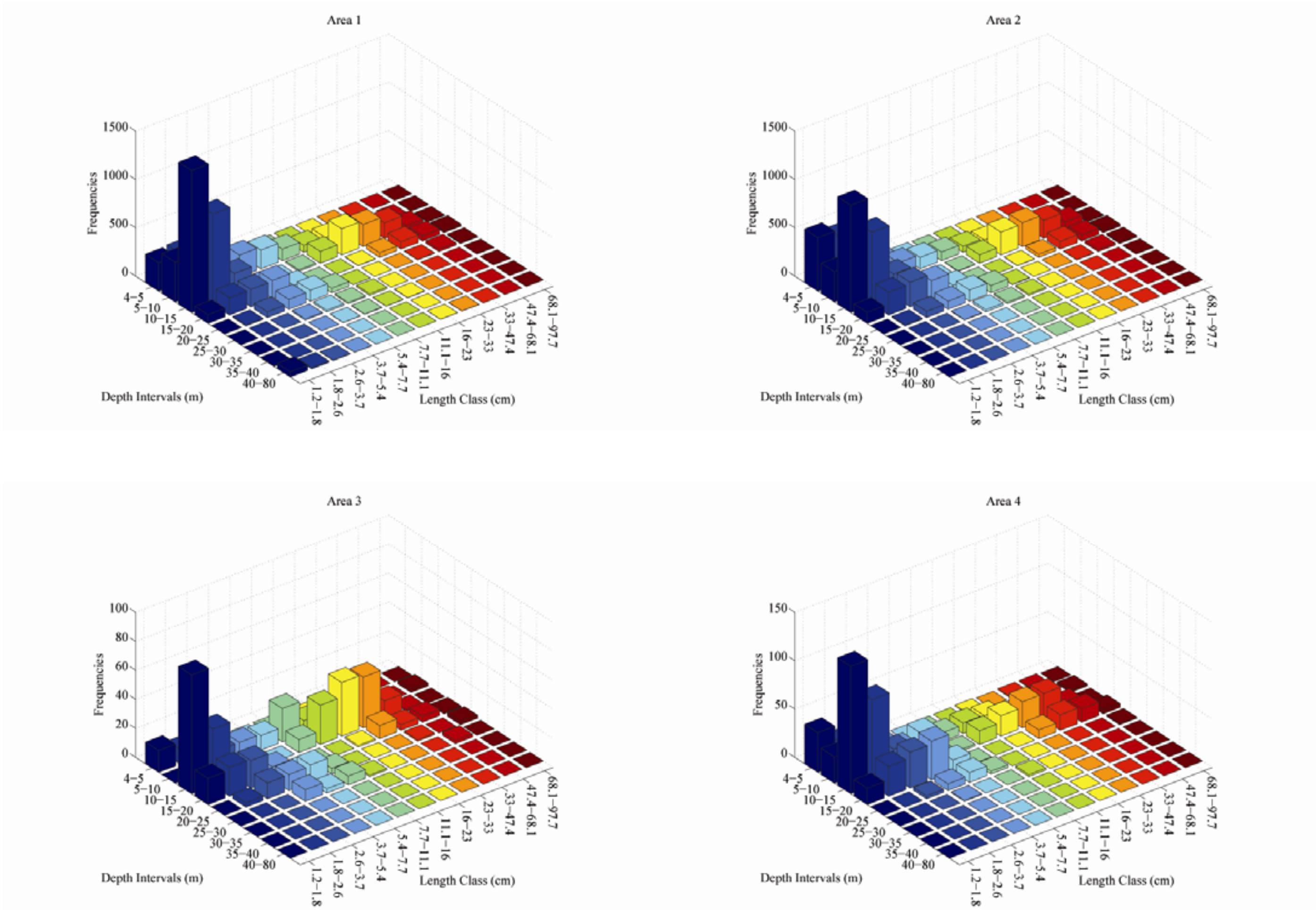

Figure 3.11: Length distributions in subareas 1, 2, 3 and 4 (Figure 2.4).

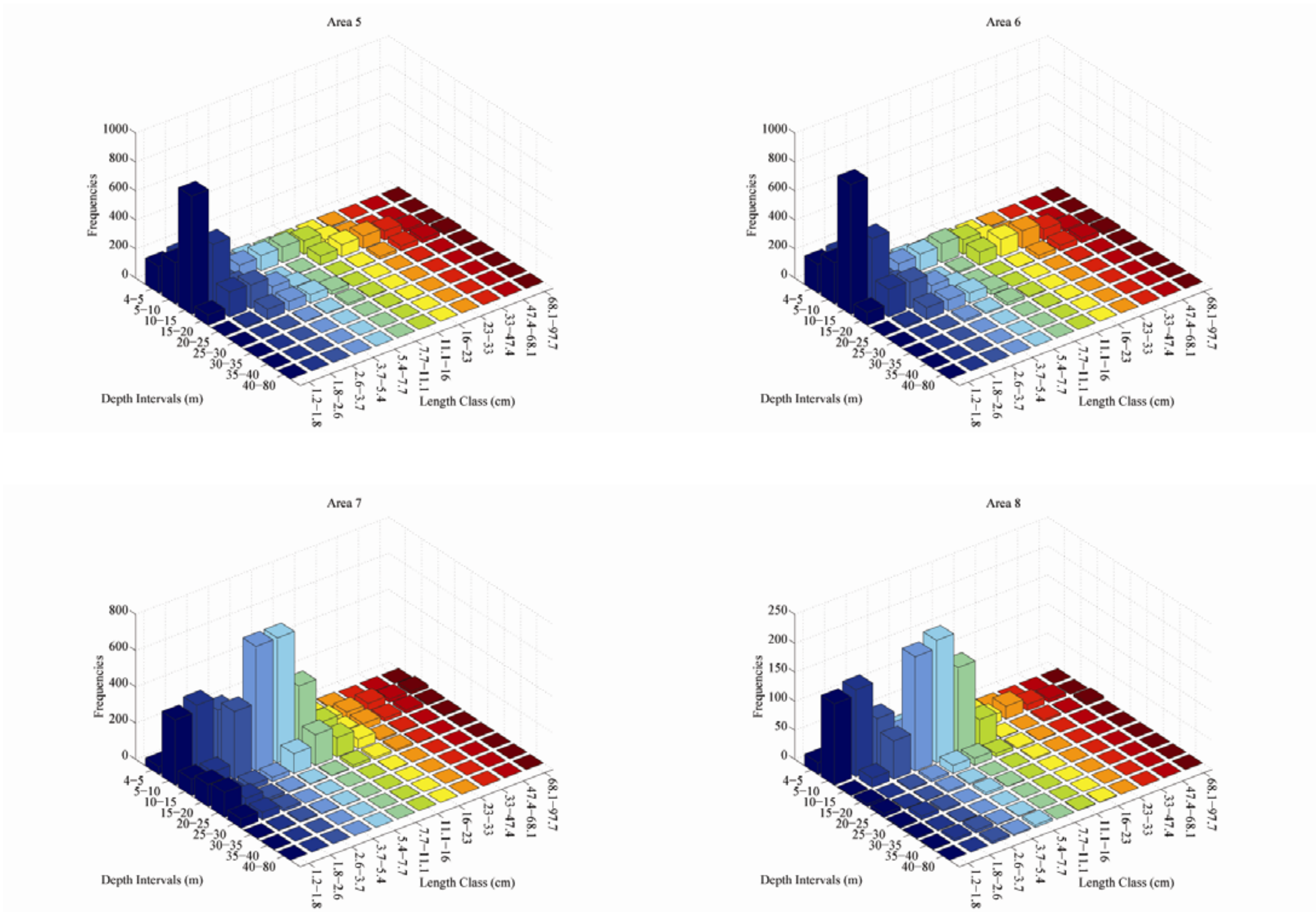

Figure 3.12: Length distributions in subareas 5, 6, 7 and 8 (Figure 2.4).

3.1.5 Biomass Distribution in the Lake - Acoustical and gill-net sampling

Biomass results were derived from combining acoustical abundance data (fish/ha) with gill-net catch composition in weight. The results show that in April, 2005, *C. mossulensis* and *A. marmid* dominated in biomass of fish species in the lake (Figure 3.13).

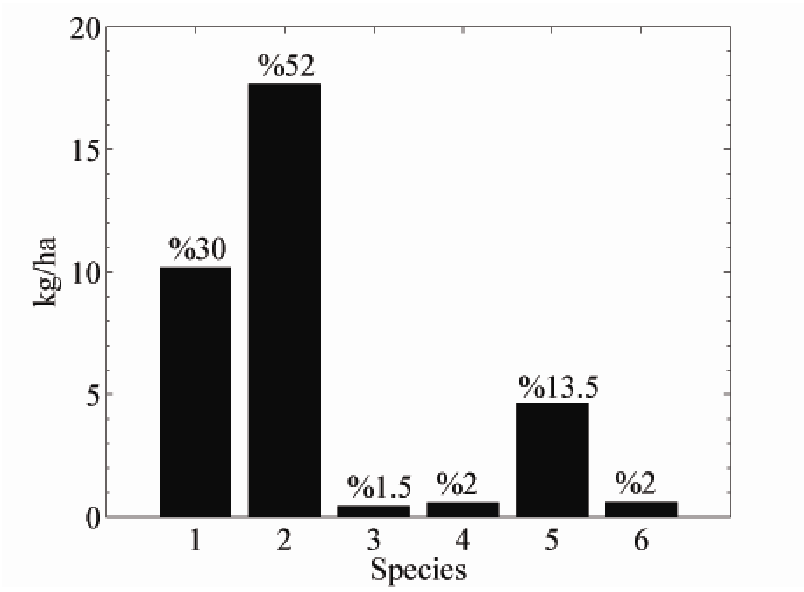

Figure 3.13: Biomass distribution of some important fish species in Atatürk Dam Lake in April, 2005 (1 = *A. marmid*, 2 = *C. mossulensis*, 3 = *C. luteus*, 4 = *C. macrostomus*, 5 = *C. trutta*, 6 = *M. abu*).

In September, 2005, *A. marmid*, *C. trutta* and *C. mossulensis* followed each other in contribution to biomass of fishes in the lake with 44 %, 19 % and 14 %, respectively (Figure 3.14).

Relative biomass distributions were derived from the Table 3.1. In the table biomass and abundance distributions of fish are given for 8 subareas. Biomass distributions indicated that the unit weight of fish per hectare was about three times higher in April compared to September. The total biomass for the whole lake area (81700 hectare) was about 2781 tonnes in April and 841.5 tonnes in September. The number of fishes present in the lake in April was 116e6 and in September were 51e6 individuals.

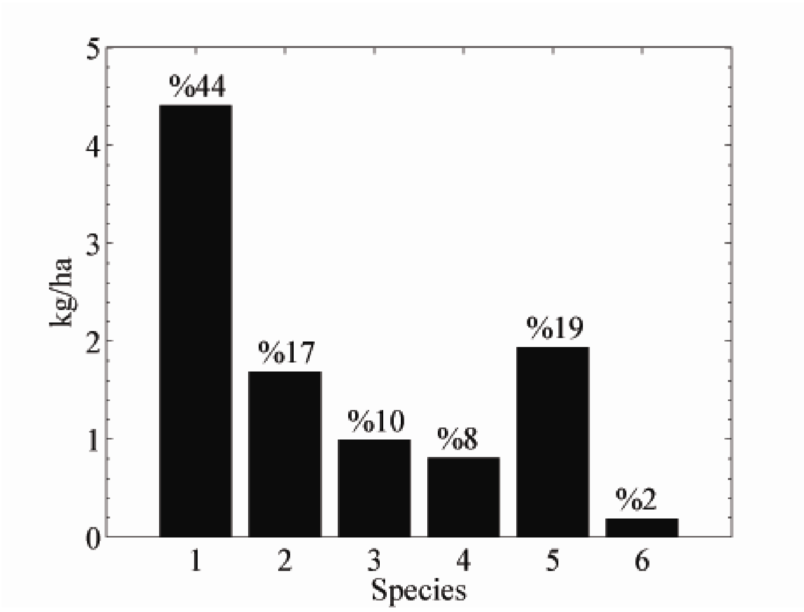

Figure 3.14: Biomass distribution of some important fish species in Atatürk Dam Lake in September, 2005 (1 = *A. marmid*, 2 = *C. mossulensis*, 3 = *C. luteus*, 4 = *C. macrostomus*, 5 = *C. trutta*, 6 = *M. abu*).

Table 3.1: Biomass and abundance distribution of fishes in the lake.

Region / Time	**April 2005**		**September 2005**	
	no. of fish / ha	**kg / ha**	**no. of fish / ha**	**kg / ha**
1	1451	34.82	2117	33.78
2	1252	30.07	1000	15.97
3	1455	34.93	347	5.54
4	2490	59.77	524	8.36
5	843	20.24	438	7
6	734	17.63	139	2.22
7	2152	51.66	89	1.42
8	967	23.2	375	5.99
Average	**1418**	**34.04**	**628**	**10.03**

3.1.6 Temperature Profiles

The temperature profiles in the lake were measured at 6 different stations in April and 4 stations in September. These profiles are shown in Figures 3.15 and 3.16.

In April, there was no distinct stratification in the lake. The temperature values started to decrease from surface with increasing depth. Except Station 2, the temperature values showed a steep decrease from surface down to 20 meters depth. Below 20 meters, the decreasing trend continued but the steepness of the slope of the temperature line decreased.

In September, a distinct thermocline layer was observed. The beginning of the thermocline layer was detected to be between 10 meters and 15 meters depth. Above this layer, the temperature gradient was more or less stable, whereas a slight decrease occurred, indicating the presence of a mixed zone. Below the thermocline, the decrease in the temperature was less instant and the temperature decreased with increasing depth.

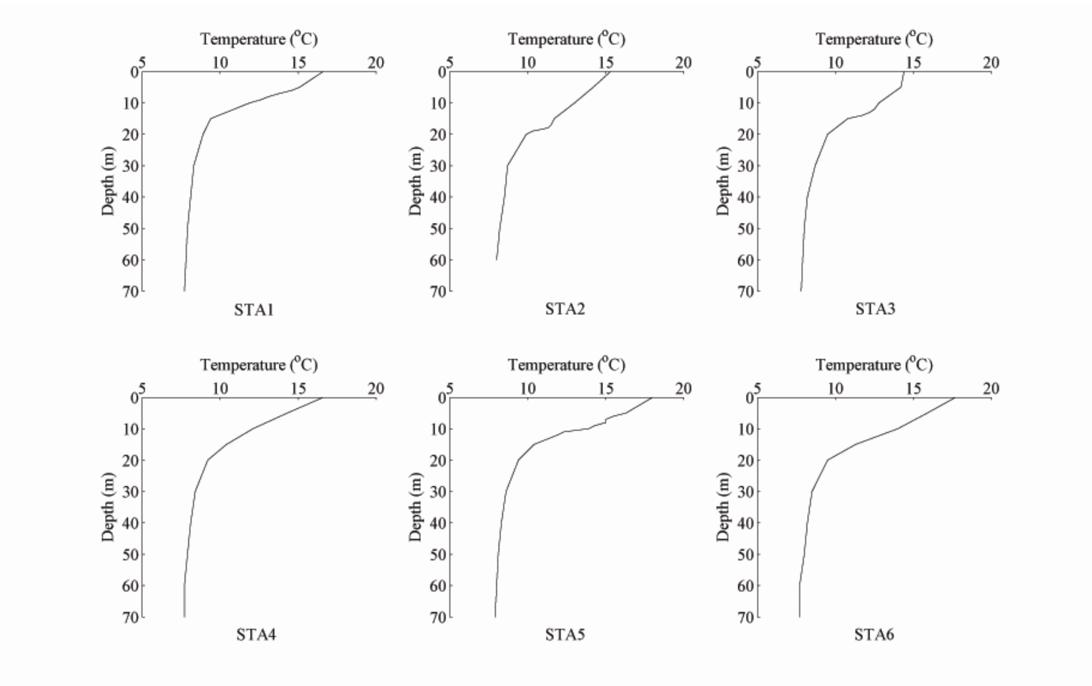

Figure 3.15: Temperature profiles in 6 stations in April, 2005.

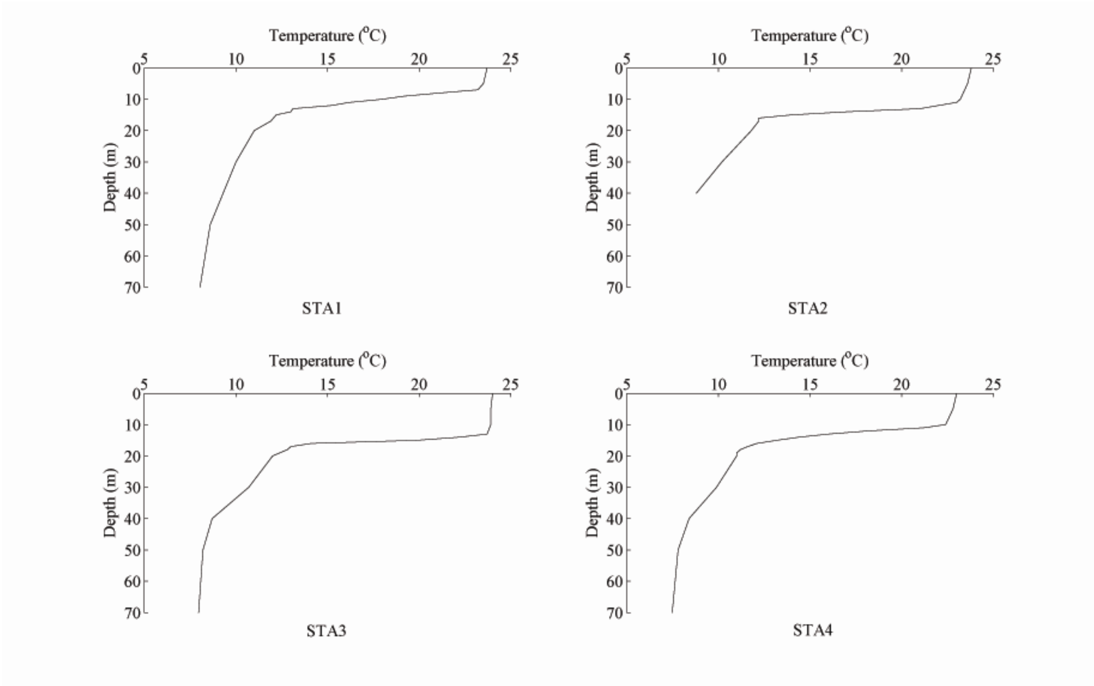

Figure 3.16: Temperature profiles in 4 stations in September, 2005.

3.1.7 Length - Frequency Distribution

Length frequency distributions of the fish species were given in Tables 2.4, 2.5, 2.6 and 2.7 in Chapter 2. Only for 4 of the 16 fish species' length frequency distributions were plotted since they were so abundant in catches that length-frequency graphs could logically be plotted. These species are *M. abu*, *C. luteus*, *A. marmid* and *C. mossulensis* (Figures 3.17, 3.18, 3.19 and 3.20). In Figures 3.21 and 3.22, selected length frequency distributions of these 4 species are shown for April and September since selected distributions were used in calculation of fish biomass. Some rarely occurred species in catches such as *C. regium*, *B. rajanorum mystaceus*, *S. triostegus*, *C. carpio* (mirror), *C. carpio*, *M. simack*, *L. leusiscus*, *C. auratus*, *T. grypus*, *C. trutta* and *C. capoeta umbla*, instead, gave ironic curves. Analysis of this type of distributions was not possible to create meaningful and statistically sound regressions (see Table 3.4).

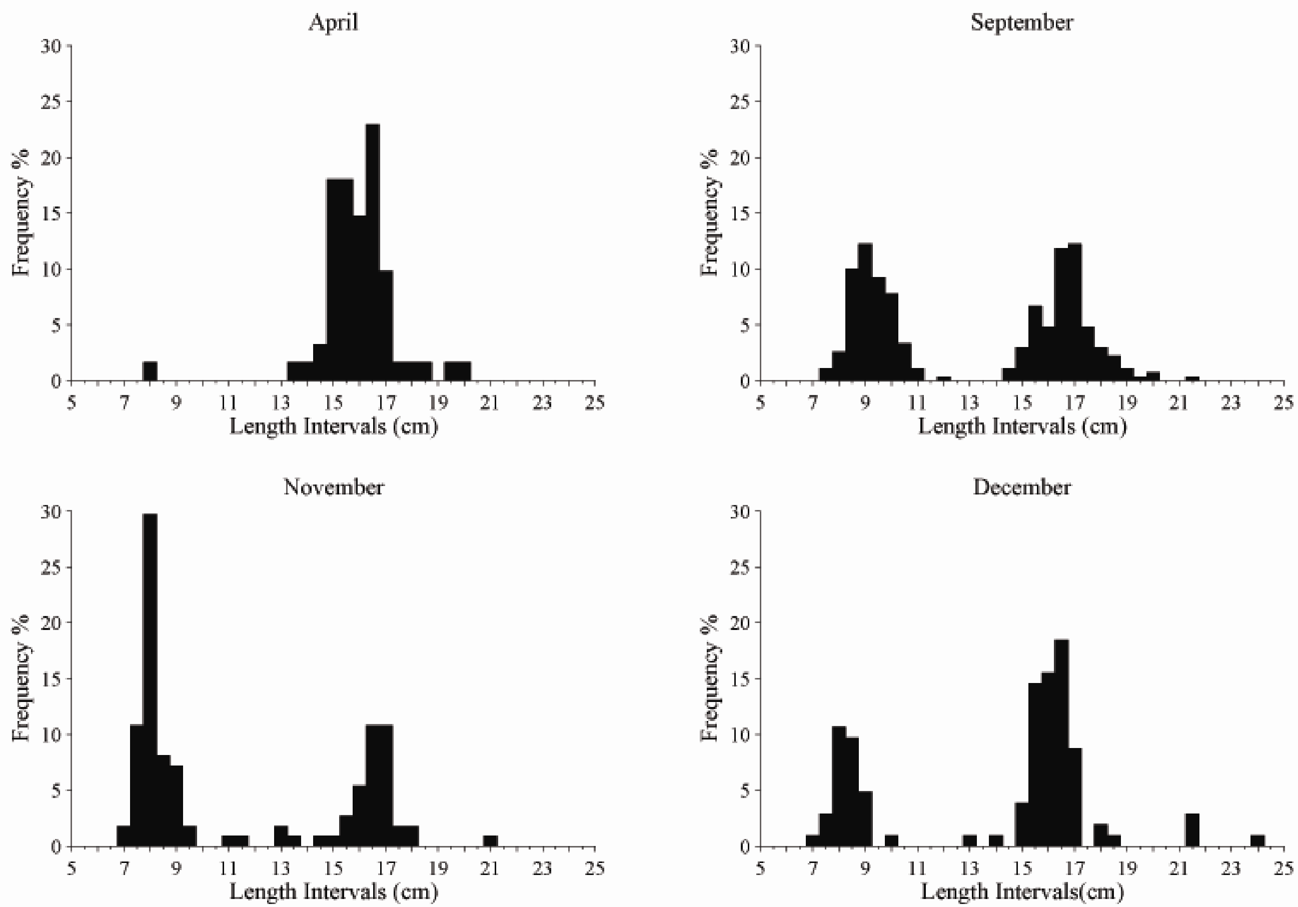

Figure 3.17: Length-frequency distributions of *M. abu* in 4 sampling months.

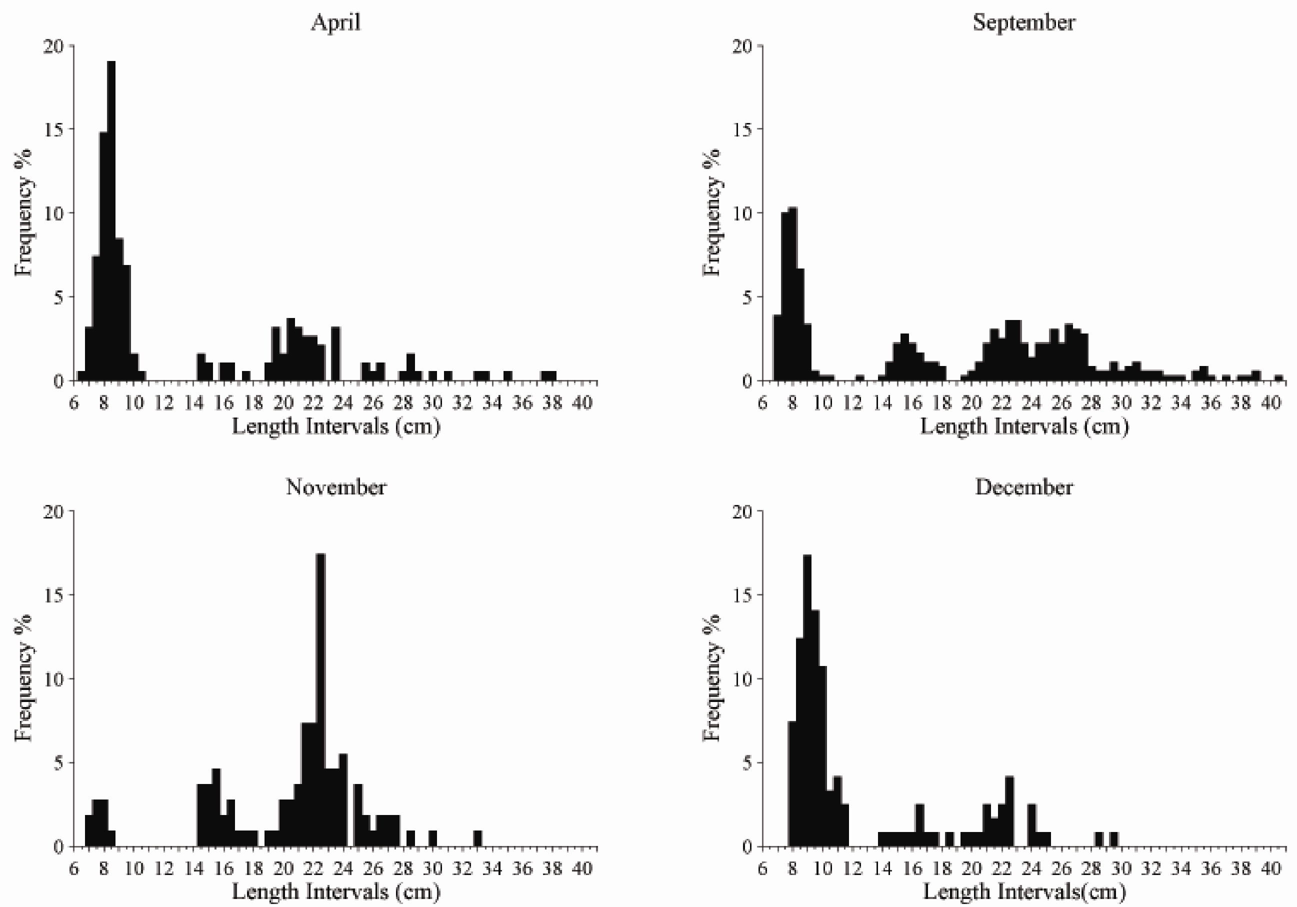

Figure 3.18: Length-frequency distributions of *C. luteus* in 4 sampling months.

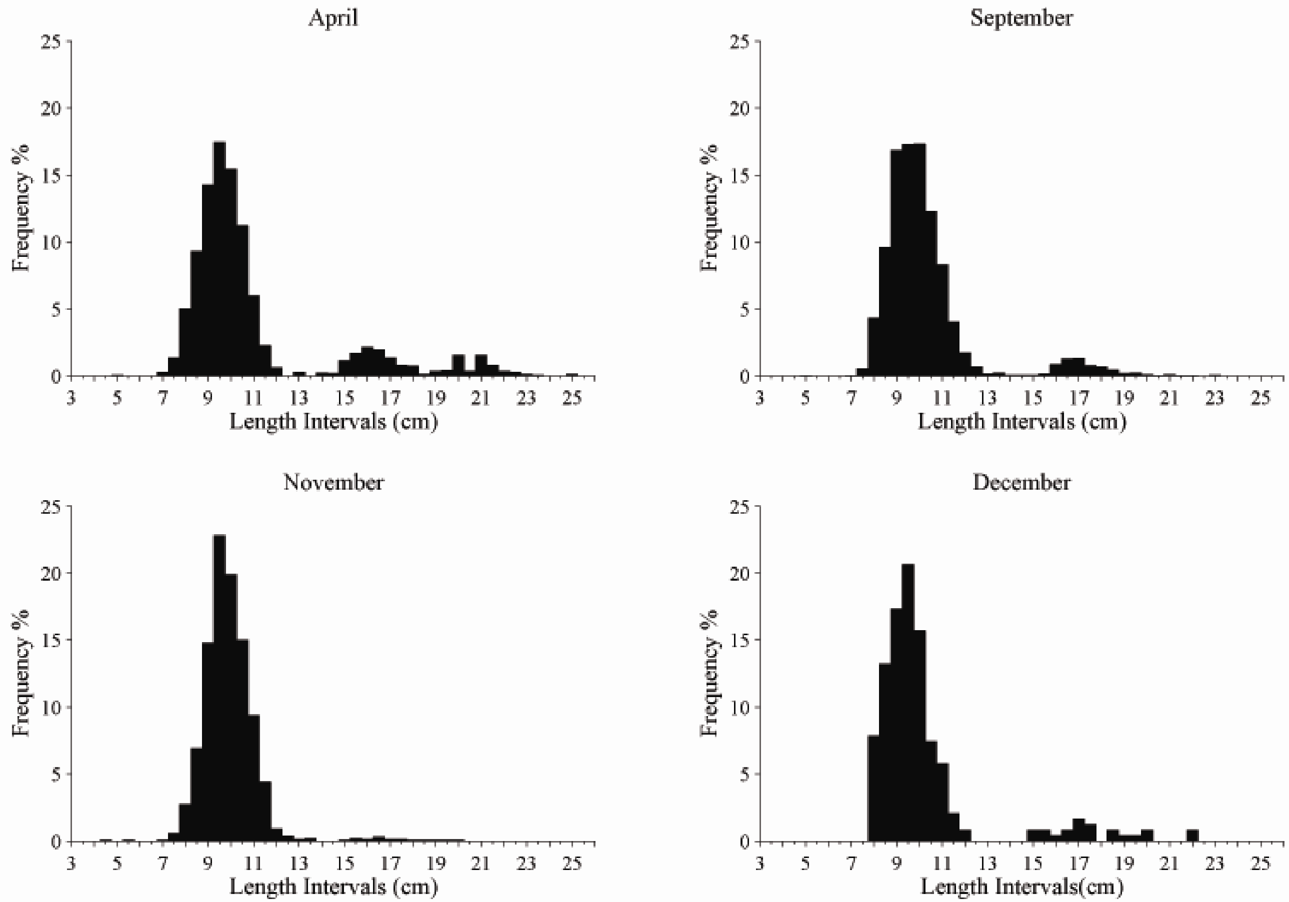

Figure 3.19: Length-frequency distributions of *A. marmid* in 4 sampling months.

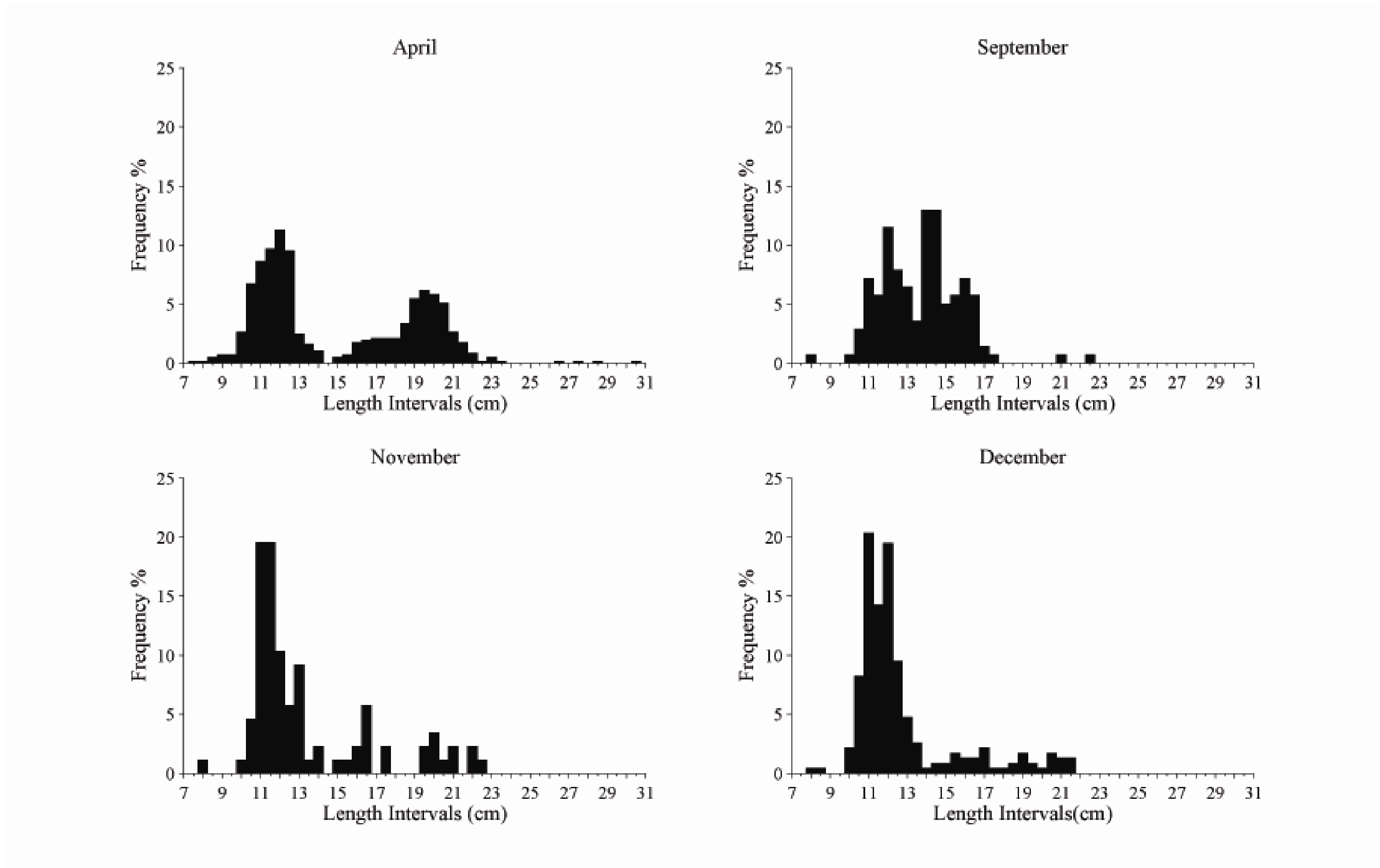

Figure 3.20: Length-frequency distributions of *C. mossulensis* in 4 sampling months.

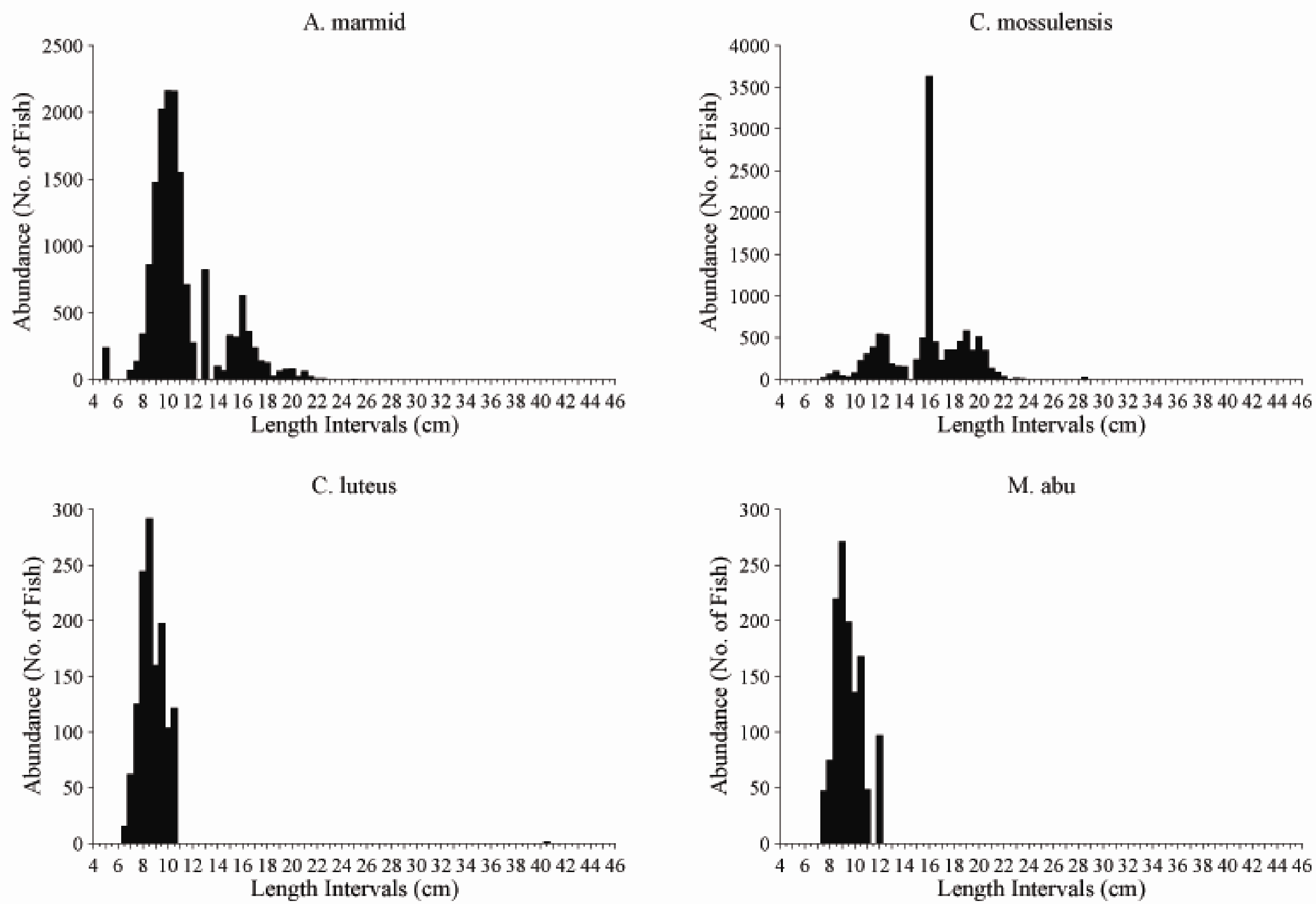

Figure 3.21: Selected length-frequency distributions of *A. marmid, C .mossulensis, C. luteus* and *M. abu* in April.

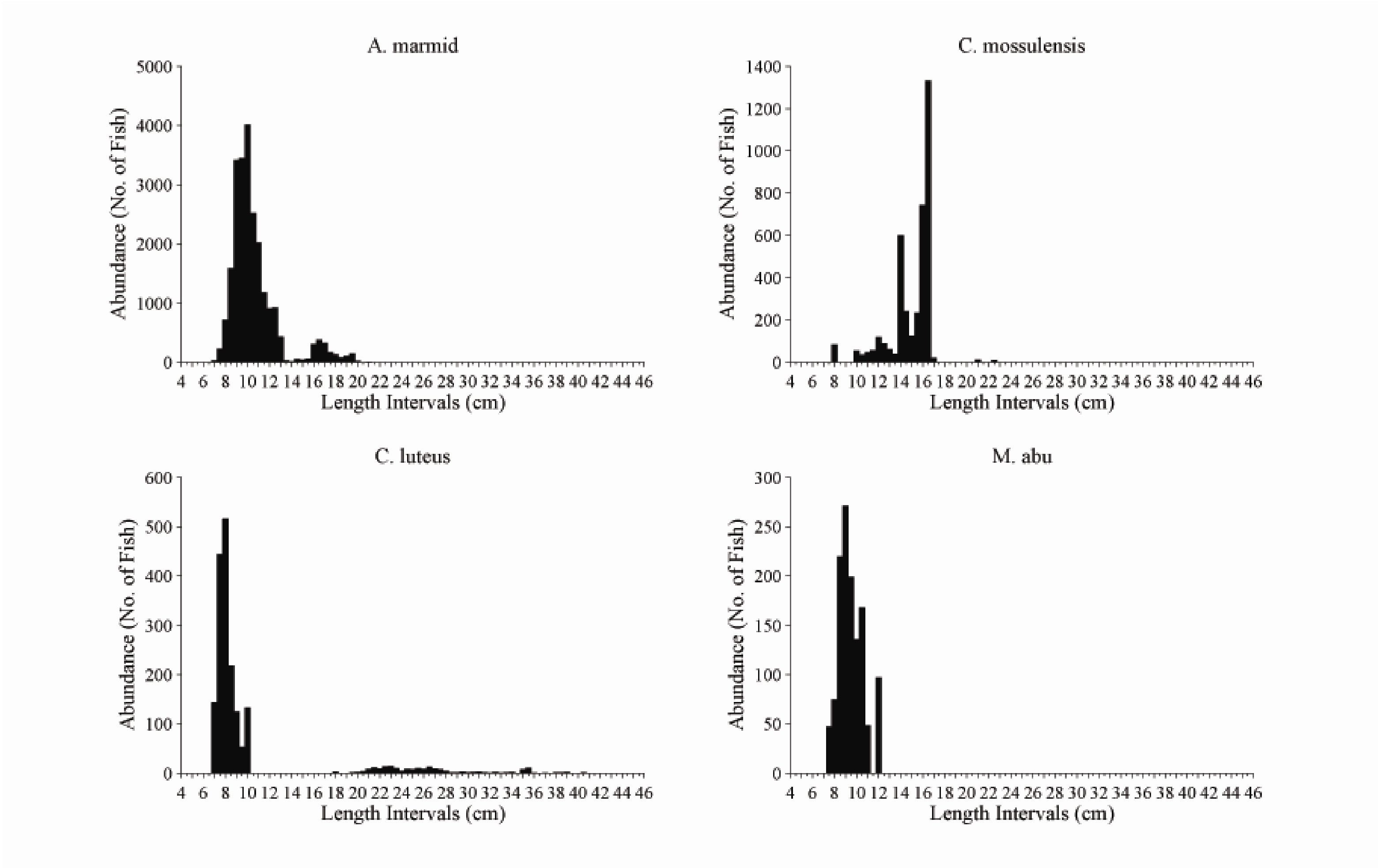

Figure 3.22: Selected length-frequency distributions of *A. marmid, C .mossulensis, C. luteus* and *M. abu* in September.

3.2 Catch and Catch Composition (Gill-net Sampling)

Results of gill-net sampling indicated the presence of the fish assemblages in the upper littoral zone down to 20 meters depth. No fish below 5 centimeters in length was sampled.

Abundance distributions obtained from gill-net catch statistics are shown in Table 3.2 in absolute numbers. The table summarizes the catch data regardless of the sampling stations.

Table 3.2: Abundance of gill-net catches and its distribution among fish species.

Species	Months							
	April		September		November		December	
	No. of fish	%	no. of fish	%	no. of fish	%	no. of fish	%
M. abu	61	2.17	270	6.75	111	6.24	103	5.63
C. auratus	0	0	0	0	1	0.06	2	0.11
C. carpio (mirror)	1	0.04	14	0.35	1	0.06	0	0
C. carpio	15	0.53	11	0.27	4	0.22	5	0.27
T. grypus	2	0.07	5	0.12	6	0.34	2	0.11
L. leuciscus	0	0	2	0.05	0	0	0	0
C. luteus	189	6.71	359	8.97	109	6.12	121	6.61
C. macrostomus	99	3.51	134	3.35	108	6.07	36	1.97
A. marmid	1634	58	2680	66.98	1311	73.65	1282	70.05
C. mossulensis	567	20.13	139	3.47	88	4.94	231	12.62
B. rajanorum mystaceus	0	0	3	0.07	4	0.22	4	0.22
Orthrias spp.	4	0.14	87	2.17	4	0.22	1	0.05
C. regium	42	1.49	17	0.42	0	0	0	0
M. simack	1	0.04	3	0.07	0	0	0	0
S. triostegus	0	0	9	0.22	0	0	1	0.05
C. trutta	195	6.92	261	6.52	33	1.85	42	2.3
C. capoeta umbla	7	0.25	7	0.17	0	0	0	0
Total	**2817**	**100**	**4001**	**100**	**1780**	**100**	**1830**	**100**

The abundance distribution in April showed that two relatively small pelagic species namely *Acanthobrama marmid* and *Chalcalburnus mossulensis* dominated in the lake with 58 % and 20 %, respectively. These species are considered to be economically unimportant but the latter is known to be exploited commercially by the local people. Following these two species come *Carasobarbus luteus* and *Capoeta trutta*, which are relatively bigger in size and commercially important, with 7 % abundance (Table 3.2).

Examination of the September abundance distributions reveals that *Acanthobrama marmid* was the dominant species with 67 %, but this time it was followed by *Carasobarbus luteus* with 9% abundance. Other species were *Mugil abu*, *Capoeta trutta* and *Chalcalburnus mossulensis*, the first two with 7 % and the latter with 3 % contribution to total abundance.

In November, *Acanthobrama marmid* was dominant with 74 %, followed by other species namely *M. abu*, *C. luteus* and *C. mossulensis* with equal contribution with 6 % each.

A. marmid was also the dominant species in December with 70 %. That species was followed by another small pelagic species, namely *C. mossulensis* with 13 %, and *C. luteus* and *M. abu* were represented with 7 % and 6 % respectively.

The weight distribution of species in gill-net catch composition in April indicated that the three most dominating species were *C. trutta*, *A. marmid* and *C. mossulensis* with 45 %, 18 % and 16 % respectively (Table 3.3).

In September, *C. trutta*, *C. luteus* and *A. marmid* dominated in weight distribution. The percentages were found to be 45 %, 23 % and 14 %. Other species constituted less than 20 % of the total weight of catch.

In November *C. luteus*, *A. marmid* and *C. trutta* followed each other with 35 %, 28 % and 16 % respectively.

In December *C. trutta*, *C. luteus*, *C .mossulensis* and *M. abu* were represented with 36 %, 16 %, 14 % and 14 % respectively.

The weight distribution of species in gill-net catch composition in April indicated that the three most dominating species were *C. trutta*, *A. marmid* and *C. mossulensis* with 45 %, 18 % and 16 %, respectively (Table 3.3).

In September, *C. trutta*, *C. luteus* and *A. marmid* dominated in weight distribution. The contributions to total biomass were found to be 45 %, 23 % and 14% respectively. Other species constituted less than 20 % of the total weight of catch.

In November *C. luteus*, *A. marmid* and *C. trutta* followed each other with 35 %, 28 % and 16 % respectively.

In December *C. trutta*, *C. luteus*, *C .mossulensis* and *M. abu* were represented with 36 %, 16 %, 14 % and 14 % respectively.

Table 3.3: Weight of gill-net catches and its distribution among fish species (Quantities are in grams (gr)).

Species	Months							
	April		September		November		December	
	Weight	%	Weight	%	Weight	%	Weight	%
M. abu	2953	2	8556	4	2409	6	3688	14
C. auratus	0	0	0	0	110	0	409	2
C. carpio (mirror)	6	0	4195	2	273	1	0	0
C. carpio	3130	3	2033	1	436	1	323	1
T. grypus	747	1	1692	1	1433	4	471	2
L. leuciscus	0	0	1199	1	0	0	0	0
C. luteus	12336	10	44304	23	13236	35	4350	16
C. macrostomus	546	0	2141	1	695	2	269	1
A. marmid	21692	18	27818	14	10658	28	2703	10
C. mossulensis	19739	16	2825	1	1770	5	3760	14
B. rajanorum mystaceus	0	0	663	0	1003	3	749	3
Orthrias spp.	33	0	764	0	29	0	6	0
C. regium	3851	3	803	0	0	0	0	0
M. simack	541	0	1148	1	0	0	0	0
S. triostegus	0	0	6528	3	0	0	203	1
C. trutta	55166	45	86603	45	5888	16	9649	36
C. capoeta umbla	1176	1	2208	1	0	0	0	0
Total	**121915**	**100**	**193480**	**100**	**37940**	**100**	**26582**	**100**

3.2.1 Catch per Unit of Effort

The gill-net sampling was applied with 2 sets of 430 meter-long and 1.5 meter high gill-nets for 6 days in April. Each day the nets remained immersed in water for 12 hours. The catch per unit of effort (cpue) in April was 1.312 gr fish / hour / m^2 of net area.

In September, November and December the CPUEs were calculated as 1.56, 1.22 and 0.86 gr fish / hour / m^2 of net area respectively.

3.2.2 Length - Weight Relationships

The length-weight relationships of the fish species in the lake were calculated for the fish species that were abundant enough ($n \geq 7$) in the gill-net catch composition (Table 3.4). The relationships were calculated monthly and since there was no difference observed in the regression analysis between the sampling stations, all populations of each species were considered to be parts of a single unit. The comparison of the regression equations were made according to the Zar's algorithm.

These data were used to calculate W_∞ values from calculated L_∞ values via von Bertalanffy growth function. W_∞ and L_∞ were also calculated for each species in all sampling stations to determine whether individuals of each species sampled from different gill-net stations belong to the same population or not. However, the data were not given in this section because it was found that all of the sampled groups of each species from different stations belonged to the same population of that species.

Table 3.4: Length - weight relationships (N.A. = Not Available (n < 5)).

Parameters	*M.abu*	*C. carpio (mirror)*	*C. carpio (common)*	*T. grypus*	*C. luteus*	*C. macrostomus*	*A. marmid*	*C. mossulensis*	*Orthrias sp.*	*C. regium*	*S. triostegus*	*C. trutta*	*C. capoeta umbla*
	April												
Intercept	-1.927	N.A.	-2.086	N.A.	-2.289	-2.031	-2.622	-2.573	N.A.	-1.779	N.A.	-2.131	-1.863
Slope	2.990	N.A.	3.123	N.A.	3.267	2.958	3.489	3.380	N.A.	2.842	N.A.	3.106	2.891
r^2	0.889	N.A.	0.998	N.A.	0.994	0.886	0.981	0.965	N.A.	0.986	N.A.	0.959	0.999
Fulton factor	0.012	N.A.	0.008	N.A.	0.005	0.009	0.002	0.003	N.A.	0.017	N.A.	0.007	0.014
n	61	N.A.	15	N.A.	189	99	870	567	N.A.	42	N.A.	195	7
	September												
Intercept	-2.199	-1.663	-1.975	N.A.	-2.079	-2.202	-2.148	-2.212	-1.858	-1.288	-1.929	-0.615	-2.039
Slope	3.187	2.905	3.069	N.A.	3.103	3.177	3.037	3.046	2.868	2.254	2.846	2.047	2.958
r^2	0.990	0.990	0.921	N.A.	0.996	0.977	0.952	0.925	0.865	0.712	0.995	0.566	0.786
Fulton factor	0.006	0.022	0.011	N.A.	0.008	0.006	0.007	0.006	0.014	0.052	0.012	0.243	0.009
n	270	14	11	N.A.	359	134	2677	139	87	17	9	261	7
	November												
Intercept	-2.166	N.A.	N.A.	-2.330	-2.100	-1.442	-1.970	-2.640	N.A.	N.A.	N.A.	-2.515	N.A.
Slope	3.133	N.A.	N.A.	3.120	3.126	2.346	2.837	3.381	N.A.	N.A.	N.A.	3.315	N.A.
r^2	0.989	N.A.	N.A.	0.996	0.996	0.487	0.840	0.899	N.A.	N.A.	N.A.	0.976	N.A.
Fulton factor	0.007	N.A.	N.A.	0.005	0.008	0.036	0.011	0.002	N.A.	N.A.	N.A.	0.003	N.A.
n	111	N.A.	N.A.	6	109	108	1311	87	N.A.	N.A.	N.A.	33	N.A.
	December												
Intercept	-2.159	N.A.	N.A.	N.A.	-2.624	-1.809	-2.443	-2.581	N.A.	N.A.	N.A.	-2.211	N.A.
Slope	3.137	N.A.	N.A.	N.A.	3.500	2.728	3.311	3.338	N.A.	N.A.	N.A.	3.106	N.A.
r^2	0.994	N.A.	N.A.	N.A.	0.992	0.951	0.977	0.942	N.A.	N.A.	N.A.	0.987	N.A.
Fulton factor	0.007	N.A.	N.A.	N.A.	0.002	0.015	0.004	0.003	N.A.	N.A.	N.A.	0.006	N.A.
n	103	N.A.	N.A.	N.A.	121	36	242	231	N.A.	N.A.	N.A.	42	N.A.

3.2.3 Growth Constants

Von Bertalanffy Growth Function (VBGF) parameters were estimated applying ELEFAN I routine to the length-frequency distributions of a few fish species where suitable data were available. These species are *Chalcalburnus mossulensis*, *Carasobarbus luteus, Acanthobrama marmid* and *Mugil abu*.

The obtained growth curves and growth parameters are shown in the Figures 3.23, 3.24, 3.25 and 3.26.

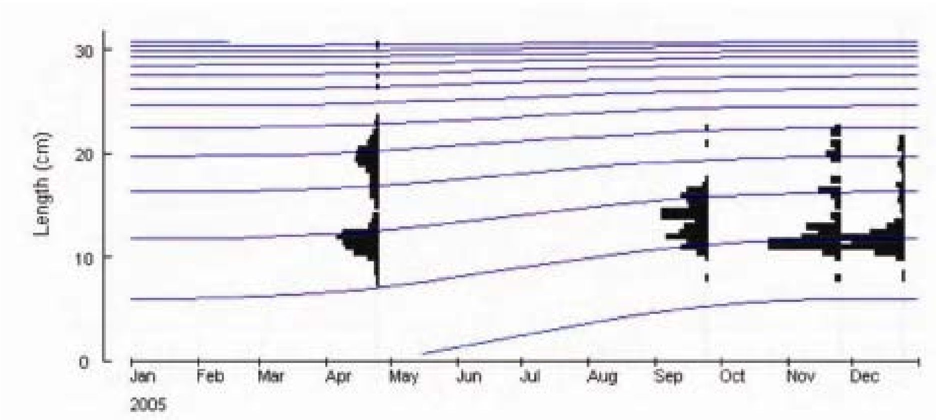

Figure 3.23: *Chalcalburnus mossulensis* ELEFAN I plot and VBGF parameters (L_∞ = 32.03 cm, L_{max} = 30.5 cm, K = 0.25 and t_0 = -0.3235).

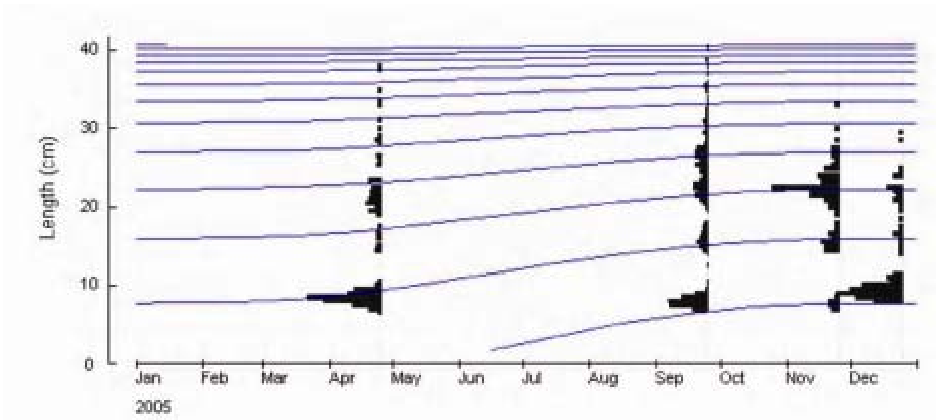

Figure 3.24: *Carasobarbus luteus* ELEFAN I plot and VBGF parameters (L_∞ = 42.53 cm, L_{max} = 40.5 cm, K = 0.27 and t_0 = -0.3152).

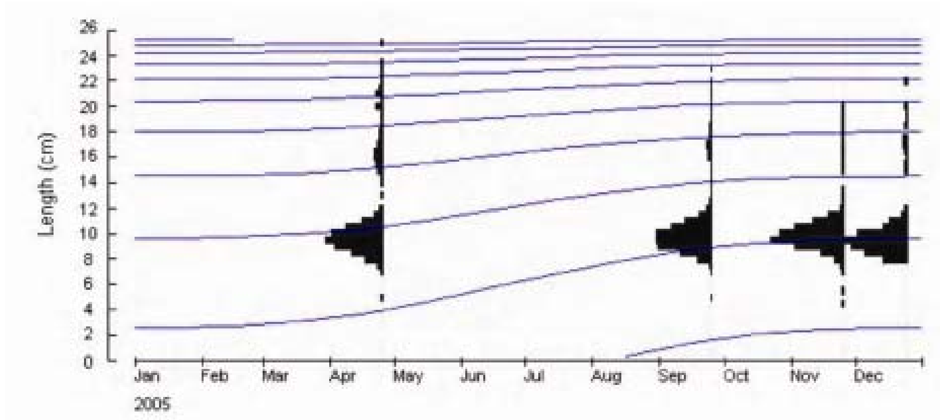

Figure 3.25: *Acanthobrama marmid* ELEFAN I plot and VBGF parameters (L_∞ = 26.25 cm, L_{max} = 25 cm, K = 0.35 and t_0 = -0.3281).

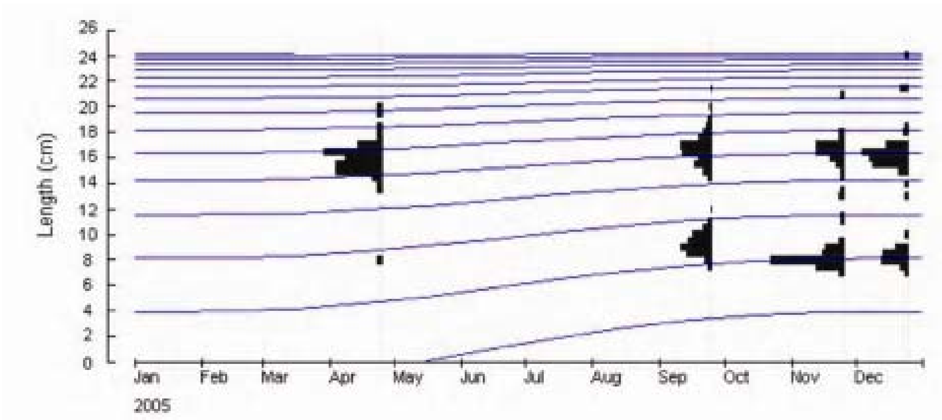

Figure 3.26: *Mugil abu* ELEFAN I plot and VBGF parameters (L_∞ = 25.2 cm, L_{max} = 24 cm, K = 0.22 and t_0 = -0.2662).

3.3 VBGF Growth Curves

The VBGF curves show the growth of fish in length over time. The steeper is the curve; the faster is the growth. The curves give information about growth of four different species namely *A. marmid*, *C. luteus*, *C. mossulensis* and *M. abu* (Figures 3.27 and 3.28).

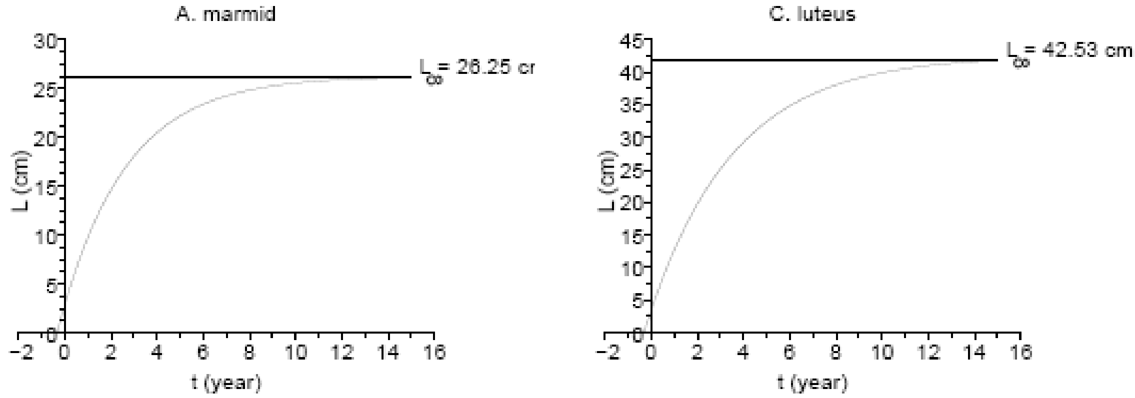

Figure 3.27: curves of *A. marmid* and *C. luteus* based on von Bertalanffy growth function.

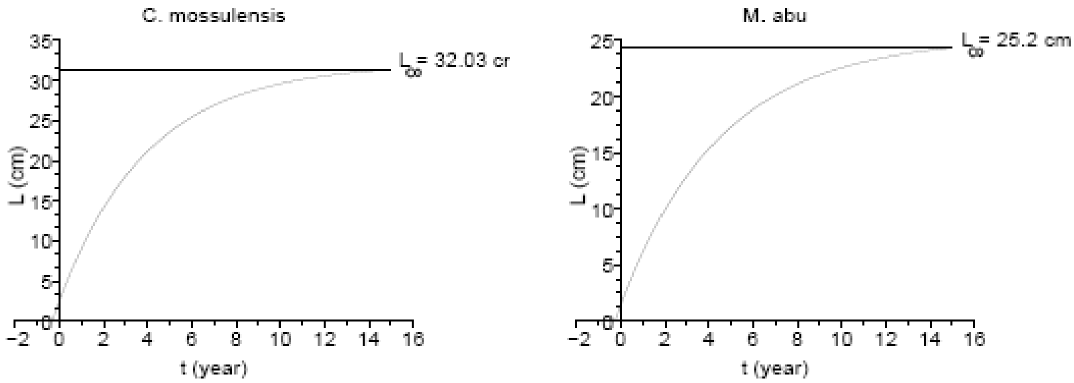

Figure 3.28: Growth curves of *C. mossulensis* and *M. abu* based on von Bertalanffy growth function.

3.4 Yield Curves from Recruitment

Yield curves of the four species of which growth parameters were estimated are shown in Figures 3.29, 3.30, 3.31 and 3.32. The shaded areas in the figures indicate the area of best fishing. The curves are isoyield curves and the corresponding Y/R (Yield per Recruit) value of each curve is shown on the second y-axis. The first y-axis shows t_c (age of first capture) and corresponding l_c (length of first capture) values. On the x-axis the fishing pressure levels are shown. Along each curve, the Y/R is constant and equals to the corresponding values shown in the second y-axis.

In Table 3.5, the variables used in Y/R curves' calculation were listed. The total mortality (Z), fishing mortality (F) and natural mortality (M) were calculated as described in section 2.6. The asymptotic weight (W_∞) was calculated by using length-weight relationships of fishes from L_∞ values obtained by ELEFAN I analysis. As seen in the table, fishing mortalities are so low since fishing in the lake has been legally prohibited since the construction of Atatürk Dam.

Table 3.5: Mortality and W_∞ values of the four fishes used in yield analysis.

Species	Growth Parameters			
	Z ($year^{-1}$)	F ($year^{-1}$)	M ($year^{-1}$)	W_∞(gr)
M.abu	1.0788	0.4972	0.5816	185.93
C. luteus	0.7239	0.1492	0.5747	1046.93
A.marmid	0.8662	0.0870	0.7792	178.8
C. mossulensis	0.7239	0.1325	0.5914	368.04

Analysis of catch data for *Acanthobrama marmid* provided the following parameters; the fishing mortality (F) caused by the illegal fishery was calculated as low as 0.09 for this species, over 90 % of the individuals sampled in the lake was caught by the 22x22 mm knot to knot mesh sized nets. The mean length (l_c) of this species caught by the illegal fishery was calculated as 17.64 cm. The asymptotic weight (W_∞) was estimated to be 178.8 gr by using the length-weight relationship and calculated L_∞ value via ELEFAN I analysis. Based on these findings, the yield per recruit analysis revealed that the yield amount obtained for this species fell in the underfishing zone when the F value is matched to its corresponding l_c in Figure 3.29.

The fishing mortality (F) for *Carasobarbus luteus* was calculated as 0.15. The W_∞ value was estimated as 1046.94 gr based on the length-weight relationship and L_∞ value for this species. *Carasobarbus luteus* was most frequently caught by the 30x30, 40x40 and 50x50 mm mesh sized gill-nets. The mean length for catches of this species was 28 cm. Evaluating these findings, the yield per recruit analysis revealed that the corresponding yield per recruit for F and l_c was about 9 gr (Figure 3.30), concluding that this species was also underfished.

For *Chalcalburnus mossulensis* the calculated F and l_c values were found to be 0.1325 and 20.2 cm respectively. 22x22 mm knot to knot mesh sized nets caught over the 90 % of this species and the mean length of catches was calculated for this mesh sized net. The yield per recruit analysis concluded that with the given F and l_c values, the current yield harvested by the illegal fishery was about 1 gr per recruit. If Figure 3.31 is examined, it is evident that this species was also underfished by the fisheries.

For *Mugil abu*, the F and l_c values were calculated as 0.4972 and l_c was estimated to be 19.52 cm for the nets with 22x22 knot to knot mesh size. The yield calculated for the fishery of this species was found to be 1.3 gr per recruit approximately. Examining the yield isopleth diagram in Figure 3.32, it is to conclude that the current yield per recruit obtained by the fishery of this species was in the underfishing zone.

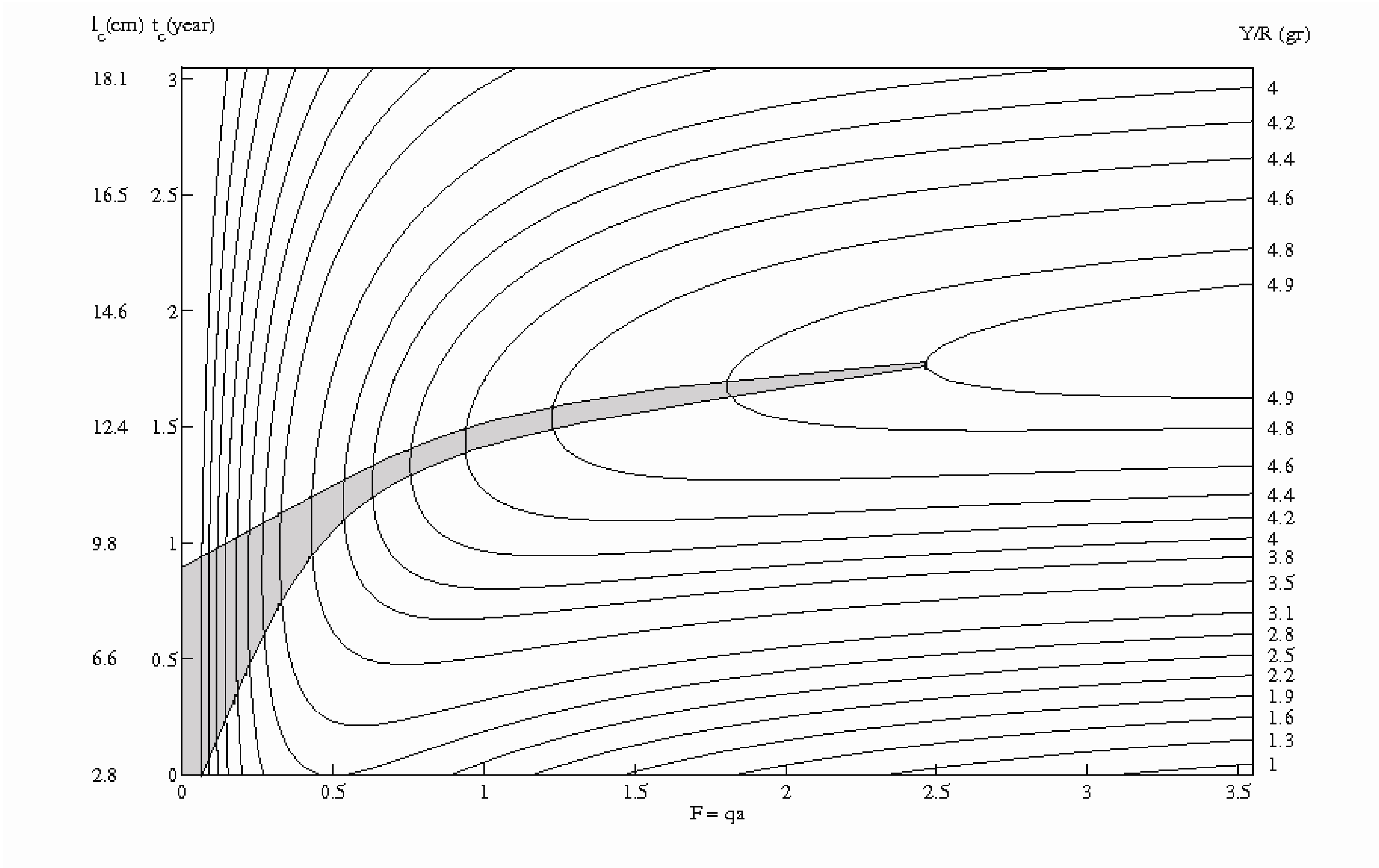

Figure 3.29: Yield curve for *Acanthobrama marmid* (F = 0.087, l_c = 17.64cm).

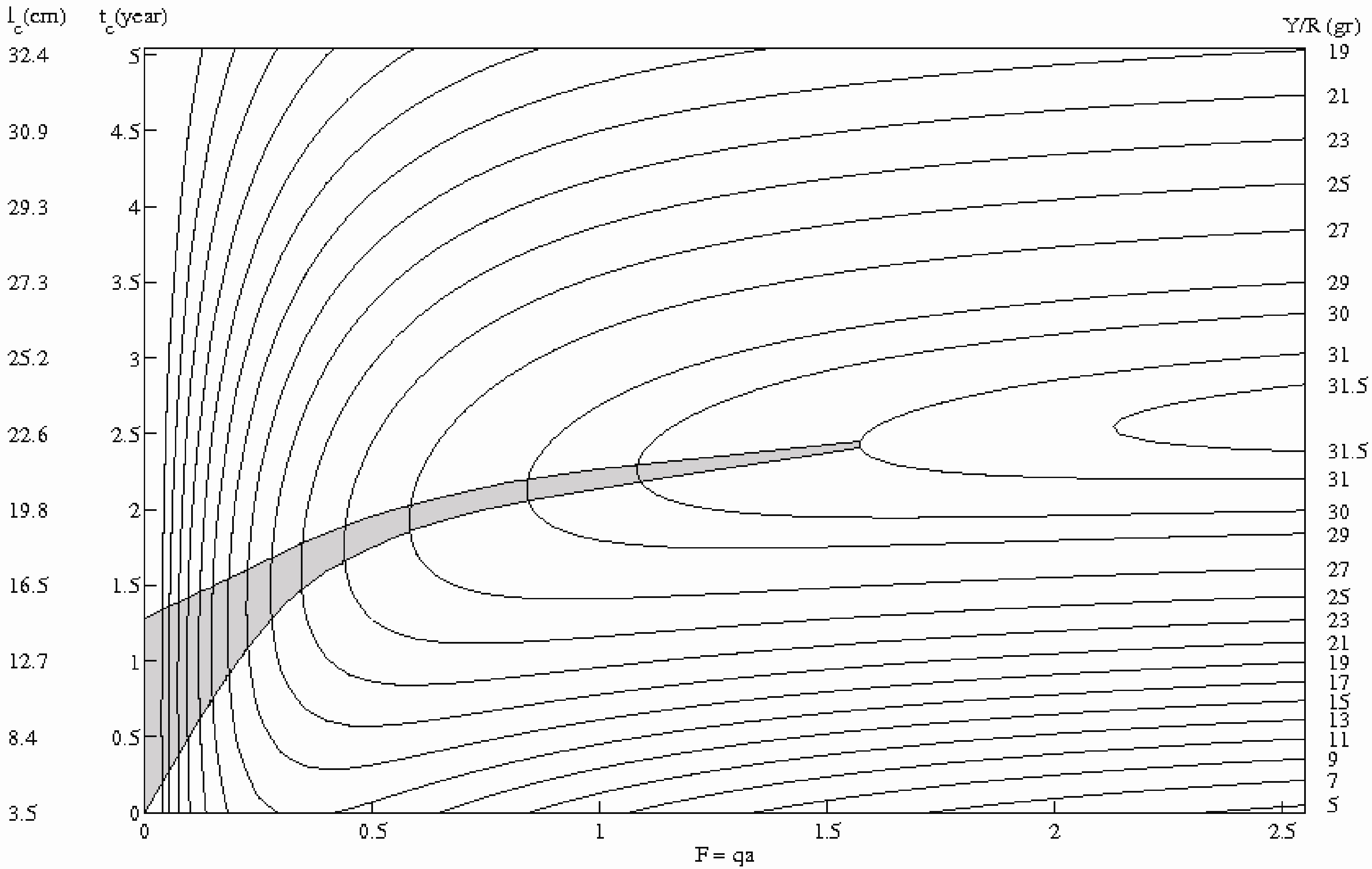

Figure 3.30: Yield curve for *Carasobarbus luteus* (F = 0.1492, l_c = 28.06cm).

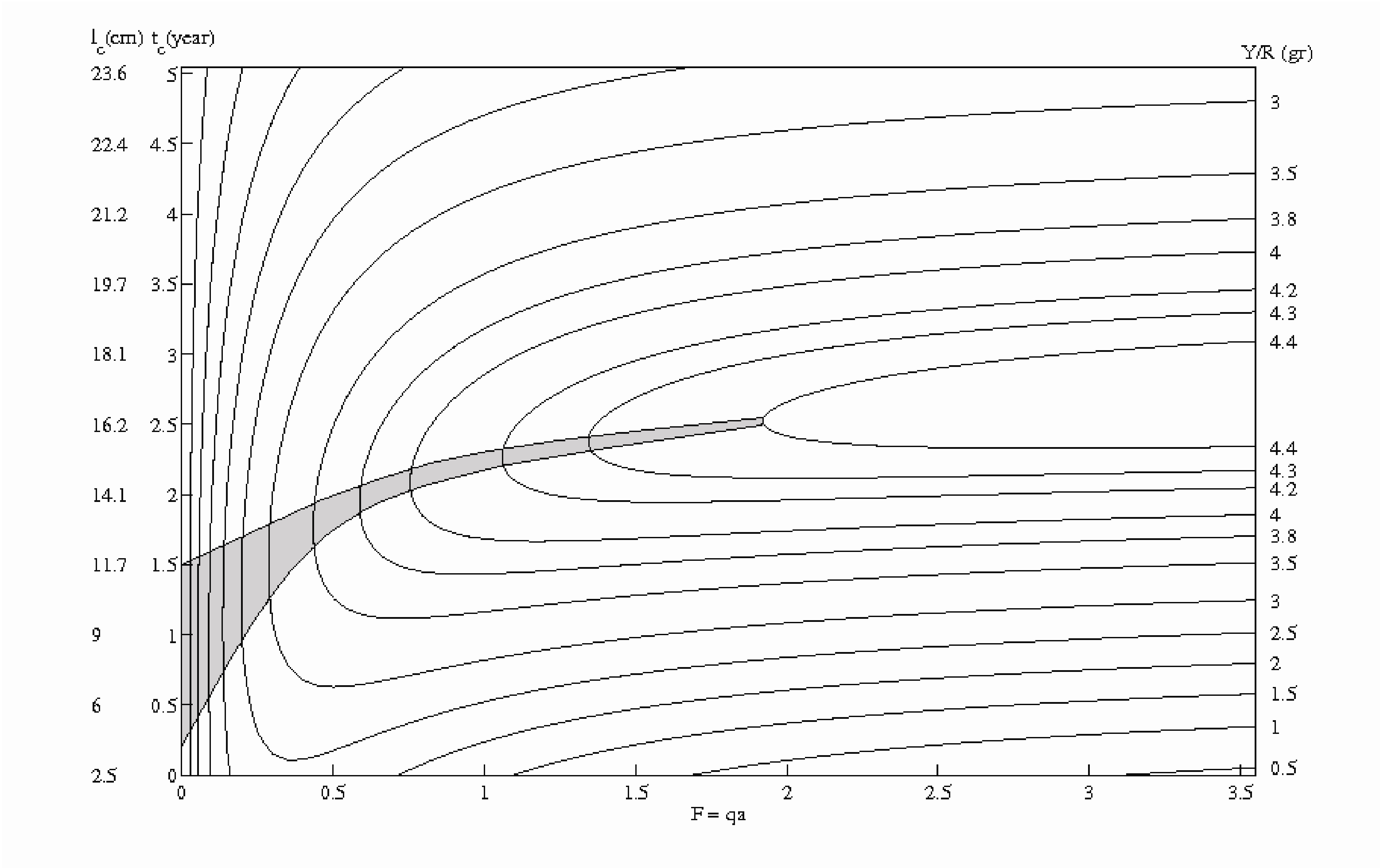

Figure 3.31: Yield curve for *Chalcalburnus mossulensis* (F = 0.1325, l_c = 20.2cm).

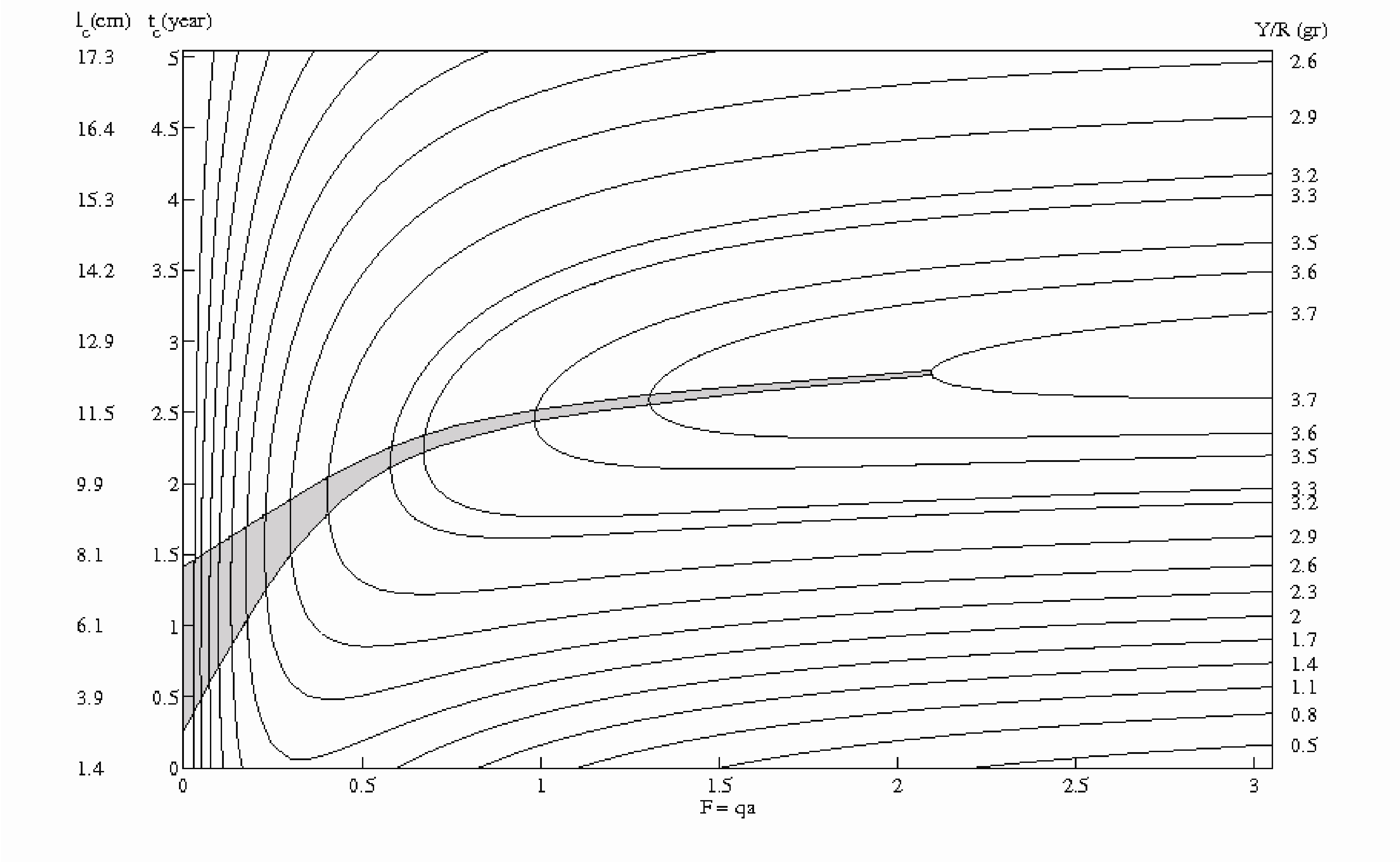

Figure 3.32: Yield curve for *Mugil abu* (F = 0.4972, l_c = 19.52cm).

4 DISCUSSION

4.1 Acoustics

4.1.1 Bathymetry

The examination of the bathymetry of the lake revealed that it is a deep lake and the structure observed in the acoustic echograms showed great variation in terms of elevations making it impossible for sampling with active gears such as trawling.

Before the construction of Atatürk Dam, some villages lied in the area of the lake. After the completion of the dam these villages, farms and remains were flooded by the water from Fırat River. Therefore, it is difficult to apply some conventional fishing methods in the lake such as bottom trawls, beam trawls or dredges. However mid-water trawling and small seine nets might be applicable. On the other hand those sampling gears were not within the scope of this study.

The bathymetric map in Figure 3.1 indicates that the middle part of the lake is deep and below 100 meters. The deep red colored part lying in the middle of the map from west to east is the Fırat River channel. The area surrounding the channel is deeper parts of the lake. The northwestern parts where Akpınar and Bağpınar villages are located are shallow and below 60 meters. Also the Bozova horn is shallow and mostly below 40 meters depth. The channel joining the lake in the mid part is the channel of the Kahta River tributary of Fırat and includes relatively deeper regions.

4.1.2 Distribution of Area Back Scattering Coefficient (s_a)

The s_a frequency distributions were analyzed in order to determine the depth strata. However, it was almost impossible to analyze the whole frequency distributions since millions of pings (acoustical tracks) were present for the whole lake. Therefore, a 5-meter-resolution was selected to constitute the depth strata down to 40 meters in order to provide a better resolution of the fish distribution within the most populated zone by fish. Below 40 meters down to 80 meters was treated as a whole single stratum.

The mean s_a values shown in Figures 3.5, 3.6, 3.7 and 3.8 give information about the fish distribution in the subareas of the lake within the predetermined depth strata. When it is in an increasing trend this means that the fish assemblages density in terms of abundance or biomass increases with increasing depth or vice versa. In the figures it is clear that there was no consistent increasing or decreasing trend in all subareas. In April, the mean s_a values generally showed an increasing trend with increasing depth and then after a certain depth the trend reversed to decreasing, whereas in September this was not the case. In September, it is not possible to derive such kind of generalization for trends. In regions 1, 4 and 6 (Figures 3.7 and 3.8) the mean s_a values decreased with increasing depth. In region 8 (Figure 3.8), it was more or less stable. On the one hand, this may be the result of low coverage of the area by acoustical survey; on the other hand it may be the result of changing behavior of fish species, which was not studied in detail.

4.1.3 Target Strength Distribution

It is understood from the Figures 3.9 and 3.10 that -67 - -54 dB interval constituted a reasonable quantity of the TS distributions. This may be the evidence of small pelagic fishes' presence.

The TS-converted length distributions of fish species (Figures 3.11 and 3.12) showed that the majority of fish was below 20 centimeters length. This is an indication that fish fauna of the lake mainly comprised small sized fishes. The larger fish species were less in quantity. The distribution of the fishes also indicated that the majority of the fish assemblages were confined to the 0 to 20 meters depth layer.

4.1.4 Biomass and Abundance Distributions

The biomass distribution in April (Figure 3.13) is supportive of the TS distribution in the lake. Two fish species namely *C. mossulensis* and *A. marmid* dominated in the biomass with about 18 kg/ha and 10 kg/ha respectively.

In September, the biomass of two small fish species *A. marmid* and *C. mossulensis* was again dominant. C. trutta and C. luteus had also significant biomass values with about 1 kg/ha and 0.8 kg/ha respectively.

The general biomass and abundance distributions throughout the lake shown in Table 3.1 indicated that in April the abundance and biomass values of fish per hectare were 1418 fish/ha and 34 kg/ha respectively. These were significantly higher than the values (628 fish/ha abundance and 10 kg/ha biomass) that was observed in September. The steep decrease in biomass and abundance values between April and September may be attributed to 3 factors:

1. In April, mature fishes may have migrated to the spawning grounds which are shallow and near the shore, therefore contributing higher biomass because inshore areas were covered much more intensely as compared to deeper parts of the lake.

2. For almost all species in the lake, the spawning period occurs in between April and August. Therefore, in September, spent fishes may have migrated back to deeper depths in the middle part of the lake, which was acoustically less surveyed to optimize the cruise time. This may have caused lower biomass and abundance values.

3. High abundance of recently born small fishes contributed to the biomass in a marginal quantity but their contribution to abundance was higher and thus, the abundance values did not show a steep decrease as compared to the biomass values.

4.2 Temperature Profiles

The temperature profiles indicated that there was stratification in the lake both in April and September (Figures 3.15 and 3.16). When the profiles are compared with the vertical distribution of fish species, it is concluded that the fish assemblages were mostly found within and above the thermocline layer at depths of 20 meters both in April and September.

4.3 Gill-net Sampling

Catch composition of gill-net samplings is not an estimator of fish biomass and abundance in the lake without the acoustical results since gill-net samplings were applied in a limited number of stations and only down to a depth of 20 meters. For this reason, the catch results presented here are only a primitive estimator of the composition of fish assemblages.

The gill-net catch abundance distributions are shown in Table 3.2. It is evident that fish abundance in gill-net catches was dominated by *A. marmid*. *C. mossulensis* followed that species both in April and December. In September and November, the contributions of other species were more or less the same. This situation again indicates that small pelagic fishes dominated in the lake.

In November and December, gill-net sampling was applied much less in frequency, only in 4 stations each month, as compared to April and September. But it is obvious that the composition of abundance distributions in these months showed similarity with the results obtained in April and September.

The gill-net catch compositions in biomass are shown in Table 3.3. The biomass distributions indicated that *C. trutta* dominated in the catches in terms of biomass in April, September and December. In September and December it was followed by *C. mossulensis* and in April by *A.marmid*. In November the dominating species was *C. luteus* and it was followed by *A. marmid.*

The catch per unit effort (CPUE) values can be used to make estimations about the fishing mortality and the density of exploited stock (Gulland, 1975). However, since fishing is forbidden in the Atatürk Dam Lake, there are no data available according to the fisheries in this aspect. Although illegal fishery has been present since the first construction of the dam, the research in this area is very limited. Therefore, the CPUE values calculated in this study as 1.312 gr fish / hour / m^2 of net area for April and 1.56, 1.22, 0.86 gr fish / hour / m^2 of net area for September, November and December respectively were given for reference only.

4.3.1 Length-weight Relationships

The length weight relationships for the fish species which were abundant enough to constitute a regression analysis is shown in Table 3.4. The regression analysis was applied seasonally but in this section, only the values which belonged to the highest sample sizes were used to compare with different findings in various studies.

The functional regression value b = 3 describes isometric growth, characterizing a fish having an unchanged body form and specific gravity. If "b" values are greater or less than 3, this condition is described as allometric growth, which is the inverse case of isometry in growth (Ricker, 1975).

The analysis of length weight relationships for each species caught in each sampling station was carried out separately in order to determine whether the different sampled groups of the same species in each station belonged to the same population. The presence of differences in the length-weight relationships of the same species in discrete areas are an indicator of the presence of different populations because feeding and nutritional conditions vary between different groups of the same species. In this study, the analyses of length-weight data according to the statistical routine proposed by Zar (1984) showed that there were no significant differences between different sampled groups of each species, and hence, indicated that all belonged to the same feeding and nutritional condition.

The findings in this study were compared with various findings from different studies carried out in the same Tigris - Euphrates basin. It is anticipated that the length-weight relationships of different groups of fish would be different. Since the findings from different studies of different populations of the same species will vary, the presented relationships form various authors below were given in order to compare the different nutritional conditions between different stocks of the same species in the same basin.

The length weight relationships of fish species studied here and that whose data could be found within the adjacent area (in the Middle East) were summarized in Table 4.1.

Table 4.1: Length-weight relationships of *Mugil abu*, *Carasobarbus luteus*, *Acanthobrama marmid, Clacalburnus mossulensis, Cyprinion macrostomus* and *Capoeta trutta* in various studies.

Author	Sex	a	b	Region
Mugil abu				
Al-Yamour et al. (1988)	♂♀	0.034	2.6	Al-Daoodi Drain, Baghdad
Al-Shamma'a & Jasim (1993, c.f. URL 2, 2007)	♂♀	0.009	3.119	Tigris River, Iraq
This study	♂♀	0.006	3.187	Atatürk Dam Lake
Carasobarbus luteus				
Esmaeili & Ebrahimi (2006)		0.0232	3.036	Iran
Al Hazzaa (2005)	♀	0.013	3.05	Euphrates River, Syria
	♂	0.019	2.98	Euphrates River, Syria
Başusta et al. (2006)	♂♀	0.01265	2.97	Atatürk Dam Lake
This study	♂♀	0.008	3.103	Atatürk Dam Lake
Acanthobrama marmid				
Aydın et al. (1995)	♂♀	0.004	3.19	Atatürk Dam Lake
Younis et al. (2001)	♂♀	0.0219	2.32	Iraq
Başusta and Çiçek (2006)	♂♀	0.00563	3.168	Atatürk Dam Lake
This study	♂♀	0.007	3.037	Atatürk Dam Lake
Chalcalburnus mossulensis				
Yıldırım et. al. (2003)	♂	0.0129	2.913	Karasu River, Erzurum
	♀	0.073	3.136	
Turkmen et al. (2000)	♂	0.0162	2.828	Karasu River, Erzurum
	♀	0.0081	3.082	
Başusta and Çiçek (2006)	♂♀	0.00395	3.313	Atatürk Dam Lake
This study	♂♀	0.003	3.38	Atatürk Dam Lake
Cyprinion macrostomus				
URL 2 (2007)	♂♀	0.027	2.67	Al-Nibaey Lakes, Baghdad
This study	♂♀	0.006	3.177	Atatürk Dam Lake
Capoeta trutta				
Başusta and Çiçek (2006)	♂♀	0.00307	3.335	Atatürk Dam Lake
This study	♂♀	0.243	2.047	Atatürk Dam Lake

As seen in Table 4.1, within each species, the Fulton's condition factors show differences indicating different feeding conditions. Generally, the condition factors of the species studied are smaller in the Atatürk Dam Lake as compared to other regions, implying that the nutritional conditions for these fish species in the lake are not just favorable. This might be one fact. However another (the most important) fact is the seasons (sampling period) of the studies. It is well known that food supply is changing between seasons. Furthermore, the physiological stage of the individuals may also significantly affect the condition. Short after spawning, individuals of the parent population may display low condition than at other periods. Since the studies refferred above were carried out in different times of the year, the condition factors are not directly comparable.

4.3.2 Growth Constants

The study of growth is the determination of the body size as a function of time (age). Therefore all stock assessment methods work with age composition data. In temperate waters such data can be obtained via the counting of annual rings on scales and otoliths since these rings are formed due to strong changes in the physiology of organisms and fluctuations in environmental conditions. However, in tropical areas changes in environmental parameters are not significant and hence annual rings do not always successfully occur. Since the annuality of the ring formation in the Atatürk Dam Lake was not studied and the techniques require long lasting work until remarkable results obtained, it is decided to utilize seasonalized length frequency techniques as presented in Sparre et. al., (1989).

In this study, the growth constants of *Chalcalburnus mossulensis* was found as L_∞ = 32.03 cm, K = 0.25 and t_0 = -0.3235. The maximum length observed in the catches was 30.5 cm. In another study carried out by Ergene (1993) in Karasu River in Turkey, it was found that there were 4 age groups present for this species in the study area. Ergene (1993) found 22 centimeters for maximum length for this species. In another study in Karasu River in Erzurum growth parameters of the species was studied (Türkmen and Akyurt, 2000). The method used by Türkmen et al. (2000) for calculation of von Bertalanffy growth parameters was length at age data. The L_∞

found in this study was higher than findings of Turkmen and Akyurt (2000). The K values are similar. Yıldırım et. al. (2003) studied this species in Karasu River. They used age length keys to calculate VBGF parameters. The results of the studies of Türkmen and Akyurt (2000) and Yıldırım et al. (2003) are summarized in Table 4.3.

Table 4.2: Growth parameters of *C. mossulensis* in various studies

Author	**Sex**	**L_∞ (cm)**	**K**	**t_0**
Türkmen and	♂	20.41	0.2485	-1.47
Akyurt (2000)	♀	21.59	0.1978	-2.19
Yıldırım	♂	19.88	0.187	-2.3
et. al (2003)	♀	21.87	0.169	-2.1
This study	♂♀	32.03	0.25	-0.32

The growth constants of *Carasobarbus luteus* was found as L_∞ = 42.53 cm, K = 0.27 and t_0 = -0.3152. The maximum length was 40.5 cm. This species was also studied Ahmed (1982) and reported a maximum length of 38 centimeters.

Hazzaa (2005) investigated the growth of this species in Tigris River in Syria and found that L_∞ = 54.71 cm, K = 0.11, t_0 = -0.163 for males and L_∞ = 56.93 cm, K = 0.105, t_0 = -0.377 for females. Hazzaa (2005) calculated the von Bertalanffy growth parameters via Ford-Walford Method whereas in this study ELEFAN I analysis was used. The calculated VBGF parameters show differences either because of different methodologies were used or direct age readings were not present in this study.

The results found in this study for *Acanthobrama marmid* were 26.25 cm for L_∞, 0.35 for K and -0.3281 for t_0. This fish was previously studied in Keban Dam Lake. Its maximum reported length is 21.1 centimeters by Aydın et. al. (1995). In this study, the maximum length was found to be 25 centimeters. Çolak (1982) found K = 0.27, L_∞ = 29.34 cm, t_0 = -1.674 for 1+ year old fish and K = 0.579, L_∞ = 25.55 cm and t_0 = -0.551 for 2+ age groups in Keban Dam Lake. L_∞ value calculated in this study was similar to Çolak (1982)'s findings.

Mugil abu was found to have a K value of 0.22 and L_∞ was 25.2 cm. The t_0 value was found as -0.2662. The maximum length observed in the catches was 24 cm.

4.3.3 Yield Isopleth Diagrams

The yield curve for *Acanthobrama marmid* is shown in Figure 3.29. In this figure the point where F and corresponding mean length (l_c) value coincide is in the underfishing zone. The maximum optimum yield which can be obtained for this species was 4.9 gr per recruit. However, in order to harvest this yield per recruit the fishing pressure should be increased about 3 times.

Examining the yield curve of *Carasobarbus luteus* in Figure 3.30, it can be understood that the mean length caught by fishery fall into the underfishing zone with the given F value. To reach optimum fishery, the effort should be raised 10 times more than the current value.

Examining the Figure 3.31, it can easily be seen that the fisheries fall in the underfishing zone for *Chalcalburnus mossulensis*. However, a yield at around 4.2 gr per recruit can be obtained for the fisheries if the fisheries reach a value at around 1.

For *Mugil abu* again the yield falls in the underfishing zone for the fisheries in the lake (see Figure 3.32). A yield of 3 gr per recruit can be obtained for this species without changing the situation the fisheries of this species.

For all of the fishes mentioned in this section, it is possible to obtain better amounts of yield per recruit either by empowering or regulating the fisheries. The yield per recruit amount may increase if the fishing in the lake is permitted. However, first of all, the question whether permitting fishing in the lake would be wise to recommend should be answered. The answer to this question is simple; no. The reasons for this can be given as follows:

Application of well-regulated fisheries to obtain economical profit may be applicable for a lake ecosystem that is in balance within its all trophic levels. However, in dam lakes these balances mostly occur differently. The Atatürk Dam Lake is a relatively young and artificial reservoir which has its roots in terrestrial environmental character. The biomass and size distributions of the fishes indicate that the fish fauna of the lake is mostly comprised of small sized planktivorous fish species of which lengths are below 20 cm. The overpopulation of small sized individuals is an indicator of absence of larger predators of these fishes. Absence of predatory fish indicates that the fishery ecosystem, in other words, the dam ecosystem is not mature. Therefore, considering the present situation of the lake's ecosystem, it is strongly advised to continue the fishing ban until the ecosystem structure is well developed and reach its balance. Since it is hard to speculate a certain time for the lake's sustaining this balance, similar studies should be reimplemented before opening the lake for utilization for fishing purposes.

5 CONCLUSION

This study is the first work investigating the fish stocks' current situation in the Atatürk Dam Lake as a whole. The stock sizes and biological characteristics of the fish species were studied. It was found out that there are 16 fish species present in the dam lake. The biomasses of fishes in the lake in April 2005 and September, 2005 were estimated to be 34 kg/ha and 10 kg/ha respectively. *Acanthobrama marmid* and *Chalcalburnus mossulensis* were found to be the most populated fish species in the lake. The fish assemblages were mostly confined to upper 20 meters depth layer and consisted of small sized individuals mostly below 20 cm in length.

Yield per recruit analysis of *Acanthobrama marmid*, *Chalcalburnus mossulensis*, *Carasobarbus luteus* and *Mugil abu* revealed that these species are underfished by the illegal fishery carried out by the local people in the lake. Some management measures were proposed in order to obtain better yield amounts from the fishery of these species, however, considering the current situation of the balance of the lake's ecosystem; it is strongly advised to continue the fishing ban until the lake's ecosystem reaches a mature state. Once this balance is reached in the lake, similar studies should be carried out again to investigate the situation of the fish stocks and to develop new management measures pertaining to that new situation.

The Atatürk Dam Lake bears a potential for fisheries and if management measures taken in advance, the economical profits that fisheries will bring to the local community will be high. The findings of this study provided some important data about the current situation of the fish stocks in the lake, thus, providing a background for the management measures for the fisheries.

Further, this study has also led to a computer program written in MATLAB programming language for the processing of acoustical records of fishes obtained in the field. A more sensitive algorithm was also developed for bottom tracking of acoustical records as compared to the available commercial software in this field. By this way, the time required to post-process the acoustical records in order to successfully separate the false bottom echoes from the fish echoes would be much less.

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APPENDICES

Appendix A: Source Code of Bathymetry Data Extraction Script from SIMRAD EY500 Telegrams

```
flag1='GL';
flag2='D1';
[a b] = fileparts('/September/0');
c = str2num(b);
% begin to define filename
while c <= 148;
c = c + 1
if c < 10;
d = num2str(c);
e = ['0' '0' d];
elseif 9 < c < 100;
d = num2str(c);
e = ['0' d];
end
if c > 99;
d = num2str(c);
e = d;
end
%end filename definition
f = fullfile(a,e);
fid = fopen(f, 'rt');
fid2 = fopen('/home/skipper/Desktop/Bathymetry.txt',        'a+');
while feof(fid) == 0;
        GPS = fgetl(fid);
%search for GPS data
```

```
A = findstr(GPS, flag1);
n1 = length(A);
n0 = length(GPS);
if (n1 > 0) && (n0 == 34);
        DEPTH = fgetl(fid);
B = findstr(DEPTH, flag2);
n2 = length(B);
if n2 > 0;
D = DEPTH(13:18);
% get depth value
DEPTHFIN1 = str2double(D);
DEPTHFIN = DEPTHFIN1 - 0;
if DEPTHFIN > 0;
\begin GPS data extraction
        X1 = GPS(13:14);
X2 = GPS(15:20);
Y1 = GPS(24:26);
Y2 = GPS(27:32);
%end GPS data extraction
LAT1 = str2double(X1);
LAT2 = str2double(X2);
LONG1 = str2double(Y1);
LONG2 = str2double(Y2);
LAT = LAT1 + (LAT2/60);
LONG = LONG1 + (LONG2/60);
% print to file
fprintf(fid2,'%2.5f\t',LAT);
fprintf(fid2,'%3.5f\t',LONG);
fprintf(fid2,'%2.2f\n',DEPTHFIN); %end print to file
end
end
elseif (n1 > 0) && (n0 == 39); DEPTH = fgetl(fid);
B = findstr(DEPTH, flag2);
n2 = length(B);
```

```
if n2 > 0;
D = DEPTH(13:18);
DEPTHFIN1 = str2double(D);
DEPTHFIN = DEPTHFIN1 - 0;
if DEPTHFIN > 0;
X1 = GPS(20:21);
X2 = GPS(22:27);
Y1 = GPS(31:33);
Y2 = GPS(34:39);
LAT1 = str2double(X1);
LAT2 = str2double(X2);
LONG1 = str2double(Y1);
LONG2 = str2double(Y2);
LAT = LAT1 + (LAT2/60);
LONG = LONG1 + (LONG2/60);
fprintf(fid2,'%2.5f\t',LAT);
fprintf(fid2,'%3.5f\t',LONG);
fprintf(fid2,'%2.2f\n',DEPTHFIN);
end
end
else
end
end
end
fclose(fid);
fclose(fid2);
```

Appendix B: Source Code of Acoustic Post-processing Program

```
file_path = input('Please enter the file path of your ...
SIMRAD EY500 ascii telegrams \nex. /home/user/files/: ','s');
file_range = input('Please enter the name range, \nwith a ...
comma in between the numbers,\nwhich you want the program to read ... ex. 1,13:
','s');
file_parts = fileparts(file_path);
file_range = textscan(file_range,'%d %d','delimiter',',');
fidout = fopen('/home/ea/Desktop/213Samiles','a+');
% open new file for writing and each time append to the end        of        the
        file
start = file_range{1};
stop = file_range{2};
for t = start:stop

if t < 10
% if loop counter is smaller than 10 d = num2str(t);
e = ['0' '0' d];
% append 2 zeros before the number to construct filename elseif 9 < t < 100
% if loop counter is in between 9 and 100 d = num2str(t);
e = ['0' d];
% append 1 zero before the number to construct filename
end
if t > 99
% if loop counter is bigger than 99
d = num2str(t);

e = d;
end
full_file = fullfile(file_parts,e);
fid = fopen(full_file,'r');
fprintf('%s %s\n',full_file,...
```

```
' tagged file is being read...');
 % do nothing
% construct full filename
% open file for reading as text
% write the process step to screen


M = textread(full_file,'%s','bufsize',100000095,'whitespace',''); M = char(M);
f_Q1 = findstr('Q1',M);
f_GL = findstr('GL',M);
clear M;
NO_OF_AVAILABLE_MODULES = length(f_Q1); NO_OF_GL = length(f_GL);
PROCESSED = 0;
MISSING_GPS = 0;
NO_ECHO_VALUE = 0;
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE =          0;
while feof(fid) == 0;
% till the end of file...
LINE = fgetl(fid);
% get one line from file
SEEKGL = findstr(LINE,'GL');
% search for string 'GL' in LINE
if isempty(SEEKGL) == 0
% if 'GL' is found
WE = strcmp(LINE(end),'E');
% determine if the character at the end of the          line     is        'E'
if WE == 1
% if the character at the end of the     line     is        'E'
LATLONGSTR = textscan(LINE,...
'%*s %*d %s %*s %s %*s',...
'delimiter',',');
% use this format to read the line
else
% if the character at the end of the     line     is        something       else
```

```
LATLONGSTR = textscan(LINE,...
'%*s %*d %*d %s %*s %s',...
'delimiter',',');
% use this format to read the line
end
GPS1 = cellstr(LATLONGSTR{1});
GPS1 = char(GPS1);
GPS2 = cellstr(LATLONGSTR{2});
GPS2 = char(GPS2);
if length(GPS2) < 3
MISSING_GPS = MISSING_GPS + 1;
continue
end

LATINT = str2num(GPS1(1:2));
% separate digits of latitude for conversion LATDEC = str2num(GPS1(3:end));
% separate digits of latitude for conversion LAT = LATINT + LATDEC/60;
% conversion equation for latitude*
LONGINT = str2num(GPS2(2:3));
% separate digits of longitude for conversion LONGDEC = str2num(GPS2(4:end));
% separate digits of longitude for conversion LONG = LONGINT + LONGDEC/60;
% conversion equation for longitude*


if feof(fid) == 1
break
end
LINE = fgetl(fid);

% get another line from file starting from where
SEEKQ1 = findstr(LINE,'Q1');
% search for string 'Q1' in LINE
SEEKGL = findstr(LINE,'GL');
POSITION3 = ftell(fid);
```

```
while isempty(SEEKQ1) && isempty(SEEKGL) % till string ’Q1’ is found in line...
if feof(fid) == 1
break
end

LINE = fgetl(fid);
% get another line from file starting from where
SEEKQ1 = findstr(LINE,’Q1’);
% search for string ’Q1’ in LINE
SEEKGL = findstr(LINE,’GL’);
end
POSITION4 = ftell(fid);
if feof(fid) == 1
break
end
if isempty(SEEKQ1)
fseek(fid,POSITION3-POSITION4,’cof’); continue
end
SV = textscan(LINE,...
’%*s %*d %s %f’,...
’delimiter’,’,’);
% use this format to read the line
TSVSSV = strcmp(’Sv’,SV{1});
% determine if SV{1} matches the string ’Sv’
last ’fgetl’ command left off
last ’fgetl’ command left off

DEPTH1 = -SV{2};
% set depth*
DEPTH =((20-DEPTH1)-((20-DEPTH1)...
^0.965))+DEPTH1;
% clean the false bottom risk area from depth
if TSVSSV == 1 && DEPTH < -4
```

```
% check if echogram values are of type Sv and DEPTH is smaller than 0 LINE =
fgetl(fid);
 % get another line from file starting from where last
PELAGIC = textscan(LINE,...
'%s %f %f',...
'delimiter',',');
% use this format to read the line
MAINRANGESTART = char(PELAGIC{1});
% read starting depth of main echogram range MAINRANGESTART =
str2num(MAINRANGESTART(12:end)); ECHOGRAMVALUES = PELAGIC{3};
% read number of echogram values
MAINRANGESTOP = PELAGIC{2};
% read end depth of main echogram range


if ECHOGRAMVALUES > 0
% check if echogram values are present

LINE = fgetl(fid);
% skip one line to the begining of echogram values
MATRIX = [];

if ECHOGRAMVALUES == 250
% if number of echogram values is 250 do: for counter = 1:41
MATRIX = [MATRIX fgetl(fid)];
% read 41 lines
end
elseif ECHOGRAMVALUES == 500
% if number of echogram values is 500 do: for counter = 1:69
'fgetl' command left off
 MATRIX = [MATRIX fgetl(fid)];
% read 69 lines
end
else
```

```
% if number of echogram values is 700 do: for counter = 1:94
MATRIX = [MATRIX fgetl(fid)];
% read 94 lines
end
end
MATRIX = textscan(MATRIX,'%f','delimiter',','); % use this format to read the echogram matrix MATRIX = cell2mat(MATRIX);
% convert cell matrix into double matrix
STEPSIZE = MAINRANGESTOP/ECHOGRAMVALUES;
% depth interval between each echogram value points BOTTOMVALUE = ceil(abs((DEPTH+...
MAINRANGESTART)/STEPSIZE));
% order of the last value of the pelagic screen
if BOTTOMVALUE < length(MATRIX)
if MATRIX(BOTTOMVALUE) > -25;
% removal of side-loop effects.
while MATRIX(BOTTOMVALUE) < MATRIX(BOTTOMVALUE-1);
% as long as this condition is true do:
BOTTOMVALUE = (BOTTOMVALUE-1);
% substract 1 from BOTTOMVALUE
end
while MATRIX(BOTTOMVALUE) > MATRIX(BOTTOMVALUE-1);
% as long as this condition is true do:
BOTTOMVALUE = (BOTTOMVALUE-1);
% substract 1 from BOTTOMVALUE
end
end
else
BOTTOMVALUE = length(MATRIX);
end
SURFACEVALUE = ceil(4/STEPSIZE);
MATRIX = MATRIX(SURFACEVALUE:BOTTOMVALUE); % truncated MATRIX, bottom excluded
MATRIX(find(MATRIX > -25)) = NaN;
```

```
% replace MATRIX values bigger than -25 with      NaN MATRIX =
MATRIX(~isnan(MATRIX));
% remove NaN elements in MATRIX
MATRIX = ((10.^(MATRIX./10))*...
(1852^2)*(4*pi)*STEPSIZE);
% linearize the dB logarithmic scale RESULTING = sum(MATRIX);
% find sum of matrix elements
fprintf(fidout,'%f %f %f %f\n',LAT,LONG,... DEPTH1,RESULTING);
% print results to file


PROCESSED = PROCESSED + 1;


if feof(fid) == 1
break
end


LINE = fgetl(fid);
SEEKQ1 = findstr(LINE,'Q1');
SEEKGL = findstr(LINE,'GL');
POSITION1 = ftell(fid);
while isempty(SEEKQ1) && isempty(SEEKGL)


if feof(fid) == 1
break
end

LINE = fgetl(fid);
SEEKQ1 = findstr(LINE,'Q1');
SEEKGL = findstr(LINE,'GL');
end
```

```
POSITION2 = ftell(fid);
if feof(fid) == 1
break

end
if isempty(SEEKQ1)
fseek(fid,POSITION1-POSITION2,'cof'); continue
end

SV = textscan(LINE,...
'%*s %*d %s %f',...
'delimiter',',');
% use this format to read the line
TSVSSV = strcmp('Sv',SV{1});
% determine if SV{1} matches the string 'Sv' DEPTH1 = -SV{2};
% set depth*

DEPTH =((20-DEPTH1)-((20-DEPTH1)...
^0.965))+DEPTH1;
% clean the false bottom risk area from depth
if TSVSSV == 1 && DEPTH < -4
% check if echogram values are of type Sv and DEPTH      is        smallerthan     0
LINE = fgetl(fid);
% get another line from file starting from where last 'fgetl'  command       left      off
PELAGIC = textscan(LINE,...
'%s %f %f',...
'delimiter',',');
% use this format to read the line
MAINRANGESTART = char(PELAGIC{1});
% read starting depth of main echogram range
MAINRANGESTART = str2num(MAINRANGESTART(12:end));
ECHOGRAMVALUES = PELAGIC{3};
% read number of echogram values
MAINRANGESTOP = PELAGIC{2};
```

```
% read end depth of main echogram range
if ECHOGRAMVALUES > 0
% check if echogram values are present
LINE = fgetl(fid);
% skip one line to the begining of echogram values
MATRIX = [];


if ECHOGRAMVALUES == 250
% if number of echogram values      is      250     do:
for counter = 1:41
MATRIX = [MATRIX fgetl(fid)];
% read 41 lines
end
elseif ECHOGRAMVALUES == 500
% if number of echogram values      is      500     do:
for counter = 1:69
MATRIX = [MATRIX fgetl(fid)];
% read 69 lines
end
else
% if number of echogram values      is      700     do:
for counter = 1:94
MATRIX = [MATRIX fgetl(fid)];
% read 94 lines
end
end

MATRIX = textscan(MATRIX,'%f','delimiter',','); % use this format to read the
echogram matrix MATRIX = cell2mat(MATRIX);
% convert cell matrix into double matrix
STEPSIZE = MAINRANGESTOP/ECHOGRAMVALUES;
% depth interval between each echogram value points BOTTOMVALUE =
ceil(abs((DEPTH+...
```

```
MAINRANGESTART)/STEPSIZE));
% order of the last value of the pelagic screen
if BOTTOMVALUE < length(MATRIX)
if MATRIX(BOTTOMVALUE) > -25;
% removal of side-loop effects.
while MATRIX(BOTTOMVALUE) < MATRIX(BOTTOMVALUE-1); % as long
as this condition is true do:
BOTTOMVALUE = (BOTTOMVALUE-1);
% substract 1 from BOTTOMVALUE
end
while MATRIX(BOTTOMVALUE) > MATRIX(BOTTOMVALUE-1);
% as long as this condition is true do:
BOTTOMVALUE = (BOTTOMVALUE-1);
% substract 1 from BOTTOMVALUE
end
end
else
BOTTOMVALUE = length(MATRIX);
end


SURFACEVALUE = ceil(4/STEPSIZE);
MATRIX = MATRIX(SURFACEVALUE:BOTTOMVALUE); % truncated
MATRIX, bottom excluded
MATRIX(find(MATRIX > -25)) = NaN;
% replace MATRIX values bigger than -25 with      NaN MATRIX =
MATRIX(~isnan(MATRIX));
% remove NaN elements in MATRIX
MATRIX = ((10.^(MATRIX./10))*...
(1852^2)*(4*pi)*STEPSIZE);
% linearize the dB logarithmic scale RESULTING = sum(MATRIX);
% find sum of matrix elements
PROCESSED = PROCESSED + 1;

fprintf(fidout,'%f %f %f %f\n',LAT,LONG,... DEPTH1,RESULTING);
```

```
% print results to file
else
NO_ECHO_VALUE = NO_ECHO_VALUE + 1;
end
else
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE = ...
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE + 1;
end
else
NO_ECHO_VALUE = NO_ECHO_VALUE + 1;
end
else
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE = ...
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE + 1;
end
end
end
TOTAL = PROCESSED + MISSING_GPS + NO_ECHO_VALUE + ...
TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE;
sprintf('NO_OF_AVAILABLE_MODULES = %d\nNO_OF_GL = ...
%d\nPROCESSED = %d\nMISSING_GPS = %d\nNO_ECHO_VALUE = ...
%d\nTS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE = %d\nTOTAL = ...
%d',NO_OF_AVAILABLE_MODULES,NO_OF_GL,PROCESSED,MISSING_GP
S,...
NO_ECHO_VALUE,TS_OR_DEPTH_BIGGER_THAN_CRITICAL_RANGE,TO
TAL)
end
```