EVALUATION OF THE DEMERSAL FISH ASSEMBLAGES OF THE NORTHEASTERN LEVANT SEA

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Approval of the Graduate School of Marine Sciences

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ABSTRACT

EVALUATION OF THE DEMERSAL FISH ASSEMBLAGES OF THE NORTHEASTERN LEVANT SEA

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Ecosystem-level changes have taken place in the Mediterranean Sea over the last decades due to both anthropogenic interferences and natural perturbations. Compared to the western Mediterranean Sea, influences of these factors especially on flora and fauna characteristics are much more dramatic and intense in the eastern part, particularly in the northeastern Levant Sea where the study area is located. In this study, life history traits of some core species (both native and immigrant) occupying the continental shelf of the northeastern Levant Sea were studied in this changing ecosystem to improve limited ecological understanding of the demersal fish assemblages of the northeastern Levant Sea. For this purpose, the annual patterns in allocation and utilization of energy in demersal fish species, temporal and bathymetrical trends in fish distribution with respect to biological requirements of the species and strategies adapted by the species in growth, reproduction and energy storage were investigated by examining growth parameters, biological indices and abundance and biomass variations. Influences of environmental variables on spatiotemporal distribution and biological characteristic of *Mullus barbatus* were also explored by generalized additive models. Biological data were collected at monthly intervals between May 2007 and May 2010 by trawl sampling while sample collection of environmental variables (temperature and salinity) was performed from December 2008 to May 2010. Results of this study reveal that the components of the demersal fish assemblage in the region fulfill their biological activities within a short period of time when the highest productivity is reached in the area. Moreover, results indicate that within this short period of time, some native components of the demersal fish assemblages studied (*Mullus barbatus* and *Pagellus erythrinus*) exhibit strategies such as fast growth, early maturation, short reproduction season, secondary spawners to cope with the environmental peculiarities. On the other hand, the successful exotic colonizers develop strategies as well but these successful immigrants also use time (*Lagocephalus suezensis*) and space (depth) (*Upeneus pori*) slot that the native species avoid. In some of the species examined (*Mullus barbatus* and *Lagocephalus suezensis*), growth is fast, sexual maturity is early, reproduction period is short, and reproduction potential is high. With the peculiar environmental condition, these life history traits are attributed to the “r-strategy” of the species. In this study, generalized additive models of *Mullus barbatus* explain 81.5 % variations in Gonadosomatic Index (GSI), 55.2 % in Hepatosomatic Index (HSI) and 43.9 % in Condition Factor (K). The time component in the GAM model captures the same cyclic pattern observed in GSI of *Mullus barbatus*. Besides, The GAM results suggest that the highest GSI values associated with the bottom water temperature are between 18 – 19 °C while the partial effect of bottom salinity is at 38.7 psu. A positive effect of depth on GSI of the species starts after 60 meters depth and increasing trend continues until 125 meters depth and then decreases. The HSI results are almost identical to GSI outputs indicating that the effects of the parameters concerned act in a similar manner. The results of the GAM models failed to explain influence of environmental parameters on vertical and seasonal distribution of adult *Mullus barbatus*. However 83.5 % variances were explained in distribution of juveniles. The salinity and temperature have the highest impact on the distribution of juveniles among the parameters evaluated. The results indicate that the occurrence of Atlantic Water in the area has a positive influence on *M. barbatus*, particularly on the recruits through either by its low salinity or by another factor associated with this water mass. The vertical distribution range are set by the high temperatures (>27 °C) at the shallow depths during summer and the low temperatures on the shelf break zone (<16 °C). A comparison of vertical abundance distribution of *Mullus barbatus* and the vertical temperature variations indicate that the species may tolerate up to 27 °C and then individuals move to the deeper depths so that to the cooler waters when the temperature exceeds their tolerance limit. As well as the life history traits adopted by the species, there are some other factors providing advantages to the species. The fisheries regulations, particularly the time limits applied in the area are in favor of the species especially of pre-recruits. In the study area the pre-recruitment phase and summer YOY aggregations in shallow waters of most species studied in this thesis take place during a time when the fishing season is closed.

Key words: Demersal fish assemblages; life history traits; spatiotemporal distribution; generalized additive models; Northeastern Levant Sea.

ÖZ

KUZEYDOĞU LEVANT DENİZİNDEKİ DEMERSAL BALIK TOPLULUKLARININ DEĞERLENDİRİLMESİ

Ok, Meltem

Doktora, Deniz Biyolojisi ve Balıkçılık Bölümü

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Akdeniz insan ve doğal kaynaklı faktörler sebebiyle son yıllarda ekosistem düzeyindeki değişimlere sahne olmaktadır. Batı Akdeniz ile karşılaştırıldığında ve özellikle fauna ve flora karakteristikleri açısından bakıldığında bu faktörlerin etkileri doğu Akdeniz'de özellikle de çalışma alanın da içinde bulunduğu kuzeydoğu Levant denizinde çok daha dramatik ve yoğun olarak yaşanmaktadır. Bu çalışmada değişen bu ekosistem içerisinde Levant Denizi demersal balık topluluklarını ekolojik olarak daha iyi anlamak üzere kuzeydoğu Levant Denizi kıta sahanlığında dağılım gösteren bazı ana türler (yerel ve Kızıldeniz göçmeni) ve yaşam öyküleri incelenmiştir. Bu amaçla, demersal balık türlerinde yıl boyunca enerjiyi dağıtma ve kullanım biçimleri, biyolojik gereksinimleri dahilinde zamansal ve derinliğe bağlı olarak dağılımları, büyüme, üreme ve enerji depolamada türler tarafından sergilenen stratejiler türlerin büyüme parametreleri, biyolojik indeksleri, bolluk ve biyokütle değişimlerinden faydalanılarak araştırılmıştır. Çevresel değişkenlerin *Mullus barbatus* zamana ve derinliğe bağlı dağılımı ile biyolojik karakteristikleri üzerine etkisi genel eklemeli modeller ile incelenmiştir. Biyolojik veriler Mayıs 2007- Mayıs 2010 tarihleri arasında aylık olarak yapılan trol örneklemeleri ile toplanmıştır. Çevresel değişken (tuzluluk ve sıcaklık) örneklemeleri trol örneklemeleri sırasında Aralık 2008 – Mayıs 2010 tarihleri arasında gerçekleştirilmiştir. Çalışma sonuçları türlerin biyolojik gereksinimlerini bölgede üretimin en yüksek seviyede olduğu kısa bir dönem içerisinde gerçekleştiklerini ortaya koymaktadır. Dahası bu kısa süre zarfında çevresel etkiler ile baş edebilmek için demersal balık topluluklarının bir parçası olan yerel türler (*Mullus barbatus* ve *Pagellus erythrinus*) hızlı büyüme, erken olgunlaşma, kısa üreme sezonu ve ikincil yumurtlayıcılar gibi stratejiler sergilemektedirler. Diğer taraftan, Kızıldeniz göçmeni türler de çeşitli stratejiler göstermektedirler ancak ekosistemde oldukça başarılı olan bu istilacı türler ayrıca yerel türlerin yararlanamadıkları zaman (*Lagocephalus suezensis*) ve alan (derinlik) (*Upeneus pori*) boşluklarını kullanmaktadırlar. İncelenen bazı türlerde (*Mullus barbatus* ve *Lagocephalus suezensis*) büyüme hızlı, cinsel olgunluk erken, üreme dönemi kısa ve üreme potansiyeli yüksektir. Uç seviyelerde gözlenen çevresel faktörlerin (yüksek sıcaklık ve tuzluluk, düşük üretim gibi) etkisi altında türlerde gözlenen bu tip özellikler bu türlerin r-stratejist olduğuna bağlanmaktadır. Bu çalışmada genelleştirilmiş eklemeli modeller kullanılarak *Mullus barbatus*'da gonadosomatik, ve hepatosomatik indeksleri ile somatik kondisyon faktöründeki varyansın sırasıyla % 81.5, % 55.2 ve % 43.9'u açıklanmıştır. Modeldeki zaman bileşeni *Mullus barbatus*'da gözlenen GSI değerleri ile uyumludur. Bunun yanından genelleştirilmiş model sonuçlarına göre en yüksek GSI değerleri 18 – 19 °C sıcaklık ve 38.7 psu tuzluluk değerlerine sahip dip sularıyla örtüşmektedir. Derinliğin pozitif etkisi ise 60 metreden 125 metrelere kadar artarak devam etmekte, daha derin derinliklerde düşmektedir. Hepatosomatik ve gonadosomatik indekste gözlenen değişimler birbirine oldukça paraleldir ve benzer şekilde etkilendiklerini işaret etmektedir. Genelleştirilmiş eklemeli model sonuçları çevresel parametrelerin *Mullus barbatus*'un dikey ve mevsimsel dağılımı üzerine etkisini açıklamada yetersiz kalmıştır. Ancak cinsel olgunluğa juvenillerin dağılımlarındaki varyansın % 83.5 açıklanabilmiştir. Buna göre değerlendirilen değişkenler içerisinde juvenillerin dağılımına etki eden en önemli parametreler tuzluluk ve sıcaklık olarak bulunmuştur. Model sonuçlarına göre, bölgede gözlenen Atlantik suyunun sahip olduğu düşük tuzluluk veya bu su kütlesiyle alakalı diğer faktörler sebebiyle *Mullus barbatus*, özellikle de sürüye yeni katılan bireyler üzerine pozitif bir etkisi vardır. Türün dikey dağılım aralığı sığ sularda yüksek sıcaklığa göre (>27 °C), kıta sahanlığının sona erdiği bölgelerde ise düşük sıcaklara (<16 °C) göre ayarlanmaktadır. *Mullus barbatus*'un dikey bolluk dağılımları ve sıcaklık değişimleri bu türün 27 °C'e kadar olan sıcaklıkları tolere edebildiğini ancak bu değerin üzerine çıktığında bireylerin daha düşük sıcaklıklara sahip derin sulara doğru hareket ettiğini göstermektedir. Türlerin geliştirdikleri stratejiler yanında türlerin avantaj sağlamasını sağlana başka faktörler de vardır. Balıkçılık düzenlemeleri, özellikle de uygulanan av sezonu sınırlaması bölgede yaşayan türlerin özellikle de sürüye yeni katılanların lehinedir. Birçok türde sürüye katılma öncesi safha ve genç bireylerin yazın kıyıda sığ sularda yoğunlaşmaları balıkçılığın kapalı olduğu dönemde gerçekleşmektedir.

Anahtar Kelimeler: Demersal balık toplulukları, yaşam öyküsü, zamana ve derinliğe bağlı balık dağılımı; genelleştirilmiş eklemeli modeller, Kuzeydoğu Levant denizi.

To my family and my friends

Thank you for encouraging me to pursue the things that make me happy

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1 INTRODUCTION

1.1 Motivation and Definition of the Problem

The Mediterranean marine ecosystem has experienced rapid changes mainly due to the direct and indirect effect of human activity in the last few decades. Perturbations in marine and coastal environment include pollution, over-exploitation of marine living resources, habitat erosion, climatic changes (e.g. through the greenhouse effect), introduction of non-indigenous species and other human activities leading to environmental degradation. The impact of pressures is expected to be more significant as the Mediterranean marine ecosystem is a high-diverse and highly vulnerable to environmental perturbations (EEA and UNEP, 1999). In Levant Sea, changes due to the influence of these perturbations are more dramatic and observed more intensively. Fish populations respond to these environmental changes in various ways; biomass and abundance, geographical distribution, recruitment, growth, energy allocation and reproduction pattern may behave differently due to the environmental changes. There is enormous number of studies focusing on various aspects of fish species biology and distribution but few studies have analyzed respond of fish populations to these environmental changes in the eastern Mediterranean, particularly in Northeastern Levant Sea.

1.2 Objectives of the study

This study was designed to test the hypothesis that energy allocation and utilization strategies facilitates coexistence of major demersal fish species, hydrographic conditions in particular sea water temperature plays a key role in their bathymetric distribution and strategies adapted by the species in growth, reproduction and energy utilization are mainly being shaped by the extreme hydrographic conditions of the environment.

Therefore, the aims of this research were to explore

- the annual patterns in allocation and utilization of energy in demersal fish species
- temporal and bathymetrical trends in fish distribution with respect to biological requirements of the species
- strategies adapted by the species in growth, reproduction and energy storage

As well as the aims mentioned above, time series biological data on the species sampled were evaluated to obtain up to date information on reproductive cycle, growth, energy allocation and length at first maturity of the species and to provide up to date information for the species.

1.3 The system: Northeastern Levant Sea – An overview

1.3.1 Geomorphology and bathymetry

The Mediterranean Sea is a semi-enclosed sea connected to the North Atlantic thought the narrow and shallow Strait of Gibraltar (320 m depth and 14 km wide). It has also connection to the Red Sea and Indian Ocean through the Suez Channel and Black Sea through the Turkish Straits Systems (Dardanelle and Bosporus). The Mediterranean Sea has two main parts, namely the Western and Eastern Mediterranean. The Eastern Mediterranean sea is comprised of four main basins called Ionian, Adriatic, Aegean and Levantine basins (Özsoy et al., 1993; Demirov and Pinardi, 2002) (Figure 1.1). The Levantine basin is one of the major basins of the eastern Mediterranean. It is surrounded by the coast of Libya, Egypt, Israel, Lebanon, Syria, Turkey, Cyprus and part of the Cretan passage. Bingel et al. (1993) termed the northern Levantine basin as the area north of the 34^{o}N latitude. It is one of the interesting basins where significant changes in fauna and flora have been taking place due to immigrant species with Indo-Pacific origin (Por, 1978).

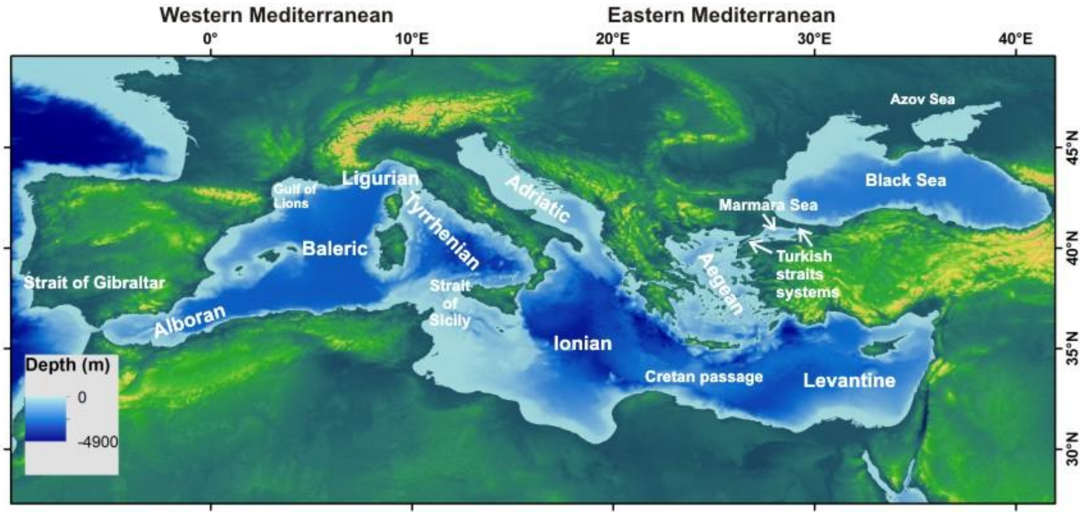


Figure 1.1. Mediterranean Sea geography and the major basins and straits (modified from Robinson, 2001).

The continental shelf of the Levantine basin is generally narrow with the exception in Mersin and İskenderun Bays. Because of that the area including Mersin and Iskenderun bays has been extensively utilized as a major fishing ground in the region. In Mersin Bay where the study area is located, the shelf gradually widens due to the higher sediment supply from Seyhan, Tarsus, Göksu and Lamas rivers. The southwest shelf of the bay (between the mounts of Göksu and Lamas rivers) has a steep slope from 0-50m depth and it becomes gentler offshore. Between Erdemli and the eastern edge of the Mersin Bay, the sea floor has a gentle slope from coastline to 50 m depth and from that depth it flattens until 200m depth (Tunç, 2008).

1.3.2 Physical and Chemical Characteristics of the Northeastern (NE) Mediterranean Sea

Differences in the level between Mediterranean Sea and Atlantic Ocean lead to the formation of the Atlantic Stream System (Demirov and Pinardi, 2002). During its transport to the Levantine Basin the branch of Atlantic Stream System entering Strait of Sicily forms the Ionian – Atlantic Stream, which travels across the basin and become the mid-Mediterranean Jet. The mid-Mediterranean Jet flows eastward between the cyclonic Rhodes gyre to the north and the anticyclonic Mersa-Metruh gyre and the area of the Shikmona gyre to the south. A branch of the mid-Mediterranean Jet moves towards the north in the eastern side of the Cyprus and forms the Asia Minor current, which flows westward along the Turkish coast (Demirov and Pinardi, 2002) (Figure 1.2).

The salinity of Atlantic water entering the Mediterranean though Gibraltar is 36.15 psu and it is modified during its transport by continuously mixing with surrounding waters reaching a salinity of 38.6 psu in the Levantine Basin (Özsoy et al., 1989). Intermediate convection in the Levantine basin produces Levantine Intermediate waters during winter, which are transported westward at a depth between 300 m and 500 m towards the Strait of Sicily and then towards Gibraltar. The eastern Mediterranean deep water which is formed in the Adriatic or the Aegean seas sinks into the deeper parts of the basins through the considerably narrow and shallow straits (Roether and Schlitzer 1991; Roether et al., 1996). This sinking water transports all the nutrients down to the deeper layers, where it will be lost forever. This is one of the reasons why the Levantine basin is one of the world's poorest water bodies in terms of nutrient sources. Levantine deep water has five times lower nutrient content than deeper layers of the Atlantic Ocean but it is still quite high in nutrient content among the other water bodies mentioned above (Salihoğlu et al., 1990).

Four distinct water masses may be recognized though the vertical profiles of water column in the Levantine basin due to the different features of hydrography and climatology. The first one is the Levantine Surface Water –the upper mixed layer- that is warmest (16-25 ^{o}C) and saltiest (38.8-39.4 psu). Below this layer between 50-100 meters depth, Atlantic water is observed with a temperature of about 17 ^{o}C and salinity between 38.77-38.86 psu. Below the Atlantic Water the Levantine Intermediate Water, represented by a subsurface salinity maximum, is located. Maximum salinity of this layer is observed at about 245 m (39.1 psu) and typical temperature at this depth is 15.5 ^{o}C throughout the year. Finally, the Levantine Deep Water with salinity of 38.7 psu and a temperature of 13.6 ^{o}C at the depths exceeding 600-700 meters is established (Özsoy et al., 1993).

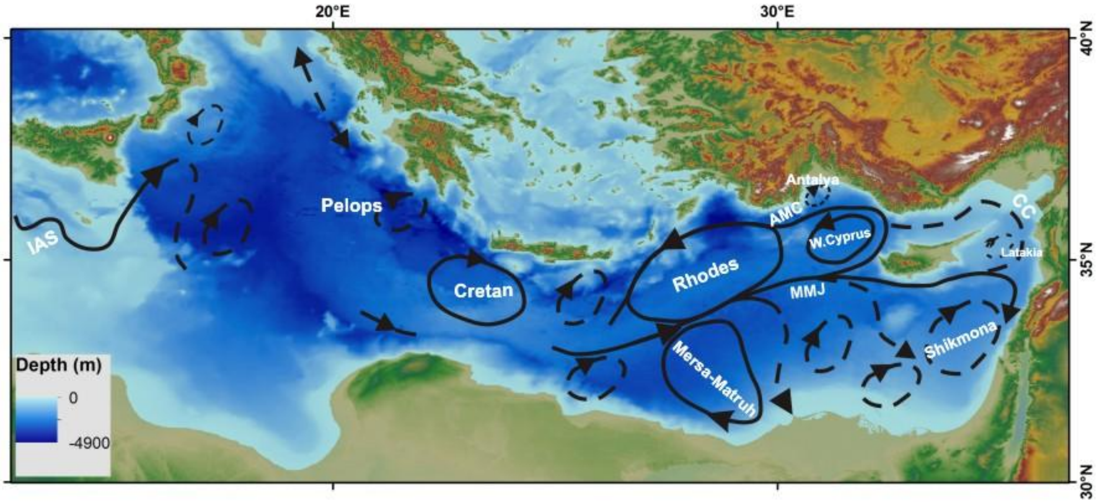


Figure 1.2. Circulation characteristics in Eastern Mediterranean. IAS: Ionian – Atlantic Stream, CC: Cilician current, AMC: Asia Minor current, MMJ: Mid – Mediterranean Jet (modified from Özsoy et al., 1991).

The Eastern Mediterranean has some of the world's most optically clear waters (Berman et al., 1985; Ediger and Yılmaz, 1996). The depth of subsurface chl-*a* maximum layer is found as deep as 120 meters, and in some cases, it is deeper than the compensation depth. Besides, the Secchi disc transparency ranges from 20-38 meters depth (Ediger and Yılmaz, 1996). Uysal and Köksalan (2006) reported the annual average Secchi Disc Depth as 8.64 meters, being lowest (1.94 meters depth) in April and highest (20.2 meters depth) in December.

Ediger and Yılmaz (1996) divided the Levantine basin of the northeastern Mediterranean into three regions due to the hydrodynamics and hydrochemistry: the cyclonic basin, the anticyclonic basin and a transitional zone between them. In the anticyclonic basin (Cilician basin), as well as freshwater influence (Uysal and Köksalan, 2006) the nutricline (a steep nutrient gradient zone) and the nutrient-rich Levantine Deep Water are able to supply sufficient amount of nutrients to the euphotic zone to maintain phytoplankton growth.

As underlined before, the Mediterranean Sea is considered as one of the world's oligotrophic seas due to the low nutrient supply to its surface waters from both intermediate depths and external sources such as atmospheric input, riverine discharges and Atlantic flow (Bethoux et al., 1992). In addition to low nutrient concentrations, the eastern Mediterranean has low plankton biomass and production (Stergiou et al., 1997). Nutrient concentrations are higher in the western Mediterranean compared to the eastern part mainly due to the higher outflow of polluted river waters into the sea. Compared to other seas and oceans, both the eastern and the western Mediterranean deep waters are poor in nutrients although there is quite high nutrient input to the western Mediterranean. Nitrate and phosphate concentrations in the deep waters of the eastern Mediterranean are also lower than in the western Mediterranean because as mentioned before, there is limited external input to the surface waters of the eastern Mediterranean. Surface waters of the eastern Levantine basin are extremely nutrient depleted and therefore it is ultra-oligotrophic. Phosphate concentration is generally below 0.008 μM and nitrate does not exceed 0.6 μM. The nutricline begins to be evident at 150-200 m depths and maximum concentrations are observed at 600 m depth (Yacobi et al., 1995). Yılmaz and Tuğrul (1998) stated that the euphotic zone waters of the eastern Mediterranean have very low concentrations of phosphate (<0.02-0.03 μM) and nitrate (0.1-0.3 μM) throughout the year, except during the winter upwelling period in the Rhodes cyclonic region. Uysal and Köksalan (2006) observed significant fluctuations in nitrate and phosphate concentrations over most of the year and claimed that fluctuations observed during winter could be mainly due to storms and turbulence that help mixing of the water column. They also pointed out that observation of high nitrate and phosphate levels in the surface waters could be due to the intense river input during spring.

The eastern Mediterranean is generally considering to be a phosphate limiting area because of the high N:P ratio (29-27:1) (Krom et al., 1991). Zohary and Robarts (1998) also reported that phosphorus is the primary limiting nutrients in pelagic waters of eastern Mediterranean. Therefore production in this area depends on regenerated material. Only 30 percent of the total production is new production and more than half of this new production is dependent on the vertical advection of nutrients (Bingel et al., 1993; Yılmaz and Tuğrul, 1998). The productivity of the area is also highly influenced by the current regime of the basin together with the riverine input, resulting in local and seasonal production (Azov, 1991).

1.3.3 Biological characteristic of the Northeastern Mediterranean Sea: Phytoplankton, Zooplankton and Benthic communities

Many phytoplankton studies have been performed in the Northeastern Mediterranean and diatoms were found to be the most abundant phytoplankton group in the region (Lakkis and Lakkis, 1981; Eker and Kıdeyş, 2000; Eker and Kıdeyş, 2000; Uysal et al., 2003; Uysal and Köksalan, 2006; Yılmaz, 2006). Eker and Kıdeyş (2000) have reported diatoms as the most abundant group in the coastal area of northeastern Mediterranean and dinoflagellates and coccolithophores were the next most abundant groups. Later Eker-Develi et al. (2003) have found similarly that while contribution of diatoms to the total abundance was high at shallow waters, coccolithophores (especially *Emiliana huxleyi*) were more abundant than diatoms at deeper waters of the Northeastern Mediterranean Sea. In general, there is a significant decrease in biomass and abundance of phytoplankton towards offshore throughout the year (Uysal et al., 2003).

It is stated by several authors that studies focusing on phytoplankton have generally overlooked heterotrophic bacteria and *Synechococcus* (Uysal and Köksalan, 2006;

Bayındırlı, 2007) which is regarded as an important component of the phytoplankton in the highly oligotrophic Mediterranean Sea (Li et al., 1993; Agawin and Agusti, 1997; Eker and Kıdeyş, 2000; Uysal and Köksalan, 2006). In the Northeastern Mediterranean Sea, there have been several studies focusing on heterotrophic bacteria and *Synechococcus*. Köksalan (2000) has studied weekly temporal variability and abundance of *Synechococcus* spp. in 1998 and reported that this group was more abundant during summer and early autumn. Bayındırlı (2007) studied changes in the abundance and biomass of picoplankton (cyanobacteria *Synechococcus* and heterotrophic bacteria) in monthly intervals in the Cilician Basin (Eastern Mediterranean) and stated “coastal station was more abundant and had much higher bacterial (heterotrophic bacteria) and cyanobacterial (*Synechococcus*) biomass than the offshore station as it receives substantial amount of freshwater from the nearby Lamas River throughout the year” and found that the abundance of both populations were influenced by temperature and nitrate concentration in the area.

In terms of species diversity of phytoplankton, Kimor and Wood (1975) have identified 248 phytoplankton species during their study conducted in the eastern Mediterranean in the 1960’s. Kıdeyş (1987) reported 117 phytoplankton species in Cilicia basin. Eker and Kıdeyş (2000) have reported total 175 phytoplankton species in the harbor of the Institute of Marine Science (IMS) of the Middle East Technical University (METU) Erdemli. Polat (2000) has also identified 170 phytoplankton species during the study performed 1994-1995 in İskenderun Bay, northeastern Mediterranean. Eker (2004) reported the identification of total of 213 species in December 2000-April 2002 and March-June 1999 in both surface waters of deep and shallow stations located off METU-IMS institute. Yılmaz (2006) has identified 81 and 87 phytoplankton species during sampling period at the deep and shallow stations, respectively.

Eker and Kıdeyş (2000) observed the main phytoplankton bloom in February during 1995 and 1996 in northeastern Mediterranean. Lakkis and Lakkis (1981) observed the highest abundance in May during 1973-1975 along the coastal waters of Lebanon, southeastern Mediterranean. Yılmaz (2006) stated that different seasonality in the abundance peaks could be due to river input. The author also indicated that abundance may not reflect biomass peaks and recommends the usage of Chl-a values when evaluating phytoplankton biomass rather than the abundance.

Generally low Chl-a concentrations were recorded in the eastern Mediterranean exceeding 1 μg l^{-1} even in coastal waters (Azov, 1986). In the eastern Mediterranean, maximum Chl-a concentrations occur during late winter, with the onset of mixing of the upper water layers (Azov, 1986; Krom et al., 1991; Ediger and Yılmaz, 1996). Ediger et al. (2005) reported that the main phytoplankton bloom in the eastern Mediterranean is probably seen in winter-spring period as revealed from Chl-a concentrations.

In the eastern Mediterranean, primary production is as low as 45 mg $Cm^{-2}d^{-1}$, and bacterial production corresponds to about half of the algal production (Robarts et al., 1996).

Zooplankton holds a key position in the pelagic food web as the transformation of the organic energy produced by unicellular algae through photosynthesis to higher trophic levels is performed by this heterotrophic component of the plankton that drift in the water column (Lenz, 2000). Siokou-Frangou (1996) indicated that studying zooplankton communities is particularly important for understanding the functioning of coastal ecosystems because of combined influences of the land and ocean. Besides, Lenz (2000) stated that apart from predation, it is regarded as the most important biological factor controlling the year class strength of the large number of commercial fish stocks known to be subject to strong fluctuations. There are various zooplankton studies focusing on the distribution, composition and nutritional environment of zooplankton in the eastern Mediterranean Sea (Kimor and Wood, 1975; Gücü, 1987; Siokou-Frangou, 1996; Siokou-Frangou, 1998; Uysal et al., 2002; Uysal et al., 2003; Lakkis et al., 2003; Zenginer-Yılmaz, 2007). Gücü (1987) studied species composition and dynamics of zooplankton biweekly over a 1-year period in the region. He reported that the 75 % of the total zooplankton was comprised of copepods and a total of 56 species belonging to 34 genera have been recorded. He noted that the copepod species were distributed evenly in the water column due to the mixing process in the winter, and they aggregated in the surface water down to 25 m depth where optimum temperature was present in spring and autumn. A study by Siokou-Frangou (1996) focused on the annual cycle of the zooplankton community in the eastern Mediterranean over a period of 2 years and found that maximum values of total zooplankton abundance were observed in summer months up to early autumn and partially in spring and copepods dominated during most of the year. In a follow-up study Siokou-Frangou et al. (1998) stated that the zooplankton composition was affected by environmental variables such as eutrophication, temperature, water mass circulation, hydrology, and topography. Uysal et al. (2002) performed qualitative and quantitative analysis of zooplankton on the northern Levantine basin shelf waters during the period 1998–1999 and showed the presence of 200 copepod species of which 76 were reported for the first time in the region. They also state that the existence of Indo-Pasific species in the Levantine Sea verified the fact that the distribution of copepod species was related to the current regime in the region. Moreover, they reported that there were significant fluctuations both in abundance and biomass of copepods throughout the year. Distinct seasonal zooplankton assemblages were found throughout the year and temperature was found to be the main factor rather than salinity that determines copepod assemblages. Lakkis et al. (2003) compared zooplankton diversity between Levantine Basin and Black Sea with reference to alien species. The authors reported that the species diversity in Levantine Basin is considerably higher than that in the Black Sea. Within the scope of their study, they also found that 70-90 % of the total zooplankton was comprised of copepods and 45 % of existing species in the Levantine basin are also present in the Red

Sea. Besides, 65 % are common with the western Mediterranean. Zenginer-Yılmaz (2007) investigated annual variations in biochemical composition of seston and zooplankton community to characterize the nutritional environment of zooplankton in the Mersin Bay, northeastern Mediterranean Sea. In terms of zooplankton abundance and biomass, particulate organic matter and chl-a, the nearshore waters were more productive than the offshore waters. Higher abundance in zooplankton was observed in spring and autumn. In terms of biomass, higher values were observed in summer and autumn in the entire water body, but in spring and autumn in the surface waters. Copepods were the most abundant zooplankton group and dominated the total zooplankton.

Being food for fish and cycling nutrients between the sediment and the water column, benthic communities play an important role in the marine ecosystems. These communities are also good indicators of organic pollution and are sensitive to toxic pollutants. Benthic organisms are used in biological monitoring as they are more or less sessile and either feed upon sediment dwelling animals or the sediment (Kröncke, 1995). Connection or link between demersal fish and benthic animals may be also explained via benthic animals (Ergev, 2002). The amount of matter stored in the bottom fauna, the approximate order of amount of production and the part which is passed on the demersal fish can be estimated qualitatively and quantitatively (Arntz, 1978). Most of the benthic studies conducted in the Mediterranean Sea concentrated on the western part (Tselepides et al., 2000). Species richness in the Mediterranean Sea is reported as approximately 7250 animals (Fredj et al. 1992) but these numbers could be more than that with the further studies on unknown groups and introducing of new lessepsian species as stated by Ergev (2002). Number of species of some zoobenthic groups in the whole Mediterranean Sea was as follows: 1 000 Polychaeta species, 2 000 Mollusca, 154 Echinodermata, 1 935 Arthropoda (Amphipoda 451, Decapoda 340, Isopoda 165, Anisopoda 43, Cumacea 91 and miscellaneous 845 species), 33 Sipuncula, 500 Bryozoa and 622 Porifera (UNEP/MAP 2004). However these numbers in the benthic community differ greatly around the Mediterranean Sea. For instance, Bingel et al. (1995) reported a total of 141 species in Manavgat (Antalya Bay, the northeastern Mediterranean Sea) and the dominant groups were Annelida (67) and Mollusca in the benthic community. Following years, Gücü et al. (1999) identified 76 species in İskenderun Bay (the northeastern Mediterranean Sea) and within these species Annelida (40) and Mollusca (15) were again the dominant groups. Uysal et al. (2008) studied the distribution and ecological status of macrobenthic organism over three transects located in Anamur, Mersin and İskenderun regions from 10 to 200 meters depth. The authors identified 692 species throughout the study period. According to results of various studies conducted on the benthic communities in the different parts of the Mediterranean Sea (Çınar et al., 1998; Tselepides et al., 2000; Gücü et al., 2001; Ergev, 2002; Mutlu and Ergev, 2008; Uysal et al., 2008; Mutlu et al., 2010) Annelida (Polychaeta) was the main dominant group in the benthic communities and it was generally followed by either Mollusca or Crustacea. A detailed study on benthic communities in the Northeastern Mediterranean sea was conducted by Ergev (2002). In this study, Macrobenthic infaunal communities in three transect from 10 to 200 m depth between Kumkuyu and Erdemli (in the northeastern Mediterranean) were investigated within the four season of year 2000. During this study, a total of 396 species were identified and the highest number of species was observed in Annelida (203). Besides, epifaunal species were also investigated in 6 stations from 5 to 150 meters. 122 speceis were determined and number of species belonging to the phylum Annelida was again the highest. In this study, as well as the most frequent species over depth, most abundant species and the highest species biomass according to the depth were listed. Throughout the year the most frequent and abundant species were from Spincula and Polychaeta, respectively. Numbers of species and biomass values of epi and infauna were reached their maximum values. Later, Uysal et al. (2008) studied the benthic community in the region along three different transect (Anamur, Mersin and İskenderun) and identified 692 macrobenthic organism. Polychaeta is again the dominant group in this study. The authors reported that among transects, the highest species number was found in Anamur transect which was more noticeable in November. There was no statistical differences between transects in terms of average number of species per $m^{2.}$ There are seasonal and bathymetrical differences in species abundance among transects. This was more obvious during the period from January to July. The number of species was higher along the zone between 0-100 meter depths. Abundance gradually decreases with increasing depth. Number of species decreased from January to November. Number of individuals in cold seasons was found to be higher than in warm seasons. Higher biomass values were observed in Mersin transect in March.

1.4 The Demersal Fishery in the northeastern Mediterranean Sea (NE Levantine Basin)

The Mediterranean Sea has a long history of marine resource exploitation. Fishing in the Mediterranean Sea has traditionally targeted many high-value species and it is one of the major economic activities, in terms of employments, incomes and food supply in the Mediterranean countries. The reported mean annual landings in the Mediterranean represented in 2007 is about 1.5% of the world marine fisheries and about 25% of the total European Union landings (Lleonart and Maynou, 2003; FAO, 2007).

The Mediterranean fisheries can be divided into three main categories: small-scale fisheries, trawling and purse seining. This categorization may be considered similarly for the Turkish Mediterranean fleet. In general, Lleonart and Maynou (2003) characterized the Mediterranean fisheries by the following attributes. It has fragmented fleets, usually composed of small vessels; there are a large number of landing sites, multi-species catches and low Catch Per Unit Effort’s CPUEs. Fish are commercialized mainly fresh and the prices are generally very high. These factors make it difficult and expensive to get extensive and reliable data time series and to get biological samples. Most of the fish caught in the Mediterranean are recruits (1 year old) of the main target species. Since the recruitment is much more uncertain than the abundance of adult stages, the assessment is also more uncertain. Furthermore, no TACs (Total Allowable Catch) or adaptive management is in place, so the administrations do not require monitoring in order to manage the fisheries. The continental shelf is narrow (with some exceptions) (Figure 1.3) and there are few stocks shared between two or more countries.

Relative to Mediterranean standards, potential of fishing grounds along the Northern Levantine Basin was realized during the 1940's (Gücü and Bingel, 1994a). Studies by Numann (Özarslan, 1974 cf. Gücü and Bingel, 1994a), Aasen and Akyüz (1956), Akyüz (1956) are pioneering scientific studies on fisheries that were carried out in the region during the 1950's. Later, Bingel (Bingel, 1981; Bingel, 1987; Bingel et al., 1993), Gücü (Gücü, 1991; Gücü and Bingel, 1994a and 1994b; Gücü, 2009), Can et al. (2004) and Martin et al. (2006) have studied and focused various aspects of fisheries in the region.

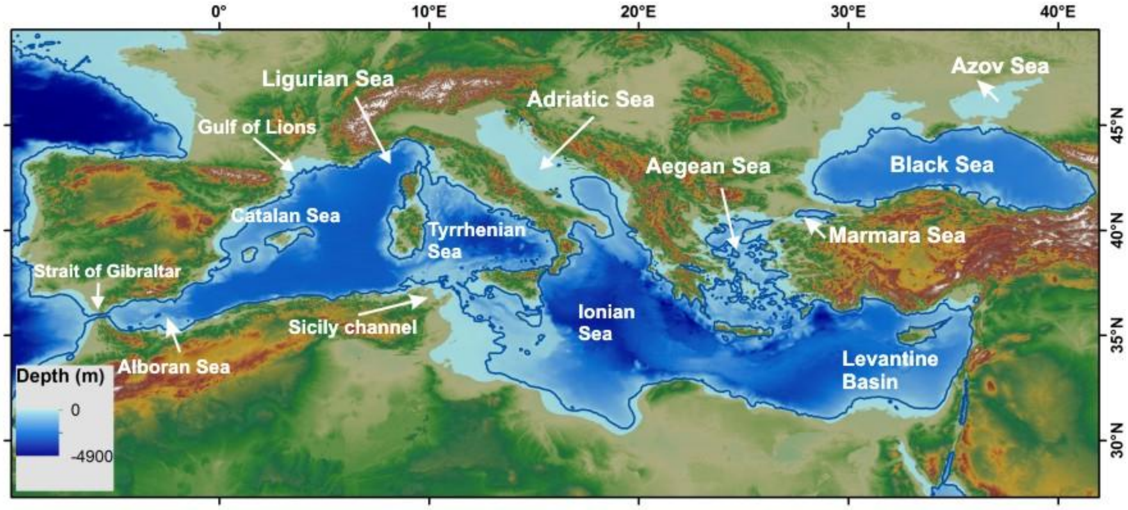


Figure 1.3. Map of the Mediterranean and Black Seas. The shelf zone (0-200 m) and its border are marked in light blue and dark line respectively.

Bingel et al. (1993) detailed the fishery in the Turkish Mediterranean coast as follows:

- Operation in biologically poor waters,
- Predominant catches of bottom-dwelling species of high diversity including red sea emigrants,

- Landing of relatively high price fish,
- Relatively high number of small boats (of 8-10 m length, usually with about 10 HP inboard diesel engines) operated mostly by two persons,
- High number of recreational (hobby fishermen) boats whose fishing equipment is not exactly known (note: it is assumed that most of these fishermen use hooks and lines, while a few of them may also use gill and entangling nets of varying mesh sizes),
- Small and distinct landing places,
- Bottom trawlers and seine boats of 15-25m lengths with engines of 100-150 and more HP. While bottom trawlers are operated by 4-6 men, the seine boats need much higher manpower (approximately 16 men),
- The beach seine net is not a frequently used gear in the coastal area. Nevertheless, it has some application along the coastline. Small sized nets are operated by hand. On the other hand, Berkes (1986) notes also a net operated from a boat of 10-15 m length by mechanized means.

Later, Gücü and Bingel (1994a) characterized the fishery as mainly coastal and artisanal, meaning that operation of fishing boats were limited to coastal shallow zone and did not expand to the continental shelf. The number of registered trawlers was ten times higher than purse seiners in those days. Typical trawlers had mainly wooden hull vessels with a length ranging between 10-20 m and engine power of 80-200 HP at that time. Bingel (1987) indicated that there was practically no purse seiners operation (only one boat) in Mersin Bay before 1982. Later, Gücü and Bingel (1994a) stated that there was an increasing contribution of purse seiner to the fisheries of the Northeastern Mediterranean Sea. The authors also indicated that the trawling is the most effective fishing method for the area since the continental shelf is rather wide compared to the other parts of the eastern Mediterranean and its margins are bordered by rather shallow water (40-100 meters on average). They also indicated that the best fishing grounds in the region are within Iskenderun, Mersin and partly in Antalya bays. However, these regions have been suffering from eutrophication for years due to the population increase, rapid urbanization, and intense industrial and agricultural activities, especially in İskenderun Bay. Besides, three major ports (in İskenderun, Mersin and Antalya) the Botaş-Yumurtalık pipeline terminal, the Mersin refinery and the İskenderun terminal for petroleum products cause heavy tanker traffic in the region. Although the deep water of the northern Levantine Basin was considered as still unpolluted, highly toxic compounds such as orgonotins and orgonomercurials found to exceed permission level in some commercially important species of fish in the region (Bingel et al., 1993).

Annual yields of the Turkish fleet in the Mediterranean are given in the Figure 1.4. Bingel et al. (1993) stated that since the collection of the fisheries statistics, which is based on questionnaires of the fishermen, are generally believed not to be strictly reliable and the values cannot always reflect the real catch data. This should also be taken into account for the recent annual yields presented in Figure 1.4.

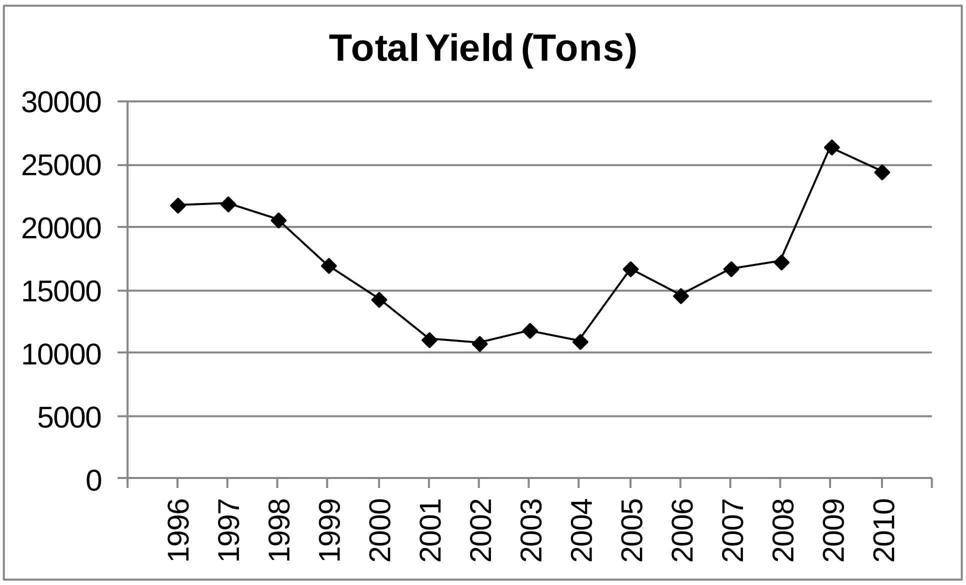


Figure 1.4. Yields of Turkish Mediterranean fishing fleet for the years 1996-2010 (DIE,1996-2010).

On the basis of trawlable fish data, Bingel et al. (1993) found a maximum sustainable yield (MSY) (only for trawl fishery) of 3702 tons from the original data set of the years 1968-1977 and 11,172 tons from yield adjusted data set of the years 1978-1987. Later, Gücü and Bingel (1994a) found a MSY (only for trawl fishery) as 7.700 tons for the years 1978-1991. In terms of fishing effort, Bingel et al. (1993) suggested fishing power (total HP) as 21,714 HP. Close to that, Gücü and Bingel (1994a) reported that it must be around 20.000 HP.

The faunal composition of the Turkish Mediterranean coast has been changed dramatically due to the construction of Suez Channel in 1869. Besides, compilation of the Aswan High Dam across the Nile River reduced the inflow of freshwater and nutrient-rich silt from the Nile into the Eastern Mediterranean worsening the impact of invasive species (Galil and Zenetos, 2002; Mavruk and Avsar 2007). Invasive species have become a major component of the Mediterranean ecosystem and have serious impacts on the Mediterranean ecology, endangering many local and endemic Mediterranean species. In total 62 species of non-native marine fishes arrived to NE Mediterranean by natural dispersal via the Suez Canal (Goren and Galil, 2005). About 63% of the exotic fishes occurring in the Mediterranean are of Indo Pacific origin, introduced into the Mediterranean through the Suez Canal. The impacts of some lessepsian species in the Levantine basin of the Mediterranean have proven to be considerable high, where they are replacing native species and becoming a “familiar sight”. A study conducted in 1980–1984 in the Northeastern Turkish coasts showed that lessepsian fishes constituted up to 74.5% of fish landings during the study period (Gücü and Bingel, 1994b). According to estimates of Golani and Ben-Tuvia (1995), the percentage (in weight) of lessepsian colonizers was 47% in the catch.

Bingel et al. (1993) listed economically important and locally marketed species as follows: Brushtooth lizardfish (*Saurida undosquamis*), Red mullet (*Mullus barbatus*), Goldband goatfish (*Upeneus moluccensis*), Common sole (*Solea solea*), Common pandora (*Pagellus erythrinus*), European hake (*Merluccius merluccius*), the Common shrimp (*Penaeus sp.)* and the Common cuttlefish (*Sepia officinalis*). Species with highest percentage in main catch in both Mersin and Iskenderun bays is Brushtooth lizardfish (*Saurida undosquamis*). In addition, when applying the yield per recruit (Y/R) model to the stocks whose population parameter were estimated, Bingel et al. (1993) showed that except Brushtooth lizardfish (*Saurida undosquamis*) all other stocks were overfished in the region (these were namely, Scaldfish (*Arnoglosus laterna*), Wide-eyed flounder (*Bothus podas*), Atlantic spotted flounder (*Citharus linguatula*), Slimys (*Leiognathus kluzingeri*), Red mullet (*Mullus barbatus*), Common pandora (*Pagellus erythrinus*), Common sole (*Solea solea*), and Goldband goatfish (*Upeneus moluccensis*). Catch composition (the top 10 species and their percentage in the total yield in Mediterranean) of the Turkish Mediterranean fleet throughout the years are shown in Table 1.1. Generally pelagic species are the dominant component of the composition. Parallel to this, Bingel et al. (2002) analyzed long-term catch data of the Turkish commercial fishery to find out if any signs of change existed in the ecosystem’s trophic state. They indicated that many authors had pointed out the significant shifts towards eutrophication from different angles. They concluded that the considerable nutrient loads have been causing a shift of the community structure from demersal to pelagic forms and suspected the Turkish Mediterranean, Aegean and southwest Black Sea were subjected to this shift.

In general, according to the results gathered by the Scientific Advisory Committee (SAC) of the General Fisheries Commission for the Mediterranean (GFCM, 2001; FAO, 2001), hake is overexploited in almost all parts of the Mediterranean. The status of other demersals including *M. barbatus*, red shrimp and blue whiting is not so clear. The small pelagics assessments give very diverse results, depending on the species and the area. Swordfish and bluefin tuna are the large pelagics regularly analyzed by ICCAT (The International Commission for the Conservation of Atlantic Tunas), but assessment of large pelagics was not presented to the last meeting due to lack of data. There are no conclusive results for any of these species, although the overexploitation of both species seems quite clear (Lleonart and Maynou, 2003).

Table 1.1. Top 10 species landed in Turkish Mediterranean Sea in 1996-2010 and their percentage in the total catch of Turkish Mediterranean Sea (DIE, 1996-2010).

	Species/Year	Yield in Tons	% in Total Catch	Species/Year	Yield in Tons	% in Total Catch	Species/Year	Yield in Tons	% in Total Catch
	1996			**1997**			**1998**		
1	Hake	3455	15.85	Hake	3513	16.05	Pilchard	2970	14.41
2	Grey Mullet	2319	10.64	Pilchard	2976	13.59	Grey Mullet	2925	14.19
3	Pilchard	1897	8.70	Grey Mullet	2527	11.54	Chub mackerel	2726	13.22
4	Chub mackerel	1567	7.19	Chub mackerel	1731	7.91	Bluefin tuna	1891	9.17
5	Sea bass	1291	5.92	Sea bass	1692	7.73	Leer Fish	1130	5.48
6	Leer Fish	1158	5.31	Leer Fish	1291	5.90	Hake	795	3.86
7	Sea Bream	937	4.30	Common sole	686	3.13	Sea Bream	659	3.20
8	Common sole	798	3.66	Picarel	674	3.08	Sea bass	652	3.16
9	Red Mullet	792	3.63	Sea Bream	644	2.94	Red Mullet	608	2.95
10	Two banded bream	713	3.27	Red Mullet	792	2.92	Bogue	606	2.94
	Total Yields (Tons)		21794	Total Yields (Tons)		21894	Total Yields (Tons)		20615
	1999			**2000**			**2001**		
1	Pilchard	2563	15.08	Pilchard	3200	22.38	Pilchard	1690	15.23
2	Grey Mullet	1842	10.83	Grey Mullet	2172	15.19	Grey Mullet	1549	13.96
3	Leer Fish	1605	9.44	Chub mackerel	2061	14.41	Chub mackerel	1028	9.27
4	Chub mackerel	1423	8.37	Hake	614	4.29	Sea Bream	661	5.96
5	Hake	1359	7.99	Bluefin tuna	548	3.83	Horse mackerel	583	5.26
6	Lizardfish	786	4.62	Red Mullet	508	3.55	Red Mullet	424	3.82
7	Red Mullet	765	4.50	Picarel	465	3.25	Picarel	403	3.63
8	Horse mackerel	754	4.44	Lizardfish	359	2.51	Lizardfish	392	3.53
9	Picarel	630	3.71	Bogue	358	2.50	Scad	389	3.51
10	Bogue	595	3.50	Sea Bream	336	2.35	Atlantic bonito	387	3.49
	Total Yields (Tons)		17001	Total Yields (Tons)		14299	Total Yields (Tons)		11094
	2002			**2003**			**2004**		
1	Bluefin tuna	2060	19.09	Bluefin tuna	2970	25.10	Pilchard	1270	11.59
2	Grey Mullet	1204	11.16	Pilchard	1183	10.00	Grey Mullet	1247	11.39
3	Pilchard	856	7.93	Grey Mullet	1104	9.33	Bluefin tuna	967	8.83
4	Horse mackerel	800	7.41	Horse mackerel	673	5.69	Lizardfish	754	6.88
5	Red Mullet	456	4.22	Sea Bream	490	4.14	Horse mackerel	741	6.77
6	Sea Bream	432	4.00	Lizardfish	483	4.08	Sea Bream	543	4.96
7	Lizardfish	377	3.49	Chub mackerel	338	2.86	Red Mullet	352	3.21
8	Blue fish	364	3.37	Blue fish	320	2.70	Chub mackerel	320	2.92
9	Chub mackerel	343	3.18	Bogue	315	2.66	Bogue	299	2.73
10	Atlantic bonito	282	2.61	Striped bream	288	2.43	Blue fish	289	2.64
	Total Yields (Tons)		10793	Total Yields (Tons)		11832	Total Yields (Tons)		10953
	2005			**2006**			**2007**		
1	Pilchard	3159	18.88	Hamsi	1746	11.96	Pilchard	2870	17.15
2	Horse mackerel	2384	14.25	Pilchard	1518	10.40	Grey Mullet	2043	12.21
3	Lizardfish	1047	6.26	Lizardfish	864	5.92	Lizardfish	938	5.60
4	Grey Mullet	1017	6.08	Scad	813	5.57	Bluefin tuna	840	5.02
5	Red Mullet	863	5.16	Red Mullet	809	5.54	Red Mullet	734	4.38
6	Bluefin tuna	734	4.39	Horse mackerel	757	5.19	Albacore	672	4.01
7	Common sole	641	3.83	Grey Mullet	723	4.95	Horse mackerel	624	3.73
8	Picarel	515	3.08	Little tunny	631	4.32	Chub mackerel	617	3.69
9	Chub mackerel	497	2.97	Bluefin tuna	600	4.11	Picarel	574	3.43
10	Atlantic bonito	487	2.91	Picarel	574	3.93	Common sole	447	2.67
	Total Yields (Tons)		16733	Total Yields (Tons)		14598	Total Yields (Tons)		16739
	2008			**2009**			**2010**		
1	Pilchard	4301	24.90	Pilchard	9506	35.9762	Pilchard	7564	30.94926
2	Lizardfish	1136	6.58	Lizardfish	1531	5.79419	Lizardfish	1409	5.765139
3	Scad	954	5.52	Grey Mullet	1111	4.20467	Red Mullet	1166	4.770867
4	Red Mullet	695	4.02	Atlantic bonito	1083	4.0987	Atlantic bonito	966	3.952537
5	Sea Bream	691	4.00	Red Mullet	910	3.44397	Chub mackerel	762	3.11784
6	Horse mackerel	666	3.86	Leer Fish	906	3.42883	Grey Mullet	760	3.109656
7	Bluefin tuna	641	3.71	Bluefin tuna	849	3.21311	Picarel	720	2.94599
8	Grey Mullet	606	3.51	Chub mackerel	833	3.15256	Horse mackerel	715	2.925532
9	Chub mackerel	521	3.02	Picarel	697	2.63785	Scad	704	2.880524
10	Picarel	483	2.80	Scad	681	2.5773	Leer Fish	695	2.843699
	Total Yields (Tons)		17274	Total Yields (Tons)		26423	Total Yields (Tons)		24440

In terms of implication of research and management, many researchers made recommendations on the fisheries in the Mediterranean and specifically the Turkish Northeastern Mediterranean. Bingel (1987) found a logarithmic relationship between the biomass and the number of boats working on the fishing ground. Later, Bingel et al. (1993) implied that the monitoring of trawlable biomass could probably give a reasonable idea about the yield possibilities of the fleet and the region. Moreover, potential yield could be estimated using the swept area method. Therefore they made several suggestions which are listed below. These are:

- the continuation of biomass estimation studies that utilize swept area method,
- enlargement of the coverage of these studies to continental shelf areas along the Mediterranean coast, continuation of closed seasons regulation since better and more suitable data on stocks were not readily available,
- consideration of multispecies situation in stock assessment investigations where single species assessment do not give proper results,
- the introduction of hard bottom trawl nets since the larger part of the Turkish Mediterranean coast has hard bottom structure, but after the introduction of hard bottom nets, limitation of vessel sizes and numbers should be followed to avoid the stock depletion.

They also concluded that to deal with local and overall fishery problems, there is a need for proper action of countries bordering the Mediterranean Sea and required extended critical research activities of these countries. Gücü and Bingel (1994a) stated the urgent need of renewal of the fisheries management policy since it was outdated and not relevant to the state of fishery. They suggested several improvements on ongoing regulation measures. Briefly, these were license control; reduction of fishing season duration; periodical closure of the different fishing grounds depending on the average maturity age of the species, rather than mesh size and minimum size limitations; application of a quota to all species (since there is no single mesh size that could catch a desired fish size); direction of the fishing fleet to more profitable and virgin fishing grounds and/or alternative resource exploitation (i.e. cephalopod stocks); region based fishing license i.e. grid-based management system.

Although over exploitation of the fish stock of the region has been mentioned many times, the exempt of excise tax (ÖTV) for fuel oil used by the fishermen came into effect in December 2003 to support the fishery in Turkey. This decision resulted in revival and increase of the fleet and it is believed that it may unfortunately contribute the depletion of fish stocks by increasing fishing pressure due to the quite cheap fuel oil (Gücü and Bingel, 2009).

In the Mediterranean, the management is reactive, never adaptive and still less protective generally. There is a scarcity of feedback among the three main groups for an adaptive management: administration, fishermen and scientists (Lleonart and Maynou, 2003). The same authors have listed several actions that should be implemented to overcome limitations in the assessment and to improve the management of Mediterranean fisheries. It should be noted that the following list has similarities to the recommendations mentioned above.

- Integration of the countries around the Mediterranean regarding data collection, assessment, and management co-ordination. Reinforcement and promotion of the General Fisheries Council for the Mediterranean (GFCM).
- International scientific review of the assessments, even for non-shared stocks. Standardization of the presentation of the assessment, including the basic data.
- Development of specific methods of data collection for the Mediterranean that take the use of easy, cheap to obtain data and geographic (country-to country, region to region, etc.) differences into account.
- A multi-species approach to assessment, incorporating measures of uncertainty both in the data and the process.
- Development of simulation methods integrating biological and economic aspects.
- Development and enforcement of a common Mediterranean policy.
- Implementation of adaptive management schemes, which should establish close relationships between data gathering, assessment and management, and between administrators, fishermen and scientists.
- Implementation of management pilot projects and marine protected areas.

1.5 The species

1.5.1 Red mullet, *Mullus barbatus* (Linnaeus, 1758)

Many studies on *M. barbatus* have been conducted targeting the various aspect of its biology and population dynamics including its diet and feeding (Wirszubski, 1953; Caragitsou and Tsimenidis, 1982; Bizsel, 1987; Golani and Galil, 1991; Golani, 1994; Labropoulou and Eleftheriou, 1997; Ünlüoğlu et al., 2002; Bautista-Vega et al., 2008), reproduction (Wirszubski, 1953; Çelik and Torcu, 2000; Del Arbol et al., 2004; Metin, 2005; Tirasin et al., 2007; Cherif et al., 2007), population parameters, age, growth and mortality (Bougis and Muzinic, 1958; Bingel, 1981 and 1987; Demestre et al., 1997; Fiorentino et al., 1998; Voliani et al., 1998; Özbilgin et al., 2004; Özvarol et al., 2006), general ecology (Wirszubski, 1953; Haidar, 1970) and fisheries and selectivity (Bingel, 1981 and 1987; Gücü and Bingel, 1993; Tosunoğlu et al., 2003; Özbilgin and Tosunoğlu, 2003). Comparative studies of *M. barbatus* and the sympatric species *M. surmuletus* have involved feeding (Golani and Galil, 1991; Golani, 1994; Labropoulou and Eleftheriou, 1997), morphology (Bougis, 1952; Aguirre, 1997; Lombarte and Aguirre, 1997; Mamuris et al., 1998) and spatial segregation aspects (Golani, 1994; Lombarte et al., 2000; Somarakis et al., 2004).

1.5.1.1 Taxonomy and morphological description

The body of *M. barbatus* is moderately compressed. The head is very short and the snout is short as well, with a steep anterior profile. The eyes are positioned near the top of the head. The mouth is small, positioned low on the head. There is no spine on opercle. The species has a pair of stout barbells under the chin. These barbells have a sensory function and are used in searching for prey. The color is uniformly pink, the back is darker and the belly is white Figure 1.5. The fins are without any well-defined coloration (Hureau, 1986). The number of rays in the fins is the following: D1:VII-VIII, D2: I+7-8, A: II+6-7, P: 15-17, V: I+5 (Hureau, 1986).

Figure 1.5. Red mullet, *Mullus barbatus* (Linnaeus, 1758).

1.5.1.2 Geographic and Bathymetric distribution

M. barbatus is distributed in the eastern Atlantic – along the European and African coasts from the British Isles to Dakar, the Azores, the Canaries; also in the Mediterranean Sea. In Turkey its distribution extends from the Black Sea to the Mediterranean Sea including Aegean and Marmara Seas. A subspecies named *Mullus barbatus ponticus* occurs in the

Black Sea and Azov Sea (Hureau, 1986) but existence of the subspecies is still not clear. It is a benthic species, found mostly on muddy bottoms in a depth range of 5 to 250 m (Hureau, 1986; Relini et al., 1999 c.f. Adriamed, 2010a; Tserpes et al., 2002). Although the species is widely distributed, the relative index of the population abundance decreases with depth (Machias and Labropoulou, 2002; Maravelias and Papaconstantinou, 2006). Maravelias and Papaconstantinou (2006) found that *M. barbatus* was distributed in shallow water depths (<100 m) throughout the Greek seas, particularly in the northern part of the Aegean Sea. Abundance of the species declined with increasing depth (Machias and Labropoulou, 2002; Maravelias and Papaconstantinou, 2006). Several authors stated the inshore-offshore migration behavior in the species (Jardas, 1996 c.f. Adriamed, 2010a; Machias and Labropoulou, 2002; Voliani, 1999; Vassilopoulou and Papaconstantinou, 1991). In summer, juveniles are concentrated very close to shore, while in autumn, they move towards deeper bottoms (Vassilopoulou and Papaconstantinou, 1991; Voliani, 1999). On the other hand, two migration types were reported by Haidar (1970 c.f. Adriamed, 2010a) that the migration of the young fish from the coast towards the open sea in the central and northern Adriatic and the spring migration of adult spawning fish towards channels region along the Croatian coast at depths between 50-85 meters.

1.5.1.3 Feeding behavior and predators

M. barbatus is a carnivorous species. It exhibits active feeding from sunrise to sunset (Bizsel, 1987; Ünlüoğlu et al., 2002; Bautista-Vega et al., 2008). Benthic sea organisms (endo-, meso- and epi-) form the bulk of its food (Golani and Galil, 1991). They pray mainly on polychaetes and crustaceans. The importance of polychaetes in the diet of *M. barbatu*s has been found in numerous studies (Ben-Eliahu and Golani, 1990; Golani, 1994; Labropoulou and Eleftheriou, 1997; Machias and Labropoulou, 2002).

Several factors such as sex and size have influence on the prey category of *M. barbatus* (Bizsel, 1987). Jukić and Županović (1965) showed that, in the eastern Adriatic, the *M. barbatus* eat continuously throughout the year but trophic activity of *M. barbatus* was positively associated with higher values of light intensity, as has been found in later studies (Ünlüoğlu et al., 2002). The maximum feeding intensity occur in the early morning, following dawn, and decreases sharply again in the early evening, following sunset, depending on the seasonal variations of daytime. *M. barbatus* has been reported as a prey organism in several studies that was conducted to understand the trophic ecology of number of fish species. Predators of *M. barbatus* are *Sarda sarda* (Yoshida, 1980), *Saurida undosquamis* (Bingel and Avsar, 1988), *Seranus cabrilla* (Labropoulou and Eleftheriou, 1997), *Pagrus pagrus* (Labropoulou et al., 1999), and *Merluccius merluccius* (Carpentiere et al., 2000). Bingel and Avsar (1988) found that *M. barbatus* form 36.8 % of the diet of *Saurida undosquamis*. Percentage contribution of *M. barbatus* by weight to diet of *Serranus cabrilla* found as 4.73

by Labropoulou and Eleftheriou (1997). Similarly 3.45 % of the diet of *Pagrus pagrus* (between 148–186 mm fork lengths) was formed by *M. barbatus* (Labropoulou et al., 1999).

1.5.1.4 Growth and Age Estimation

Several published works exist on age and growth of the species in the Mediterranean Sea (Gharbi and Ktari, 1981 c.f. ICES, 2009; Vassilopoulou and Papaconstantinou, 1991; Fiorentino et al., 1998; Kalagia et al., 2004 c.f. ICES, 2009); however, no agreement is always obvious among their results. The maximum estimated age in years among the exploited Mediterranean stocks is 7 years for females and 6 years for males (Vassilopoulou and Papaconstantinou, 1991); however, this was reported as 5 age groups for females and 4 for males in most of studies (Gharbi and Ktari, 1981; Livadas, 1989; Tursi et al., 1994).

According to Hureau (1986), *M. barbatus* grow up to about 30 cm. The usual total length in catches is 10 to 20 cm. On average, females have greater body length than males (Jardas, 1996 c.f. Adriamed, 2010a). They also grow faster, which can be already noticed in the first year of their life (Haidar, 1970 c.f. Adriamed, 2010a). Therefore, almost all the bigger specimens are females (28 to 29 cm). Males do not grow more than to about 20 cm (Relini et al., 1999 c.f. Adriamed, 2010a). On the other hand, Voliani (1999) reported the maximum total length (TL) of *M. barbatus* in the Mediterranean as 28-29 cm in females and 23 cm in males.

Studied conducted for the length-weight relationship shows that the growth of this species is generally allometric. According to Županović and Jardas (1989), there are two different inflexion points in the length-weight relationship of females, one at 12-13 cm (corresponding to the first sexual maturity) and the other one between 16 and 17 cm. There is only one male inflexion point, between 11.5 and 12 cm and it corresponds to the length at first sexual maturity.

1.5.1.5 Reproduction

M. barbatus reproduction in the Mediterranean Sea takes place between May and July in the Gulf of Lion (Vasilopoulou and Papaconstantinou, 1992 cf. Bougis, 1952), in the Gulf of Tunis (Cherif et al., 2007), in Iraklinon Gulf (Machiasa and Labropoulou, 2002) and in İzmir Bay (Metin, 2005), while it is between April and July in the Alboran Sea (Del Albol et al., 2004). The maturity and spawning period of *M. barbatus* in İzmir bay covers five months for females (January-May) and four months for males (February-May) (Metin, 2005). Similarly, Bingel (1981) reported this period is between April and June with a spawning peak during May in Mersin Bay. Also, in the Aegean Sea (Edremit Bay), the reproduction of *Mullus barbatus* is longer and occurred between March and September (Çelik and Torcu, 2000). The most intensive spawning occurs at depths of 60 to 70 m. After spawning, post larvae move towards shallower water (30-40 m) and coast (Županović and Jardas, 1989 c.f.

Adriamed, 2010a). Larvae, post larvae and juveniles up to 4-5 cm of total length are pelagic. According to Sabatés and Palomera (1987), larvae are found strictly in surface waters (0-1.5 m depth) mainly between June and July in the Mediterranean Sea. After that, individuals move towards sandy coastal areas and become demersal. Later, dispersion is started towards sandy, muddy and gravel grounds at depths between 10 and 250 m (Relini et al., 1999 c.f. Adriamed, 2010a). Recruitment occurs in coastal bottoms in summer–early autumn (Vassilopoulou and Papaconstantinou, 1991; Levi et al., 2003) at lengths 5-6 cm (Voliani, 1999).

The sex ratio is very variable in the different regions studied. It is demonstrated through analysis of the literature that in the eastern Mediterranean including the Adriatic Sea, females predominate while an inverse situation is observed in the Western Mediterranean (Županović, 1963 c.f. Adriamed 2010a). Cherif et al. (2007) reported that females predominate in all months of the sampling period. The overall sex-ratio value was estimated as 68 % in favour of females. Females were also dominant in all size classes.

Vassilopoulou and Papaconstantinou (1992) reported that the length at first maturity is around 11-12 cm TL for both males and females. According to Metin (2005), total length at first maturity of females and males of *M. barbatus* in Izmir bay are 14.2 and 12.4 respectively. The estimated mean size at which 50% of females are mature was reported as 13.94 cm, whereas this was estimated 13.87 cm for males in the study carried out by Cherif et al. (2007).

1.5.2 Por's goatfish *Upeneus pori* (Ben-Tuvia and Golani, 1989)

Upeneus pori is a lessepsian migrant species which penetrates into the Mediterranean Sea through the Suez Channel (Ben-Tuvia and Golani, 1989) and inhabits the western Indian Ocean (from the Red Sea to southern Oman. *U. pori* was misclassified as *Upeneus tragula* and *Upeneus vittatus* (Fischer et al., 1987; Golani et al, 2002), and some information about this species was given under this name (Hureau, 1986). *U. pori* is a commercially important demersal species, living mostly in sand, muddy sand or gravel bottoms (Golani, 1994). There are only very few attempts to describe the comprehensive biology and ecology of *U. pori*. Ben-Tuvia and Golani (1989), Gucu et al (1994), Golani (1996), Golani (1998) provided information about the distribution of the species. Golani and Galil (1991) provided some information on the feeding habits of the species. Golani (1994) dealt with niche separation between colonizing and indigenous goatfishes of the Mediterranean coast of Israel. Taskavak and Bilecenoglu (2001) studied length weight relationships for 18 lessepsian immigrant fish species including *U. pori* in the eastern Mediterranean coast of Turkey.

Body of *U. pori* is elongated, subcylindrical in front and somewhat compressed from midpoint. It has two well-separated dorsal fins. First dorsal spine is the longest. Second dorsal fin is opposite to anal fin. Caudal fin is deeply forked. A pair of barbels is present in the chin and their length are 15-20 % from standart length (Figure 1.6). Villiform teeth arrange in 3-4 rows in front and 1-2 in the back. Elliptic patches are on the palatine. Four scales are located between dorsal fins. Meristic formula for the species is as follows: D1, VII; D2, 8-10; A, I + 6-8; P, 13-16; V, I + 5; LL, 28-33; GR, 24-28 (Golani et al., 2002).

Figure 1.6. Por's Goatfish *Upeneus pori* (Ben-Tuvia and Golani, 1989).

It is distributed in the Red Sea and Gulf of Oman. However, it was introduced to the Mediterranean during the 1950's. It was recorded for the first at Iskenderun, Turkey (İşmen 2006 cf. Kosswig, 1950) as *Upenoides* (= *Upeneus*) *tragula*. Then it was successively recorded in Israel (Ben-Tuvia, 1953) (as *Upeneus sp.*), Egypt (El Sayed, 1994), Tunisia and Gokova Bay, Turkey (Golani et al., 2002).

Both *U. pori* and *U. moluccensis* inhabited shallow water. *U. pori* dominated the sandy bottom at a depth of 20 m with particularly young individuals in Israeli waters (Golani, 1994).

U. pori feeds on mainly crustaceans and to a lesser extent polychaetes which it detect with its barbels. According to the study of Golani and Galil (1991), *U. pori* mainly feeds on small organism regardless of its size. Since *U. pori* smaller than *U. moluccensis*, it feeds necessarily upon smaller prey. Besides, although small percentage of fish prey exists in the diet of *U. mollucensis*, *M. barbatus* and *M. surmuletus*, it was not observed in the diet of *U. pori*.

Spawning season of the species lasts from April to September. Settlement occurs 6-9 months after hatching, upon reaching length of 3-4 cm (Golani et al., 2002).

1.5.3 Common pandora *Pagellus erythrinus* (Linnaeus, 1758)

Valdes et al. (2004) stated that “the common pandora, *Pagellus erythrinus* (Linnaeus, 1758) is one of the most captured species for the small-scale fishing fleet in many Mediterranean countries, playing an important role in the local micro-economy by the volume of catches and by its high price”. Several studies have been carried out on *P. erythrinus* both in the Mediterranean and north Atlantic. Several aspects of its fishery biology and population dynamics have been studied, including its diet (Ardizzone and Messina, 1983; Ghannudi, 1984; Andaloro and Giarritta, 1985; Caragitsou and Papaconstantinou, 1988; Benli et al., 2001), reproduction (Pajuelo and Lorenzo, 1998; Hoşsucu and Türker Çakır, 2003; Valdés et al., 2004), population parameters, age, growth and mortality (Pajuelo and Lorenzo, 1998; Somarakis and Machias, 2002; Hoşsucu and Türker Çakır, 2003), bathymetric distribution (Katsanevakis and Maravelias 2009), fisheries and selectivitiy (Erzini et al. 1998; Tosunoğlu et al., 2003; Özbilgin and Tosunoğlu, 2003; Ates et al., 2010). Comparative studies of *P. erythrinus* and the sympatric species *Pagellus acarne* have involved spatial segregation aspects and ecology (Spedicato et al., 2002).

The body of the *P. erythrinus* is long, oval and laterally flat. The diameter of the eye is much shorter than the length of the snout; the pectoral fins are pointed, of the same length as head. The caudal fin is big and forked (Figure 1.7). The color is pink-red with a silvery glint. The sides are paler and the belly is whitish. There are several small bluish spots on the back and sides of the grown specimens. The inside of the mouth is whitish or grayish. Sometimes a dark red mark is present at the base of the last dorsal rays. The number of fin rays is the following: D: XII+9-11, A: III+8-9, P: 15, V: I+5 (Fisher et al., 1987; Relini et al., 1999).

Figure 1.7. Common pandora *P. erythrinus* (Linnaeus, 1758).

P. erythrinus is distributed in the eastern Atlantic - from Scandinavia to Senegal, and in the entire Mediterranean. It is rare in the Black Sea (Bauchot and Hureau, 1986; Fisher et al., 1987; Relini et al., 1999).

The species are found mostly in depths down to 300 m (Froese and Pauly, 2010). There are no distinct bottom preferences of *P. erythrinus*. It can be found on various bottoms including rocks, gravels, sand and mud (Bauchot and Hureau, 1986).

The *P. erythrinus* can grow up to 60 cm but its usual length in catches is 10 to 30 cm (Bauchot and Hureau, 1986). During the MEDITS expedition, the range was from 4 to 27 cm (average value 14.72 cm) (Vrgoč, 2000), in the same area. Generally, longer fish were caught in deeper water (Adriamed, 2010b).

P. erythrinus is a protogynous hermaphroditic species. First years of their life, all individuals are females and then they become males. Because of protogonic hermaphroditism, females are always dominant in the population. This was confirmed during MEDITS expedition that sex ratio was in favor of females (83% females and 17% males).

According to the study of Caragitsou and Papaconstantinou (1988), polychaetes and brachyurans constituted the main food items of *P. erythrinus* in different gulfs in Ionian Sea. Fishes and cephalops occur occasionally while isopods, cumacea and mysids represented negligible source of their food. Polychaetes were consumed mainly during winter while brachyurans showed extreme dominance in diet of the species during the rest of the year. There is a positive relationship between length of the species and length of its prey. Smaller size individuals feed mainly on polychaetes while bigger size classes replaced it to the brachyurans.

Later Benli et al. (2001) studied the feeding periodicity and diet of *P. erythrinus* in Hisaronu Bay of the southern Aegean coast of Turkey. The author reported that *P. erythrinus* is predominantly a diurnal feeder. More intensive feeding started in the afternoon, reaching its maximum value in the evening and continued until dusk. The minimum feeding intensity occurred during the night. The diet was found to be primarily consisting of polychaetes, especially glyceridae, and crustaceans, mainly natantia. No significant diel variation was observed in the diet composition of *P. erythrinus*.

1.5.4 Goldband goatfish *Upeneus moluccensis* (Bleeker, 1855)

Upeneus moluccensis (Bleeker, 1855) is a lessepsian migrant species and found in the Indo-Pacific region to the northern coasts of Australia, and also westward to East Africa. After the opening of the Suez channel in 1869, *U. moluccensis* entered the eastern Mediterranean (northward to Aegean Sea) and now inhabits benthic and tropical inshore waters. The first report of this species from the Turkish seas was made by Kosswig in 1950. Very few studies conducted on the comprehensive biology and ecology of this species. In the Eastern

Mediterranean Sea, several studies conducted on aspects of its reproduction (Kaya et al., 1999; Becer Ozvarol et al., 2010) and food intake, (Golani and Galil, 1991), most of the work deals primarily with its distribution and biology (Por, 1978; Ben-Tuvia, 1985; Hureau, 1986; Ben-Tuvia and Golani, 1989). Papaconstantinou (1990) reported that the species was distributed around the Dodecanese Islands in the Southern Aegean Sea, and it was also found further north in Izmir Bay. Most of the studies from Turkish Seas are mainly limited to the distribution of the species (Kaya et al., 1999 cf. Aksiray, 1954, 1987; Gucu and Bingel, 1994, Gucu et al., 1994), although Turan (2006) studied genetic and morphological divergence and phylogenetic relationships of four species of Mullidae including *U. moluccensis*, Kaya (1999), İşmen (2005) and Becer Özvarol et al. (2010) included observations on its age, growth, reproduction and food in Turkish seas.

Body elongated subcylindrical in the first half of body, becoming somewhat compressed towards the tail. It has two well-separated dorsal fins. First dorsal spine is minute, second spine is the largest. Second dorsal fin is located opposite the anal fin. Caudal fin deeply forked. A pair of barbles on the chin is not reaching rear of preoperculum margin. Villiform teeth are located on jaws, vomar and palatine. 5 - 7 scales between dorsal fins Back is pinkish-red while belly is white. Running from eye to caudal fin base, there is a distinct single longitudinal yellow stripe. Upper caudal fin lob is striped (Golani et al., 2002). This species is distinguished by the following characters: D VIII,9; pectoral fins 14-16; gill rakers 7-8 + 18-20 = 26-27; lateral line scales 33-35 (Figure 1.8).

In general, Golani et al. (2002) stated that it is demersal species located in sandy or muddy substrate down to 100 m (single record at 200 m).

U. moluccensis feeds on benthic and sub-benthic organisms detected by chemoreceptor-rich barbles on the chin. It has crustaceans dominating diet, with fish becoming progressively important as size of this species increases (Golani et al., 2002). Ben-Tuvia (1966) stated that macrurid crustaceans were the principal prey in the diet of this species. Later, Golani and Galil (1991) listed copepoda, mysidacea and polychaeta as dominant prey. Kaya et al. (1999) reported that except for the autumn, the decapod crustaceans were the dominant prey in the diet throughout the year. The abundance and occurrence frequencies of other prey groups changed seasonally.

Figure 1.8. Goldband goatfish *U. moluccensis* (Bleeker, 1855).

Spawning season of *U. moluccensis is* from end of July to September. Ripe eggs diameter 0.3-0.4 mm. Eggs and larvae are planktonic. Benthic settlement in *U. moluccensis* is at size of 4-5 cm. The species matures at age of 12 months, when size is about 10 cm (Golani et al., 2002).

1.5.5 Suez blassop *Lagocephalus suezensis* Clark & Gohar, 1953

Legocephalus suezensis Clark & Gohar, 1953 is a lessepsian migrant species endemic to the Red Sea (Golani et al., 2002). It is belonging to the family Tetraodontidae which is represented by seven species in the Mediterranean Sea: *Ephippion guttiferum* (Bennett, 1831), *Lagocephalus lagocephalus* (Linnaeus, 1758), *Lagocephalus spadiceus* (Richardson, 1844), *L. suezensis* (Clark & Gohar, 1953), *Lagocephalus sceleratus* (Gmelin, 1789), *Sphoeroides pachygaster* (Muller & Troschel, 1848) and *Torquigener flavimaculatus* Hardy & Randall, 1983 (Tortonese, 1986; Golani et al., 2002; Akyol et al., 2005). Four of these species, *L. spadiceus, L. suezensis*, *L. sceleratus* and *T. flavimaculatus* are lessepsian immigrants, i.e. invasive species that have entered the Mediterranean Sea from the Red Sea, via the Suez Canal (Golani, 2002). According to the Golani et al. (2002) the species was first mentioned in the Mediterranean Sea by Mouneimne (1977) as *L. sceleratus.* The authors also stated that Mouneimne (1977) had specimens of *L. suezensis*, which is clearly separated from *L. sceleratus* by having irregularly shaped brown to grey spots of various sizes on the dorsum, as compared to equal sized black spots on the dorsum in *L. sceleratus*. Later it was recorded in the Mediterranean from Israeli waters (Golani, 1996) and from Rhodes (Golani et al., 2002). It was recorded in Turkey for the first time from off Iskenderun Bay, Turkey by Bilecenoğlu et al. (2002). The studies on this species both in Turkish waters and in Mediterranean sea are rather limited and only on occurrence of the species

(Bilecenoğlu et al., 2002; Akyol et al., 2005) and the weight-length relationships (Ergüden et al., 2009).

Body of *L. suezensis* is inflatable. When it is not inflated, elongated and round in front, tapering toward caudal fin. Pointed short-bases dorsal and anal fins with posterior in position. Caudal fin forked to lunated. There is a pectoral fin with wide base and round margin. Pelvic fin is absent. Head of the species is large with blunt snout. It has small mouth and its jaws are beak-like with two teeth in each jaw. Gill slit is present in front of pectoral fin base. It has no scales. There are minute spinules on the belly and on the dorsal surface, extending to origin of dorsal fin. Two lateral lines are curving anteriorly around eyes. Its color is back-brown to olive grey with irregular shaped darker brown to grey dots in various sizes. There is a bright silver stripe on the side and white belly (Figure 1.9).

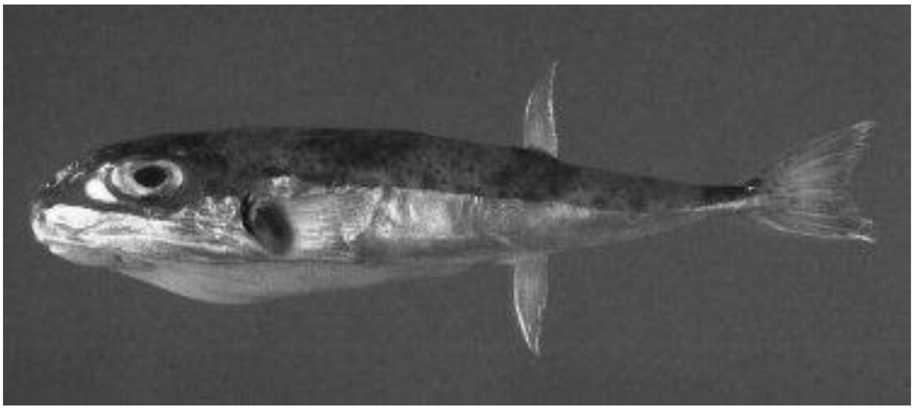


Figure 1.9. Suez blassop *L. suezensis* (taken from Golani et al. 2002, photo by David Darom).

Like other members of the family, capable when threatened to inflate its body by engulfing water or air (when taken out from the water). The species feeds on benthic invertebrates. Spawning season is in the summer. Their eggs and larvae are planktonic. It is a benthic species lives in sandy and muddy bottoms down to 40 m depth (Golani et al., 2002).

1.5.6 Brushtooth lizardfish (*Saurida undosquamis* Richardson, 1848)

S. undosquamis belonging to family Synodontidae is one of many lessepsian migrants that migrated to the Mediterranean sea from the Red Sea through the Suez Canal (Ben-Tuvia, 1953 and 1978; Ben- Yami and Glaser, 1974) and today it is one of the well established immigrants of Red sea (Gücü et al., 1994) with important economic value in the inshore region of the eastern Mediterranean coast of Turkey (Bingel 1981, 1987). Comprehensive studies on the biology and ecology of this species are limited. In the eastern Mediterranean, several studies conducted on its reproduction (Bingel, 1988a; Shenouda and Wadie,1991 cf. Golani 1993; Golani, 1993; Zienab Abdel-Baki El-Greisy, 2005; İşmen, 2003; Yılmaz and

Hoşsucu, 2007a; El-Halfawy et al., 2007), food intake and diet (Bograd-Zisman, 1965 cf. Golani 1993; Bingel and Avşar, 1988 a and b; Bingel, 1988a and b; Golani, 1993; Gücü, 1995), its general biology, distribution and growth (Ben-Yami and Glaser, 1974; Bingel 1981 and 1987; Golani, 1993; Gücü and Bingel, 1994; Gücü et al. 1994;Türeli and Erdem, 1997). Avşar et al. (1990) studied the morphometric separation of lizardfish stocks in the Gulf of Mersin using the Mahalanobis distance function.

Body is elongated and cylindrical with lizard-like head and adipose fin. Two numerous needle-like teeth are visible when mouth is closed. Teeth present also on the tongue and on the two palatine bands, the inner ellipsoid and short, the outer longer and consisting anteriorly of two rows. Pectoral fins are moderately long, reaching to level of pelvic fin base. Pelvic fin rays are almost equal in length. Adipose fin presents above anal fin. Caudal fin is forked. Its back and upper sides are brown, lower side and belly are white. 4 to 7 dark dots exist on upper edge of caudal fin. There are a series of fairly distinct dark blotches along lateral line (less distinct in specimens from colder waters). Its stomach is black; liver is striped black and white (Fischer and Whitehead, 1974; Golani et al., 2002). The number of rays in the fins is the following: D, 11-12;A, 10-12;P, 14-15;V,9;LL 48-52 (Golani et al., 2002) (Figure 1.10).

Figure 1.10. Brushtooth lizardfish (*S. undosquamis* Richardson, 1848)

It is generally distributed from the Red Sea and eastern Africa to Australia and southern Japan but it has penetrated into the eastern Mediterranean Sea via the Suez Canal. In the Mediterranean Sea, first specimens were recorded along the coast of Israel during 1953 and 266 tones were landed by commercial local trawlers just after three years (Ben-Yami and Glaser, 1974). As shown in Figure 1.11, it has also records from Northern Aegean Sea, The Adriatic and Sicily Channel (Golani et al., 2002).

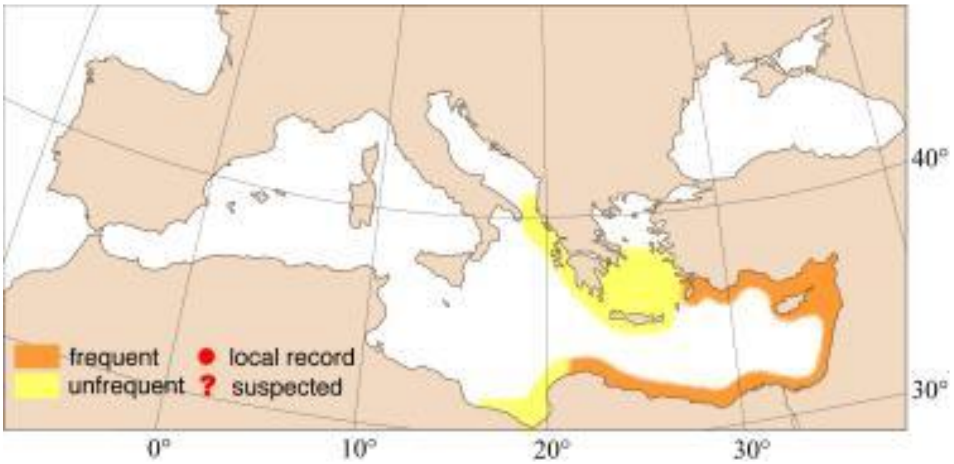


Figure 1.11. Distribution map of the species (from Golani et al., 2002).

It is a demersal species, found mostly on flat sand or muddy substrate (Golani et al., 2002).

The maximum size of this fish is reported as about 50 cm; however, in catches the common size range is between 20 and 30 cm (Bauchot, 1987).

S. undosquamis feeds mainly on fish and, to lesser extent, on decapods crustaceans (Golani et al., 2002). Ben-Yami and Glaser (1974) stated that there was no direct information on the diurnal-nocturnal feeding activity of the lizardfish in the Levant Basin. However, they also suggested that the high proportion of anchovy observed in the food of the lizardfish may indicate that either they feed on clupeoids only when clupeoids approach the bottom of the sea during the hours of light, or they go up to the upper water layers during the night where they could feed on these pelagic fish. Since the lizardfish almost never occurs in the night catches of purse seines in light fishing, the authors favored the first hypothesis. Three studies conducted by Bingel (1988b, Bingel and Avşar 1988a, 1988b) gave information on feeding behavior of this species in the Northern Cilician Basin (Eastern Mediterranean). According to the study of Bingel and Avşar (1988a), *S. undosquamis* feeds mainly on fish (97.3%) and the major items found in the stomach of it were *M. barbatus, Leiognathus kluzingeri* and *S. undosquamis*. Prey sizes of the species were investigated by Bingel (1988b) and it was found that the weight of the prey of *S. undosquamis* did not increase with increasing fish length as expected theoretically. Author also reported that the minimum prey size was observed in females and juveniles. Finally he calculated annual consumption of its prey as 750 g prey/year/specimen and concluded a production of fish flesh of 75 g/year on the basis of 1/10 food transfer. Intensive feeding of the species was found as between April-July and most intensively between September-November which overlaps the times of spawning period in the region (Bingel and Avşar, 1988b). Later Golani (1993) was studied the stomach content of *S. undosquamis* in Israeli waters. He reported similarly that 93.3 % of the food items found in the stomach of the species were fish but the most common prey was *Engraulis encrasicholus*, then *Sardinella aurita* and *M. barbatus*. The author also investigated the preying strategy of the species by looking the direction of the prey in the stomach of *S. undosquamis* and reported that almost all *S. aurita* and *E. encrasicholus* located head facing the anterior of the predator. In other words they were chased. The Author also noted that among mullids all specimens of *M. barbatus* were caught from behind while the other goatfish *U. moluccensis* was exclusively ambushed. He explained it according to the different feeding nature of these two species, *M. barbatus* digging deeper into the substratum which makes it more vulnerable to capture from behind.

1.5.7 Striped seabream *Lithognathus mormyrus* (Linnaeus, 1758)

Kallianiotis et al. (2005) stated that *L. mormyrus* is a highly valuable fish species and an important catch for the coastal fishery in the Mediterranean Sea. Many of the published studies dealt with aspects of *L. mormyrus* reproduction, age and growth, and these have been studied in the central-east Atlantic (Lorenzo et al., 2002; Pajuelo et al., 2002), in Mediterranean (Türkmen and Akyurt 2003; Kallianiotis et al., 2005; Emre et al., 2010), and in the Adriatic Sea (Kraljevi et al., 1996; Matic´-Skoko et al., 2007).

Its body is elongately ovoid and well compressed. Scales present on cheek and opercle. Snout is elongated and pointed. Eyes are rather small. In front of the each jaw, outer series of conical teeth slightly enlarged followed by inner bands of shorter teeth. At back of jaw, molariform teeth are located in 3-6 upper and 2-4 lower rows; row that next to the innermost is largest. Gillrakers are as follows: 14-17 in lower and 9-11 in upper. The number of fin rays is the following: D XI-XII + 11-12, A III + 10-11. Pectoral fin is short and ending well before anus. There are 59-65 lateral line scales is to caudal base. They are silvery grey, darker dorsally. There are 14-15 narrow, generally darker and transverse stripes. Intraocular spade and snout dark brown and their dorsal and caudal fins are generally brownish, other fins are lighter (Bauchot and Hureau 1986) (Figure 1.12).

Figure 1.12. The Striped seabream *L. mormyrus* (Linnaeus, 1758).

L. mormyrus is a demersal marine fish belonging to the Sparidae family. It is widely distributed in the Mediterranean (absent in the Black Sea), Atlantic, Red Sea and southwestern Indian Ocean (Bauchot and Hureau, 1986).

They prefer littoral waters on sandy or sand-muddy bottoms, exceptionally enters Mediterranean lagoons. It sometimes forms large schools (Bauchot and Hureau, 1986). *L. mormyrus* is a protandric hermaphrodite fish (Bauchot and Hureau, 1986). Bauchot and Hureau (1986) reported that this species spawned during spring and summer in the Mediterranean and Atlantic. Study on feeding behavior of *L. mormyrus* is very scarce. Stomach content analyses that performed by Kallianiotis et al. (2005) showed that it is a carnivorous species feeding on benthic invertebrates, mainly polychaeta and bivalve molluscs. The ontogenetic variation in the diet composition of the study of same authors showed that fish become more generalist feeders while growing. They also conclude that the species become more selective in the summer season.

1.5.8 Striped red mullet, *Mullus surmuletus* Linnaeus, 1758

M. surmuletus is a very common species along the coast of the Mediterranean and Adriatic Seas. It is also distributed in the Atlantic Ocean from the Canary Isles to southern Scandinavia and in Azores (Hureau, 1986). *M. surmuletus* is one of the commercially important demersal fish species, living mainly near the shore on sandy or rocky bottoms covered by submerged vegetation (Garcia-Rubies and Macpherson, 1995). Most of the studies on this species dealt with biological and ecological aspects. Menu and Girin (1978), Gharbi and Ktari (1981), N'Da and Daniel (1993) Renones et al. (1995) studied the sexual cycle and reproduction while Morales-Nin (1986) and Renones et al. (1995) investigated age and growth. Distribution and its habitat were focused by the study of Garcia-Rubies and Macpherson (1995). Ben-Eliau and Golani (1990), Golani and Galil (1991), N'Da (1992) and Mazzola et al. (1999) concentrated on the diet and trophic relationship of adults. Aspect of fishing was also investigated (Sanchez et al., 1993; Renones et al., 1995). Body of the species moderately compressed. A pair of stout barbels under chin, their length greater than that of pectoral fins; its opercle has no spine while snout less steep and anterior head profile is parabolic; maxilla at most reaching below anterior eye margin; the species has small villiform teeth in lower jaw; upper jaw toothless and teeth also present on roof of mouth (vomer and palatines). First dorsal fin with 7 - 8 spines, the first minute; second dorsal fin with I + 8 soft rays; 33 to 37 scales in lateral line. Colour of this species is reddish, usually with a darker red longitudinal stripe from eye to caudal fin and 3 yellow-brown lines on lower sides. Besides, there are dark markings on first dorsal fin (Figure 1.13).

Figure 1.13. Striped red mullet *M. surmuletus* Linnaeus, 1758.

This species seems to prefer deep waters and elevated temperatures, and tolerates low and high salinity (corresponding respectively to the habitats of the juvenile and adults) and is rarely found in the transitions zones of intermediate salinity. This species prefer sandy sediments (Mahé et al., 2005). A sexual dimorphism expressing growth faster for the females compared to the males were stated in the study on growth in the Eastern English Channel and the south of the North Sea (Mahé et al., 2005). *M. surmuletus* reproduce from May to September with a maximum in June in the North-East Atlantic (Mahé et al., 2005) and reaches the size at first sexual maturity at 16.2 cm for the males and 16.9 cm for the females. The period of reproduction is the same in Mediterranean Sea (Hashem, 1973 ; Gharbi and Ktari, 1981; Uçkun İlhan et al., 2009). According to the study carried out in İzmir bay by Uçkun et al. (2009), the maximum observed age was 6 for this species. The same authors estimated the length-weight relationships as $W=0.0083*L^{3.127}$ (r=0.980) while the von Bertalanffy growth equations were found as $Lt=27.85\ (1-e^{-0.193\ (t+1,578)})$ for sex combined. They also computed the growth performance index value (Φ´) as 2.175 and reported that spawning of this species occurred in spring. According to the studies on diet of the species, adults feed on mainly on crustacea, polychaeta, mollusca, echinoderma and small fishes. Golani and Galil (1991) indicated that the trophic role of decapoda in the diet of *M. surmuletus* in the eastern Mediterranean. Although according to the authors, decapoda are the most heavily preyed taxa as far as number of species is concerned, polychaeta is the most important taxa in terms of biomass. Only N'Da (1992) has studied the feeding habits of young *M. surmuletus* in Bay of Biscay and underlined the role of pelagic prey in their diet.

1.5.9 European hake, *Merluccius merluccius* (Linnaeus, 1758)

M. merluccius is one of the main target species of the Mediterranean demersal fishery and therefore various aspects of its biology (Alegria Hernandez and Jukic´, 1990), distribution (Orsi-Relini et al., 2002; Bartolino et al., 2008), growth (Belcari et al., 2006; Mellon-Duval et al., 2010), genetics (Roldan et al., 1998; Levi et al., 2004) and fisheries and exploitation (Farruggio and Papaconstantinou, 1998; Martin et al., 2002) have been documented. The body of *M. merluccius* is long and cylindrical. The mouth is large. There are two dorsal fins. The first one is short and triangular and the second one is long. The anal fin is similar in shape and size to the second dorsal fin. The ventral fins are placed before the pectoral ones. The caudal fin is cut in a straight line. The number of rays in particular fins is as follows: D1: 8-10, D2: 35-40, A: 36-40, P: 12-14, V: 7 (Fisher et al., 1987; Jardas, 1996). The colour is slate grey above and lighter on sides, the belly is whitish (Relini et al., 1999) (Figure 1.14). *M. merluccius* is most abundant at depths between 100 and 200 m, where the catches are mainly composed of juveniles (Županović, 1968; Jukić and Arneri, 1984; Flamigni, 1983; Giovanardi and Rizzoli, 1984; Bello et al., 1986; Vrgoč, 2000). Vertical migration to the higher strata occurs at nights while the species stays on the bottom during day (Jardas, 1996). The species also performs horizontal migrations in order to search for a food. In spring adults of *M. merluccuis* are mainly caught at depths of 100 to 150 m. In the spring, they migrate to more shallow coastal waters for spawning. The juveniles display migration patterns in search of food.

Figure 1.14. European hake, *M. merluccius* (Linnaeus, 1758).

During winter, after spawning, adult fish migrate towards the deeper water, wintering with the juveniles (Županović and Jardas, 1989). In the southern Adriatic medium-sized fish distribute in the stratum not deeper than 100 m. On the other hand, the largest individuals are caught in waters deeper than 200 m (Ungaro et al., 1993). Although, *M. merluccius* can grow to 130 cm of total length and live more than 20 years (Jardas, 1996), the frequent length in trawl catches is from 10 to 60 cm. Jardas (1976) reported that the length-weight relationship could be divided into three phases according to the coefficient b as juveniles, adolescents and adults. *M. merluccius* is partial spawner that spawns throughout the year but with different intensities. Tere are two spawning peaks reported in the summer and winter periods (Županović and Jardas, 1989; Jukić and Piccinetti, 1981; Ungaro et al., 1993). Females spawn usually four or five times without ovarian rests. The earliest spawning in the Adriatic occurs in winter in deeper water (up to 200 m). As the season progresses into the spring-summer period, spawning occurs in more shallow water. The recruitment of young individuals into the breeding stock occurred in the spring and in the autumn. Alegria Hernandez and Jukić (1992) stated that recruitment does not seem to be related to the parental stock. In the related literature, length at first maturity ranged between 20-33 cm in length (Županović and Jardas, 1986; Ungaro et al., 1993). Differences in the growth dynamics between males and females can be seen in the following Tables. Females attain larger size than males. Consequently, while proportion of females in the population is higher at larger sizes, the proportion of males is higher in lower length classes and. First year of their life (until 16 cm length) *M. merluccius* feeds mostly on crustaceans. Their migration to the channel regions of the eastern Adriatic coast is explained to the changes of feeding patterns as they start feeding on fish, primarily *Sardina pilchardus, Sprattus sprattus* and *Engraulis encrasicolus*. Cephalopods were also found in hake stomachs (Froglia, 1973; Jardas, 1976; Ungaro et al., 1993).

1.6 Fish Condition

Fish condition is a measure of physical and biological circumstances during some previous period, and is affected by interactions among food availability, physical factors, parasitic infections, and the physiology of the fish (Love, 1974; Parrish and Mallicoate, 1995; Francis, 1997; Shulman and Love, 1999; Lee and Khan, 2000; Yaragina and Marshall, 2000; Okuda, 2001). The condition of fishes can be assessed by a variety of criteria ranging from morphometric (weight–length) and physiological (liver and gonad weights) measures to biochemical measures such as lipid or protein content. Lipid storage and dynamics within the organism, however, are a particular important feature of fish condition (Adams, 1999). In many benthic and demersal fishes the main reserve of fat is stored in liver (Schulman and Love, 1999). Therefore, physiological and biochemical measures such as HSI or the fish fatness are accurate measures of the energy reserves of fish (Adams, 1999; Shulman and Love, 1999). Many fish store energy in their liver, so indices of liver condition can be considered as a good indicator of overall fish condition (Lambert and Dutil, 1997). Relationship between length and weight provides another simple index; the condition factor which is widely used to quantify state of well-being of fish, i.e. its energy reserves (Wootton, 1998). The use of stored energy for reproduction is one aspect of energy storage generating particular interest in life-history studies (Houston et al. 2007). Although variety of breeding strategy is possible among species, a distinction is recognized between income breeders in which reproduction is financed using current energetic income and capital breeders in which compensatory feeding takes place in advance of breeding so that reproduction is financed from stored energy capital (Houston et al. 2007). Therefore, information about breeding strategy, gonadal maturation and change in feeding intensity can be obtained from changes in Gonadosomatic Index (GSI), Hepatosomatic Index (HSI) and Somatic condition factor (Somatic K) values.

2 MATERIAL AND METHODS

Data used in this study were collected within the framework of the BAP-2007-07-01-01 project titled Monitoring the Changes in Demersal Fish Stocks of the Northeastern Mediterranean.

2.1 Study Area and field sampling

The study area is located off the Institute of Marine Sciences of the Middle East Technical University (IMS-METU) between Erdemli and Tırtar which is on the northeastern Levantine Basin (northeastern Mediterranean) (Figure 2.1).

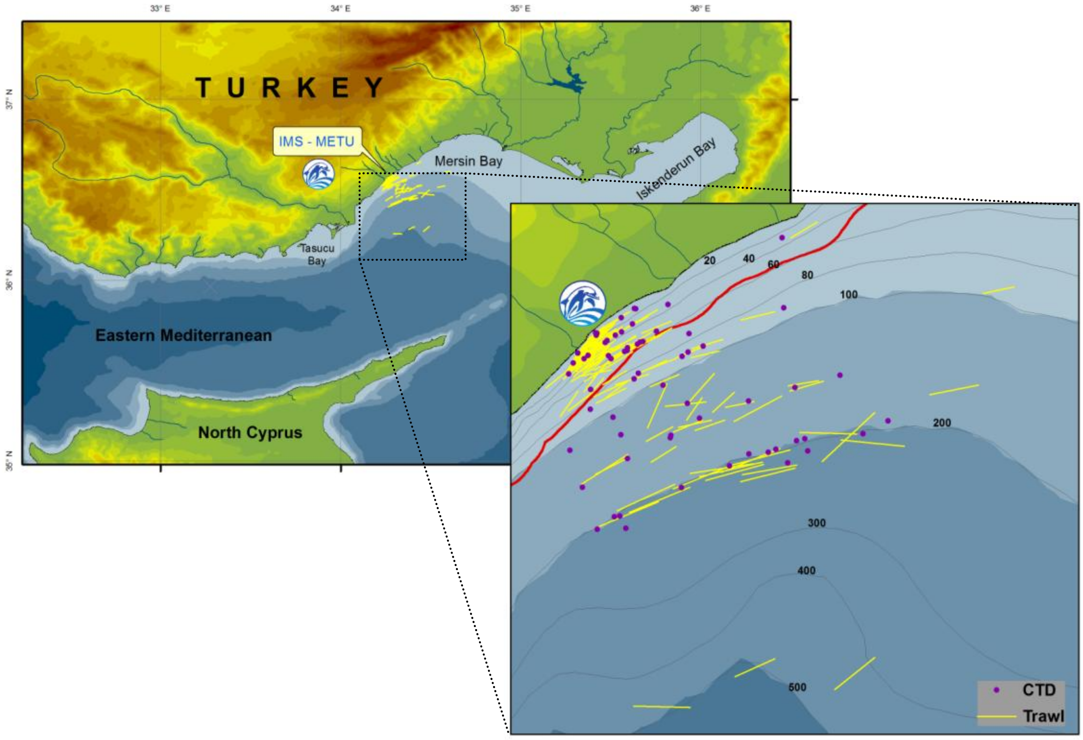


Figure 2.1. Map of the sampled area including bathymetry of the region as well as the position of the hauls and CTD profiler. Yellow lines show the trawl hauls, purple points show the CTD sampling casts. Red line shows the border of the trawl exclusive zone.

Sampling was performed between May 2007 - May 2010 in monthly intervals along the transect extending from 10 to 500 m depth (Figure 2.1). Demersal resources were sampled on board R/V *Lamas-1* of IMS-METU. To minimize the sampling error and to acquire representative data, three trawl hauls from different depths (0-25, 25-50 and 50-75 meters depth) were performed each month. Position of the stations at each depth strata was randomly selected. Three supplementary depths (75-100,150 and 200 meters depth) were added to the sampling scheme beginning in December 2008 to bathymetrically improve the sampling of the area and the represented data. During the hauls, towing speed varied between 2.5 and 2.7 knots, and except for 200 meters depth hauls whose duration was 60 minutes towing duration was limited to 30 minutes. The starting time and coordinates of the haul was defined as the moment when the warp is tightened and towing is started. The end of the haul was defined as the moment of the beginning of warp hauling. 142 trawl hauls were performed during the study period. 54 of them were out of the trawl exclusive zone (Figure 2.1). In all trawl surveys the same trawl net (locally called the Ottoman) design was used but since the all size classes in a population were aimed to be sampled, knot to knot mesh size of the cod end was smaller than those used in the commercial trawl nets as 14 mm. The number of hauls and their date location and depth details were given in Appendix 1.

Temperature and salinity profiles were recorded using a SBE 19*plus* SEACAT Oceanographic CTD Profiler. CTD data collection was initiated in December 2008 (Appendix 2). Time of the cast was generally just before the beginning or at the end of the trawl operation when the desired depth observed from echo-sounder. The CTD profiler was lowered at a rate of 0.5-0.8 m/sec and it recorded at a rate of 24 Hz. Position of the cast recorded from GPS of the research vessel. During the study period, 63 CTD probe sampling were performed. CTD sampling details were given in Appendix 2. After transferring to a PC, data were converted and processed by using the SBE (Sea Bird Electronic) Data Processing (Version 7.18) software program. Plots of temperature and salinity profiles were produced by using Ocean Data View V. 4.3.10 (Schlitzer, 2011) which is a software package for the interactive exploration, analysis and visualization of oceanographic and other geo-referenced profile or sequence data.

On board, the catch from each depth strata was sorted and then total weight and length frequency were determined and recorded by species. After that samples belonging to the following species were separated from the total catch and stored in a fridge for further analysis at the laboratory. These species are Red mullet, (*Mullus barbatus*), Por’s goatfish (*Upeneus pori),* Common pandora *(Pagellus erythrinus),* goldband goatfish *(Upeneus moluccensis),* Suez blassop *(Lagocephalus suezensis),* Brushtooth lizardfish *(Saurida undosquamis),* Striped red mullet *(Mullus surmuletus),* European hake *(Merluccius merluccius)* and Striped seabream *(Lithognathus mormyrus).* Selection of the target species to be analyzed in this study was made according to their ecological and economical importance, their order of abundance (Table 2.1) and their frequency of occurrence (Table 2.2). Besides, abundance and occurrence data obtained during the previous trawl surveys performed in the region by METU-IMS were also taken into account for the selection of the species in this study. Therefore although *Pagellus acarne* was one of the abundant species in the trawl surveys (Table 2.1), it was not included to the species to be studied due to the several factors: the occurrence of the species was not frequent in previous studies of METU-IMS and the mean length of the individuals sampled was always below the length at first maturity given in the related literature for the species. *Leiognathus kluzingeri, Spicara flexuosa, Boops boops, Trachurus trachurus, Trachurus mediterraneus, Engraulis encrasicolus* and *Sardina pilchardus* were also abundant Table 2.1 but they were not included to the sample collection since they are either semi-pelagic or pelagic species. Frequency of species observed in the trawl sampling was given in Table 2.2. The species investigated were selected according to factors mentioned below.

Table 2.1. Order of abundance of the species sampled during the trawl surveys. Grey colored rows show the species investigated in the present study.

#	The species	Order of abundance
1	*Leiognathus klunzingeri*	1.00
2	*Mullus barbatus*	0.87
3	*Upeneus pori*	0.74
4	*Pagellus erythrinus*	0.61
5	*Pagellus acarne*	0.58
6	*Spicara flexuosa*	0.39
7	*Boops boops*	0.29
8	*Upeneus moluccensis*	0.29
9	*Trachurus trachurus*	0.29
10	*Trachurus mediterraneus*	0.19
11	*Lagocephalus suezensis*	0.19
12	*Saurida undosquamis*	0.16
13	*Engraulis encrasicolus*	0.16
14	*Mullus surmuletus*	0.10
15	*Sardina pilchardus*	0.06
16	*Merluccius merluccius*	0.06
17	*Lithognathus mormyrus*	0.06

Results of the analyses were given for each species studied but some analyses either could not be performed or the result were not meaningful for the following species mentioned below: The seasonally oscillating von Bertalanffy growth function could not be fitted to the length-frequency distribution data of *L. mormyrus*. The species represented irregular occurrence on the study area, therefore it couldn’t be sampled systematically. Biological indices could not be calculated for *M. merluccius* due to the insufficient biological data on adults of this species. It is known that only the juvenile hake ascents to continental shelf and the older ages remain at the continental shelf.

Table 2.2. Frequency of occurrence of the species sampled during the trawl surveys. Grey colored rows show the species investigated in the present study.

#	The species	Frequency of occurrence
1	*Leiognathus klunzingeri*	1.00
2	*Mullus barbatus*	0.81
3	*Upeneus pori*	0.68
4	*Arnoglossus laterna*	0.58
5	*Pagellus erythrinus*	0.55
6	*Pagellus acarne*	0.52
7	*Bothus podas podas*	0.48
8	*Macrorhamphosus scolopax*	0.35
9	*Serranus hepatus*	0.26
10	*Trachurus trachurus*	0.26
11	*Upeneus moluccensis*	0.26
12	*Lagocephalus suezensis*	0.19
13	*Spicara flexuosa*	0.19
14	*Trachurus mediterraneus*	0.19
15	*Arnoglossus thori*	0.16
16	*Callionymus filamentosus*	0.16
17	*Engraulis encrasicolus*	0.16
18	*Argentina sphyraena*	0.13
19	*Boops boops*	0.10
20	*Capros aper*	0.10
21	*Chlorophthalmus agassizi*	0.10
22	*Gobius niger jozo*	0.10
23	*Lepidotrigla cavillone*	0.10
24	*Mullus surmuletus*	0.10
25	*Citharus linguatula*	0.06
26	*Glossanodon leioglossus*	0.06
27	*Gobius sp.*	0.06
28	*Lithognathus mormyrus*	0.06
29	*Saurida undosquamis*	0.06
30	*Merluccius merluccius*	0.06

Although this study aimed to evaluate the entire fish assemblages of the Northeastern Levant Sea, only nine species occupying the continental shelf were selected for this study due to the reasons given above. Among them five species were native, while rests were immigrant so it was assumed that number of species listed above is core fish species and reflects the main ecological features of the fish assemblage of the northeastern Levant Sea.

2.2 Biological parameters and indices

In general, all individuals of the species studied were taken for laboratory analyses. However, due to the large sample size of the species in some trawl catches, sub sampling (taking a representative sample from a larger sample) were performed. In that case, 10-20 fish samples representing each length class were taken for the laboratory analyses. In the laboratory, following parameters were recorded for each specimen: total length (TL, ±0.01

cm), total weight (W, ±0.01 g), and liver, stomach and gonads weights (±0.0001 g). For each individual, sex and maturity stages were also determined according to the 4 stage maturity scale was modified from Holden and Raitt (1974), Machias et al. (1998) and ICES (2007) and it was based on the macroscopic aspects (vascularization,, degree of opacity, oocytes or sperm visibility, colouration) and the dimention of gonads (Table 2.3).

Table 2.3. Female and male maturity stages based on macroscopic examination of the gonads (after Holden and Raitt, 1974; Machias et al., 1998; ICES,2007).

Stage	Description
Females	
I Immature	Ovaries are very small, situated close to vertebral column, less than one half of length of ventral cavity, pale pink to red. No granular appearance, i.e eggs not visible to naked eye. No blood capillaries.
II Developing-maturing	Ovaries becoming larger: one half length of ventral cavity or more; pinkish or yellow. Granular appearance and light blood capillaries.
III Spawning	Ovaries large filling the body cavity. Most eggs are transparent (hydrated). Eggs are extruded from the body under slight pressure. Pale yellow or yellow color.
IV Spent-resting	Ovaries flaccid; pale pink to grey/white. All viable eggs have been released. Wrinkled in appearance. Early stage of atresia visible in hynaline oocytes (white spots). No granular appearance.
Males	
I Immature	Testes very small and flat; translucent or grey. Less than half of the length of body cavity. Without sperm.
II Developing-maturing	Larger gonads with sperm on cutting.Pink/white colour. More than half of length of body cavity. Reddish blood capillaries
III Spawning	Testes white occupying more than half of the body cavity. Sperm flows on applying pressure to the abdomen.
IV Spent-resting	Testes flaccid and red; possibility of a little residual milt.

2.2.1 Length-Weight Relationships and Mean Length

Length-weight relationships (LWR) of *M. barbatus* were investigated for females, males and juveniles. Le Cren (1951) stated "The analysis of length-weight data has usually been directed towards two rather different objects. First, it describes mathematically the relationship between length and weight so that one may be converted into the other. Secondly, the variation from the expected weight for length of individual fish or relevant groups of individuals are used as a measure as indications of fatness, general 'well being', gonad development, etc." In this work length-weight Relationships was assessed to fulfill only the first objective given above. The second was assessed through evaluation of somatic condition factor.

The weight of a fish is expressed as a function of its length by the equation:

$W = a L^b$ (Ricker, 1975)…………………………………………………eq.1

where W is weight, L is length, and a and b are parameters that were estimated by linear regression of logarithmically transformed length-weight data. In general, b less than 3.0 represents fish that become less rotund as length increases and b greater than 3.0 represents fish that become more rotund as length increases. For most species and populations, b is greater than 3.0 (allometric growth). When b equals to 3.0, grow may be isometric meaning that the shape does not change as fish grow (Anderson and Neumann, 1996). The degree of association between the variables length and weight was computed by the determination coefficient, r^2. Student's t test was used to find out whether the coefficient b was significantly different from 3.

As well as LWR, mean length value (L_{mean}) of the species caught by each haul was calculated according to Sparre and Venema (1998):

$L_{mean} = \sum(\text{Length frequency*Length})/\sum(\text{Length frequency})$……………………..eq.2

2.2.2 Growth Parameters

Growth is one of the most important and reliable indicators of fish health, population production and habitat quality. The study of growth means basically the determination of the body size as a function of age. Several approaches exist to aging fish. There are a number of ways to determine fish growth namely direct observation, back-calculation of length and growth from harder parts such as from otolith, scale and spines and observation of change in length-frequency distribution through time (Devries and Frie, 1996). The latter one is mostly used and may be the only method used for species that live in tropical and temperate seas since they cannot be aged reliable with hard part due to the lack of fluctuation in environment conditions that form yearly rings in the hard parts such as scales and otoliths (Devries and

Frie, 1996; Sparre and Venema, 1998). The monthly length-frequency distributions were used to estimate the parameters of the von Bertalanffy growth function (VBGF) which is basically a model of body length as a function of age. Since the growth of fishes displays seasonal oscillation, a modified version of the von Bertalanffy growth function (VBGF) (Somer, 1988) where a sine wave modifies a standard version of the VBGF and enables a smooth transition between rapid and slow growth (in length) was used. Within the scope of this study, the ELEFAN I module implemented in FiSAT (Gayanilo et al., 1995) was used to calculate parameters for the seasonal von Bertalanffy growth function (VBGF) and expressed as:

$$L_t = L_{inf}\,(1 - \exp(-k(t-t_o)+S_{ts}-S_{to})]\text{ , where } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ eq.3}$$

$$S_{ts} = (Ck/2\prod)^{*}\sin(2\prod(t-t_s))\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{eq.4}$$

$$S_{to} = (Ck/2\prod)^{*}\sin(2\prod(t_o-t_s))\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{..eq.5}$$

Where Lt is the length at time t, L_{inf} the asymptotic total length (cm), k the growth coefficient (year^{-1}), t_0 the age of fish at zero length (year), t_s the time between t = 0 and the start of a sinusoid growth oscillation and C the amplitude of growth oscillations. The WP refers to the time of the year when growth is the slowest, and C = 0 means non seasonal growth. Initial value of L_{inf} which is required by the routine was calculated as suggested by Froese and Binohlan (2000):

$$\log L_{inf} = 0.044 + 0.9841 * \log(L_{max})\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{eq.6}$$

The growth performance index (ø) was computed according to the formula of Pauly and Munro (1984) as:

$$ø = \text{Log } K + 2 \text{ Log } L_{inf}. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{....eq.7}$$

2.2.3 Recruitment pattern

Recruitment pattern is the number of recruits entering into the stock as a function of time. In this study, it was assessed based on monthly length frequency data. It was assumed that VBGF describes the growth pre-recruit stage of fish and hence FISAT sub-routine was used.

2.2.4 Sex-ratio

Sex ratio of *M. barbatus* which is expressed as the proportion of females in the total number of individuals sexed was calculated from the pooled data. The percentage of juveniles, females and males by size class were calculated and presented as well. The sex ratio, SR, was calculated using the following equation.

$SR = 100\ (N_f / N_f + N_m)$……………………………………………eq.8

Where N_m and N_f are the number of males and females respectively.

2.2.5 Length at first maturity

Maturation size of a fish is one of the special interests in fisheries management and is widely used as an indicator of minimum-permissible capture size (Lucifora et al., 1999).The length at first maturity (L_{50}) representing the size at which 50 % of the specimens was mature, was determined for females and males of *M. barbatus* by fitting a logistic equation (Prager et al., 1994; Rampa et al., 2005) to the data:

p, the estimated proportion in each size class, was calculated as

$p = [1 + \exp(-r(L-L_m))]^{-1}$……………………………………………………………eq.9

where r is a fitted parameter, L is the total length, L_m is the length at which 50 % of the specimens was mature. The curve fitting was carried out by using the "solver" function in Microsoft Excel and the significance was tested using Chi^2 comparison test.

2.2.6 Indices

Several indices were calculated to investigate variation in a overall physiological condition of *M. barbatus* (the gonado-somatic and hepato-somatic indices, somatic condition factor) and its spatial distribution (biomass and abundance indices). These are as follows:

The gonado-somatic index (GSI) was calculated for each individual as indicated by Wootton (1998). Basically gonado-somatic index is the ratio of fish gonad weight to the somatic weight and it provides a simple index with which to describe changes in the relative size of the gonads over time (Wootton, 1998). When it is high it means that individual ready to spawn. When it starts to decrease it means that spawning has just started.

Gonado-somatic index (GSI) =100 (GW/SW) …………………………eq.10

where GW is gonad wet weight and SW is somatic wet weight.

The spawning periods of the species were determined by analyzing the monthly evolution of the GSI.

Secondly, the hepato-somatic index (HSI) which is used as a proxy of energy resources stored in the liver was computed by the following formulae:

Hepato-somatic index (HSI) = 100(LW/SW)……………………………..eq.11

where LW and SW represent liver and somatic (eviscerated) wet weights, respectively.

Another index calculated to obtain information about physiological state of the fish is the somatic condition factor. It is basically a relationship between weight and length. The heavier a fish for a given length is, the higher its condition factor. Formulation of it is as follows:

Somatic K = $100(SW/L^3)$……………………………………………………eq.12

where W is a somatic wet weight and L is a total length of a fish.

Indices (GSI, HSI and Somatic K) were calculated for the whole study period and for females and males separately. Besides, the study period was divided into three parts as May 2007 - April 2008, May 2008 - April 2009 and May 2009 - May 2010. Although the last month for the sample collection was April 2010, the month of May 2010 was also included to the calculations since the highest values especially in GSI were observed in this month and in most of the species. A liver sample collection from the species sampled was initiated in May 2008 to calculate HSI.

Biomass and abundance index estimations were performed by using the catch per unit area (CPUA) as suggested by Sparre and Venema (1998). CPUA is estimated by dividing the catch by the swept area (in square kilometers). Sparre and Venema (1998) defined the swept area as “the area of which is the length of the path times the width of the trawl called the “swept area” or the effective path swept”. Formulation of it is as follows:

a = D*hr*X2……………………………………………………………....eq.13

where D is distance covered, hr is the length of the head-rope and X2 is fraction of head rope length.

Pauly (1980) suggests the fraction of head rope length (X2) = 0.5 as the best compromise. Distance covered was calculated by the following formulation since the position of the start and the end of the trawl haul were available.

$D= 60 * \sqrt{}(Lat1-Lat2)^2 + (Lon1-Lon2)^2 * \cos^2 (0.50*(Lat1+Lat2))$………eq.14

where Lat1 and Lon 1 are latitude and longitude at start of haul, Lat2 and Lon2 are latitude and longitude at end of haul.

The length of the head-rope of the trawl net used in this study is 9.5 m.

Since the covered distance by each trawl operation was different, the catches of the hauls were standardized to unit area (1 km^2). After the standardization, the seasonal distribution of the total abundance and biomass for each stratum was calculated. Then *M. barbatus* bathymetric distribution maps (kg/km^2 and # of individuals/km^2) throughout the study period was produced by using Ocean data view (ODV) V. 4.3.10 software.

2.3 Data Exploration and Statistical Analyses

Before the data analyses, the data exploration was performed for data quality check. All variables were tested for normality and collinearity. Since there are more than three variables, series of pairplot were produced to detect the relationships between variables and to investigate collinearity between them as suggested by Zuur et al. (2007). As well as pairplot, the variables were also examined by using coplots which are a conditional scatterplots showing the relationships between two variables for different values of third or even fourth variable (Zuur et al., 2007). The conditioning variables can be nominal or continuous.

Several statistical approaches were used for data analyses. The assumption of normality of abundance, biomass and biological indices were tested by the Shapiro-Wilk test. Biological parameters were compared among sexes and maturity stages by non-parametric test (Mann-Whitney U test) with a significance level set at $p < 0.05$.

A generalized additive model (GAM) (Hastie and Tibshirani, 1990) was used to evaluate which factors are associated with the variations in GSI, HSI and somatic K of *M. barbatus*. The GAM was used to examine whether a significant relationship exists between the condition of *M. barbatus* and bathymetry together with the environmental factors. Since the impact of the factors influence condition was primarily focused, interactions between explanatory variables were not included to the model.

Basically, GAMs express the relationship between a response variable (Y) and dependent variables (or predictors) (Xi) by:

Y = link linear predictor (LP)

and:

$LP = \alpha + \sum fi\ (Xi) + \varepsilon$ ……………………………………………………………eq.15

where LP is the linear predictor. The ‘link’ function is a transformation used to accommodate different response distributions (e.g. log for Gamma or Poisson distributions, logit for a binomial one). α is the intercept and ε is the error term. The fi are smooth functions, estimated individually for each predictor. In GAM all explanatory variables are assumed to affect the dependent variable through additive, unspecified (not linear, not parametric) smooth functions (Hastie and Tibshirani, 1990; Zuur et al., 2007).

Gonadosomatic Index (GSI), Hepatosomatic Index (HIS) and Somatic condition factor (Somatic K) were selected as response (dependent) variable for each generalized additive models; time, depth, bottom temperature, bottom salinity, length, sex and reproductive stage were the predictors (independent), last two being categorical. After an examination of significance level of each parameter and the total deviance explained by the corresponding distribution and link function (Hastie and Tibshirani, 1990), the gamma distribution and a log linking was used for each model (GSI and HSI, Somatic K). The program Brodgar (version 2.6.6) and R (version 2.9.1) were used together with the package *mgvc* for the additive modeling. The fitted GAMs with multiple smoothers for the each response variable are the following:

$$Y_i = \alpha + f(\text{Average depth}_i) + f(\text{Bottom temperature}_i) + f(\text{Bottom salinity}) + f(\text{Time}_i) + f(\text{Length}_i) + \text{Sex}_i + \text{Stage}_i + \varepsilon_i$$

……………………………………………………………………………………………………..eq.16

where Y_i is the response variable (GSI,HSI, or Somatic K), α is the intercept, $f(X_i)$ is explanatory variable with smoothing function, X_i is categorical variable and ε_i is the residual or information that is not explained by the model. The optimal degrees of freedom (the amount of movement in the smoothing) were estimated by cross-validation. Default option in type of a smoother in mgcv (and therefore Brodgar) is a thin plate regression spline but different smoothers can be also selected according to the data. For example, cyclic cubic regression spline (cc) is a useful smoother since it ensures that the value of the smoother at the far left point of the gradient is the same as at the far right point of the gradient. Hence, it is a useful smoother for time variable. The plots of the best-fitting smooths for the effect of the covariates were presented as the GAM model results. The 95 % confidence intervals were also included. Relative importance of each covariate of the model was shown in y-axis. Model validations were made on the basis of numerical results and visual inspection of graphs.

The variations of overall abundance of *M. barbatus* were again modeled by using GAM to examine the distribution pattern along a transect extending from 10-600 m depth with including the additive effect of time and environmental factors. Abundance index data was used as response variable and depth, temperature, salinity and time as explanatory variables *f*(X). The selection of the suitable link function and error distribution was made on the basis of residual plots (Hastie and Tibshirani, 1990). After an examination of the residual plots, the poisson distribution with a log link function was used for modelling the variation in fish abundance. The fitted GAMs with multiple smoothers for the each response variable are the following:

$Y_i = \alpha + f(\text{Average depth}_i) + f(\text{Bottom temperature}_i) + f(\text{Bottom salinity}) + f(\text{Time}_i) + \varepsilon_i$ ……………………………………………………………………………… eq.17

where Y_i is the response variable (abundance of *M. barbatus*), α is the intercept, $f(Xi)$ is explanatory variable with smoothing function and ε_i is the residual or information that is not explained by the model. Same model validations were made on the basis of methods mentioned above.

3 RESULTS

3.1 Red mullet, *Mullus barbatus* (Linnaeus, 1758)

The lengths of 18894 individuals ranging from 3 to 25 cm were measured on board from a total catch of 50446 individuals. A total of 7372 individuals ranging from 3.9 to 25.9 cm TL was stored for a laboratory analyses (among them 2261 were females; 1914 were males; 528 were juveniles and 2669 were badly decomposed or deformed to be used in the analyses). Monthly dissected specimens throughout the study period were given in Table 3.1. Females ranged between 10.4 and 25.9 cm TL with an average of 16.6 cm TL. Males of *M. barbatus* were between 9.6 and 19.3 cm TL, averaging 13.4 cm TL.

Table 3.1. Number of *M. barbatus* individuals analyzed in the laboratory for length-weight relationship, Somatic's K, GSI, HSI calculations.

Months	**Depth ranges in meter**						**Total**
	0-25	**25-50**	**50-75**	**75-100**	**150**	**200**	
May-07	34	21	45	Not Sampled			100
Jun-07	7	1	0				8
Jul-07	526	71	21				618
Aug-07	68	71	87				226
Sep-07	0	8	165				173
Oct-07	14	155	138				307
Nov-07	104	88	81				273
Dec-07	60	86	23				169
Jan-08	73	27	4				104
Feb-08	49	90	41				180
Mar-08	Not Sampled						0
Apr-08	35	34	2	Not Sampled			71
May-08	0	50	2				52
Jun-08	24	66	58				148
Jul-08	162	150	94				406
Aug-08	Not Sampled						0
Sep-08							0
Oct-08							0
Nov-08							0
Dec-08	8	30	222	0	31	11	302
Jan-09	6	24	50	65	7	40	192
Feb-09	31	5	55	28	7		126
Mar-09	62	43	56	12	17	30	220
Apr-09	59	82	37	9	11	37	235
May-09	52	16	51	57	0	1	177
Jun-09	61	36	0	Not Sampled			97
Jul-09	94	80	89	77	18	0	358
Aug-09	0	202	114	77	Not Sampled		393
Sep-09	16	88	97	115	35	24	375

Table 3.1. (continued). Number of *M. barbatus* individuals analyzed in the laboratory for length-weight relationship, Somatic's K, GSI, HSI calculations.

Oct-09	Not Sampled						0
Nov-09	53	52	116	91	12	14	338
Dec-09	63	89	113	77	49	10	401
Jan-10	64	92	70	50	17	26	319
Feb-10	60	70	31	43	22	19	245
Mar-10	74	100	61	17	14	22	288
Apr-10	77	30	37	12	3	63	222
May-10	50	35	104	34	9	20	255

3.1.1 The length-weight relationship

The exponent of the length-weight relationship calculated for females, males and combined sexes with juveniles is significantly different from the 3 value ($P < 0.05$) indicating a positive allometry. It was described as the following equation for combined data: $W = 0.0067TL^{3.1789}$, for males: $W = 0.0063TL^{3.1886}$ and females: $W = 0.0076TL^{3.1377}$ with a good correlation between the two variables (Figure 3.1). The slopes (b) of the L-W relationship of females and males were compared and they were found statistically different ($P > 0.05$).

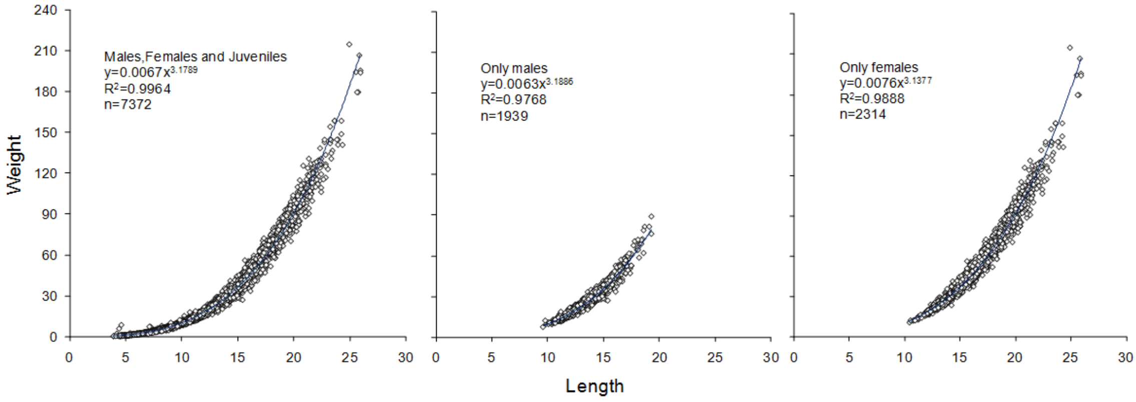


Figure 3.1. Calculated length-weight relationship (power function $W= aL^{b}$) of *M. barbatus*: for males, females and juveniles together (left), only for males (middle) and (right) only for females. a: slope; b:intercept; R^2:correlation coefficient; n:sample size).

3.1.2 von Bertalanffy growth parameters

Von Bertalanffy growth parameters of *M. barbatus* were calculated using the length frequency data of 18894 individuals collected between May 2007 and May 2010. All sexes were combined in the length frequency distributions. Young of the year (YOY) were first observed in late June – early July (5 July 2007, 26 June 2008, 17 June 2009). First they grow very fast with a rate of 1.4 cm per month. Then in November growth rate slows down until April. Young of the preceding year attains to 13 cm length next year in June – July. This seasonally oscillating growth pattern was described by seasonalized Von Bertalanffy growth model. The best fit to the length frequency distribution were obtained by the growth parameter set: L∞ = 26 cm K = 0.56, C = 0.40 and WP = 0.30 (Figure 3.2). Here, WP at which the growth rate slows down to a minimum corresponds to April.

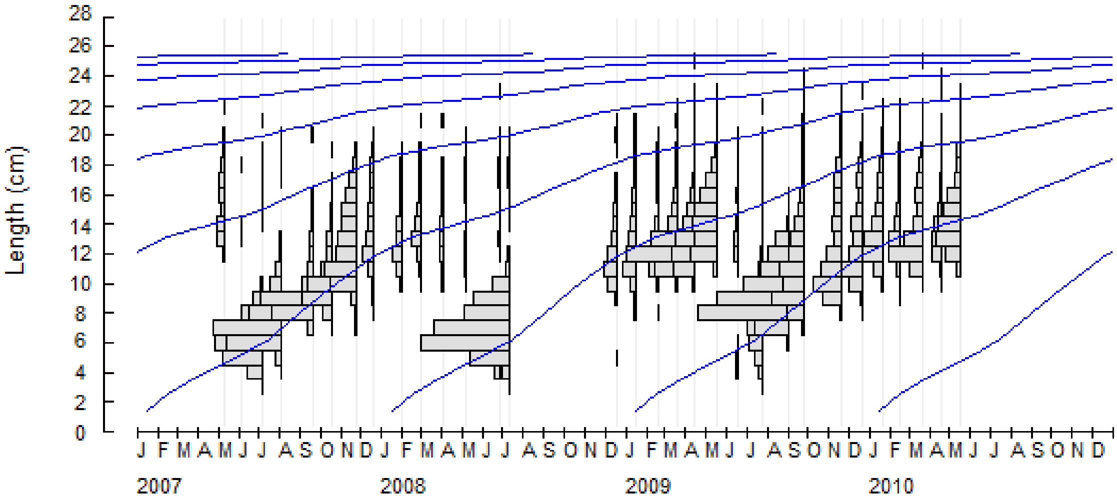


Figure 3.2. VBGF plot of *M. barbatus* covering the study period.

3.1.3 Sex-ratio and size differences in sex

The overall sex-ratio was calculated as 0.54 (1:0.85) in a slight favour to females. However as shown in Table 3.2 and Figure 3.3 this ratio changes with size; males are dominant at lengths between 9 and 13 cm while females are dominant at larger lengths. Sex could not be determined at lengths below 8 cm.

Table 3.2. Sex ratio of *M. barbatus* by length classes.

Length (cm)	Juveniles	Females	Males
3	100	0	0
4	100	0	0
5	100	0	0
6	100	0	0
7	100	0	0
8	100	0	0
9	93	0	8
10	77	3	20
11	42	4	54
12	15	13	73
13	6	24	70
14	0	51	49
15	0	74	26
16	0	79	21
17	0	91	9
18	0	95	5
19	0	98	2
20	0	100	0
21	0	100	0
22	0	100	0
23	0	100	0
24	0	100	0
25	0	100	0

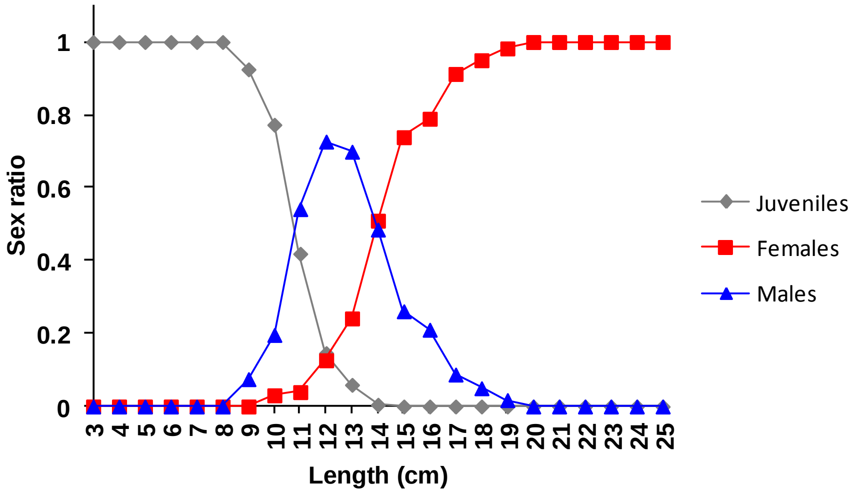


Figure 3.3. Sex-ratio in juveniles, males and females of *M. barbatus* by size.

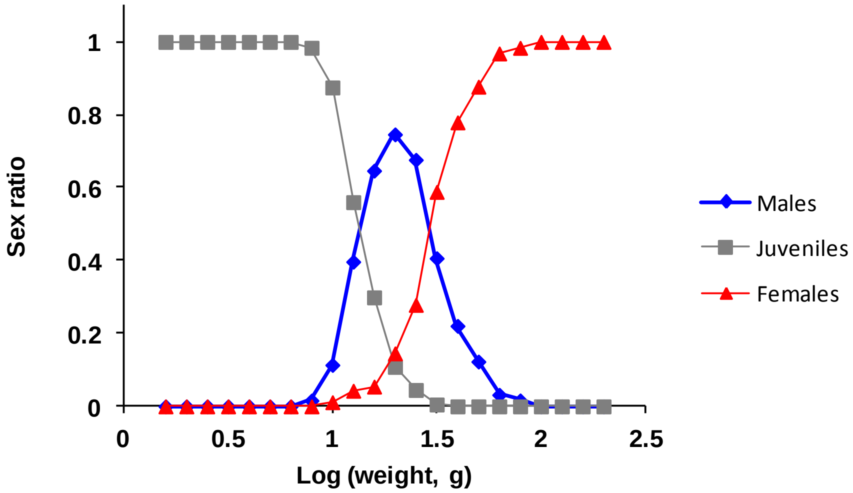


Figure 3.4. Sex-ratio in juveniles, males and females of *M. barbatus* by weight.

Concerning the weights, sex ratio individuals at weight between 5-25 g was in favor of males in the samples examined. At higher weight the ratio turned into favor of females.

3.1.4 Length at first maturity

Monthly data collected from May 2007 to May 2010 were used for length at first maturity calculation. By pooling the data from the individuals sampled from the 2007 to 2010 surveys and by fitting a logistic model to the data, the estimated length at first maturity (L_m) for females and males were 12.6 cm (r_m = 2.0) and 11.6 (r_m = 1.7) respectively (Figure 3.5 and Figure 3.6) indicating that the males generally mature at rather smaller sizes than the females.

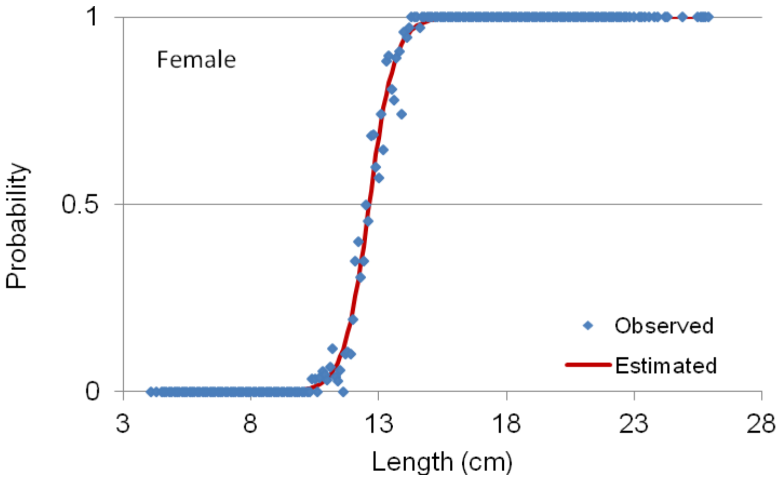


Figure 3.5.Length of first maturity calculated for females from pooled data.

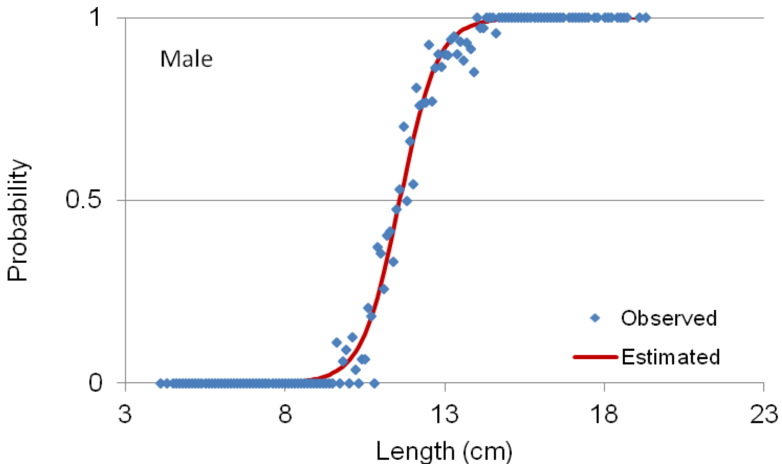


Figure 3.6.Length of first maturity calculated for males from pooled data.

3.1.5 Recruitment pattern

The monthly variation in the number of young individuals recruiting to the stock is given in Figure 3.7. The highest percentage of recruitment was observed in July and August indicating the time of recruitment.

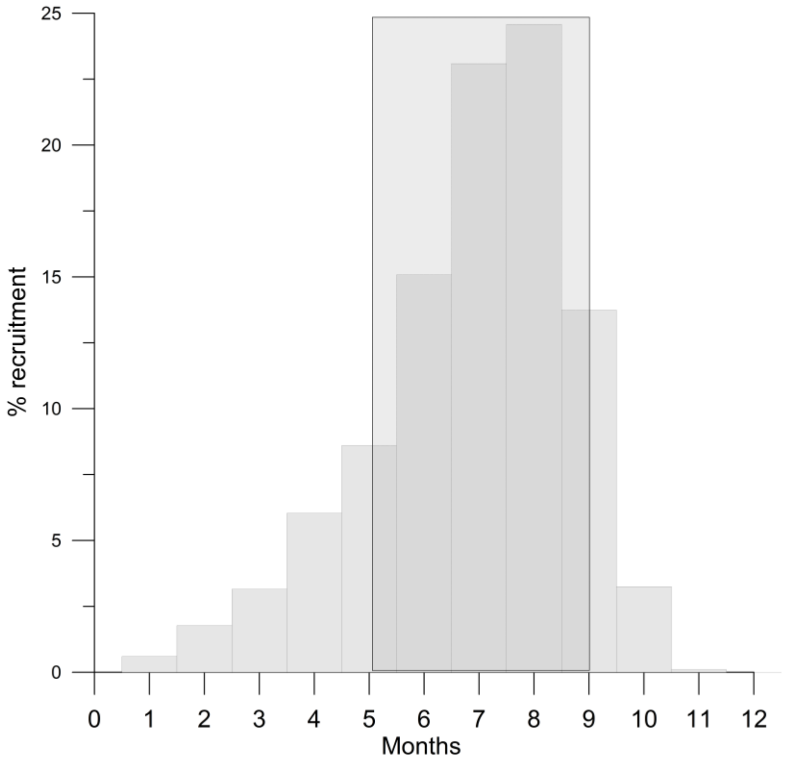


Figure 3.7. Annual recruitment pattern of *M. barbatus* - shaded area represents no-trawling season.

3.1.6 Biological indices

The GSI, HSI and Somatic K of *M. barbatus* calculated to evaluate pattern in energy allocation of the species during study are as follows:

GSI fluctuations which represent the reproductive activity of the species showed a very characteristic annual pattern repeating itself throughout the study period. This annual cycle can be summarized as follows: gonad development of females began around February; presented a sharp increase until May and then dropped suddenly. The males showed quite identical pattern to the females however it seemed that their gonad development began earlier (Figure 3.8).

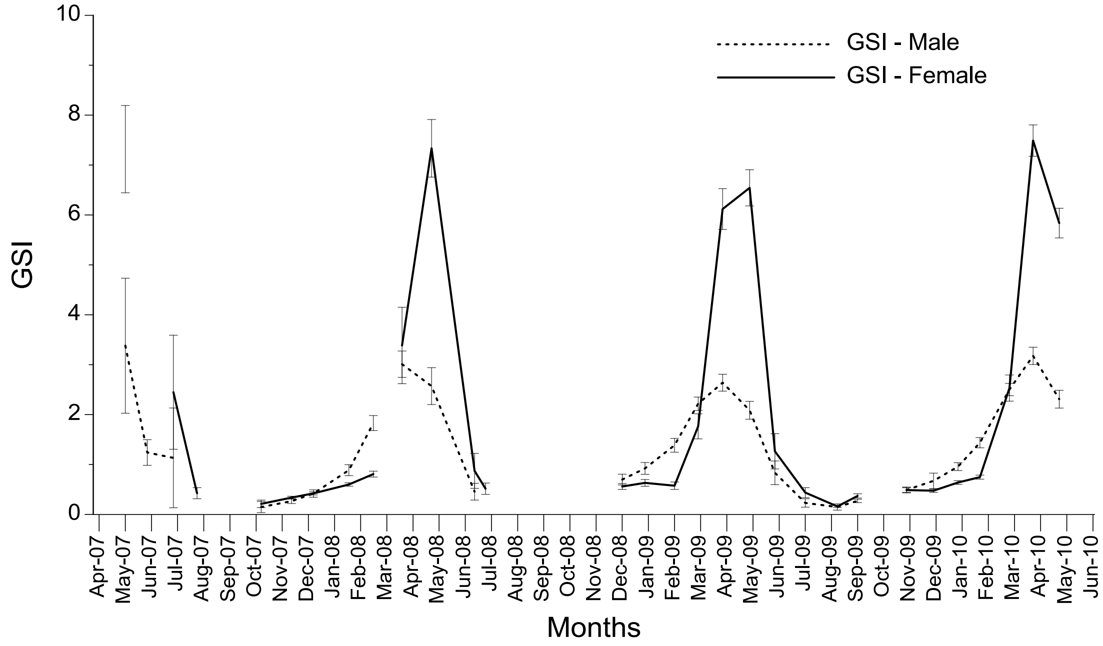


Figure 3.8. Temporal variation of mean gonado-somatic index (GSI) by sex of *M. barbatus*. Bars = Confidence intervals.

Percentage distribution of female *M. barbatus* at spawning stage within a year displayed the same annual pattern; the highest percentage of spawning females was observed in May (Figure 3.9).

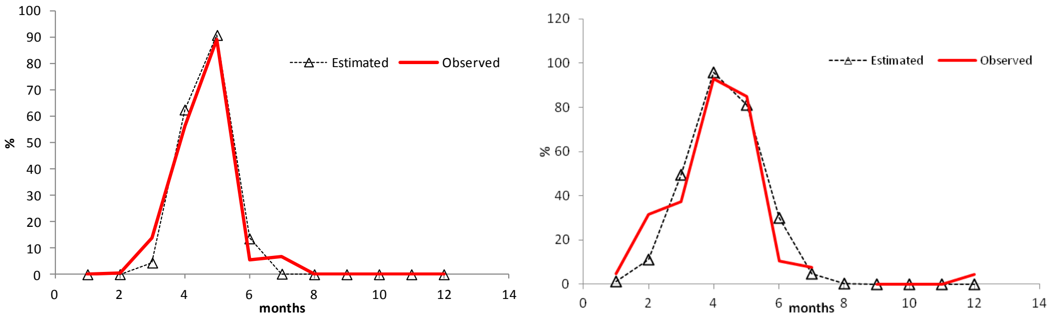


Figure 3.9. Percentage of female *M. barbatus* at spawning stage and fitted normal distribution function (left = females, right = males).

HSI in females showed an increasing trend at first, energy storage started after January and the highest values were observed in April and May. Later, they used the energy gained during gonadal development. Figure 3.10 indicated that they do not store energy before spawning. On the other hand, males showed rather different pattern in energy allocation in a year. They started to store energy around April at the onset of spawning (Figure 3.11).

Annual cycles in Somatic K of both sexes displayed irregular distribution which to a great extent masked the annual pattern. Therefore 3x running average smoothing was applied to filter the spikes in the data (Figure 3.10 and Figure 3.11). The smoothed curve of somatic K for females suggested four cycles throughout the study period. These cycles seemed to coincide with the reproductive peaks displayed in GSI curve. Smoothed K values of males showed less annual cycles than females. However it was probably due to missing data between July and October 2008. Moreover, location of these peaks on the time axis did not match with that of females, suggesting an approximately one month shift.

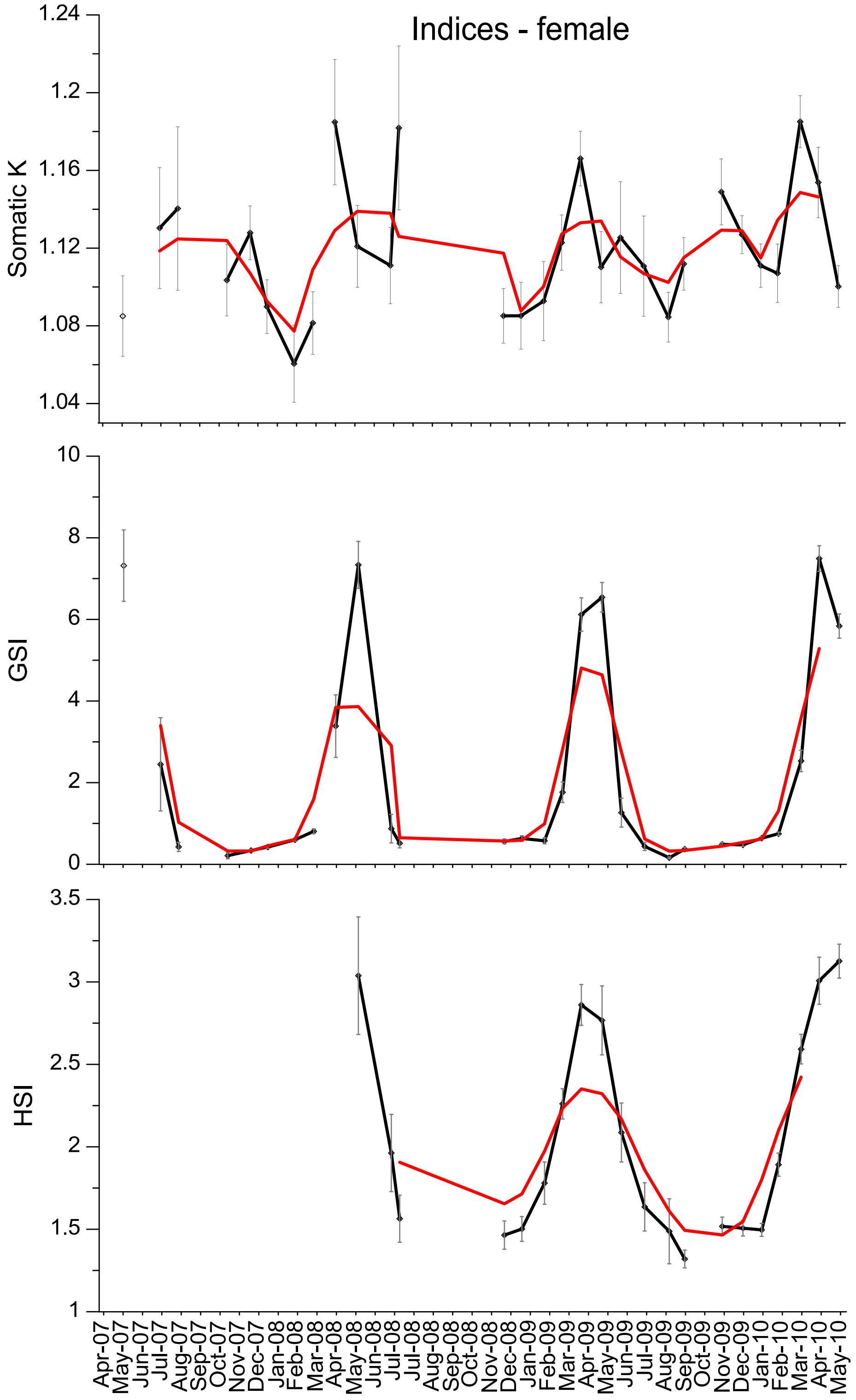


Figure 3.10. Time series of calculated biological indices of female *M. barbatus*. Continuous red lines are the 3x running averages.

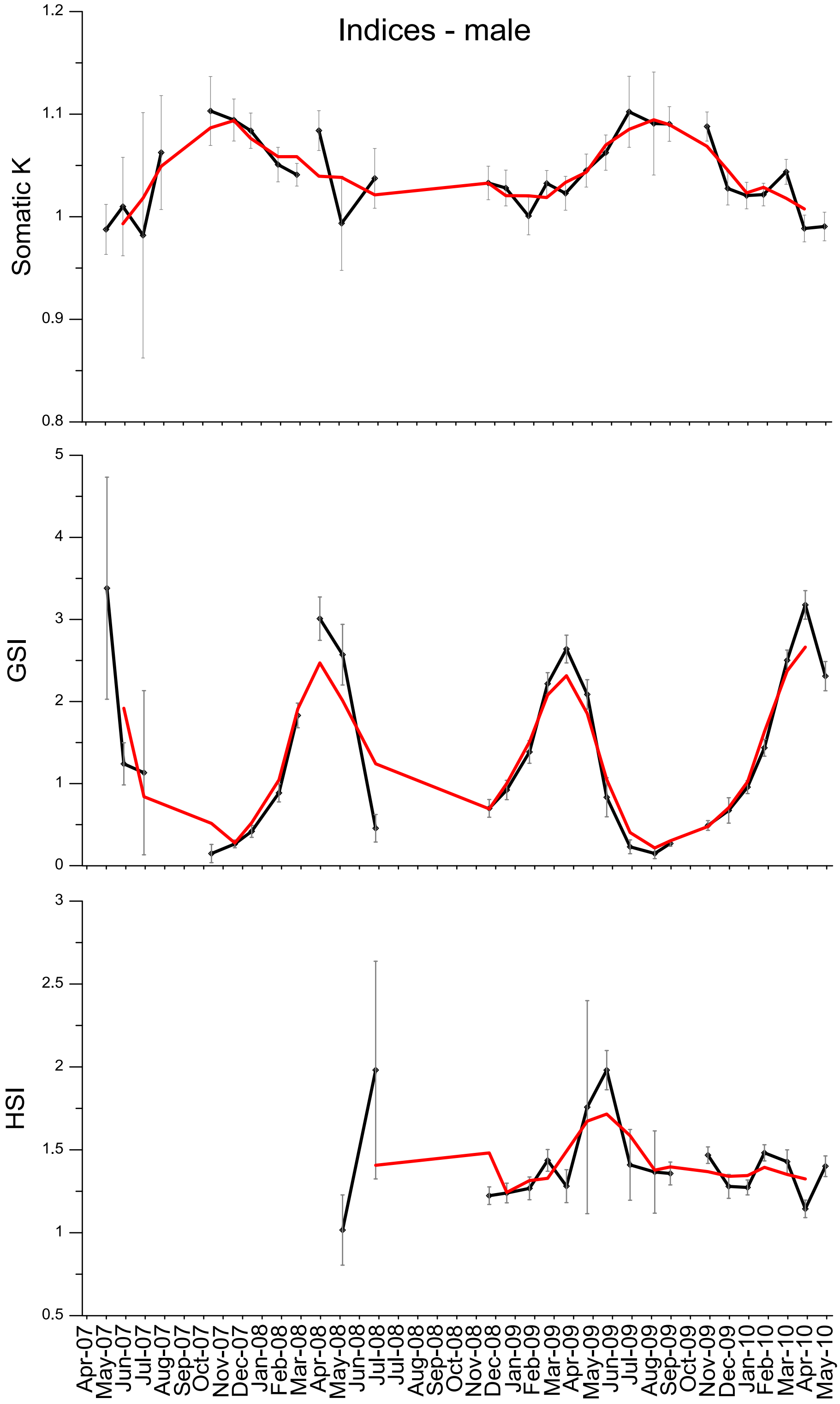


Figure 3.11. Time series of calculated biological indices of male *M. barbatus*. Continuous red lines are the 3x running averages.

3.1.7 Biomass and Abundance variations

Monthly vertical distribution of *M. barbatus* abundance in 2007-2008, 2008-2009 and 2009-2010 were depicted in (Figure 3.12) along with mean length of the individuals sampled.

Variations in total abundance through years and depth strata were given in Table 3.3. The highest total abundance was observed the first year of this study (in a year period of 2007-2008). The abundance of *M. barbatus* decreased gradually though increasing depth.

Table 3.3. Abundance variations over depth and time - *M. barbatus*. SD: Standard deviation, n: Sample size, CI: Confidence intervals.

2007-2008	**Average (ind/km^2)**	**SD**	**n**	**CI**
Total	30001	88687	33	30259
0-25 m	59443	149094	11	88108
25-50 m	21923	34179	12	19338
50-75 m	7308	10962	10	6794

2008-2009	**Average (ind/km^2)**	**SD**	**n**	**CI**
Total	14071	43461	40	13468
0-25 m	53610	88000	8	60980
25-50 m	10613	21290	8	14753
50-75 m	3922	3540	8	2453
75-100 m	2950	4422	4	4334
150 m	755	554	5	485
200 m	348	370	6	296

2009-2010	**Average (ind/km^2)**	**SD**	**n**	**CI**
Total	10859	28594	69	6747
0-25 m	18003	47541	12	26899
25-50 m	20132	44294	12	25061
50-75 m	14394	16291	13	8856
75-100 m	8443	13658	11	8071
150 m	668	518	11	306
200 m	542	362	8	251

Table 3.3.(continued). Abundance variations over depth and time - *M. barbatus*. SD: Standard deviation, n: Sample size, CI: Confidence intervals.

All Years	**Average (ind/km^2)**	**SD**	**n**	**CI**
Total	16212	52551	142	8643
0-25 m	41897	102094	31	35939
25-50 m	18424	35138	32	12174
50-75 m	9686	53084	139	8825
75-100 m	6605	11679	16	5723
150 m	695	512	16	251
200 m	459	365	14	191

In 2007-2008 the highest abundance values were observed between July and August within the upper 50 meters. As can be seen from the figure, the mean length of this group was rather small (5-6 cm) indicating the juveniles constituted to the main part of the samples. The large sized individuals (~16 cm), although not in great numbers, were located at deeper waters around 80 meters depth. In late August and early September, the surface layer (0-50 m) was almost abandoned and juveniles moved to deeper waters around 70 m and possibly deeper. In October an aggregation was observed at 50 m depth indicating that the juveniles, growing to an average length of 9 cm (Figure 3.2), begin ascending again to the shallow water. The size of the individuals and their abundance did not show a remarkable difference throughout the water column indicating that all cohorts were mixed between 0 and 80 m depth in December and January. Then another surface accumulation was observed in January.

Basic features in monthly vertical abundance observed in 2007-2008 were repeated in 2008-2009, although the monthly sampling was not complete to present the full picture (Figure 3.12). Small sized juveniles were aggregated within the upper 50 m depth in July and August. Older cohorts (~18 cm) were observed at the lowest depth range studied in the first phase of sampling in which only the upper 80 m was covered. The second shallow aggregation of *M. barbatus* observed February 2008 was also found in February 2009 at the same bathymetric range. In the second phase of the study, bathymetric range has been expanded towards shelf break (~500 m). The result showed that the vertical extend of *M. barbatus* distribution was exceeded the range covered in the first phase of the study. The individuals found in the deeper stations were significantly larger than those found in shallow depths (Mann Whitney test, $p<0.05$) although their abundance were considerably low.

In 2010, *M. barbatus* behaved as they did in previous years studied: juveniles aggregated in shallow waters before summer; leaving the shallow waters in summer to migrate to the depths deeper than 50 m; gradually ascending to the shallow waters. Significantly larger sized individuals (Mann Whitney test, $p<0.05$) were occupied deeper depths although they were less abundant compared to the shallow parts (Figure 3.12).

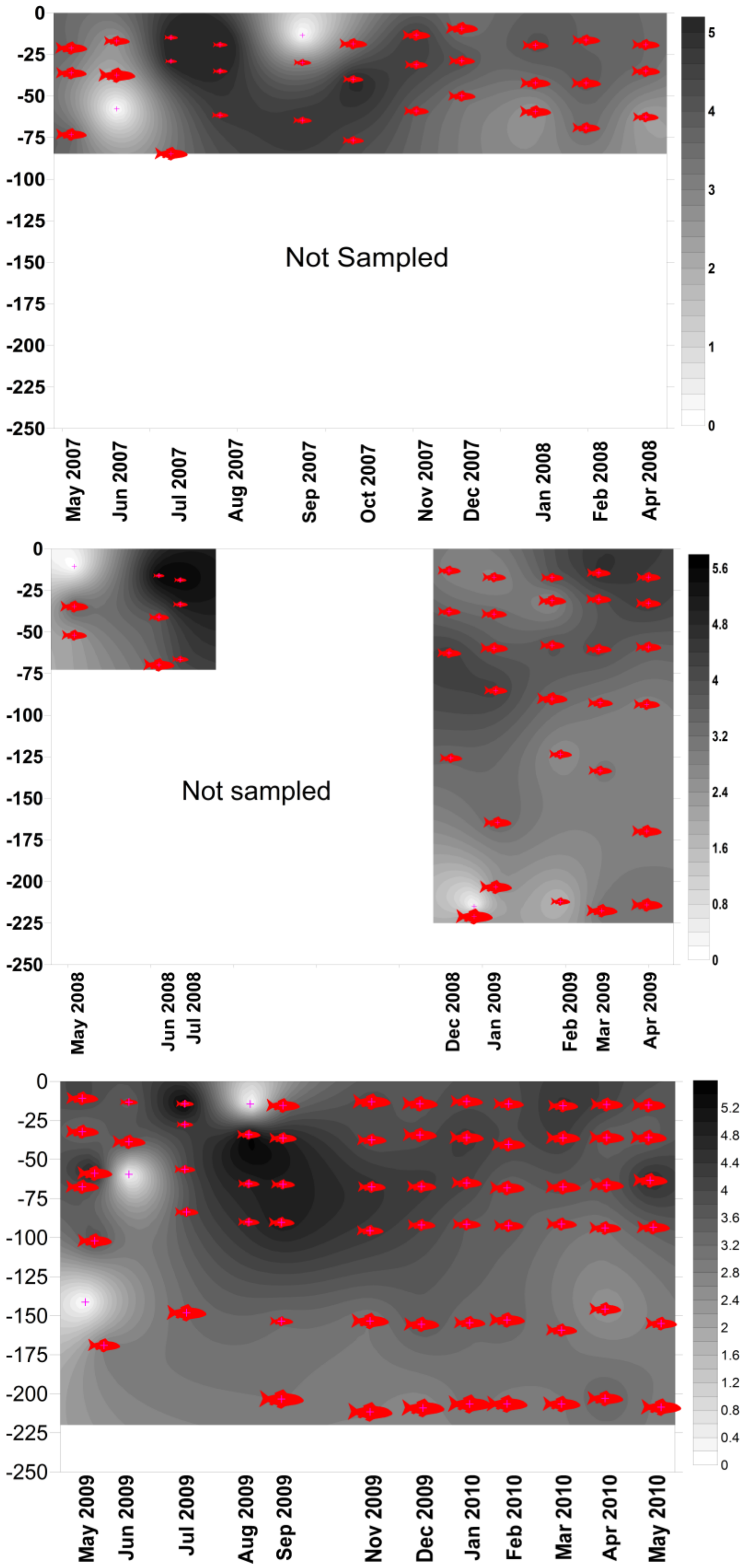


Figure 3.12.Bathymetric distribution (log transformed abundance) of *M. barbatus*. Contours in the maps show changes in biomass and abundance through depth and time. Fish symbols show the mean length proportional to symbol size. Plus signs show the sampled depth.

3.2 Por's Goatfish, *Upeneus pori* (Ben-Tuvia and Golani, 1989)

From a total of 9271 individuals caught during the trawl surveys the lengths of 3577 specimens ranging from 5 to 19 cm were measured on board. A total of 1978 individuals ranging from 5 to 19 cm TL was stored for a laboratory analyses (among them 661 were females; 600 were males; 115 were juveniles and 602 were badly decomposed or deformed to be used in the analyses). Monthly dissected specimens throughout the study period were given in Table 3.4. Females ranged between 8.3 and 19.2 cm TL with an average of 13.4 cm TL. Males of *U. pori* were between 8.0 and 16.1 cm TL, averaging 11.4 cm TL.

Table 3.4. Number of *U. pori* individuals analyzed in the laboratory for length-weight relationship, Somatic K, GSI, HSI calculations.

Months	**Depth ranges in meter**						**Total**
	0-25	**25-50**	**50-75**	**75-100**	**150**	**200**	
May-07	25	4	0	Not Sampled			29
Jun-07	32	0	0				32
Jul-07	6	20	0				26
Aug-07	61	23	0				84
Sep-07	9	0	0				9
Oct-07	23	112	0				135
Nov-07	46	49	0				95
Dec-07	75	51	0				126
Jan-08	64	0	0				64
Feb-08	36	1	0				37
Mar-08	Not Sampled						0
Apr-08	65	5	0				70
May-08	98	1	0				99
Jun-08	0	23	1				24
Jul-08	25	39	0				64
Aug-08	Not Sampled						0
Sep-08							0
Oct-08							0
Nov-08							0
Dec-08	45	70	0	0	0	0	115
Jan-09	58	8	0	0	0	0	66
Feb-09	9	0	0	0	0	0	9
Mar-09	51	3	0	0	0	0	54
Apr-09	35	0	0	0	0	0	35
May-09	45	0	0	0	0	0	45
Jun-09	39	0	0	Not Sampled			39
Jul-09	2	2	0	0	0	0	4
Aug-09	115	35	0	0	Not Sampled		150
Sep-09	55	6	0	0	0	0	61
Oct-09	Not Sampled						0
Nov-09	110	0	0	0	0	0	110

Table 3.4.(continued). Number of *U. pori* individuals analyzed in the laboratory for length-weight relationship, Somatic K, GSI, HSI calculations.

Dec-09	100	0	0	0	0	0	100
Jan-10	55	0	0	0	0	0	55
Feb-10	74	0	0	0	0	0	74
Mar-10	54	0	0	0	0	0	54
Apr-10	73	0	0	0	0	0	73
May-10	40	0	0	0	0	0	40

3.2.1 The length-weight relationship

The exponent of the length-weight relationship calculated for females, males and combined sexes with juveniles was not significantly different from the value, 3 ($P < 0.05$) indicating growth in *U. pori* is isometric. It was described as the following equation for combined data: $W=0.0067L^{3.1551}$, for males: W = $W=0.0074L^{3.1083}$ and females: $W=0.0071L^{3.1369}$ with a good correlation between constants a and b. The length-weight relationship curves of all *U. pori* samples (Figure 3.13) showed that females of the species are plumper than males at the same length.

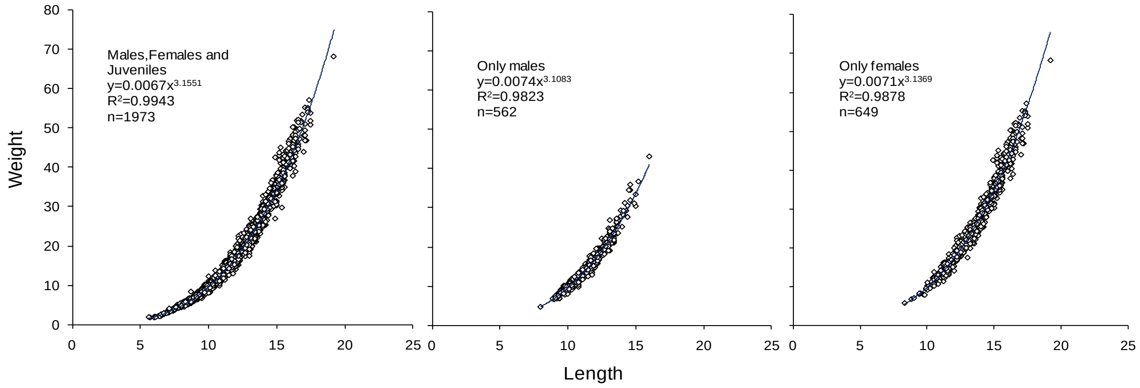


Figure 3.13. Calculated length-weight relationship (power function W= aLb) of U. pori: for males, females and juveniles together (left), only for males (middle) and (right) only for females. a: slope; b:intercept; R2:correlation coefficient; n:sample size).

3.2.2 von Bertalanffy growth parameters

VBGF parameters of *U. pori* were calculated using the length frequency data of 3577 specimens ranging from 5.0 to 19.0 cm. Computed seasonalized VBGF parameters of *U. pori* values are $L\infty = 20.0$, $K = 0.45$, $C = 0.40$, $WP = 0.20$. YoY was first observed in August when their total length was around 5-6 cm long except very few and very small individuals observed in May 2008. Amplitude of the growth oscillation (C= 0.4) suggests a quite remarkable impact of seasonality on the growth. Estimated WP value which corresponds to

February suggested that the growth was its maximum during August when YOY was observed in the samples. Following three months of fast growth phase, growth slowed down in winter. Next year the cohort reached to 12 cm length (Figure 3.14).

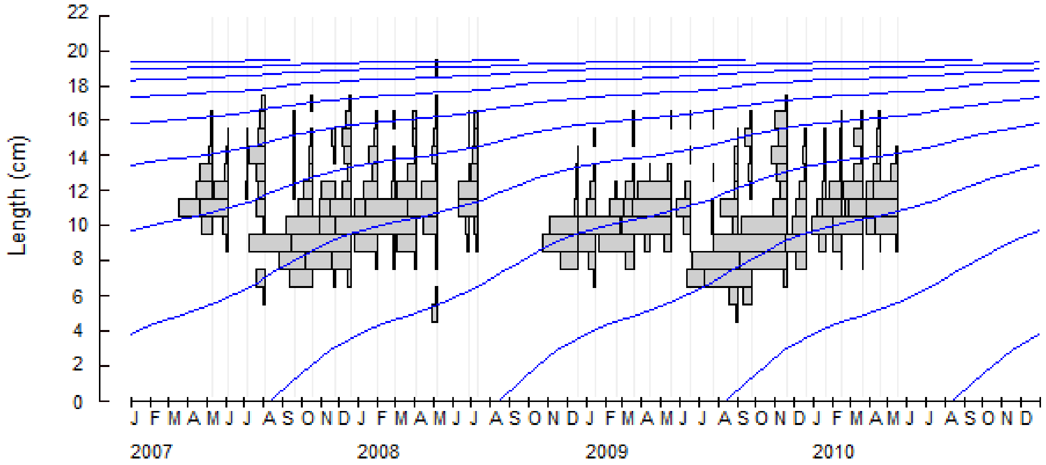


Figure 3.14. VBGF plot of *U. pori* covering the study period.

3.2.3 Sex-ratio and size differences in sex

The sex-ratio of the samples was calculated as 0.55 (1:0.82) in a slight favour to females. This ratio differed between females, males and juveniles in different sizes (Figure 3.15).

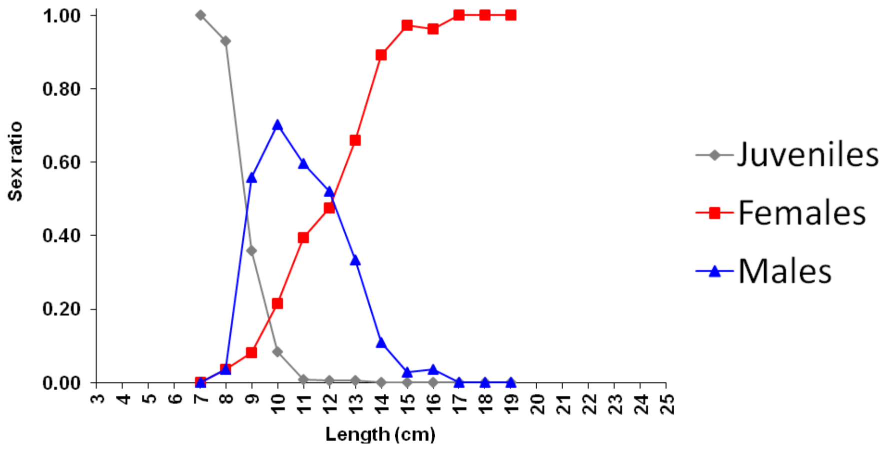


Figure 3.15. Sex-ratio in juveniles, males and females of *U. pori* by length classes.

Immature individuals belonging to the length classes of 7-8 cm could not be sexed so that they were classified as juveniles and dominated these two length classes. Males populated the length classes between 9 and 12 cm while lengths above 17 cm were exclusively females (Table 3.5).

Table 3.5. Sex ratio of *U. pori* by length classes.

Length (cm)	Juveniles	Females	Males
7	100	0	0
8	93	4	4
9	36	8	56
10	8	22	70
11	1	40	60
12	0	48	52
13	1	66	33
14	0	89	11
15	0	97	3
16	0	96	4
17	0	100	0
18	0	100	0
19	0	100	0

3.2.4 Length at first maturity (L_m)

Length at first maturity calculations were based on the monthly data collected from May 2007 to May 2010. By pooling the data from the individuals sampled from the 2007 to 2010 surveys and by fitting a logistic model to the data, the length at first maturity (L_m) for males and females were estimated as 9.5 cm (maturation rate, r_m = 2.87) (Figure 3.16) and 10.0 cm (maturation rate , r_m = 2.51) respectively (Figure 3.17). Slightly larger L_m in males indicated that the transition from juvenile to fully mature male occurred within a narrower range of length limits.

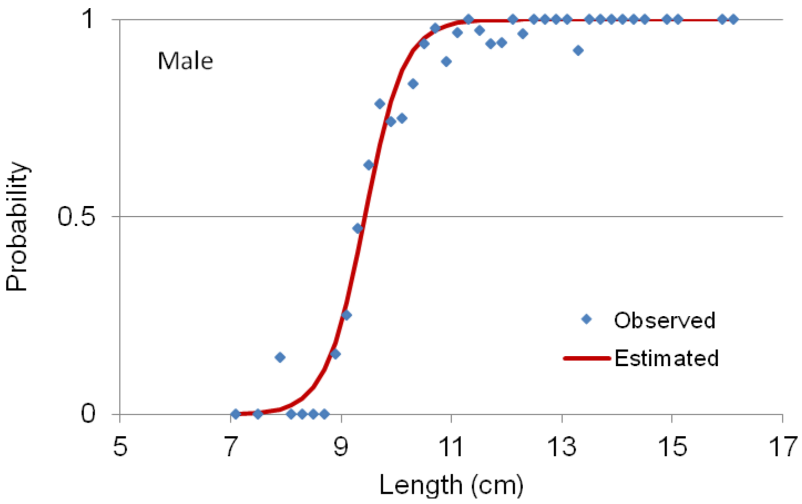


Figure 3.16. Length of first maturity calculated for male *U. pori* from pooled data.

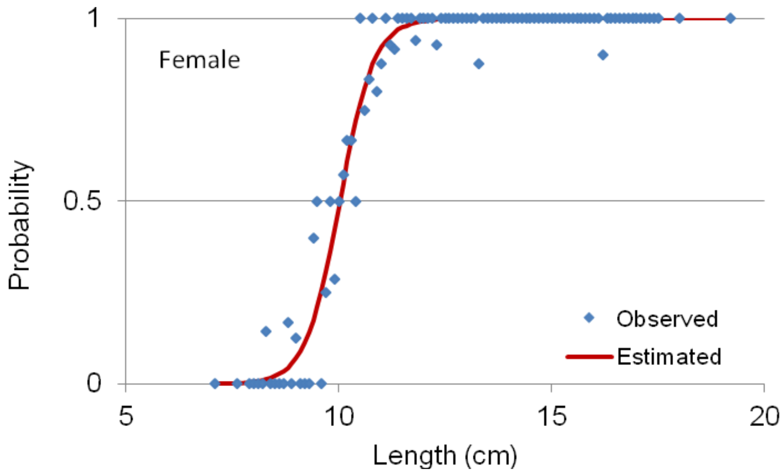


Figure 3.17.Length of first maturity calculated for female *U. pori* from pooled data.

3.2.5 Biological indices

The biological indices examined separately for males and females were summarized in Figure 3.18 and Figure 3.19. Based on 642 females dissected and analyzed, the annual reproduction cycle of female *U. pori* were given in the following: gonad development started after February. Gonad activity was at its maximum levels in April – May and then a gradual decline in GSI was observed until late summer (Figure 3.18). The males displayed almost similar pattern in the annual gonad development (Figure 3.19).

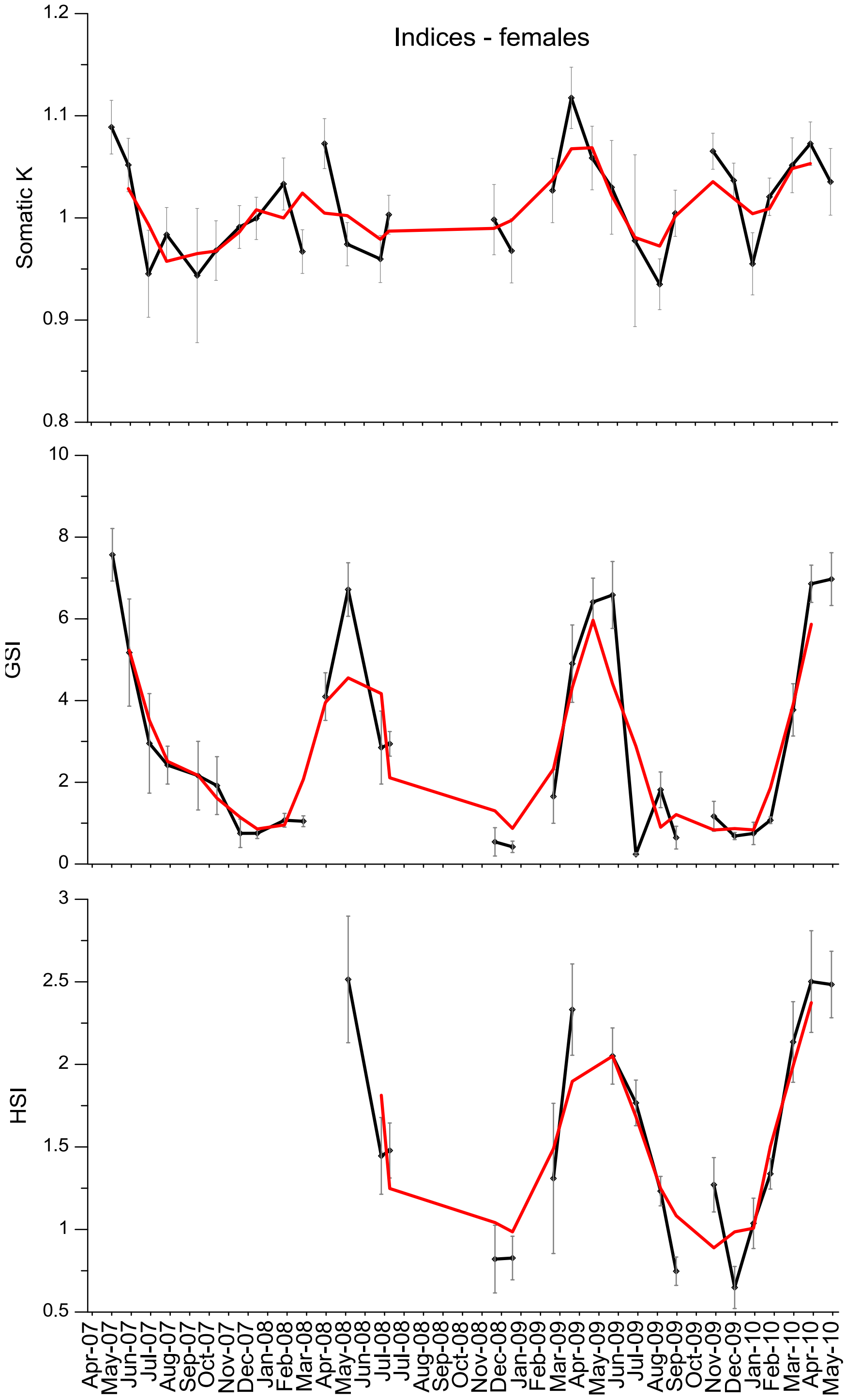


Figure 3.18. Time series of calculated biological indices of female *U.pori*. Continuous red lines are the 3x running averages.

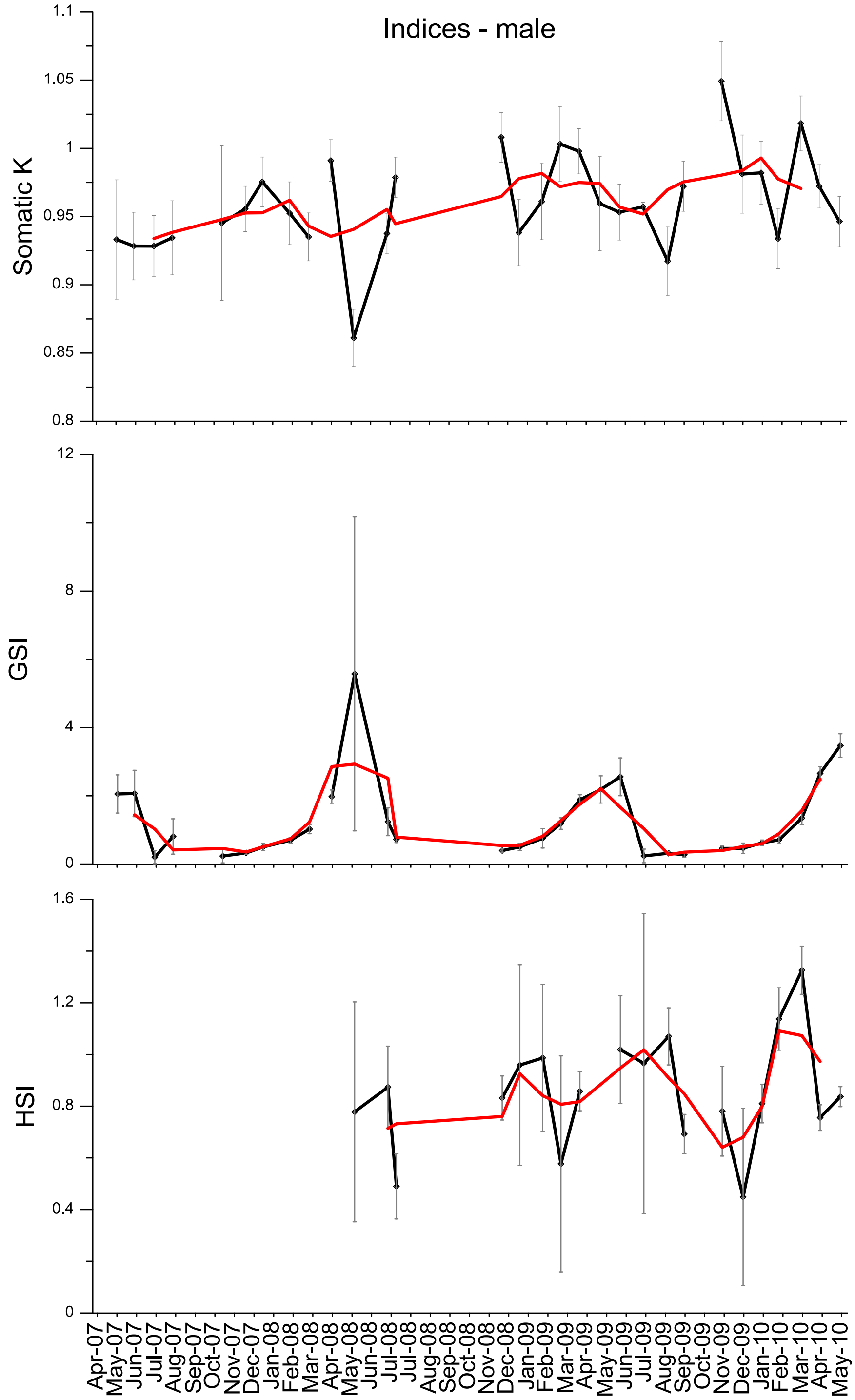


Figure 3.19. Time series of calculated biological indices of male *U. pori*. Continuous red lines are the 3x running averages.

In order to better investigate the existence of secondary spawners, two approaches were performed. The mean GSI values of the males and females at “spawning stage” and their non-outliers (3 standard deviation greater or smaller than the mean) ranges were presented in Figure 3.20. Upper non-outlier range of developing females (stage 2) was assumed as the onset of spawning so the female spawners was set over the GSI value of 3 and the upper range of the males was on 1.2.

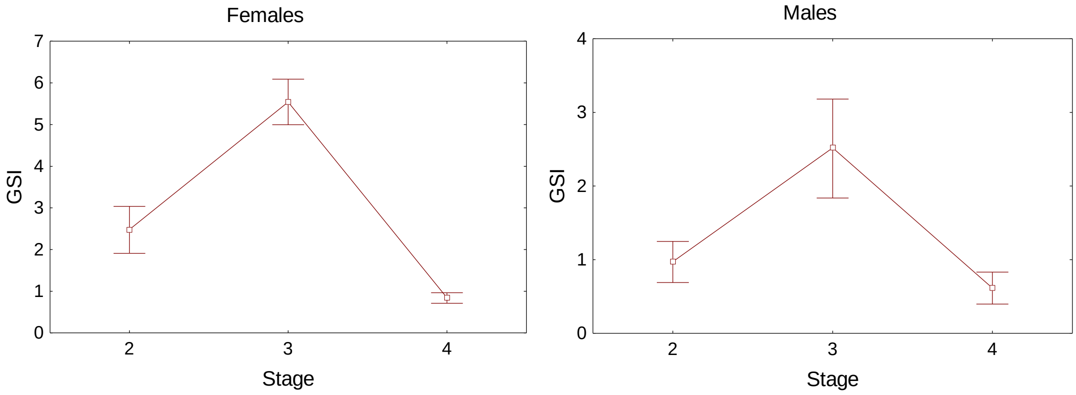


Figure 3.20. Mean GSI values at gonad stages and their non-outlier ranges (left= females; right = males).

When the average GSI values of males and females at stage 3 were compared the female GSI was found greater than the males and the difference between males and females was found statistically significant (P <0.001, Mann Whitney U test).

The seasonal variations in GSI of females (Figure 3.18) and males (Figure 3.19) in three successive years were overlaid on the annual scale in Figure 3.21. The data points accumulated over the upper non-outlier range of stage 2 indicated the onset of spawning. The values above the lines showed that gonad development starts after day 60 when a part of females began to invest on gonadal activity. At day 120 there were still some females with low GSI values. A month later, all GSI values were above 4 indicating that all females took part in spawning. The decline following the day 185 marked the time of spawning. Interestingly some of the females represented high GSI values above “3” until day 360 (Figure 3.21). Despite the differences in the absolute values, it was also observed that the males represented the same fluctuations in their GSI (Figure 3.22).

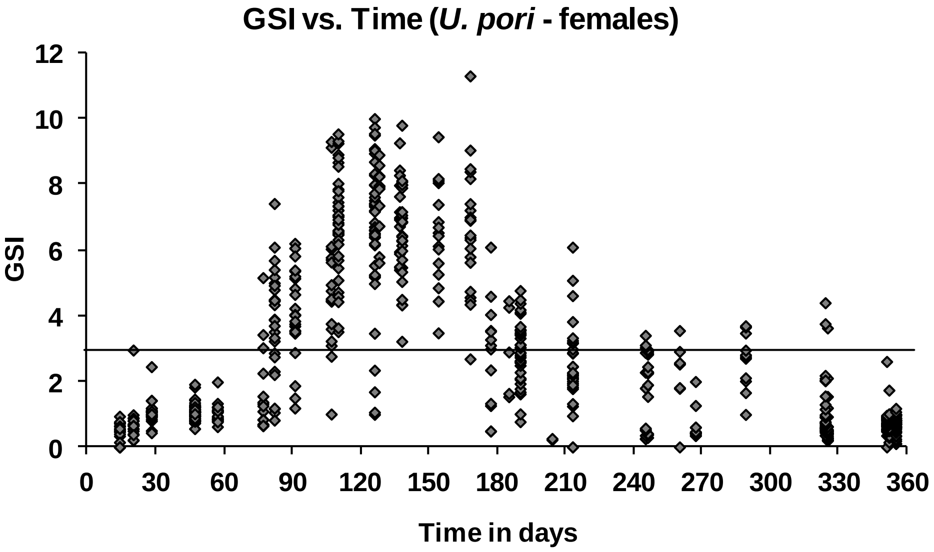


Figure 3.21. Annualized GSI values of all females dissected throughout the study.

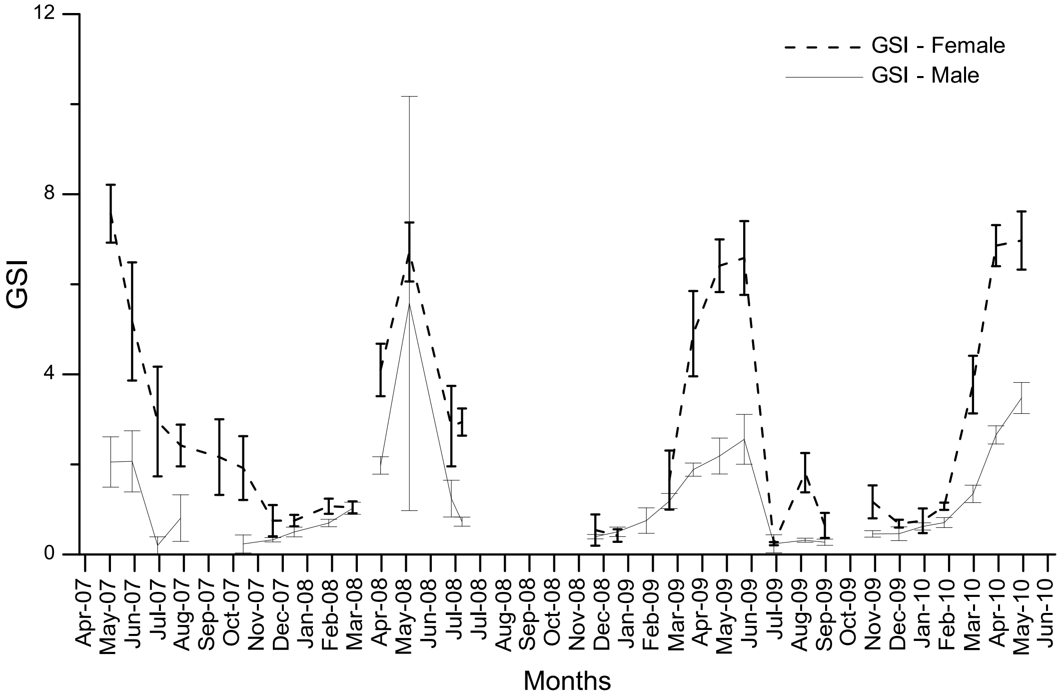


Figure 3.22. Temporal variation of mean gonado-somatic index (GSI) by sex of *U. pori*, Bars = Confidence intervals.

Percentage distribution of maturity stage in females and males through time was depicted in Figure 3.23. *U. pori* at spawning stage within a year displayed the same annual pattern; Females at developing and spent/resting maturity stages were high in January and February period. After February percentage of individuals at spawning stage increased. The highest percentage of females at spawning stage was observed in May and in November. Individuals at developing stage were observed in January and February. The highest percentage of males at spawning stage was observed in spring (in April) and autumn (in October).

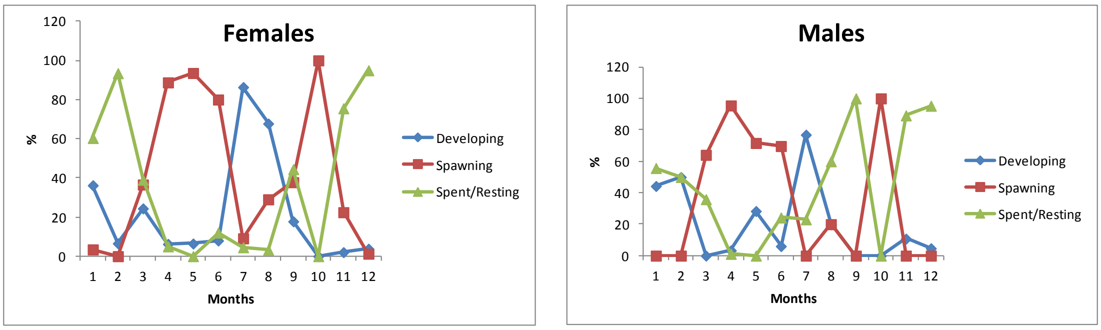


Figure 3.23. Monthly % maturity stages in female and male of *U. pori*

Two normal distribution functions fitted to the monthly percentage distribution over a year indicated that 67 % of spawning took place during the spring spawning and only 33 % occurs in autumn (Figure 3.24). For males the ratio was 78 % and 22 %, respectively.

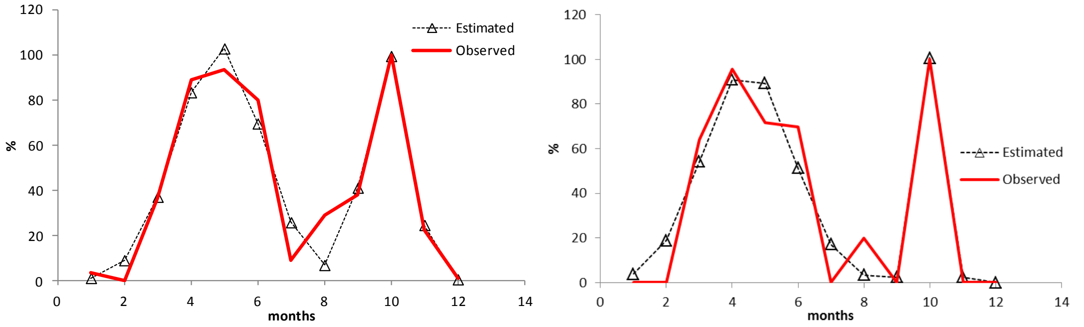


Figure 3.24. Percentage of female *U. pori* at spawning stage and fitted normal distribution function (left = female; right = male).

Table 3.6. The mean spawning date of the first and the second spawning period with 95% confidence limits.

	Spring/summer spawners				**Autumn/winter spawners**			
Sex	**Males**		**Females**		**Males**		**Females**	
% involved	78 %		67 %		22 %		33 %	
Mean date	12-Apr		24-Apr		26-Sep		22-Sep	
95% CL	20-Mar	6-May	2-Apr	30-Aug	3-Sep	19-Oct	16-May	15-Oct

The length distribution of females at stage 3 was represented in Figure 3.25. The most frequent size group is 12.5 cm. This figure shows all females regardless of time at which they were sampled. The same figure also shows the size distribution of the females at the same stage after the first spawning time (after day 185; see Figure 3.21). The length distributions were statistically tested to see if the mean length of spring and autumn spawners are significant. F-test showed that the variances of both distributions are not statistically different which allows use of parametric t-test. The results show that the late spawners were significantly larger than the spring spawners (Figure 3.26 and Table 3.7). A non-parametric test results were also presented and the same conclusion was reached; the length differences, although very small, are statistically highly significant.

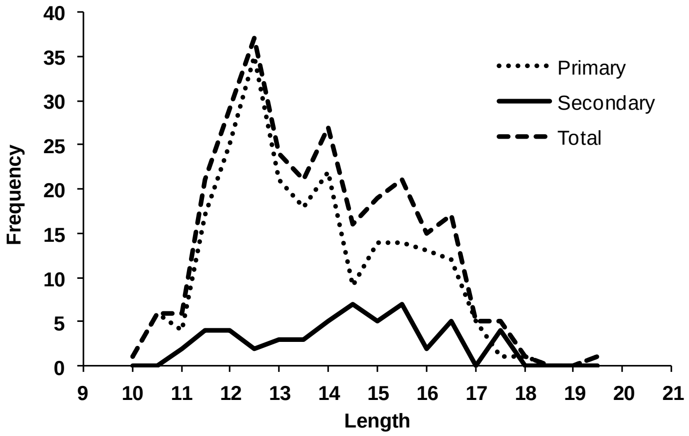


Figure 3.25. Spawning groups of *U. pori* by length.

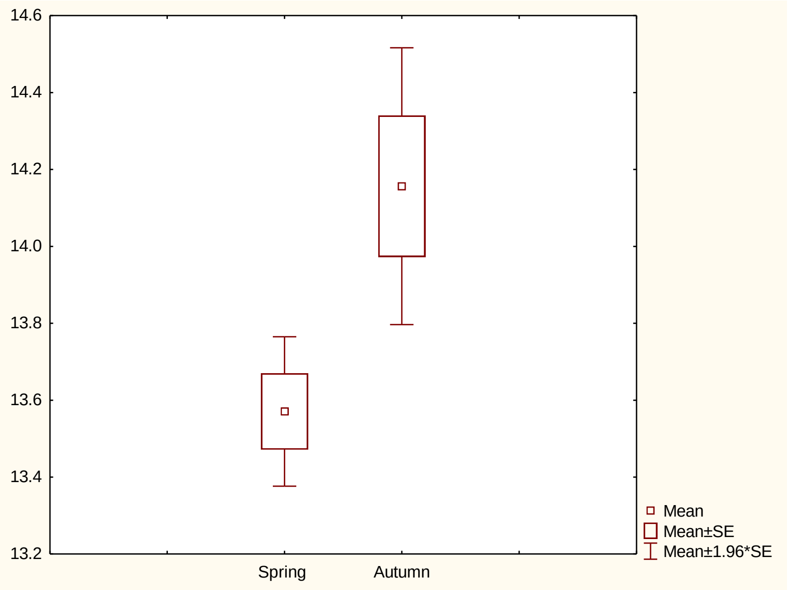


Figure 3.26. Box & Whisker Plot of length distributions of spring and autumn spawners of *U. pori.*

Table 3.7. Statistical comparison of spring and autumn group reproductively active female *U. pori* (t-test; F test and Mann-Whitney U Test) tests are significant at p <.05000.

	Between day 60 to day 185 (Spring)		**Between day 185 to 355 (Autumn)**	
L_{mean}	13.57		14.16	
Range	10.0	19.2	10.6	17.5
N	332		92	
t value	-2.769			
Df	422			
P	0.00588 (highly significant)			
st.dev.	1.80		1.76	
F-ratio	1.0497			
P	0.798 (not significant)			
Rank Sum	67670.00		22430.00	
U	12392.00			
Z	2.769017			
P	0.005623 (highly significant)			
Z-adjust	-2.769591			
P	0.005613 (highly significant)			

As the length classes on Figure 3.14 were converted to corresponding ages using vBGF function the females at age class II comprise more than 50 % of the spawning females. Age class I and III had almost equal contribution around 20 %. The highest contributors to the secondary spawners are again age class II; however the share of age class III and IV are more pronounced when compared to primary spawners (Figure 3.27).

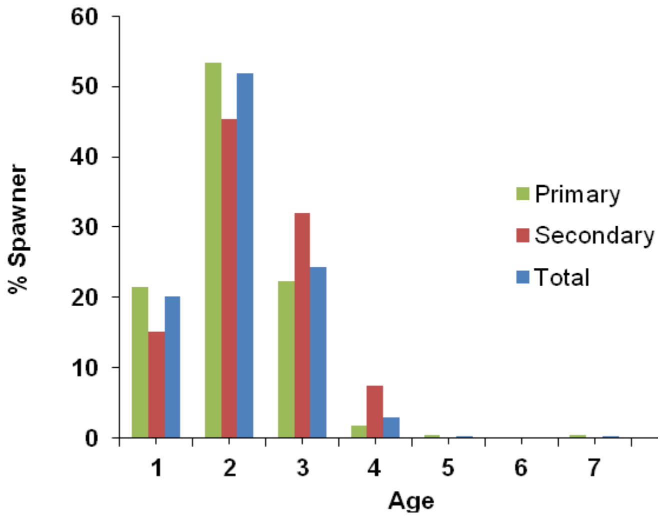


Figure 3.27. Spawning groups of *U. Pori* by age.

Variations in HSI of females were very similar to the variations in GSI. The maximum values were observed in April-May and the values were low during autumn and winter (Figure 3.18). However no clear pattern was observed in HSI of males (Figure 3.19).

Annual variations in the somatic K of both sexes were noisier than the other two indexes. Due to this irregular distribution observed in annual cycles of somatic K, 3x running average smoothing was applied to the data for better assessment of the pattern. The smoothed curve of somatic K indicated that although Somatic K varied quite sharply through the months, the main features are clear and consistent with the features observed in GSI and HSI (Figure 3.18 and Figure 3.19). The somatic condition is usually attained to its highest state just before the maximum in GSI and HSI was observed. Although the sampling frequency did not allow putting the statement further, there is almost a month difference between K and the other indexes.

3.2.6 Biomass and Abundance variations

Monthly vertical distribution of *U. pori* abundance in 2007-2008, 2008-2009 and 2009-2010 were depicted in Figure 3.28 along with the mean length of the individuals sampled.

Although *U. pori* distributed in the shallow waters starting from 9.2 m (it should be noted that it is also the minimum haul depth sampled) down to 40 meters depths, bulk of the abundance (91.8%) was concentrated between 10 and 20 meters depth strata. The deepest depth that the species sampled was 90 m in December 2009. However since this was only one single individual, it was assumed that this is an unusual observation and it does not necessarily reflect any information on the depth range of this species. The highest abundance values and the mean length were observed in 2009-2010 period. This can be seen from the very dark abundance tone in lower graph of Figure 3.28.

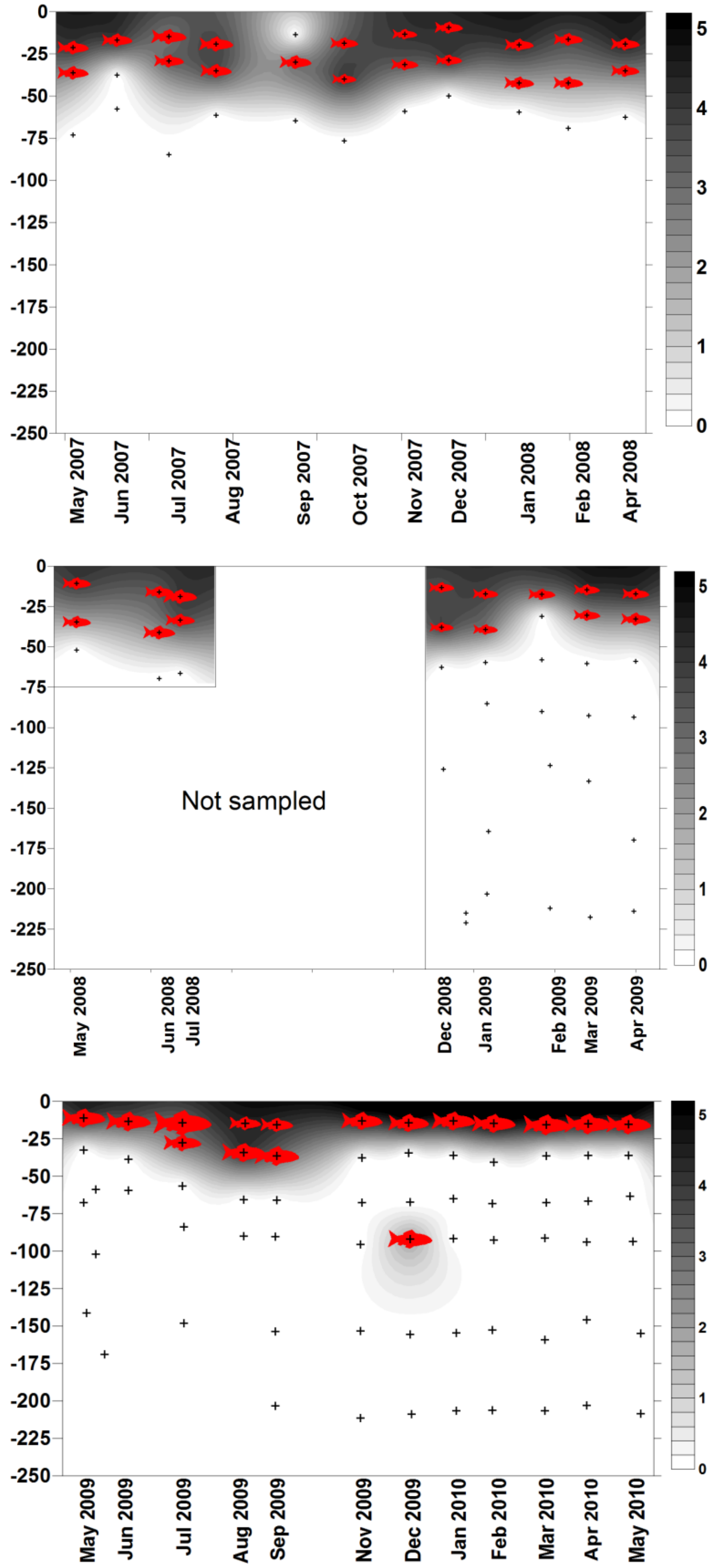


Figure 3.28. Bathymetric distribution (transformed abundance) of *U. pori*. Contours in the maps show changes in abundance through depth and time. Fish symbols show the mean length proportional to symbol size. Plus signs show the sampled depth.

The variation in the biomass of the species was depicted in Figure 3.29. The difference between years was so high that in order to see the variation on a single graph logarithmic scale was used on the ordinate. The figure shows a remarkable increase in biomass of the species after October 2009 and remained high since then. Figure also points to a seasonal vertical displacement. The biomass is always high at 0-25 m stratum. During the warm period the species seems to descent to next depth stratum and with the onset of the winter they ascent to the shallower depths. In 2009 and 2010 winter the species were totally absent at the deeper stratum.

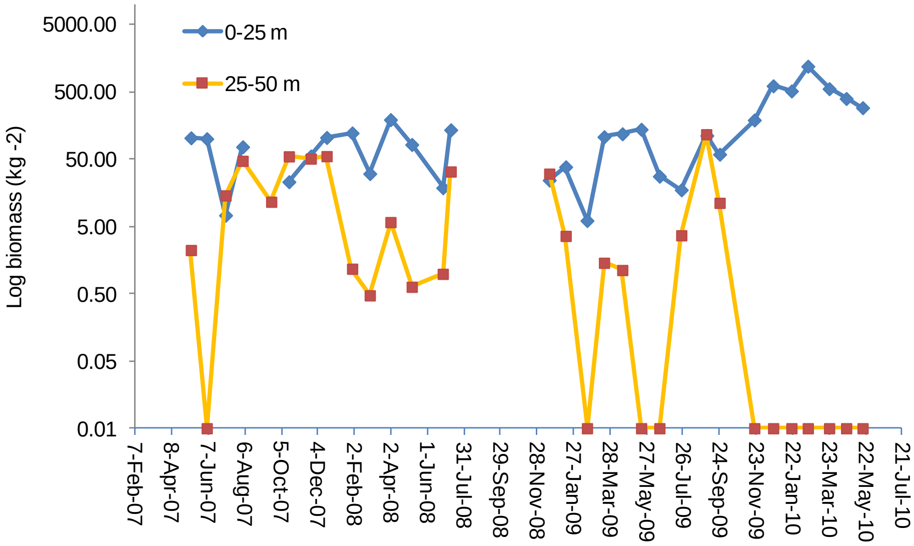


Figure 3.29. Logarithmic biomass (kg Km$^{2)}$ variations of *U. pori* in time.

3.3 Common Pandora *Pagellus erythrinus* (Linnaeus, 1758)

Of the 13655 individuals caught during the surveys, 7312 individuals were measured on board and a total of 3536 individuals ranging from 2.8 to 23.4 cm TL were dissected at the laboratory for biometric measurements. Among them 492 were females; 76 males; 829 were juveniles and 2139 were badly decomposed or deformed to be used. Monthly dissected specimens throughout the study period were given in Table 3.8. Females ranged between 11.1 and 23.1 cm TL with an average of 15.7 cm TL. Males of *P. erythrinus* were between 12.3 and 23.4 cm TL, averaging 16.5 cm TL. It is worth noting that by far the greater percentage of the individuals (62.1 %) sampled were composed of juveniles. Males formed only 5.7 % of the sample while females made up 32.2 %.

Table 3.8. Number of *P. erythrinus* individuals analyzed in the laboratory for length-weight relationship, Somatic K, GSI, HSI calculations.

Months	Depth ranges in meter						Total
	0-25	25-50	50-75	75-100	150	200	
May-07	2	0	0	Not Sampled			2
Jun-07	1	0	0				1
Jul-07	52	20	10				82
Aug-07	56	39	83				178
Sep-07	6	34	66				106
Oct-07	66	69	80				215
Nov-07	52	34	45				131
Dec-07	45	44	12				101
Jan-08	45	5	5				55
Feb-08	25	16	111				152
Mar-08	Not Sampled						0
Apr-08	18	4	52				74
May-08	38	4	2				44
Jun-08	41	87	34				162
Jul-08	45	82	78				205
Aug-08	Not Sampled						0
Sep-08							0
Oct-08							0
Nov-08							0
Dec-08	24	4	137	0	0	0	165
Jan-09	18	4	4	4	0	0	30
Feb-09	0	0	25	0	0	0	25
Mar-09	22	30	22	18	0	0	92
Apr-09	9	17	7	5	1	0	39
May-09	0	4	41	21	0	0	66
Jun-09	0	0	42	Not Sampled			42
Jul-09	35	0	208	13	0	0	256
Aug-09	79	109	194	20	Not Sampled		402
Sep-09	42	28	56	28	0	0	154
Oct-09	Not Sampled						0
Nov-09	29	70	66	22	0	0	187
Dec-09	70	29	1	9	0	0	109
Jan-10	48	35	6	1	0	0	90
Feb-10	37	13	1	10	0	0	61
Mar-10	33	38	55	54	0	0	180
Apr-10	46	11	19	10	0	0	86
May-10	0	18	14	12	0	0	44

3.3.1 The length-weight relationship

The exponent of the length-weight relationship calculated for females, males and combined sexes with juveniles is significantly different from the 3 value ($P < 0.05$).

It was described as $W=0.0109L^{3.0536}$ for pooled data; $W=0.00244L^{2.7601}$ for males and $W=0.0199L^{2.8341}$ for female with a statistically significant correlation between these two variables (Figure 3.30). Males and females showed remarkable negative allometry with b value of 2.76 and 2.83, respectively. On the other hand, when all samples including juveniles were combined the length-weight relationship show positive allometry.

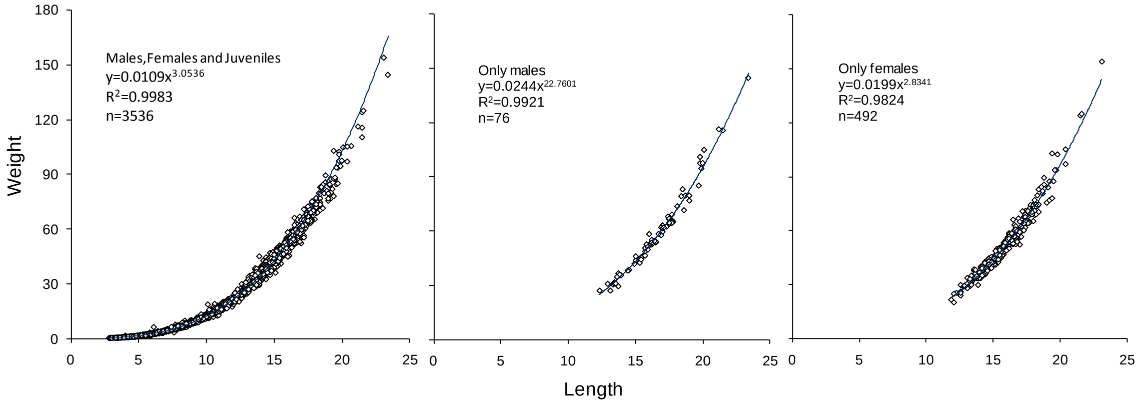


Figure 3.30. Calculated length-weight relationship (power function W= aL^b) of *P. erythrinus*: for males, females and juveniles together (left), only for males (middle) and (right) only for females. a: slope; b:intercept; R^2:correlation coefficient; n:sample size.

3.3.2 von Bertalanffy growth parameters

VBGF parameters of *P. erythrinus* are calculated based on monthly length frequency data of 7312 individuals sampled by 142 trawl operations performed between May 2007 and May 2010. During the sampling wide length spectrum ranging from 2.0 to 23.0 cm were observed. Computed seasonalized VBGF parameters of L∞ and K of the species values are 25 cm and 0.60 per year, respectively (Figure 3.31). Young of the year (YOY) was first observed in June-July. A quite strong seasonality was observed and the amplitude of the growth oscillation was calculated as 0.60. As suggested by winter point (WP) of 0.5 they represent a rather slow growth when they were first observed in June. Then they underwent a very rapid growth which accelerated in December. As stated earlier, majority of the samples were in juvenile stage, therefore II age class and older (as converted from length) were not represented in the length frequency distribution.

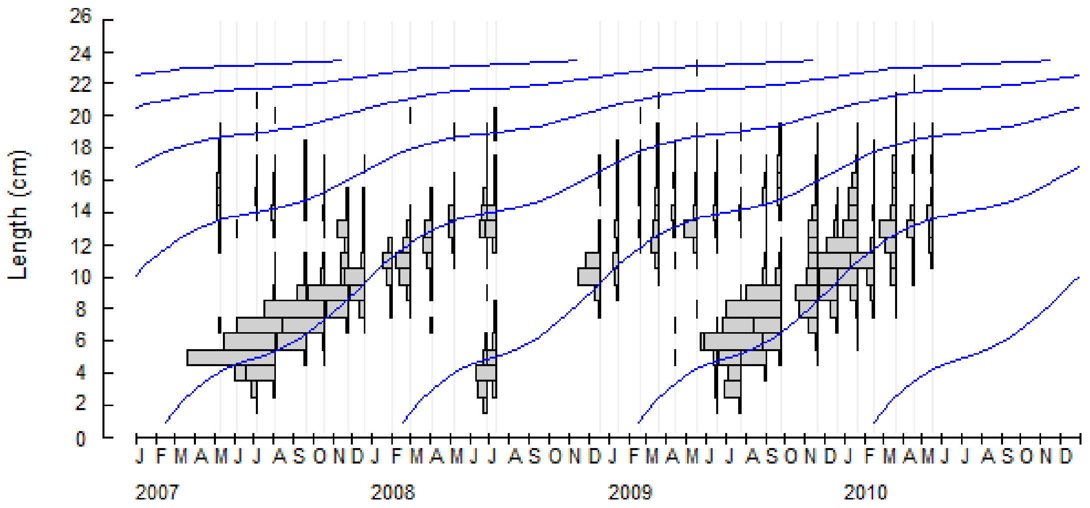


Figure 3.31. VBGF plot of *P. erythrinus.*

3.3.3 Sex-ratio and size differences in sex

The sex-ratio of the samples was calculated as 0.87 (1:0.15) in a strong favour to females. The sex ratio differs at different size classes (Table 3.9 and Figure 3.32). Immature individuals smaller than 7 cm could not be sexed; therefore they were classified as juveniles. The mean length and the range of size the males were larger than females. Size differences in sex can also be seen on Figure 3.33 and a statistically significant difference was observed between males and females (Mann-Whitney U test, P <0.001). Females were observed more frequently than males in the samples and no male was observed in the length classes smaller than 15 cm. above this limit the contribution of males gradually increases while occurrence of females gets smaller.

Table 3.9. Sex ratio of *P. erythrinus* by length classes.

Length (cm)	Juvenile	Females	Males
6	100	0	0
7	82	18	0
8	50	50	0
9	11	89	0
10	3	97	0
11	5	95	0
12	6	93	1
13	6	89	6
14	6	92	2
15	4	89	8
16	1	87	12
17	0	81	19

Table 3.9. (Continued). Sex ratio of *P. erythrinus* by length classes.

18	0	84	16
19	0	71	29
20	0	60	40
21	0	60	40
22	-	-	-
23	0	50	50

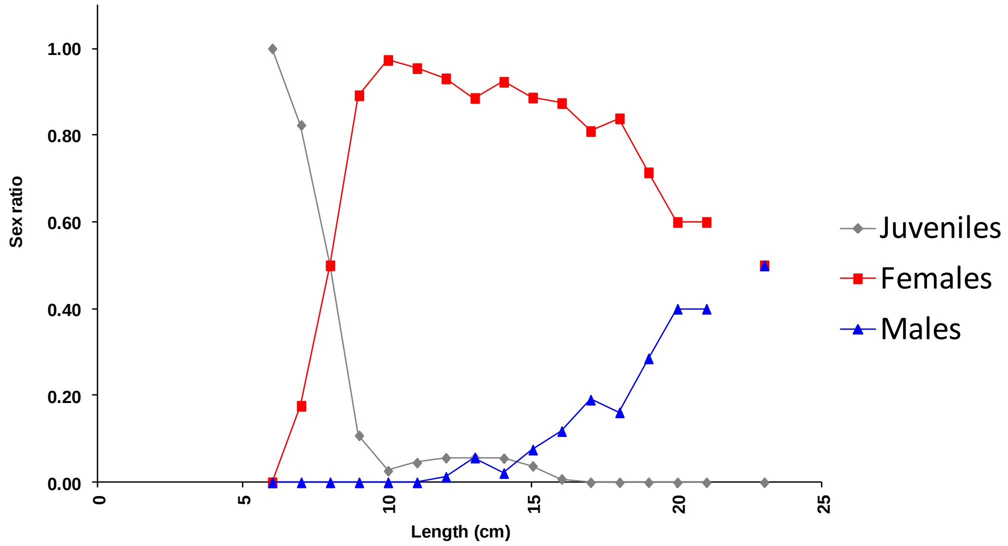


Figure 3.32. Sex-ratio in juveniles, males and females of *P. erythrinus* by length classes.

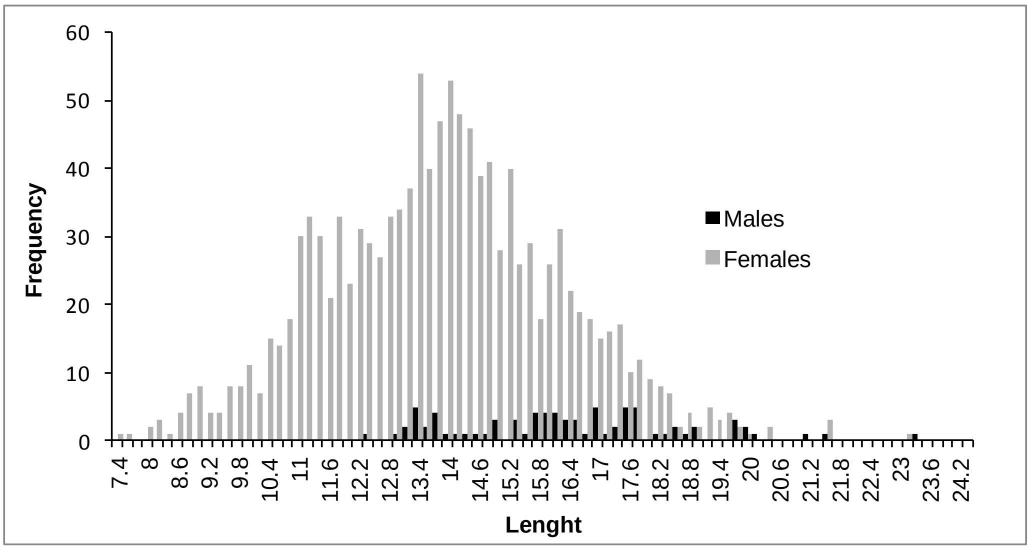


Figure 3.33. Length frequency distribution of males and females of *P. erythrinus* sampled for dissection.

3.3.4 Length at first maturity

Length at first maturity was calculated using monthly data collected from May 2007 to May 2010. The estimated length at first maturity (L_m) for males and females were 15.01 (maturation rate, r_m = 1.00) and 14.6 cm (maturation rate , r_m = 1.08) respectively (Figure 3.34 and Figure 3.35).

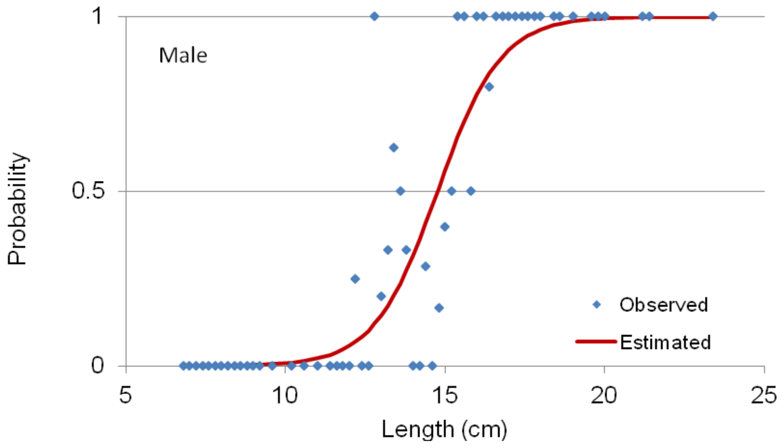


Figure 3.34.Length of first maturity calculated for males *P. erythrinus* from pooled data of dissected individuals.

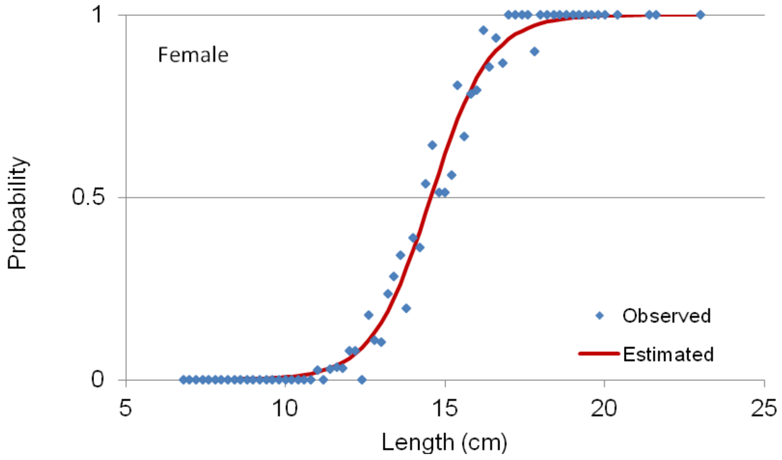


Figure 3.35.Length of first maturity calculated for female *P. erythrinus* from pooled data of dissected individuals.

3.3.5 Biological indices

The biological indices examined separately for males and females were summarized in Figure 3.36 and Figure 3.37. The variation of GSI values of female *P. erythrinus* over the study period points out a clear reproduction cycle. The development of gonads in females begins around January. The highest GSI values are reached in late spring (April to May) then the index drops gradually until July (Figure 3.36). Another, however lesser and shorter increase in gonadal activity of females is observed after August. Finally gonad development is accelerated again towards the end of the year. The GSI variation in males throughout the study period did not show any clear reproductive pattern since number of males observed in the samples were quite low (76 individuals out of 3536). Yet, the spawning males seemed to show a peak from March to May (Figure 3.37).

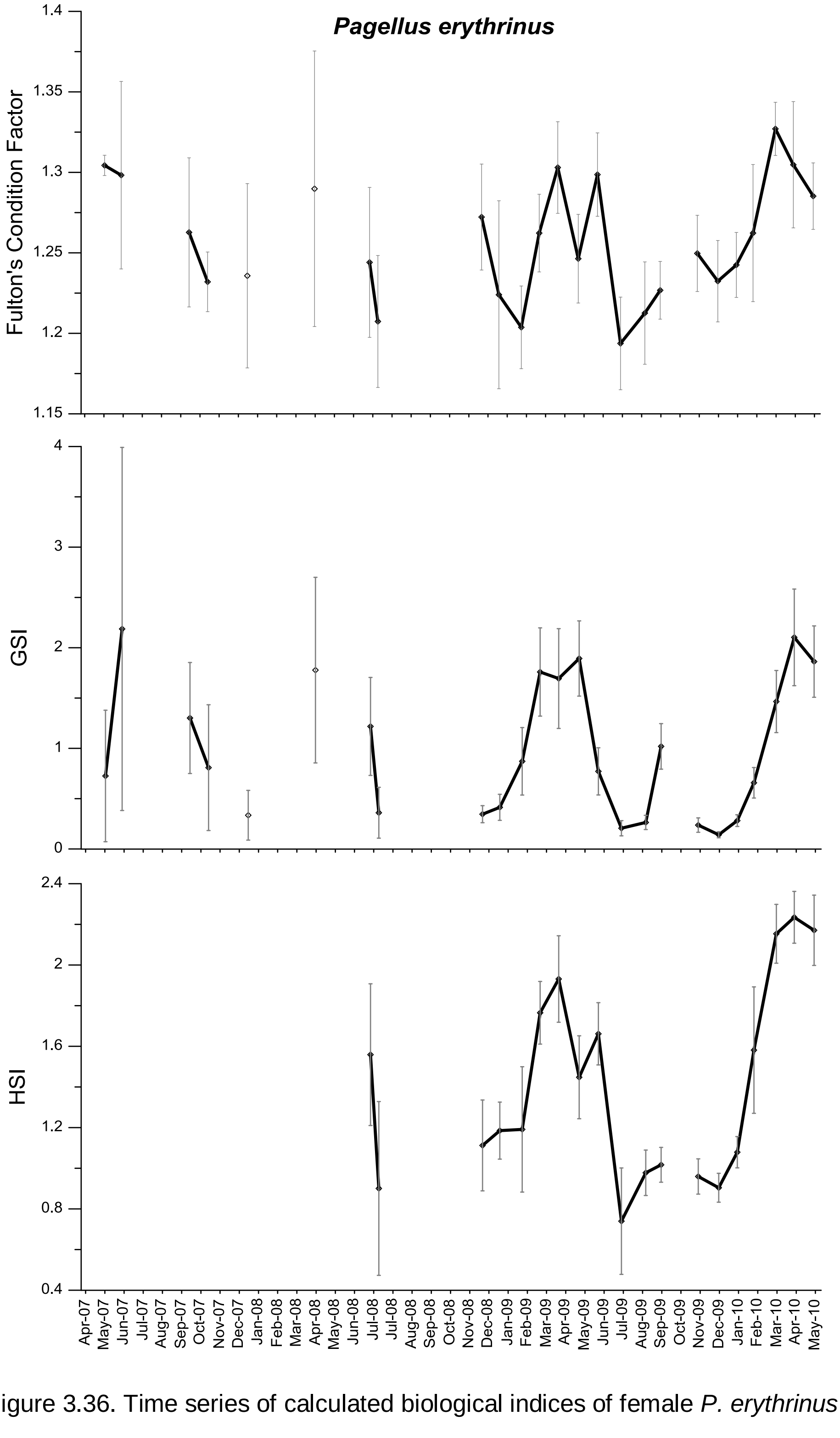


Figure 3.36. Time series of calculated biological indices of female *P. erythrinus*.

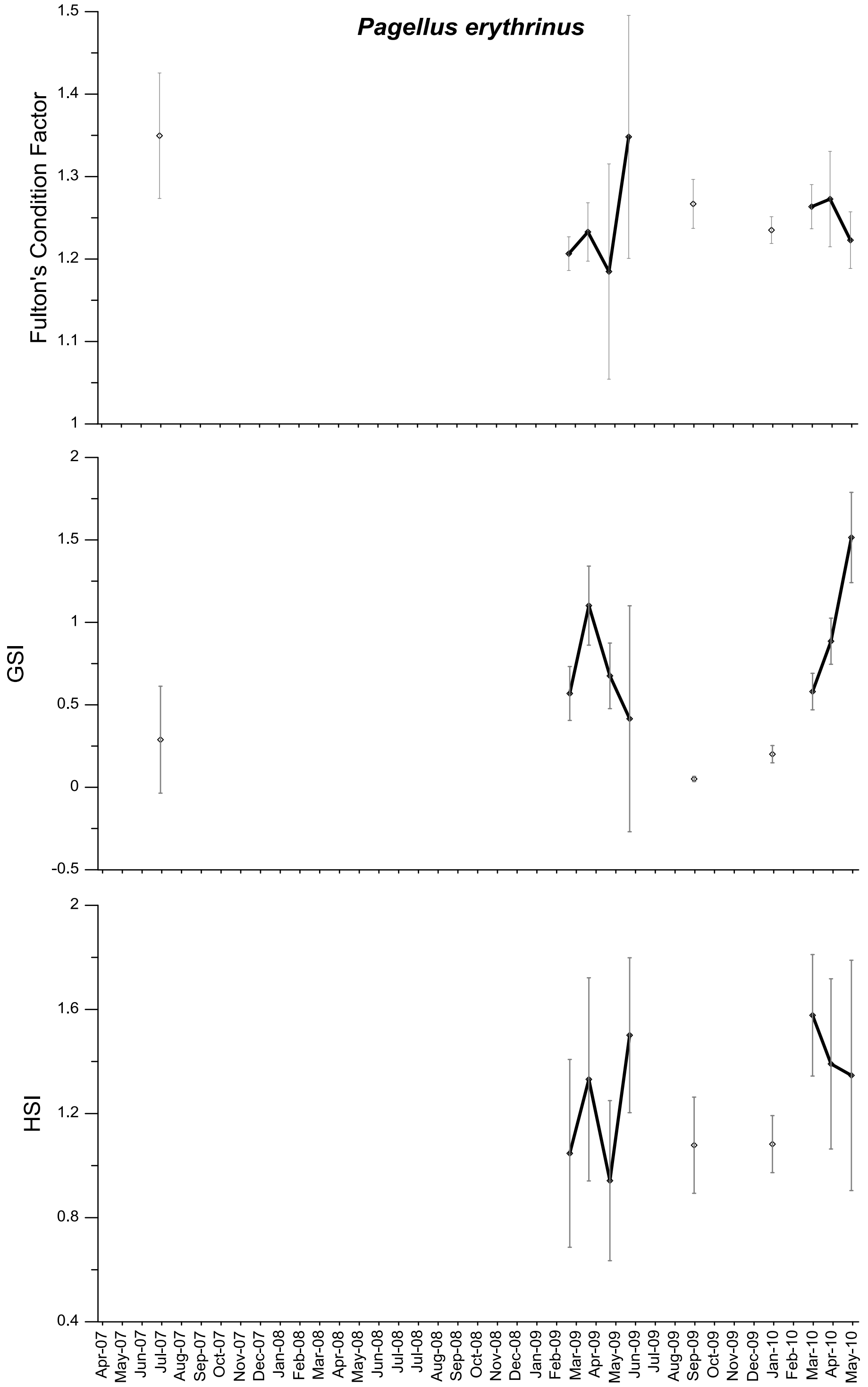


Figure 3.37. Time series of calculated biological indices of male *P. erythrinus*.

Variations in HSI in females indicated that energy storage starts after February and the highest values are observed from March to April. Figure 3.36 indicated that they do not store energy before spawning. Similar to the GSI, HSI variation in males did not show any clear pattern since number of males examined was quite low (Figure 3.37).

The period where highest values observed in Somatic K of females coincides with the reproductive peaks displayed in GSI curve. Females seemed to be good conditioned during spawning period. As mentioned above, number of males observed in samples was quite low to evaluate variation in Somatic K of males throughout a year.

Monthly variations in maturity stages of females were depicted in Figure 3.38. Percentage of females at developing gonad stages in the samples started to increase in January when the percentage of individuals at spawning stage was zero. The highest percentage of individuals at spawning stage was observed in May. Percentages of individuals having gonads at spent/resting stage were rather low in this period. Not surprisingly, proportion of individuals spawned and turned into the spent/resting stage started to increase in the following months. Later in July, percentage of individuals in spawning stage began to increase again; attained to 20% in September and then dropped to zero in October. Although the data is missing for August, this figure may indicate to the existence of secondary autumn spawners. Two normal distribution functions fitted to the monthly percentage distribution over a year indicated that 90 % of spawning took place during the spring spawning and only 10% occurs in autumn Figure 3.39.

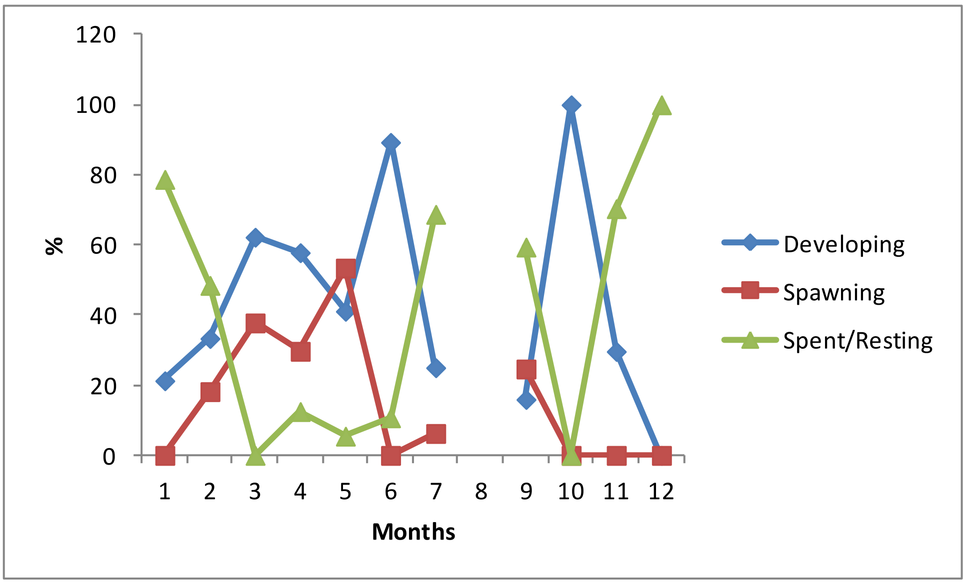


Figure 3.38. Monthly % maturity stages in females of *P. erythrinus*.

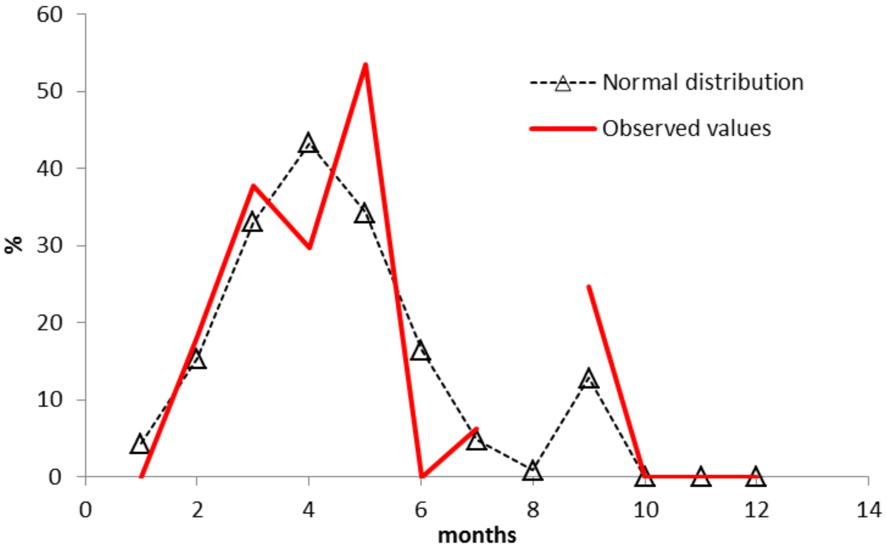


Figure 3.39. Distribution in the percentage of spawning *P. erythrinus* over a year and fitted normal distribution function.

Almost similar pattern with slight differences was observed in monthly variations in maturation stages of males (Figure 3.40). At the beginning of a year all males dissected were at resting stage. Next month, all of them begin to develop their gonads. In the following three months a part of the males begin to release gametes, as can be seen from the increase in the spawning stage. In May, the percentage of males releasing gametes were the highest as was observed in females. In June, spawning (release of sperms) was deceased; half of the males turned into resting state; while in other half the gonads were still developing. The data for the rest of the year was too few to be interpreted; however very high percentage of males at the developing stage in July followed by very high percentage of males spent their gametes in September indicate that the males must have released their gametes sometime between July and September.

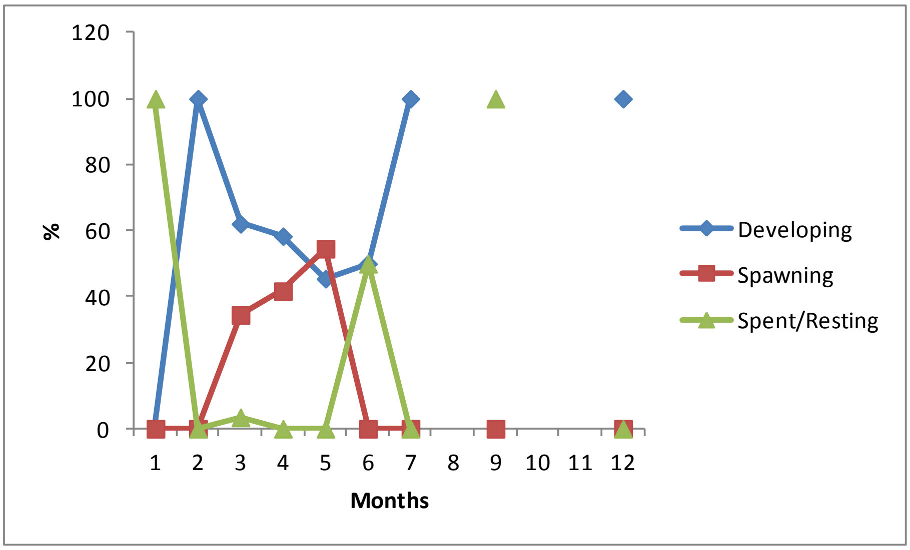


Figure 3.40. Monthly % maturity stages in males of *P. erythrinus.*

In order to see the mean GSI value at the time of spawning a box-whisker plot is presented in Figure 3.41. There are significant differences in both sexes in the mean GSI values of the individuals at different stages.

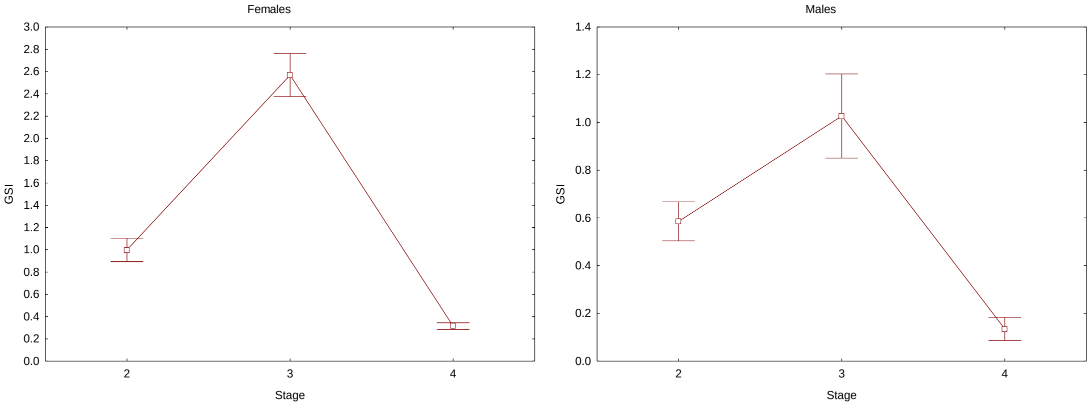


Figure 3.41. Mean GSI values of *P. erythrinus* at different stages with 95% confidence intervals.

3.3.6 Biomass and Abundance variations

Monthly vertical distribution of *P. erythrinus* abundance in years 2007-2008, 2008-2009 and 2009-2010 were depicted in (Figure 3.42) along with mean length of the individuals sampled. The highest abundance values were observed between July and August within the depth shallower than 50 meters in the time period 2007-2008 and 2009-2010. The mean length of these group were rather small (4-6 cm) indicating the main part of the samples was dominated by juveniles. Moreover, no linear relationship was observed between mean length and depth (Pearson R^2 = 0.038).

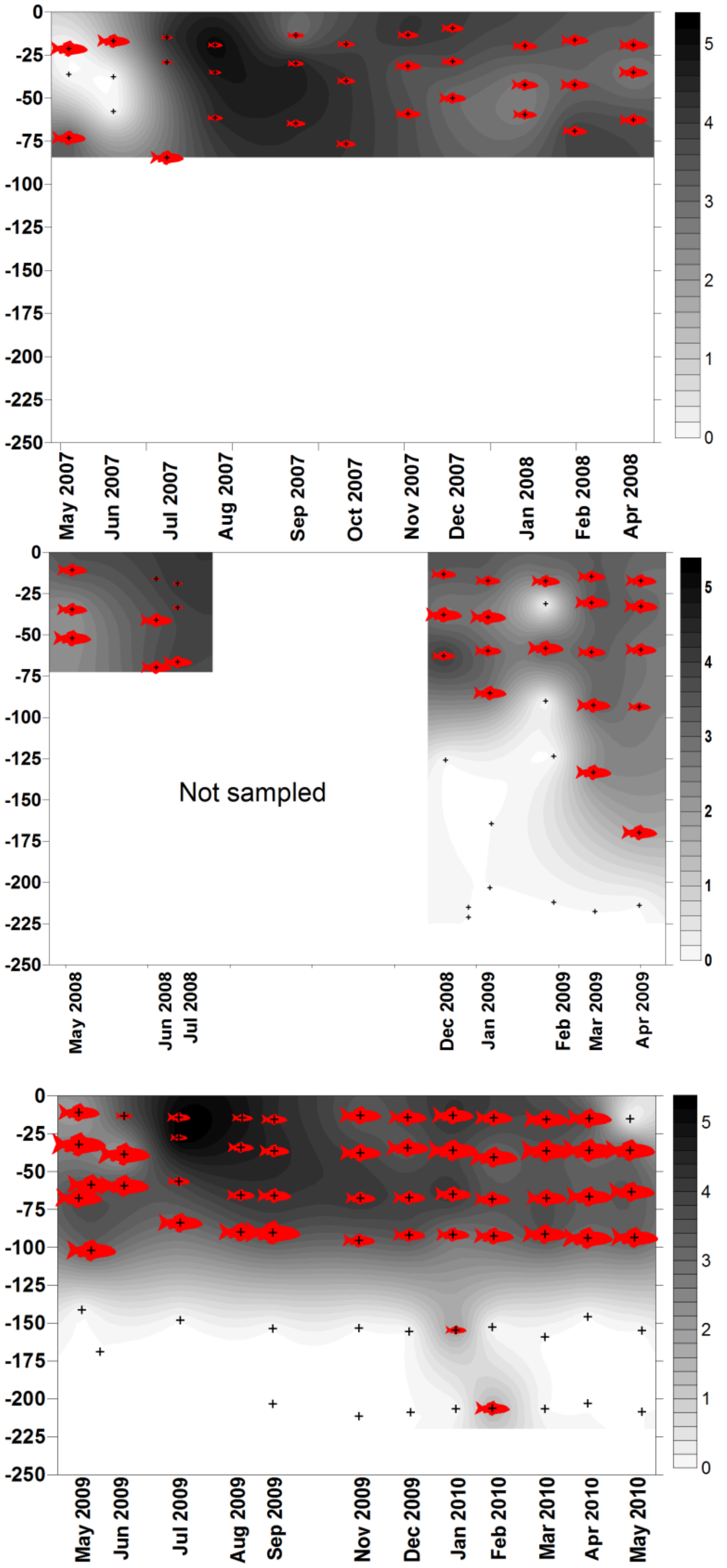


Figure 3.42. Bathymetric distribution (transformed abundance) of *P. erythrinus*. Contours in the maps show changes in abundance through depth and time. Fish symbols show the mean length proportional to symbol size. Plus signs show the sampled depth.

Spatiotemporal trend in biomass of the *P. erythrinus* was depicted in Figure 3.43. Throughout the study period, the highest biomass values were observed in summer months (mainly in July) at the depths between 25-50 m. As given above (Figure 3.31), this period represent the time when young of the year recruits into the stock. In 2007, the young group abandons this stratum immediately and moved either to the stratum above or below. The data is missing for 2008's recruitment period. In 2009, the recruits moved mainly to shallower stratum. At the same year, they returned to the depth stratum between 25-50m during winter.

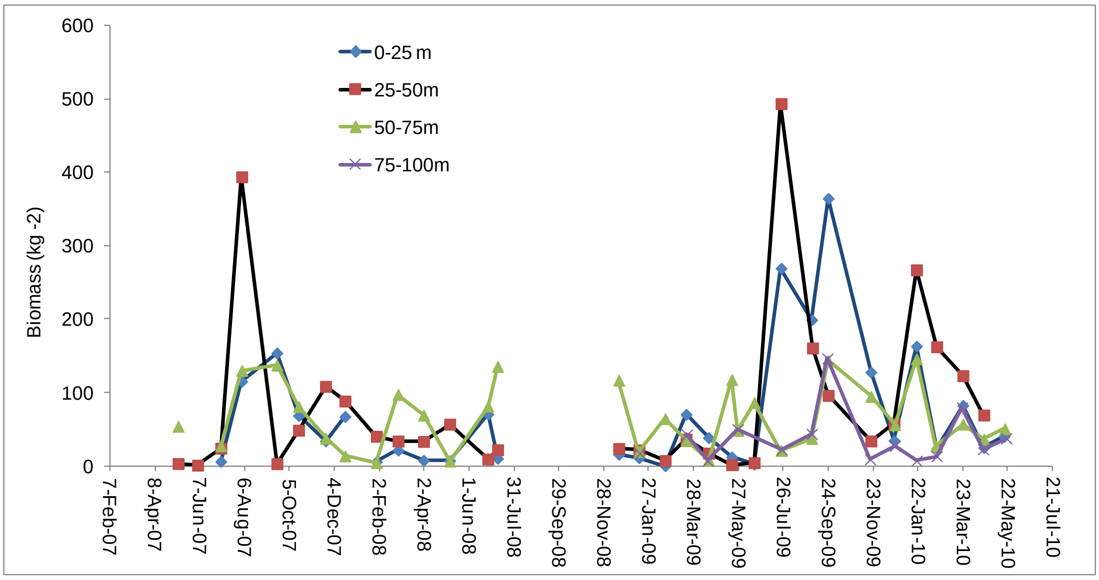


Figure 3.43.Biomass variations of *P. erythrinus* in time.

3.4 Suez Blassop *Lagocephalus suezensis* Clark & Gohar, 1953

Of 3456 individuals caught throughout the study period, lengths of the 1430 individuals ranging from 3 to 22 cm were measured on board. A total of 1060 individuals ranging from 3.3 to 21.1 cm TL was stored for laboratory analyses (among them 176 were females; 126 were males; 223 were juveniles and 535 were badly decomposed or deformed to be used). Monthly dissected individuals throughout the study period were given in Table 3.10. Females of *L. suezensis* ranged between 10.3 and 21.1 cm TL with an average of 13.6 cm TL. Males were between 10.4 and 17.6 cm TL, averaging 12.5 cm TL.

Table 3.10. Number of *L. suezensis* analyzed in the laboratory for length-weight relationship, Somatic's K, GSI, HSI calculations.

Months	**Depth ranges in meter**						**Total**
	0-25	**25-50**	**50-75**	**75-100**	**150**	**200**	
May-07	1	2	0	Not Sampled			3
Jun-07	64	0	0				64
Jul-07	11	13	0				24
Aug-07	14	0	0				14
Sep-07	106	118	0				224
Oct-07	68	22	0				90
Nov-07	25	24	2				51
Dec-07	14	4	0				18
Jan-08	68	10	0				78
Feb-08	1	1	0				2
Mar-08	Not Sampled						0
Apr-08	13	0	0				13
May-08	27	0	0				27
Jun-08	0	12	2				14
Jul-08	5	0	0				5
Aug-08	Not Sampled						0
Sep-08							0
Oct-08							0
Nov-08							0
Dec-08	3	1	20	0	0	0	24
Jan-09	16	3	1	0	0	0	20
Feb-09	18	0	0	0	0	0	18
Mar-09	0	0	0	0	0	0	0
Apr-09	0	0	2	0	0	0	2
May-09	0	0	0	0	0	0	0
Jun-09	0	0	0	Not Sampled			0
Jul-09	5	4	2	0	0	0	11
Aug-09	110	24	12	0	Not Sampled		146
Sep-09	0	0	6	0	0	0	6
Oct-09	Not Sampled						0
Nov-09	62	0	0	0	0	0	62
Dec-09	34	0	0	0	0	0	34
Jan-10	39	0	0	0	0	0	39
Feb-10	0	0	0	0	0	0	0
Mar-10	63	0	0	0	0	0	63
Apr-10	8	0	0	0	0	0	8
May-10	0	0	0	0	0	0	0

3.4.1 The length-weight relationship

The length-weight relationship described as $W = 0.0120L^{2.9981}$ for combined data, $W = 0.0136L^{2.9506}$ for male and $W = 0.00115L^{3.0252}$ for females with a good correlation between these two variables (Figure 3.44). Females showed remarkable positive allometry. However, when all samples including juveniles were combined the length-weight relationship showed negative allometry. Males also showed negative allometry.

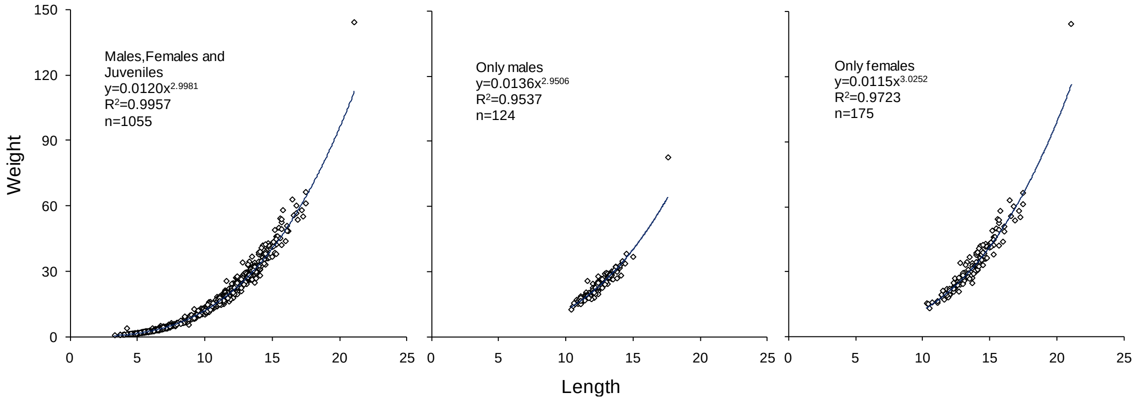


Figure 3.44. Calculated length-weight relationship (power function W= aL^b) of *L. suezensis*: for males, females and juveniles together (left), only for males (middle) and (right) only for females. a = slope; b = intercept; R^2 = correlation coefficient; n = sample size).

3.4.2 von Bertalanffy Growth Parameters

Calculation of von Bertalanffy growth parameters of *L. suezensis* were based on monthly distribution of the length frequency data of 1430 individuals measured onboard; therefore sex of the measured individuals were not taken into consideration. The seasonally oscillating growth pattern was described by seasonalized Von Bertalanffy growth model. The best fit to the length frequency distribution were obtained by the growth parameter set: L∞ = 24 cm K = 0.90, C = 0.90 and WP = 0.10 (Figure 3.45). A rapid growth and very strong seasonality was observed in the species. The seasonality in the growth followed the seasonality in the temperature as suggested by WP (at which the growth rate slows down to a minimum) corresponds to January. Young of the year (YOY) was first observed in July; however the main pulse of recruits was observed in August-September.

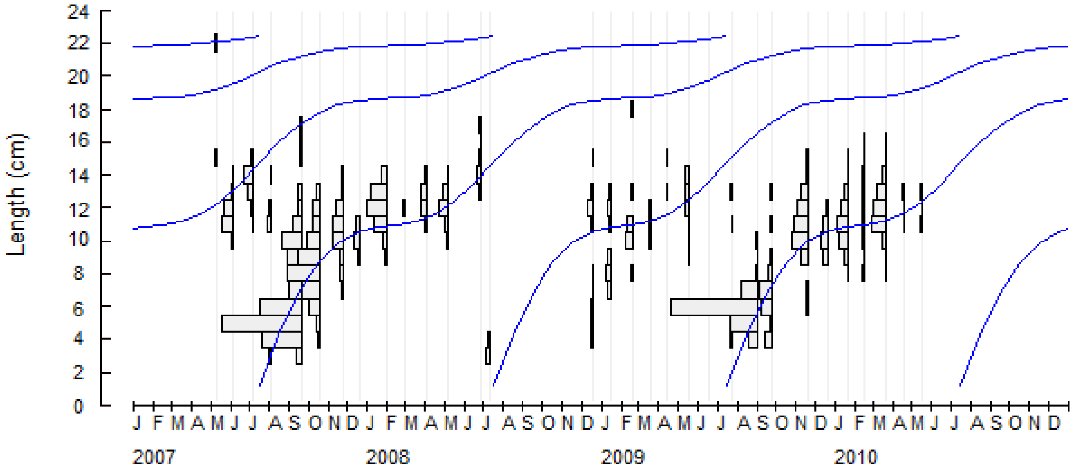


Figure 3.45. VBGF plot of *L. suezensis* covering the study period.

3.4.3 Sex-ratio and size differences in sex

The sex-ratio was calculated as 0.58 (1:0.72) in a slight favor of females. However as shown in Table 3.11 and Figure 3.46, this ratio changed with size. The individuals at 12 cm length and smaller could not be sexed. Females begin to be dominant at lengths of 15 cm and larger lengths. Above 12 cm, males and females have almost the same sex ratio. However above 19 cm all individuals examined are females.

Table 3.11. Sex ratio of *L. suezensis* by length classes.

length (cm)	Juvenile	Females	Males
6	100	0	0
7	100	0	0
8	100	0	0
9	100	0	0
10	100	0	0
11	100	0	0
12	78.7	6.6	14.8
13	40.7	24.4	34.9
14	17.0	38.4	44.6
15	12.7	50.7	36.6
16	0	85.4	14.6
17	0	90.0	10.0
18	0	100	0.0
19	0	83.3	16.7
20	0	0.0	0.0
21	0	0.0	0.0
22	0	0.0	0.0
23	0	100	0.0

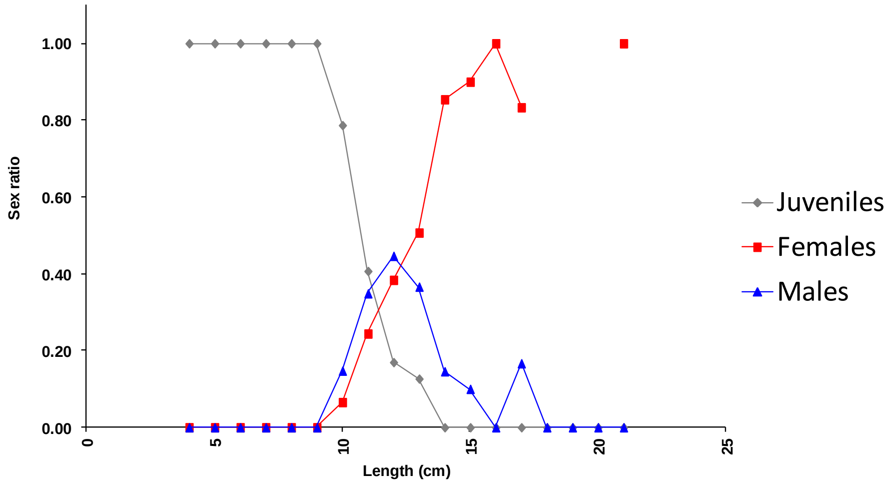


Figure 3.46. Sex-ratio in juveniles, males and females of *L. suezensis* by size.

3.4.4 Length at first maturity

Monthly data collected from May 2007 to May 2010 were used for length at first maturity calculation. The estimated length at first maturity (L_m) for males and females were 11.4 cm (maturity rate, r_m = 1.38) and 11.7 cm (r_m =1.67) respectively (Figure 3.47 and Figure 3.48). The males and females generally matured at similar lengths but the transition from juvenile to mature occurs over a wider length spectrum in females, meaning that they reach to maturity faster than males.

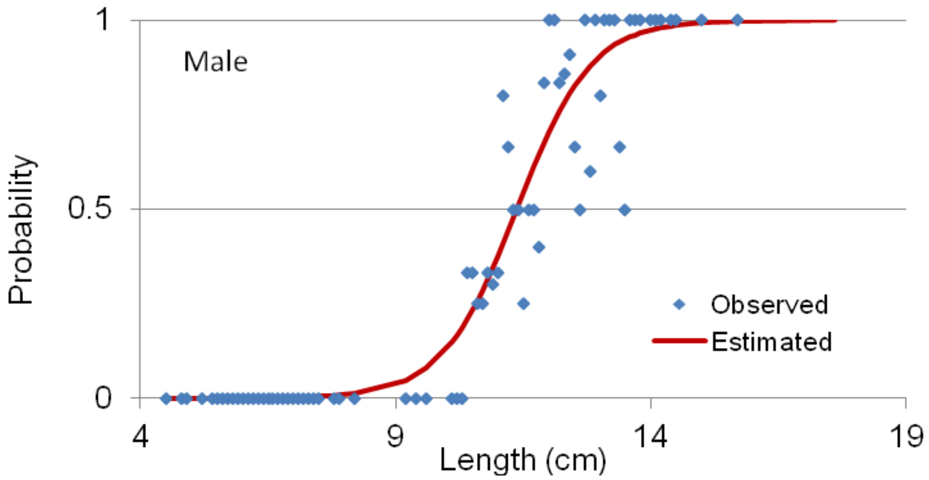


Figure 3.47.Length of first maturity calculated for male *L. suezensis* from pooled data.

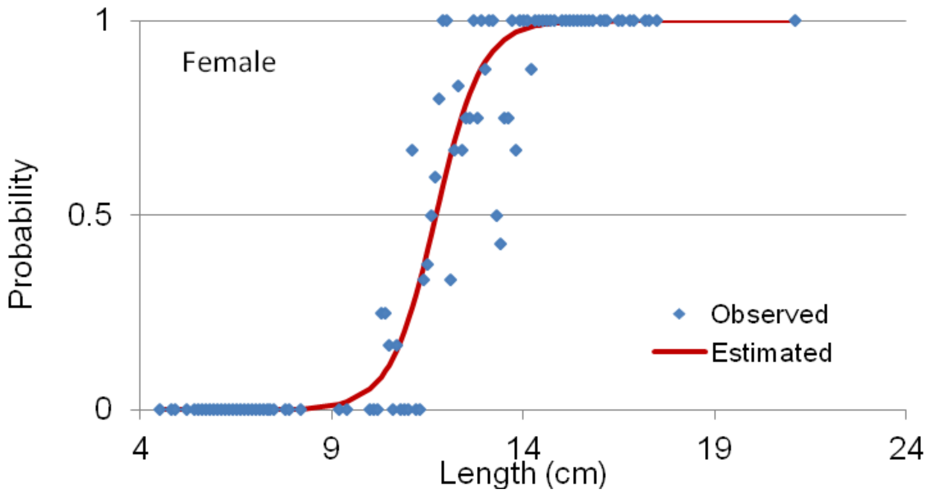


Figure 3.48. Length of first maturity calculated for female *L. suezensis* from pooled data.

3.4.5 Biological indices

Monthly variations in biological indices of the species were summarized in Figure 3.49 and Figure 3.50. Unfortunately, trends in GSI variations were rather unclear due to insufficient sample size of sexed individuals in some months. Therefore index evaluations were made based on four figures together; monthly average GSI variations (Figure 3.49 and Figure 3.50); the annualized GSI values (Figure 3.51); monthly percentage of maturity stages in females of *L. suezensis* (Figure 3.52) and percentage distribution of spawning female *L. suezensis* over a year (Figure 3.53). The figure 3.48 showed that the gonad activity in females begins after April; the highest GSI values are reached in late June and then the index drops until September. This pattern was also followed in Figure 3.50 showing the annualized GSI variations. Percentage distribution of sampled females by maturity stage was given in figure 3.51. The same reproduction pattern explained above was observed in this figure too. However, there seemed to be a month shift between individuals at developing and spent/resting stages; percentage of individuals at developing stage began to increase when females at spawning stage had been already increasing in percentage which is rather peculiar. The monthly changes in the percentage of spawning females were also depicted in Figure 3.52 where the spawning pattern was modeled by a normal distribution function. The mean date when spawning individuals was the highest, was 19th June (14 June and 23 June were the 95% confidence interval). Individuals at spawned /resting stage were high during late autumn and the winter.

To follow the pattern in reproduction cycle of the males was rather difficult than the females (due to the insufficient sample size of sexed individuals). However, the same reproduction pattern is expected in males since synchronous release of gametes by both sexes is essential. Increasing trend in percentage of individuals at developing stages followed up by the individuals in spent/resting stage. However percentage contribution males seemed to begin earlier than males. Highest values were observed in July.

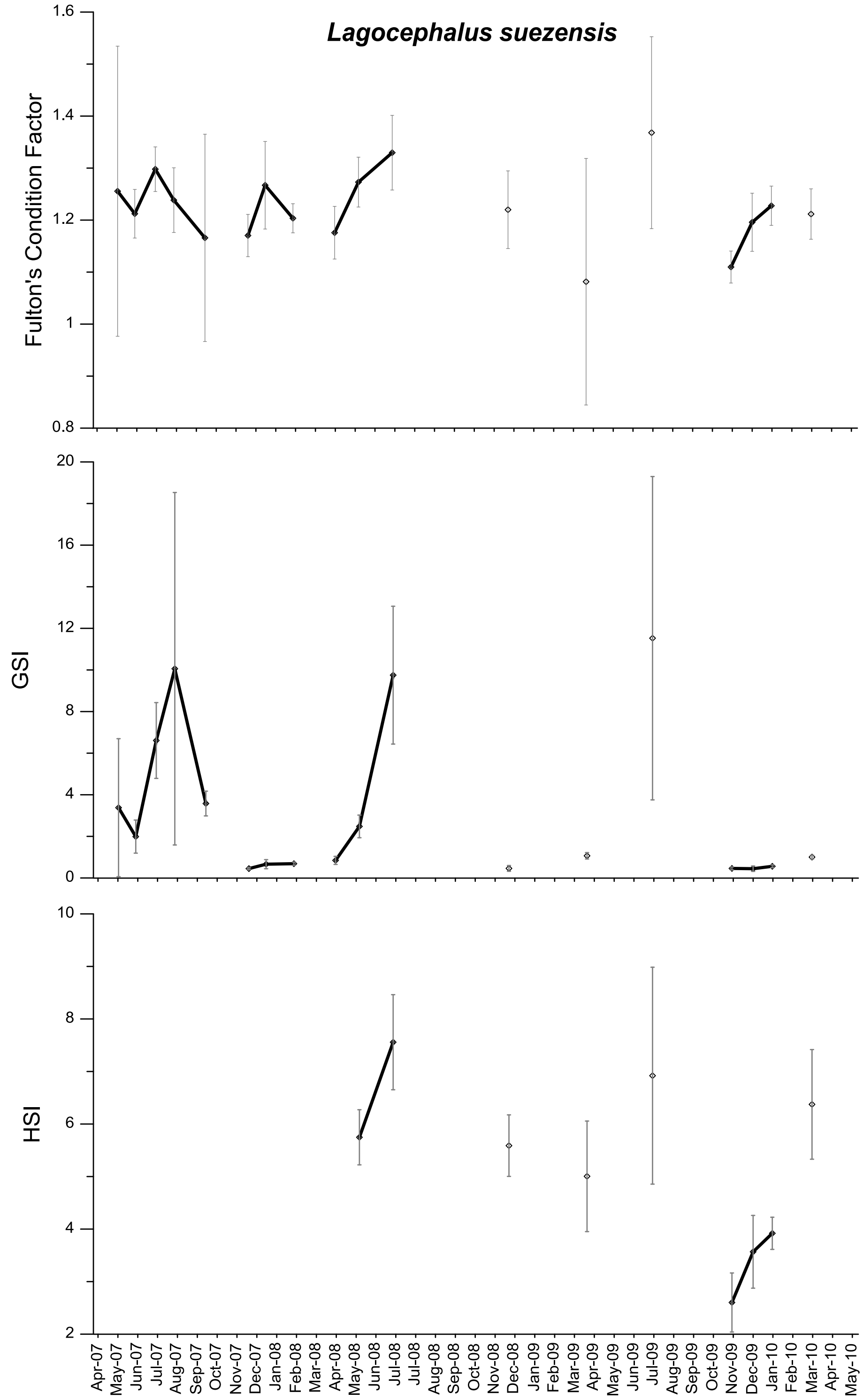


Figure 3.49. Time series of calculated biological indices of female *L. suezensis*.

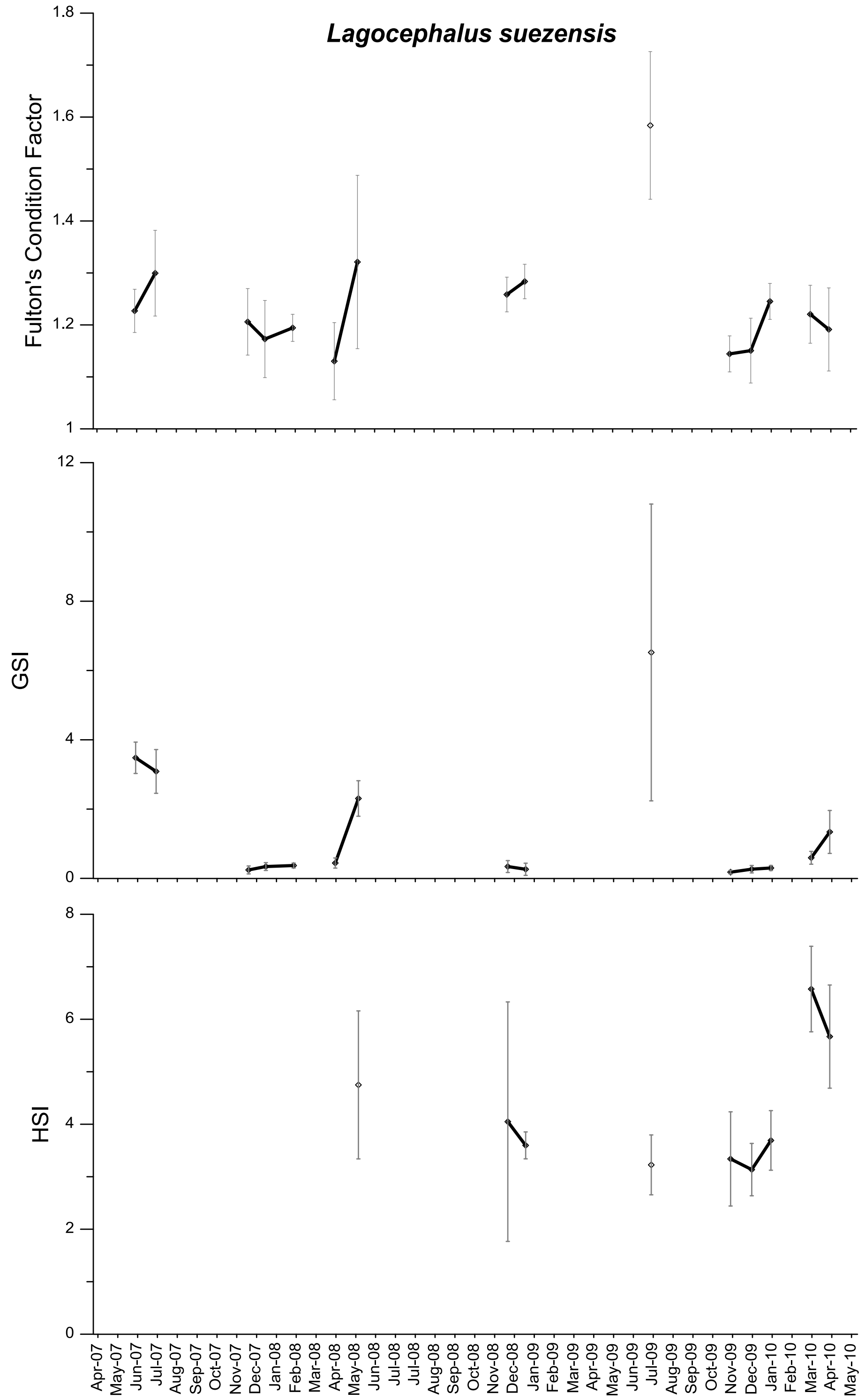


Figure 3.50.Time series of calculated biological indices of male *L. suezensis*.

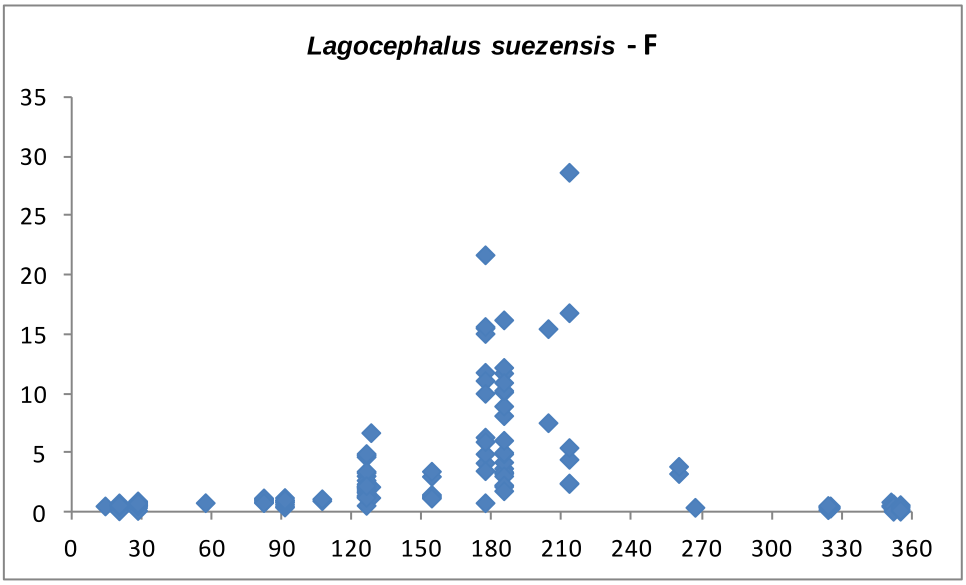


Figure 3.51. Annualized GSI values of all *L. suezensis* female dissected throughout the study.

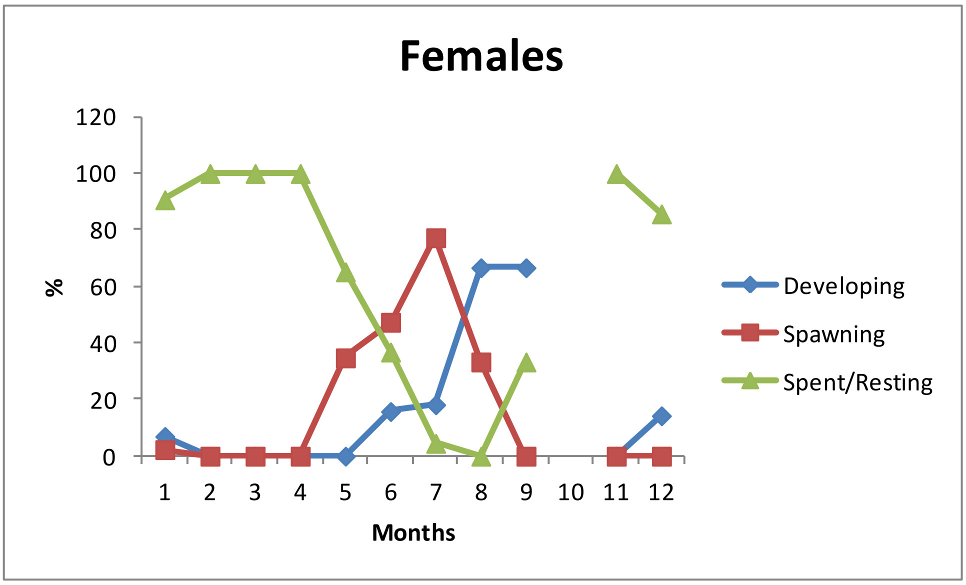


Figure 3.52. Monthly % maturity stages in female of *L. suezensis.*

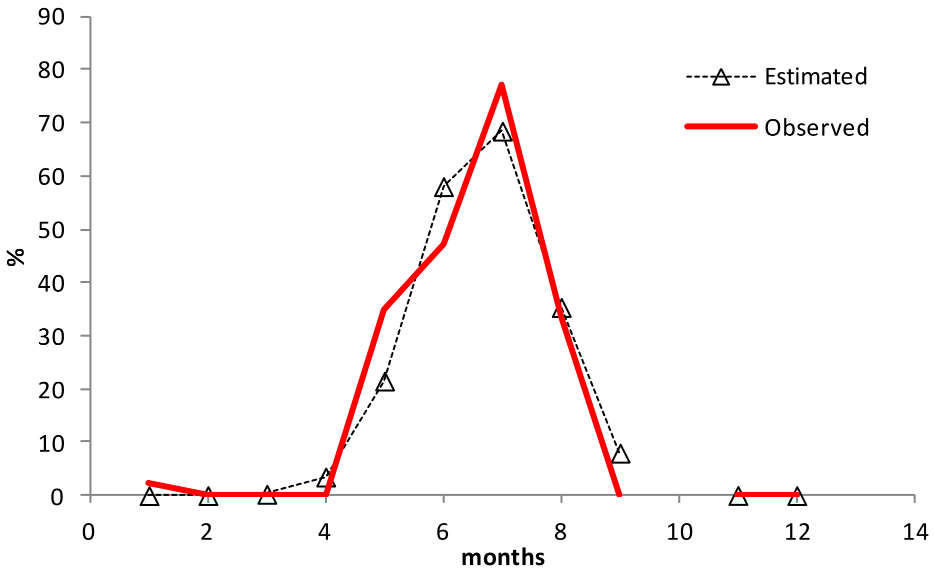


Figure 3.53. Distribution in the percentage of spawning female *L. suezensis* over a year and fitted normal distribution function.

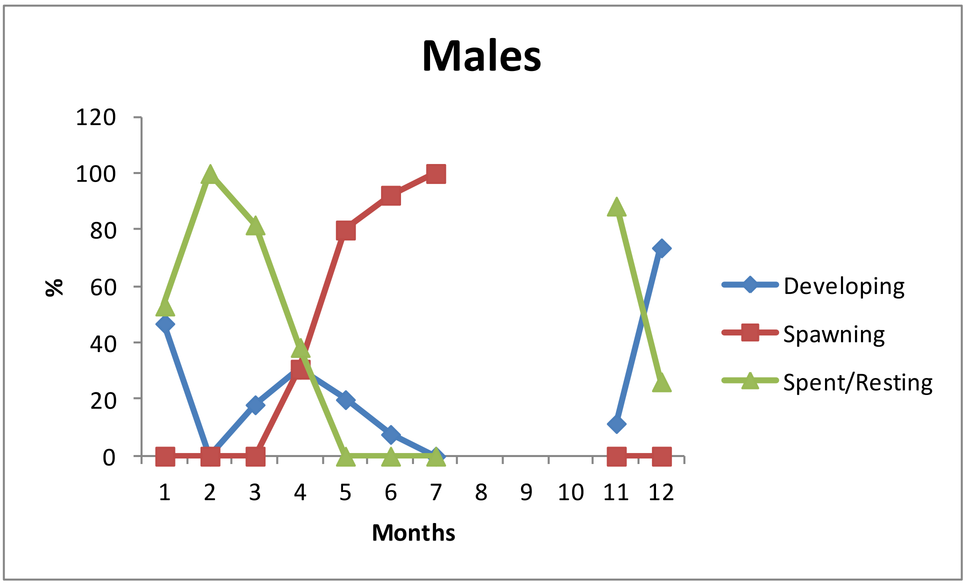
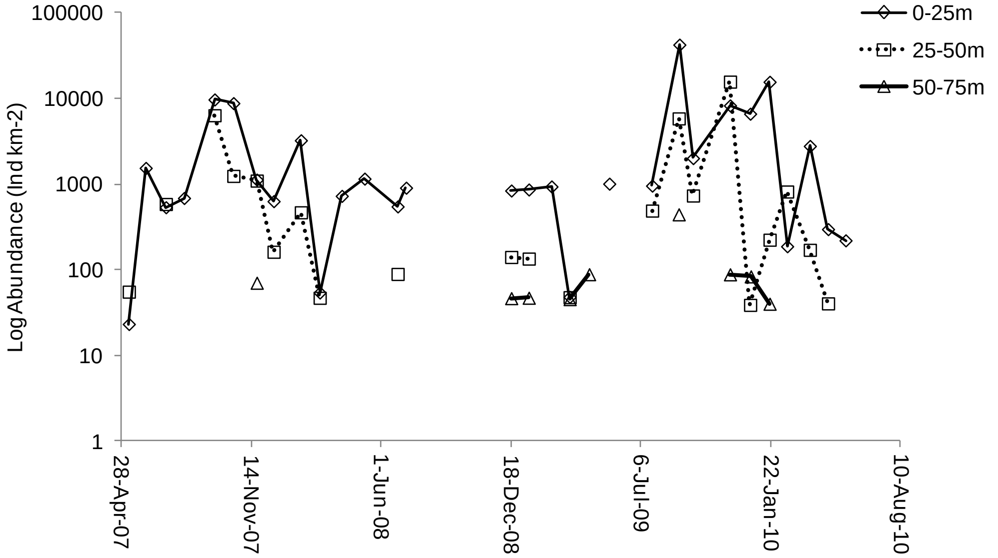


Figure 3.54. Monthly % maturity stages in males of *L. suezensis.*

3.4.6 Biomass and Abundance variations

The abundance (individual km^{-2}), biomass (kg km^{-2}) and mean length (cm) of the *L. suezensis* were presented in Figure 3.55. There are remarkable differences in the biomass and abundance of the species among the years. The differences are so high that the in the graph presented on a linear scale the peak abundance value mask the monthly variations.

The data is, therefore presented on a logarithmic scale. In the time period 2009-2010, biomass is 5 times, abundance is 4 times higher than the values observed in the previous time periods. The species mainly distributed along the depth stratum between 0-25 m but sometimes particularly after the peaks observed at the shallower depth, high abundance and biomass values were also observed at 25-50 depth stratum. A regular pattern in mean length variations was observed in time (Figure 3.55). Mean length drops to its smallest values with the addition of juveniles at 0-25 m depth stratum in mid-summer and then grow very fast following very similar rate of increase.



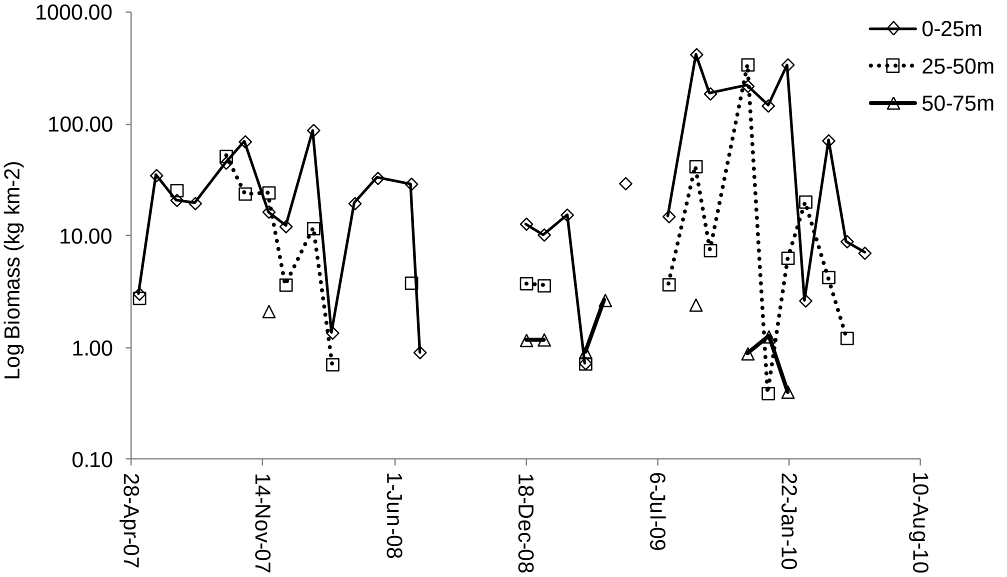


Figure 3.55. Abundance (log scale), biomass (log scale) and mean length distribution of *L. suezensis* (“x” and “+” represents 0-25 m and 25-50 m, respectively; solid line on the mean length is the linear trend line for the period between first occurrence of YOY).

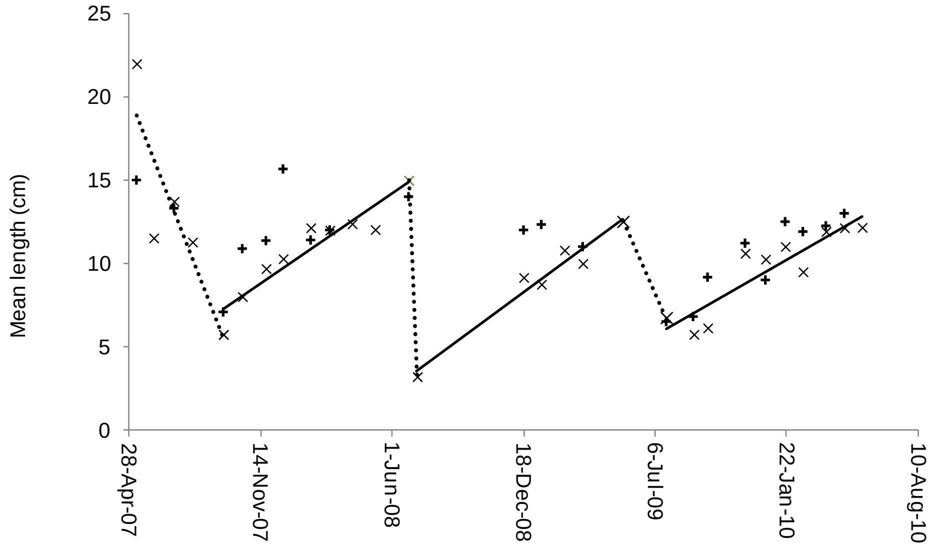


Figure 3.55. (continued). Abundance (log scale), biomass (log scale) and mean length distribution of *L. suezensis* ("x" and "+" represents 0-25 m and 25-50 m, respectively; solid line on the mean length is the linear trend line for the period between first occurrence of YOY).

3.5 Brushtooth lizardfish (*Saurida undosquamis* Richardson, 1848)

The length of the 1972 individuals caught in 143 trawl operations ranged between 4 and 37 cm. A total of 1730 individuals ranging from 4.4 to 37.9 cm TL were stored for a laboratory analyses. Among them 480 were females; 498 were males; 615 were juveniles and 137 were badly decomposed or deformed to be used in the analyses. Number of monthly dissected specimens throughout the study period was given in Table 3.12. Females ranged between 15.2 – 37.9 cm TL with an average of 23.7 cm TL while males were between 14.5 and 26.5 cm TL, averaging 19.9 cm TL.

Table 3.12. Number of *S. undosquamis* individuals analyzed in the laboratory for length-weight relationship, Somatic's K, GSI, HSI calculations.

Months	**Depth ranges in meter**						**Total**
	0-25	**25-50**	**50-75**	**75-100**	**150**	**200**	
May-07	38	42	1	Not Sampled			81
Jun-07	0	9	1				10
Jul-07	11	21	0				32
Aug-07	0	25	8				33
Sep-07	0	17	2				19
Oct-07	3	48	0				51
Nov-07	0	33	18				51
Dec-07	2	64	18				84
Jan-08	0	11	5				16

Table 3.12. (continued). Number of *S. undosquamis* individuals analyzed in the laboratory for length-weight relationship, Somatic's K, GSI, HSI calculations.

Feb-08	3	31	4				38
Mar-08	Not Sampled						0
Apr-08	8	21	0				29
May-08	0	6	8				14
Jun-08	0	5	8				13
Jul-08	2	2	1				5
Aug-08	Not Sampled						0
Sep-08							0
Oct-08							0
Nov-08							0
Dec-08	60	0	0	40	0	0	100
Jan-09	5	61	39	6	7	3	121
Feb-09	36	15	10	7	0	0	68
Mar-09	15	15	20	3	9	0	62
Apr-09	22	10	11	3	0	0	46
May-09	7	9	18	1	0	0	35
Jun-09	25	10	6	Not Sampled			41
Jul-09	0	5	36	1	0	0	42
Aug-09	1	155	12	0	Not Sampled		168
Sep-09	0	97	46	12	0	0	155
Oct-09	Not Sampled						0
Nov-09	13	89	17	5	0	0	124
Dec-09	0	63	14	4	0	0	81
Jan-10	0	0	15	39	0	0	54
Feb-10	0	21	21	3	3	0	48
Mar-10	12	21	16	5	0	0	54
Apr-10	7	1	21	0	0	0	29
May-10	5	5	16	0	0	0	26

3.5.1 The length-weight relationship

The exponent of the length-weight relationship calculated for females, males and combined sexes with juveniles is significantly different from the 3 value ($P < 0.05$) indicating a positive allometry. It was described as: W = $W=0.0029L^{3.2664}$ for combined data; $W=0.0035L^{3.2032}$ for males and $W=0.0045L^{3.1235}$ for females with a statistically significant correlation between the two variables (Figure 3.56).

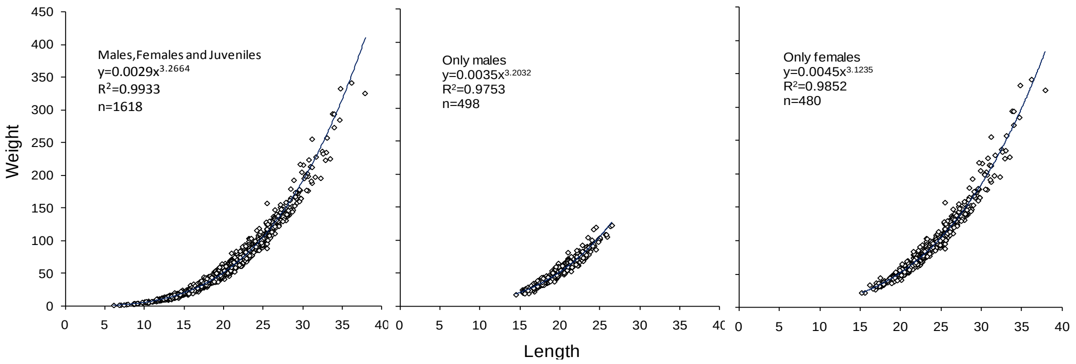


Figure 3.56. Calculated length-weight relationship (W= aL^b) of *S. undosquamis* for males, females and juveniles combined (left), only for males (middle) and (right) only for females. a = slope; b = intercept; R^2 =correlation coefficient; n =sample size.

3.5.2 von Bertalanffy growth parameters

Based on modal progression analysis the von Bertalanffy growth parameters were estimates as follows; The best fit to the length frequency distribution were obtained by the growth parameter set: L∞ = 57.3 cm K = 0.14, C = 0.1 and WP = 0.8.

The growth curve *S. undosquamis* associated with the growth parameters was presented on Figure 3.57. As can be seen from the figure the growth displays very strong seasonality. It was so high that it stops (C=1) at the beginning of winter (WP=0.8).

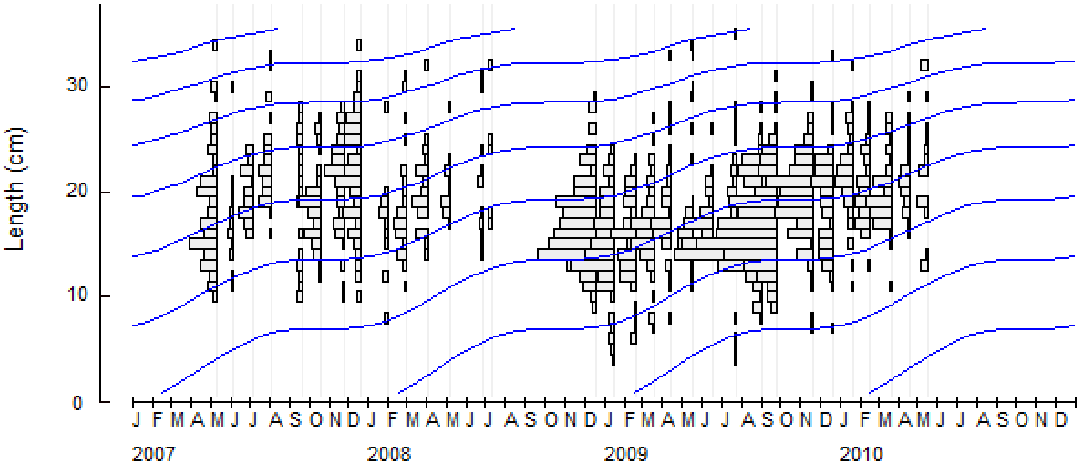


Figure 3.57. VBGF plot of *S. undosquamis* lizardfish covering the study period.

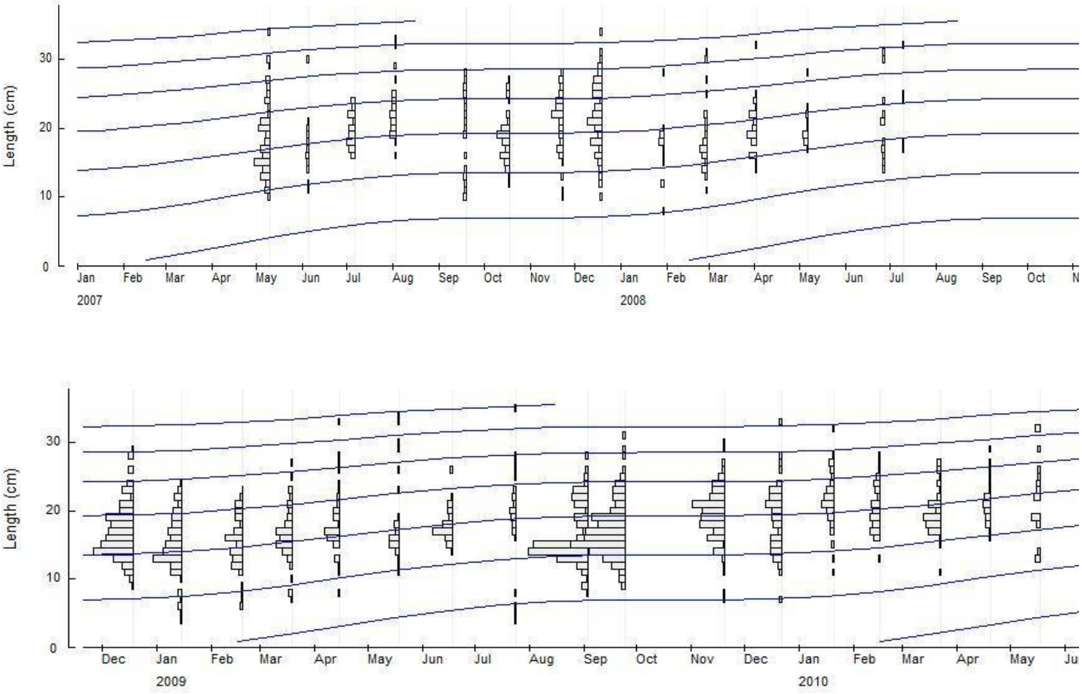


Figure 3.57. (continued). VBGF plot of *S. undosquamis* lizardfish covering the study period.

3.5.3 Sex-ratio and size differences in sex

The sex-ratio (female to male) of the sampled individuals was calculated as 0.48 (1:1.08) in a slight favour to males. However as shown in Table 3.13 and Figure 3.58 this ratio changes with size; males were dominant at length classes between 18 and 22 cm while females were dominant at larger length classes.

Table 3.13. Sex ratio of *S. undosquamis* by length classes.

Length (cm)	Juvenile	Females	Males
7	100.0	0.0	0.0
8	100.0	0.0	0.0
9	100.0	0.0	0.0
10	100.0	0.0	0.0
11	100.0	0.0	0.0
12	100.0	0.0	0.0
13	100.0	0.0	0.0
14	100.0	0.0	0.0
15	98.7	0.0	1.3
16	81.5	2.5	16.0
17	55.8	5.2	39.0
18	18.4	17.5	64.1

Table 3.13. (continued). Sex ratio of *S. undosquamis* by length classes.

19	9.1	11.4	79.5
20	5.7	25.2	69.1
21	1.8	35.4	62.8
22	0.9	42.6	56.5
23	0.0	55.8	44.2
24	1.2	66.3	32.6
25	0.0	78.0	22.0
26	0.0	88.6	11.4
27	0.0	94.7	5.3
28	0.0	100.0	0.0
29	0.0	100.0	0.0
30	0.0	100.0	0.0
31	0.0	100.0	0.0
32	0.0	100.0	0.0
33	0.0	100.0	0.0
34	0.0	100.0	0.0
35	0.0	100.0	0.0
36	0.0	0.0	0.0
37	0.0	100.0	0.0

The length classes equal and larger than 22 cm were exclusively females. Sex could not be determined at lengths below 14 cm.

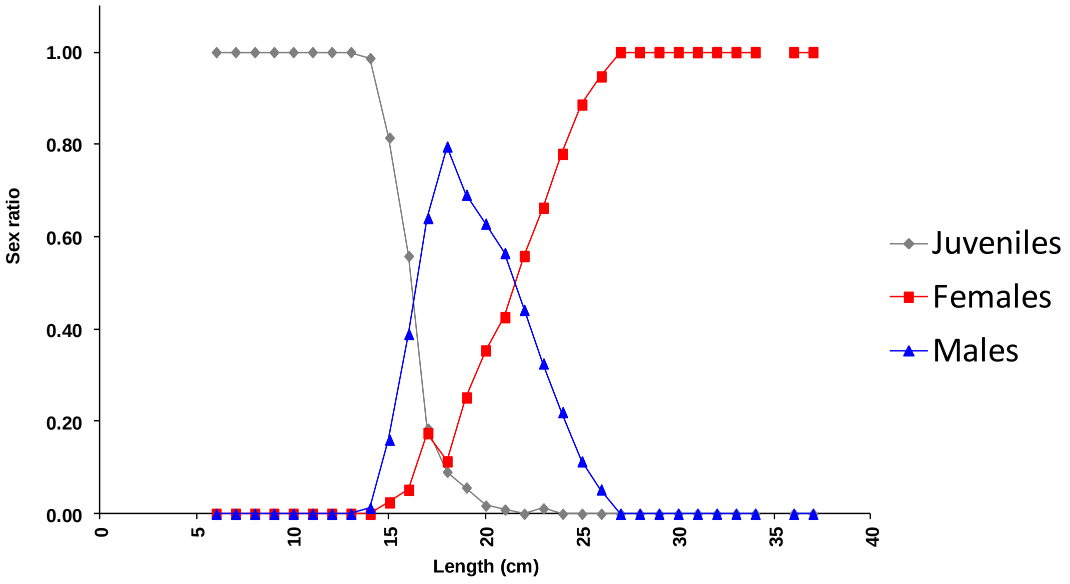


Figure 3.58. Sex-ratio in juveniles, males and females of *S. undosquamis* by size.

3.5.4 Length at first maturity

The estimated length at first maturity (L_m) for males and females were 17.2 and 19.0 cm respectively (Figure 3.59 and Figure 3.60) indicating that the males generally mature at rather smaller sizes than the females. As the associated maturation rate coefficients, “r_m” are compared males (r_m=1.02) had a larger value than the females (r_m=0.76) meaning that the transition from juvenile to fully mature male occurs within a narrower range of length limits.

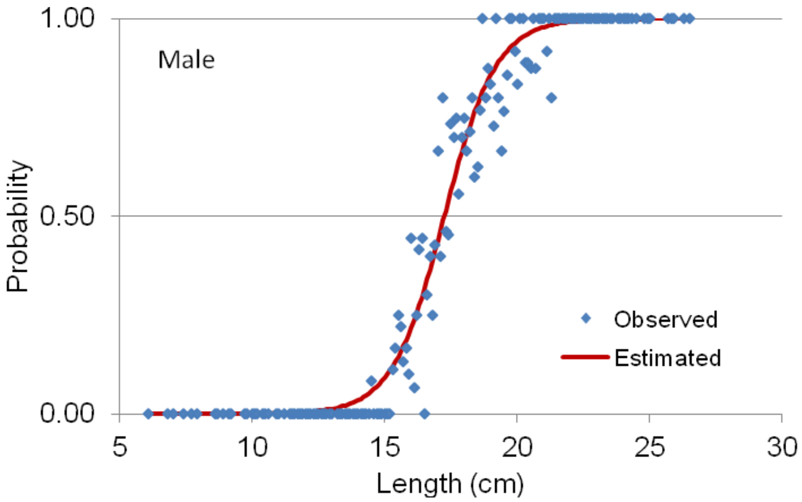


Figure 3.59.Length of first maturity calculated for male *S. undosquamis* from pooled data

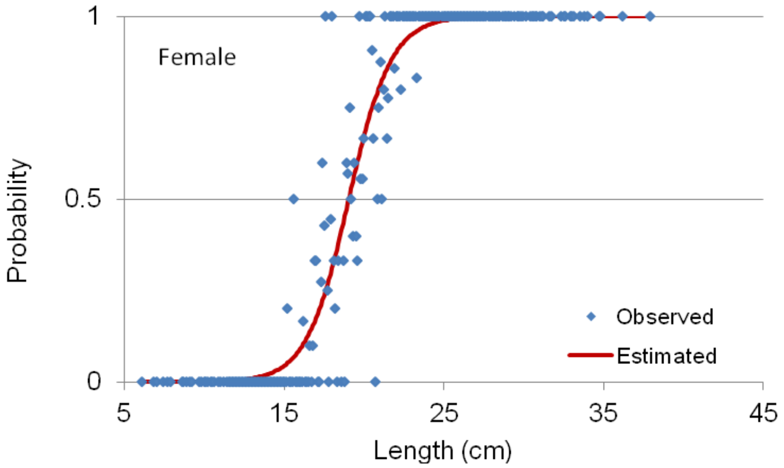


Figure 3.60.Length of first maturity calculated for female *S. undosquamis* from pooled data.

3.5.5 Biological indices

The biological indices examined separately for males and females were summarized in Figure 3.61 and Figure 3.62. The variation of GSI values of female *S. undosquamis* over the study period suggested that the species presented a quite clear reproduction cycle. The development of gonads in the females began around March. The highest GSI values were reached in late spring-early summer (May to June) then the index dropped gradually until late July - early August (Figure 3.61). The gonadal activity of females again started to increase in November-December pointing out existence of secondary spawning group and indicated that the spawning of the species occurs in, at least, two time periods.

The males displayed a rather noisy distribution however the main features of the annual gonad development pattern observed in females was still clear in Figure 3.62. The only difference was the lack of secondary peak in winter.

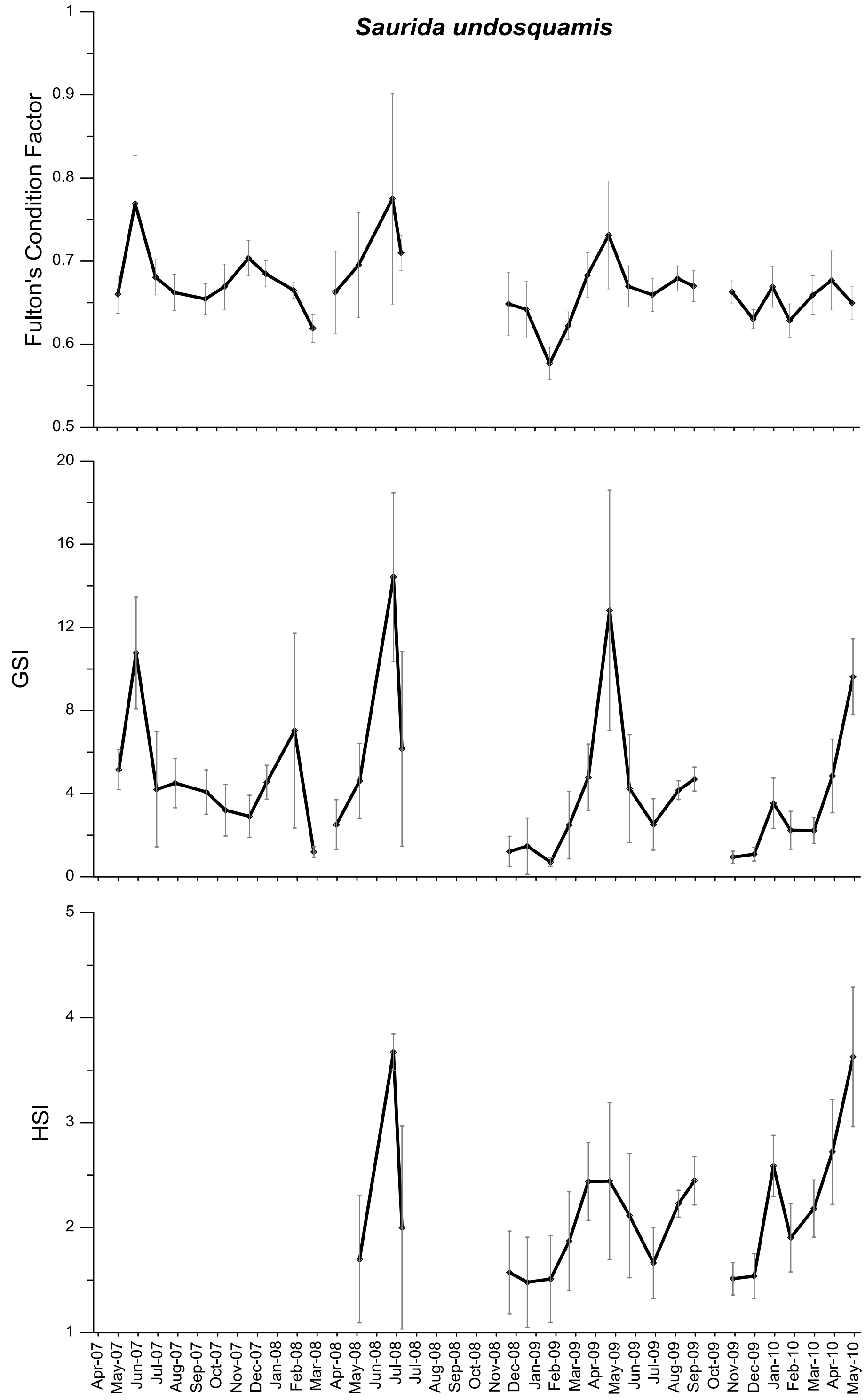


Figure 3.61. Time series of calculated biological indices of female *S. undosquamis*.

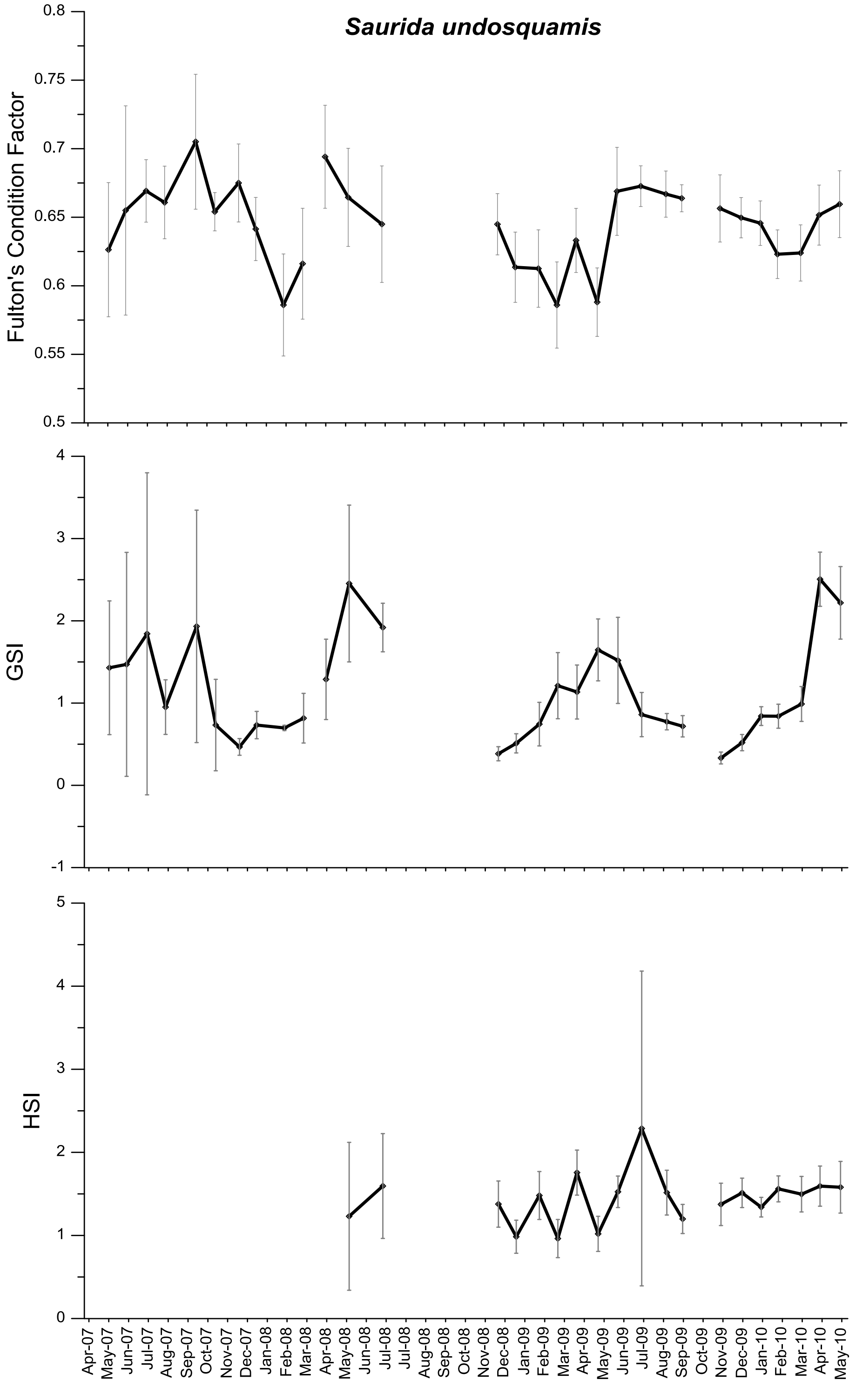


Figure 3.62.Time series of calculated biological indices of male *S. undosquamis*.

In order to better examine the existence of secondary spawners, two alternative and independent considerations were made; first possible secondary spawners masked by the non spawners were revealed. The mean GSI values of the males and females at "spawning stage" and their non-outliers (3 standard deviation greater or smaller than the mean) ranges were calculated and presented in Figure 3.63. As can be seen from the figure the lower non-outlier range of the female spawners was set over the GSI value of 6 and the lower range of the males was on 1.4.

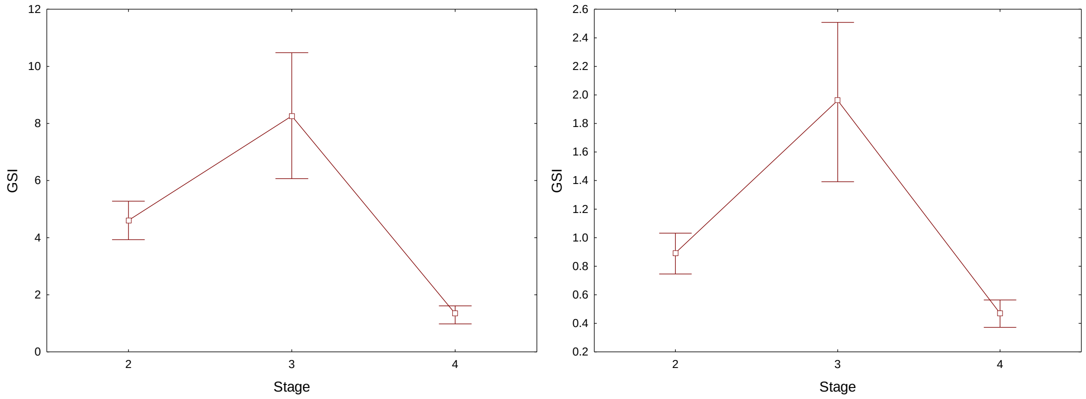


Figure 3.63. Mean GSI values at gonad stages and their non-outlier ranges (left= females; right = males).

The seasonal variations in GSI of females (Figure 3.61) and males (Figure 3.62) in three successive years were overlaid on the annual scale in Figure 3.64. The data points accumulated over the lower non-outlier range indicates the individuals at the stage of spawning. The values above the lines showed that the highest GSI values in females observed between day 77 and day 213 (between late March-early August) meaning that the most intensive reproduction activity observed within this time period. Later, the GSI increased again during the time period between day 325 and day 57 (between late November and late February) possibly indicating a secondary period of increased gonad activity. These results agreed with the earlier findings given above. As the release of gametes by both sexes must have been synchronous, the same pattern should apply to the males. Eventually, there were some males at spawning stage outside the spawning season. By comparison, of the individuals presenting a GSI value above the spawning limit, 83% of the females were localized between March and July and 17% were observed between November and February. The ration was slightly different for males; 95% of the males having a GSI value higher than critical spawning limit was accumulated between March and July and the rest are found between November and February.

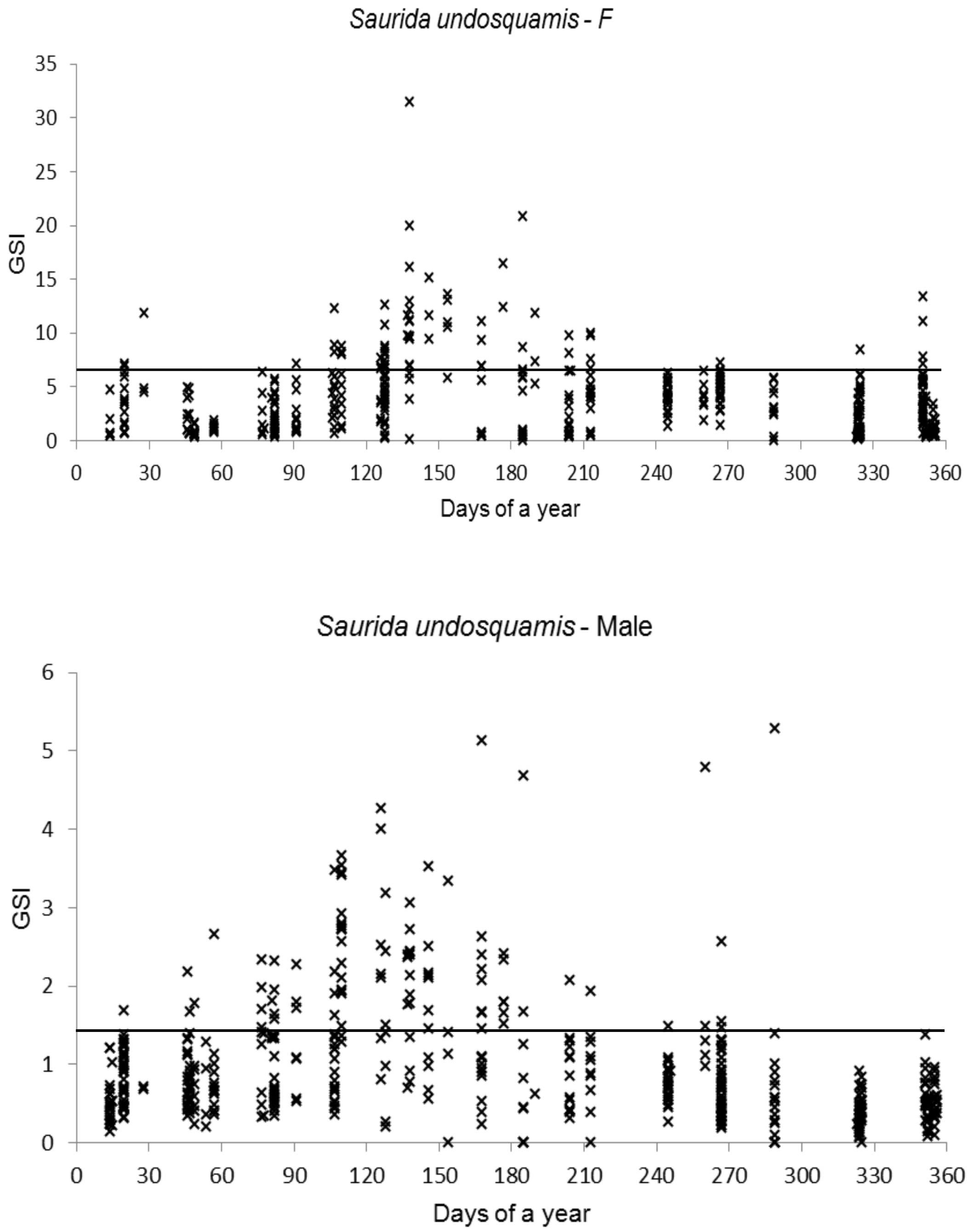


Figure 3.64. GSI of female and male *S. undosquamis* in annual scale.

The distribution of sampled individuals into the gonad maturity stage was depicted in Figure 3.65. The percentage of females developing gonads was very high in January. But later in February they surprisingly disappeared and females at spent/resting stage dominated the samples. In March a part resting females began to develop gonads. In May, the gonads ripen and the 50% of the females began to spawn while the rest of the population was still developing the gonad. Resting females were very few. June was the month when the highest percentage of spawning females was observed, however those already spawned in May were now in resting stage. There was almost female at gonad developing stage in June. In the next month, there were only very few spawning females and population was dominated by the females which spend their eggs a month before. In August, resting females began to develop gonad and development continues in the following months. However they disappeared before they spawn. In November and December, a slight increase in the number of spawners was noted.

The males displayed a similar pattern (Figure 3.65). In January, February and March they developed their gonads. In April, a part of the male population began to release the gametes. In May, percentage of ripe males were very high and remained high in the following four months, while a part of them turned into resting state after releasing their gametes. Until this month, males and females displayed the same pattern. However in October very high percentage of males were observed at the spawning stage. This was a very sharp increase, followed by an equally sharp decrease in the spawning males.

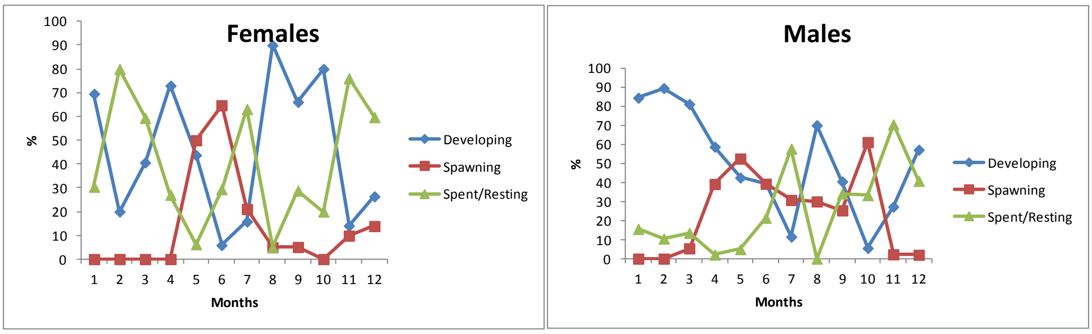


Figure 3.65. Monthly variations in the percentages of male (right) and female (left) *S. undosquamis* at developing, spawning and spent/resting gonad stages

Only the spawning females and males were separately depicted in Figure 3.66. It was assumed that spawning occurred in a normal fashion and followed a normal distribution curve. Therefore the spawning pattern was modeled by a normal distribution function, which, then, provided mean spawning date and proportion of spawners taking part at each spawning period. The model suggested statistically similar mean spawning date for the first period (Table 3.14), males presenting a higher standard deviation, hence broader distribution over time. In this period, the contribution of males (73%) is slightly lower than the females (84%).

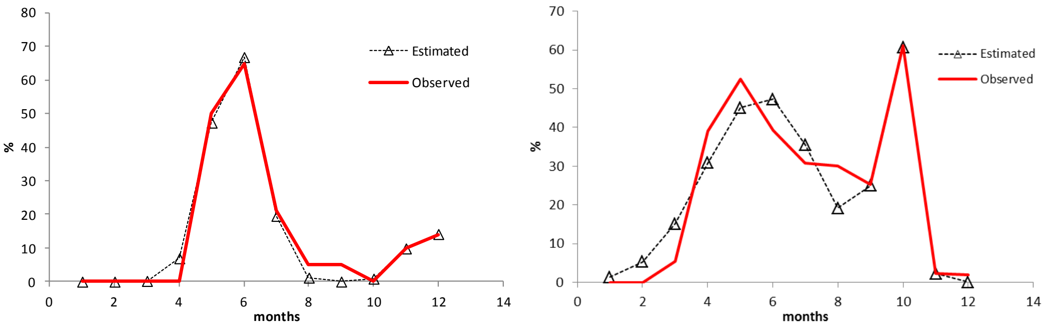


Figure 3.66. Distribution in the percentage of spawning *S. undosquamis* over a year and fitted normal distribution function (females are on the left and males are on the right hand side).

However, the spawning dates for the second spawning period estimated by the model were statistically different as the 95% confidence limits were not overlapped (Table 3.14).

Table 3.14.The mean spawning date of the first and the second spawning period with 95% confidence limits.

	Spring/summer spawners				**Autumn/winter spawners**			
Sex	**Males**		**Females**		**Males**		**Females**	
% involved	73		84		27		16	
Mean date	May, 18		May, 20		September, 18		November, 15	
95% CL	May,11	May,25	May,16	May,24	Sep,15	Sep,21	Nov,7	Nov,23

Figure 3.67 is the size distribution of the females representing GSI value of 6 and over during the first and second spawning period. The spring spawners have a broader length spectrum than the winter spawners. The distributions were tested statistically to see if the mean length of the reproductively active females is different (Table 3.15). The mean length of the spring group (25.5 cm) is slightly smaller than the winter group (27.1 cm) (Figure 3.68. F test indicated the variance of both distribution are not equal; therefore the difference was tested by non-parametric Mann_Whitney U Test and the difference is found significant (p=0.042). As the probability level is very close to the critical value, it would probably be better to accept that the differences in the appearance of the length distributions are shaped by the intensity of the members of the population taking part in spawning. In spring 84% of the females took part in spawning (almost no individual below the line in Figure 3.67) while only 16% of females sampled displayed high GSI values.

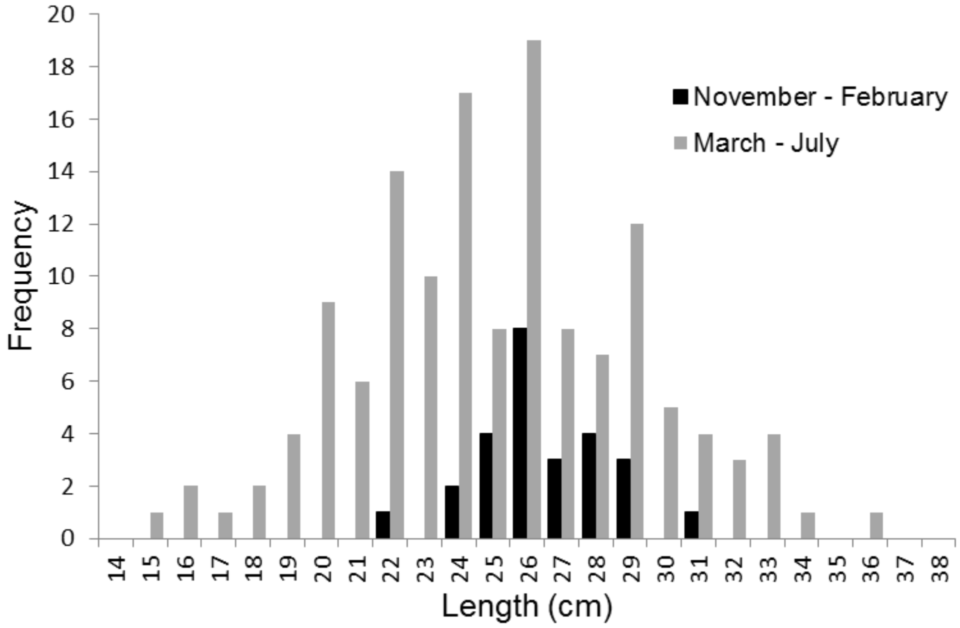


Figure 3.67. Frequency distribution of length groups in females having GSI>6.

Table 3.15. Results of statistical length comparison of spring and winter spawners.

	Between day 77and day 213 (Spring)		**Between day 325 and day 57 (Winter)**	
L$_{mean}$	25.5		27.1	
Range	15.2	36.2	22.6	31.7
n	89		26	
t value	-1.669			
df	113			
p	0.0980 (not significant)			
st.dev.	4.695539		1.922962	
F-ratio	5.96			
p	0.000005 (highly significant)			
Rank Sum	4858.5		1811.5	
U	853.5			
Z	-2.029			
p	0.0424 (significant)			
Z-adjust	-2.029			
p	0.0424 (significant)			
Mann-Whitney U Test (Saurida.sta) By variable NewVar2 Marked tests are significant at p <.05000				

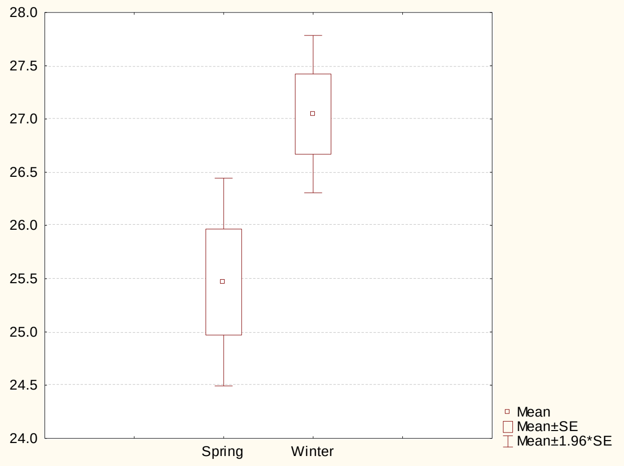


Figure 3.68. Box & Whisker Plot of *S. undosquamis* length distributions of spring and autumn spawners.

HSI in females shows an increasing trend at first, energy storage starts after February, the highest values are observed in April and May (Figure 3.61). Variations in GSI and HSI are almost overlapped meaning that *S. undosquamis* uses the energy gained during gonadal development; the species do not store energy before spawning. On the other hand, males do not show any clear pattern in energy allocation throughout the year (Figure 3.62). It fluctuates within a short time periods during the spawning season. They start to store energy around April at the onset of spawning. Annual cycles in Somatic K of females seem to coincide with the reproductive peaks displayed in GSI curve. On the other hand, somatic K values of males shows rather different pattern in yearly base than females. Similar to females, somatic K was high (they were good conditioned) in males during the spawning seasons in 2007 and in 2008. In 2009, they were in better condition just after the spawning in spring term (Figure 3.61 and Figure 3.62).

3.5.6 Biomass and Abundance variations

The monthly vertical abundance observed between May and April for three successive years were presented in Figure 3.69. The bathymetrical distribution of the species was ranged from 9.2 m to 212 m. The vertical abundances were highly variable, particularly at the shallowest depths sampled, however no clear annual pattern in the vertical displacement was observed when the three successive years are compared. 87.3 % of biomass was concentrated over the depths between 28 – 70 meters (Figure 3.70). As presented earlier (in Figure 3.61 and Figure 3.62), the main spawning activity is observed in late spring and early summer. During this period the large sized individuals (apparently the spawners) were more abundant at depths between 60-70 meters where spawning might possibly take place (Figure 3.69). Although bathymetric distribution of the species was limited to first 100 meters, occasionally some individuals were observed at the lower edge of the continental shelf.

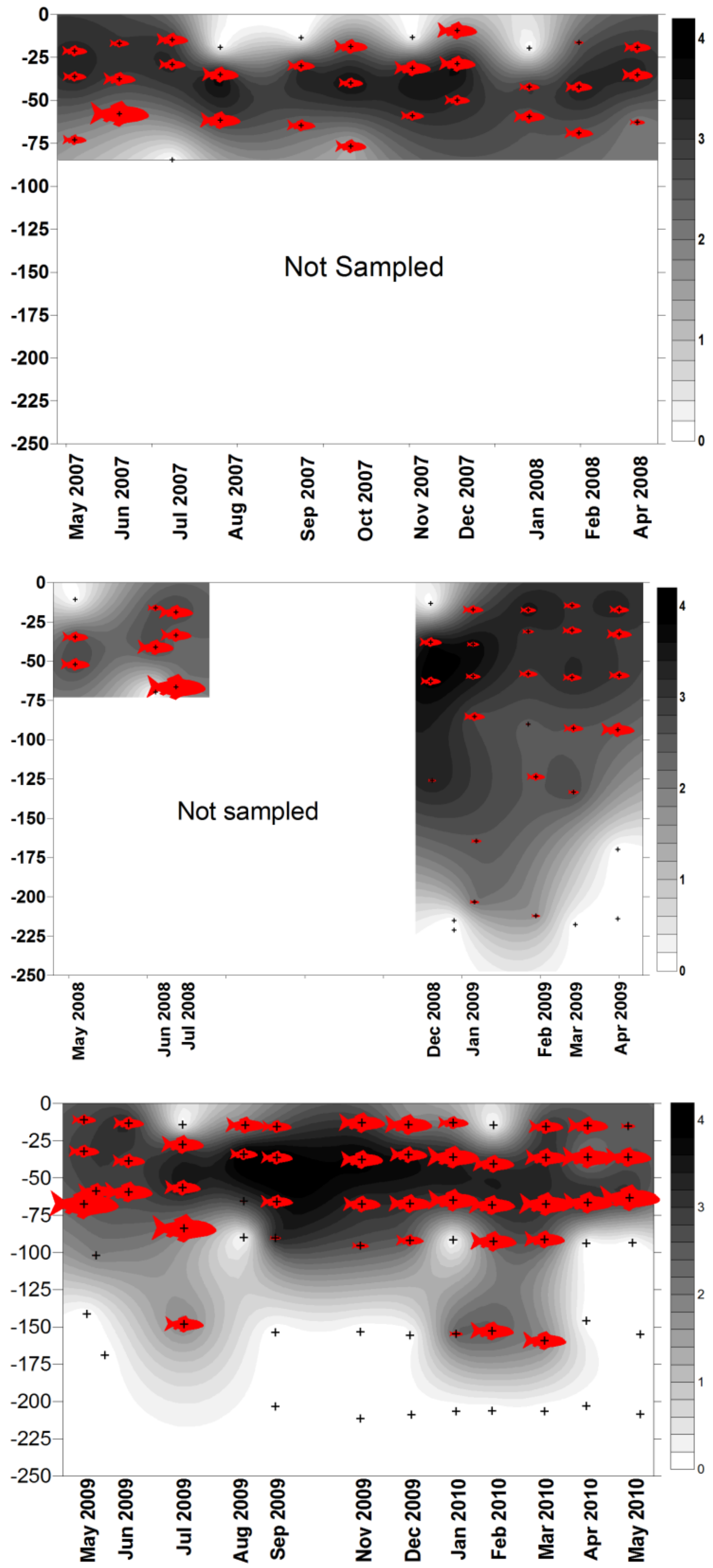


Figure 3.69. Bathymetric distribution (transformed abundance) of *S. undosquamis*. Contours in the maps show changes in abundance through depth and time. Fish symbols show the mean length proportional to symbol size. Plus signs show the sampled depth.

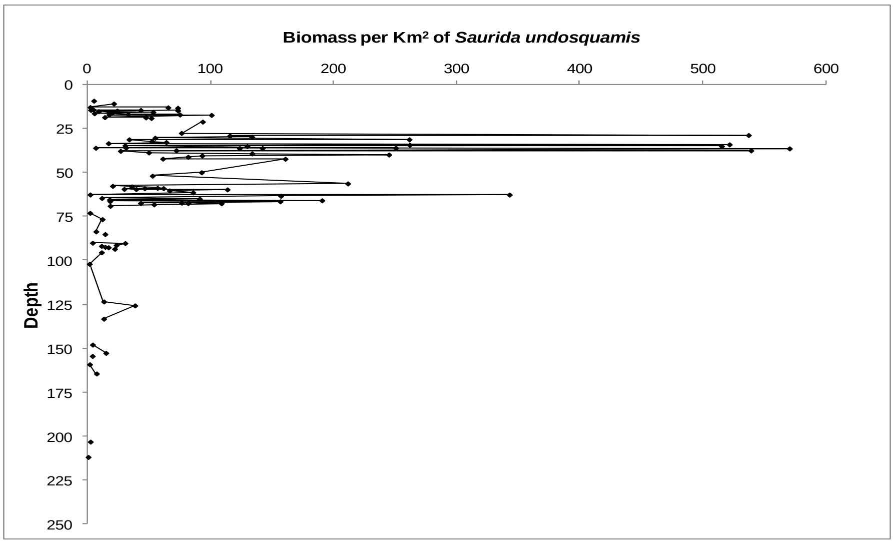


Figure 3.70. Biomass variations through depth – *S. undosquamis*

The fluctuations in the biomass at 4 major depth ranges were presented in Figure 3.71. As stated before the main part of the fish were aggregated at 25-50 m strata where strong seasonality was observed. The biomass at this stratum increased between late summer and early winter. During this period the mean length of the fishes were relatively low when compared to the rest of the year (Figure 3.69). The same pattern was observed in 2007 and 2009 however no sampling was performed during this period in 2008 to verify the persistence of the pattern. At the other strata, the fish distributed quite smoothly throughout a year except at 50-75 m stratum where the seasonality observed in the upper stratum is mimicked.

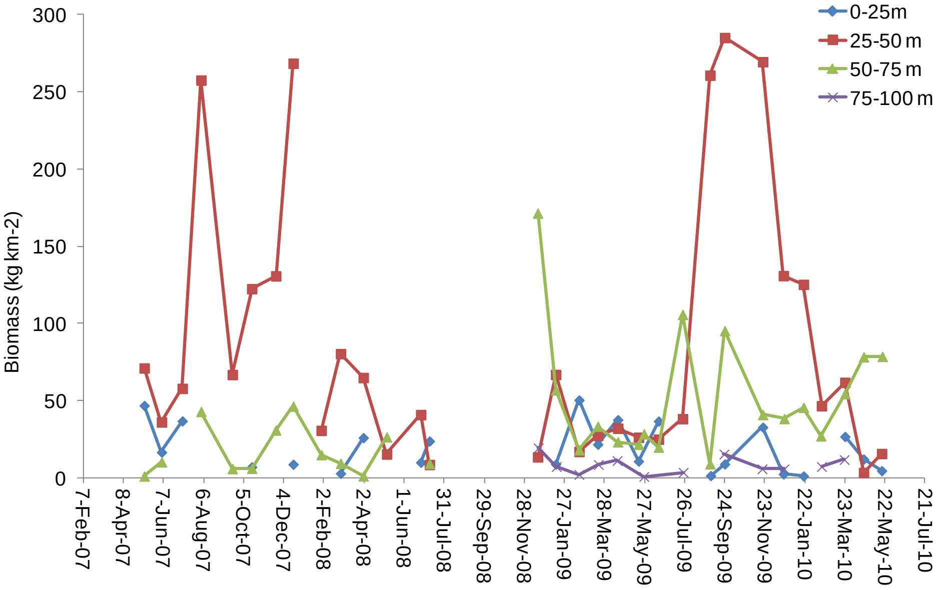


Figure 3.71. Annual biomass variations of *S. undosquamis* at four depth strata.

3.6 Other Species

The species given above were those represented by a sample size sufficient to make generalization about the biological features examined. However there some other occurring temporarily; and/or represented by very few sample not sufficient for statistical consideration; and /or represented by juveniles only. Although the reliability of results were undermined by the sparse and interrupted data set, the findings for the species of such, namely *U. moluccensis, L. mormyrus, M. merluccius* and *M. surmuletus* were given under this heading.

3.6.1 The length-weight relationship

The length-weight relationship of *U. moluccensis, L. mormyrus, M. merluccius, M. surmuletus* were presented in Table 3.16. The results are statistically sound for U. *moluccensis* and L. *mormyrus*; however sample sizes were rather low to make distinction between males and females of *M. merluccius* and *M. surmuletus*.

Table 3.16. Calculated length-weight relationship (power function W= aL^b) of the other species: a: slope; b: intercept; R2: correlation coefficient; n: sample size.

Species		***U. moluccensis***	***L. mormyrus***	***M. merluccius***	***M. surmuletus***
Male	**a**	0.0047	0.0147	0.0788	0.0081
	b	3.3124	2.9372	2.2515	3.1204
	R^2	0.9797	0.9792	0.8956	0.9889
	n	302	269	4	18
Female	**a**	0.0078	0.0211	0.0311	0.0065
	b	3.1312	2.8045	2.6024	3.2017
	R^2	0.9780	0.9780	0.9638	0.9968
	n	158	308	12	61
F+M+J	**a**	0.0050	0.0145	0.0030	0.0065
	b	3.2890	2.9376	3.2627	3.2105
	R^2	0.9933	0.9871	0.9980	0.9945
	n	1208	800	660	681

3.6.2 von Bertalanffy growth parameters

The length-frequency data was sufficiently long and meaningful only for *U. moluccensis* and *M. merluccius* and both species, and particularly the former one displayed very strong seasonality.

Table 3.17. VBGF plot of the other species studied in the study period.

Species	**L∞ (cm)**	**K**	**C**	**WP**	**To**
U. moluccensis	17	0.60	0.80	0.35	
L. mormyrus	Could not be calculated – insufficient sample size due to the irregular occurrence				
M. merluccius	65	0.23	0.40	0.70	
M. surmuletus	Could not be calculated – insufficient sample size due to the irregular occurrence				

3.6.3 Sex-ratio and size differences in sex

The over-all sex ratio (Table 3.18) and the sex ratio at different length classes (Table 3.19) could be calculated only *U. moluccensis, L. mormyrus* and *M.surmuletus.* Almost all hake samples collected were below the maturation size so that could not be sexed. Of the all species examined, females were significantly larger than males.

Table 3.18. Sex ratio of the other species by sex. N/A means related information is not available.

	U. moluccensis	***L. mormyrus***	***M.merluccius***	***M.surmuletus***
F %	0.34	0.53	N/A	0.75
M %	0.66	0.47	N/A	0.25
Sex ratio	1:1.9	1:0.89	N/A	1:0.33

Table 3.19. Sex ratio of the species among length classes. N/A means related information is not available.

	U. moluccensis			***L. mormyrus***			***M.merluccius***			***M.surmuletus***		
Length	J	♀	♂	J	♀	♂	J	♀	♂	J	♀	♂
5	0	0	0	0	0	0	N/A	N/A	N/A	100.0	0	0
6	0	0	0	0	0	0	N/A	N/A	N/A	100.0	0	0
7	100	0	0	100	0.0	0.0	N/A	N/A	N/A	99.1	0.9	0
8	100	0	0	100	0.0	0.0	N/A	N/A	N/A	93.6	5.7	0.7
9	81	2	17	0.0	0.0	0.0	N/A	N/A	N/A	71.3	23.8	5.0
10	45	12	43	0.0	0.0	100	N/A	N/A	N/A	24.0	52.0	24.0
11	14	14	72	18.2	0.0	81.8	N/A	N/A	N/A	21.4	50.0	28.6

Table 3.19. (continued). Sex ratio of the species among length classes. N/A means related information is not available.

12	2	38	60	50.0	15.8	34.2	N/A	N/A	N/A	0	100	0
13	0	80	20	9.0	28.2	62.8	N/A	N/A	N/A	0	66.7	33.3
14	0	91.2	8.8	7.9	28.1	64.0	N/A	N/A	N/A	0	100	0
15	0	100	0	3.8	51.5	44.6	N/A	N/A	N/A	0	100	0
16	0	50	50	0.0	64.7	35.3	N/A	N/A	N/A	0	0	0
17	0	0	0	0.0	76.9	23.1	N/A	N/A	N/A	0	0	0
18	0	0	0	0.0	71.8	28.2	N/A	N/A	N/A	0	0	0
19	0	0	0	0.0	92.0	8.0	N/A	N/A	N/A	0	0	0
20	0	0	0	0.0	100	0.0	N/A	N/A	N/A	0	0	0
21	0	0	0	0.0	100	0.0	N/A	N/A	N/A	0	0	0
23	0	0	0	0.0	100	0.0	N/A	N/A	N/A	0	0	0

3.6.4 Length at first maturity

The length at first maturity sizes of *U. moluccensis, L. mormyrus* and *M. surmuletus* were presented in Table 3.20. This parameter could not be estimated due to juvenile dominancy in the samples.

Table 3.20. Length of first maturity calculated for the species.

Species		***U. moluccensis***	***L. mormyrus***	***M.merluccius***	***M.surmuletus***
♂	**L_m**	10.5	12.7	N/A	11.4
	r_m	2.69	1.41	N/A	0.89
♀	**L_m**	11.5	13.1	N/A	11.7
	r_m	2.50	1.10	N/A	0.77

3.6.5 Biological indices

Due to the reasons given above, biological indexes of only 2 species could be presented under this heading. The males and females followed the same pattern indicating that even though sample size is not sufficiently high; the results are still informative (Figure 3.72). Of the two species examined gonad develop began in early spring (between May and June in *U. mollucensis* and between April and May in *L. mormyrus*) and spawning took place in summer (between June and August). The HSI was almost synchronous with GSI (Figure 3.73); however somatic K seems to be independent of other two parameters (Figure 3.74).

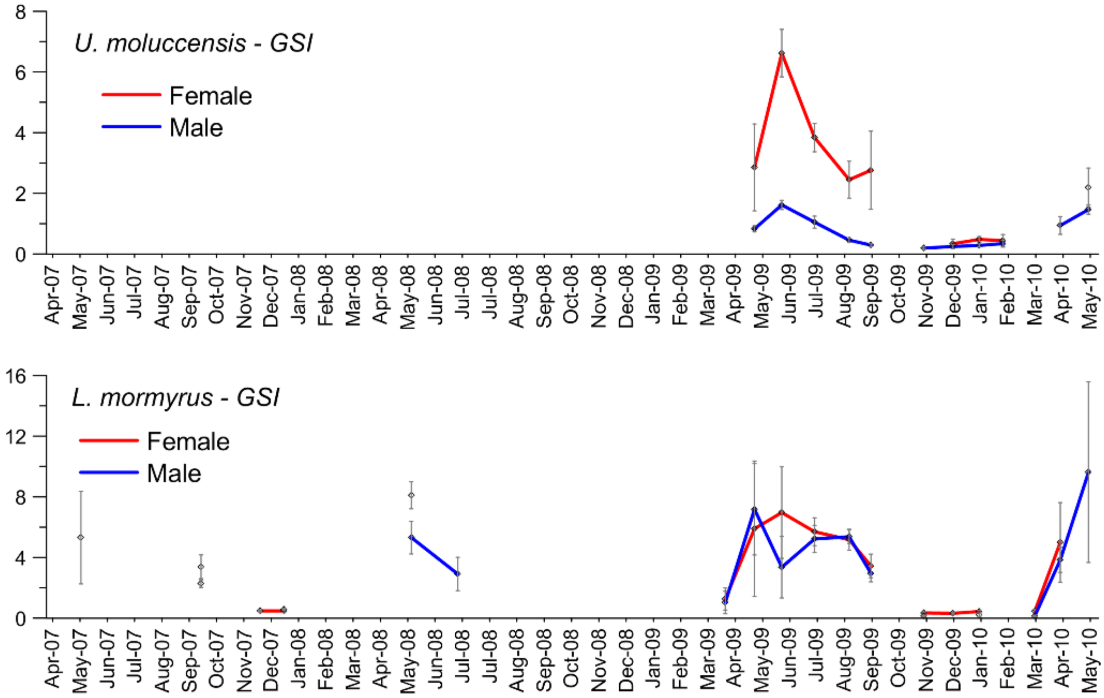


Figure 3.72. Time series of calculated GSI of female and male *U. moluccensis* and *L. mormyrus.*

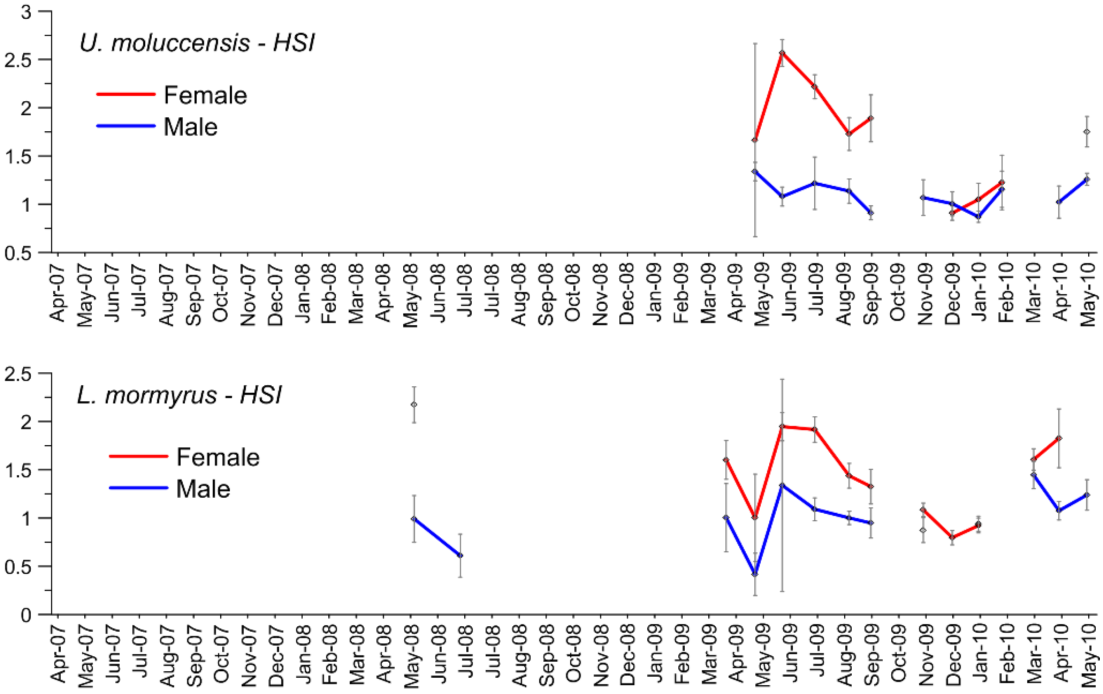


Figure 3.73. Time series of calculated HSI of female and male *U. moluccensis* and *L. mormyrus*.

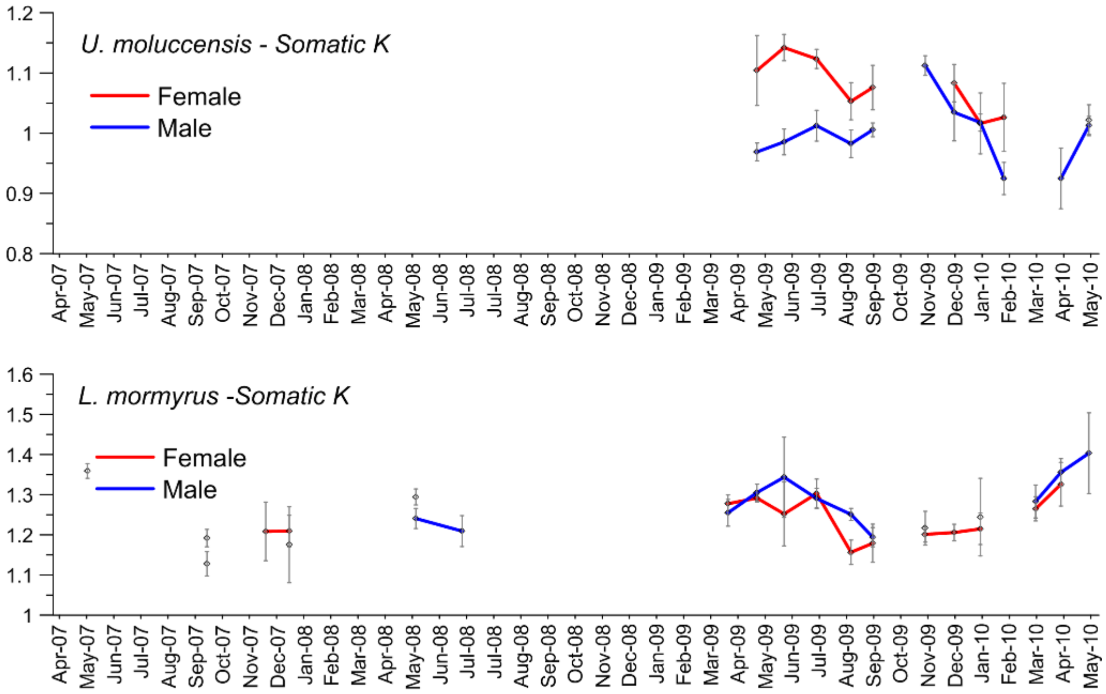


Figure 3.74.Time series of calculated Somatic K of female and male *U. moluccensis* and *L. mormyrus*.

3.6.6 Biomass variations

In order to present the occurrence periodicity and strength the monthly biomass distribution of all four species by depth was presented in (Figure 3.75, Figure 3.76, Figure 3.77, Figure 3.78). As underlined earlier *M. surmuletus* irregularly occurred in the samples. Interannual differences in *U. moluccensis* and *M. merluccius* are very severe. Both species were almost absent until the end of 2008 and suddenly appeared in significant quantities. *L. mormyrus* is a shallow water species and almost always observed after summer until May except one unusual case in June 2008.

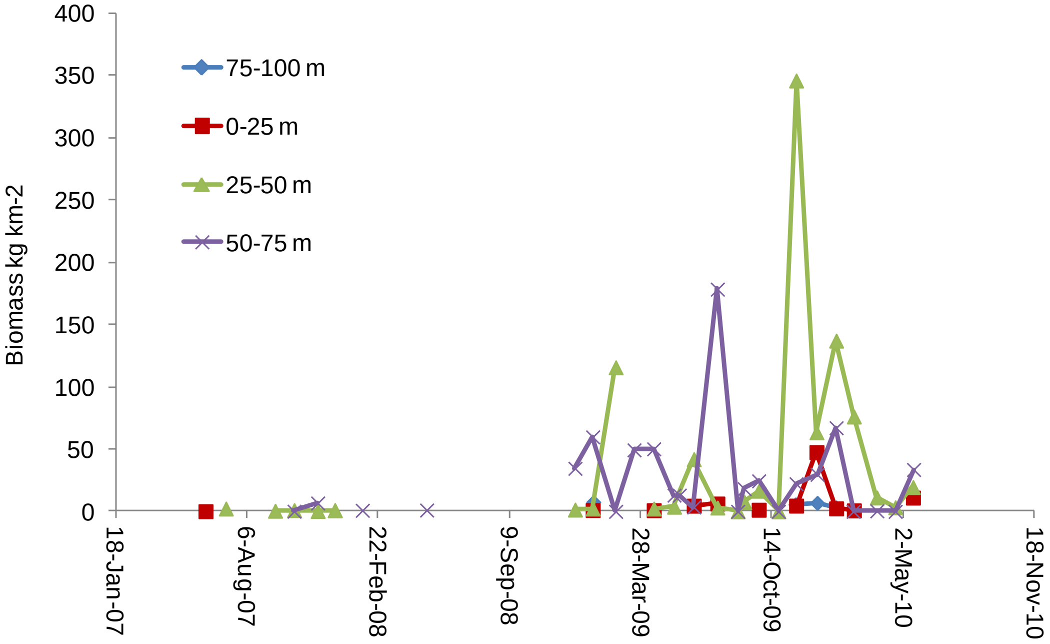


Figure 3.75. Annual biomass variations of *U moluccensis* at four depth strata.

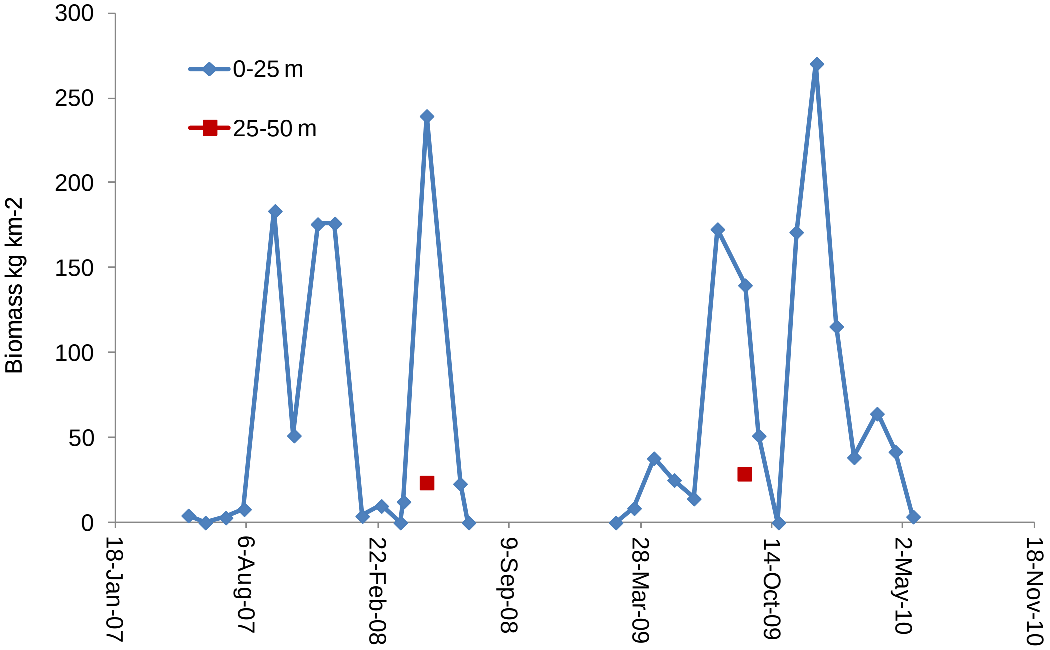


Figure 3.76. Annual biomass variations of *L. mormyrus* at four depth strata.

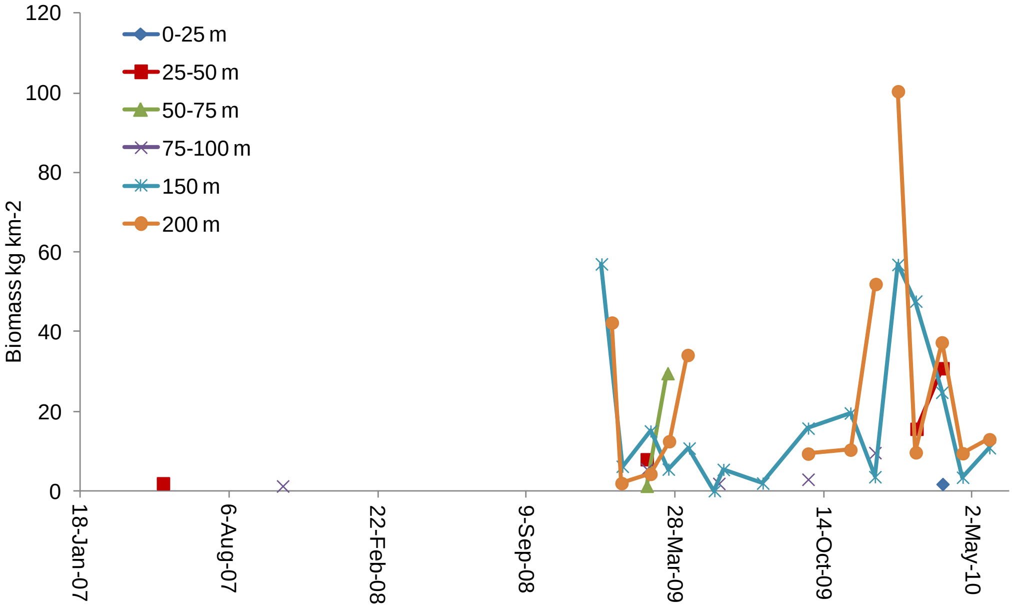


Figure 3.77. *M. merluccius* biomass variations through time and depth.

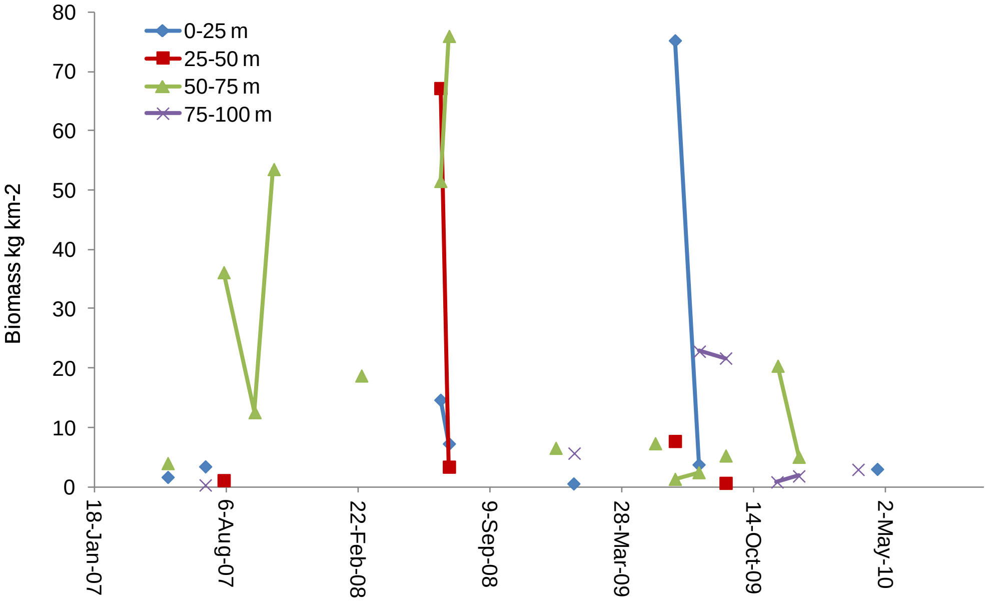


Figure 3.78. *M. surmuletus* biomass variations through time and depth.

3.7 Data Exploration

Following analyses were only performed for *M. barbatus*.

3.7.1 Biological Indices of *M. barbatus*

Absolute correlations coefficients calculated to investigate relationship between response and explanatory variables were indicated that there is not strong collinearity between response and explanatory variables. The relationships between GSI, HSI, Fulton's K and length, time (in days), average depth, bottom temperature and salinity are weak in general (Figure 3.21).

Table 3.21. The (absolute) correlations coefficients of GSI, HSI and Somatic K and explanatory variables (n=4166).

	GSI	**HSI**	**Somatic K**	**Length**
Length	0.18	0.33	0.46	1
Time	0.27	0.14	0.14	0.07
Average depth	0.03	0.086	0.29	0.23
Bottom temp	0.28	0.16	0.18	0.03
Bottom salinity	0.43	0.30	0.082	0.02

Figure 3.79 is a co-plot showing GSI variability with respect to maturation stages and sex of *M. barbatus* GSI versus average depth shows that during the pre-spawning season (stage 2) females were mainly dominant below 100 meters depth, later they also occupied deeper waters during spawning (stage 3) and post spawning (stage 4) periods. Males of *M. barbatus* in stage 2 and 3 exist through 200 meters depth then they were more dominant in waters shallower than 100-125 meters depth (Figure 3.79 - A). Both females and males seemed to prefer bottom water temperature between 16-22 ^{o}C but they existed in warmer waters during post spawning and resting phase (Figure 3.79 - B). There was not any linear trend in females in relation to the bottom salinity but males especially in stage 2 occupied waters having higher salinity (Figure 3.79 - C). There was again clear non-linear relationship between GSI and length of *M. barbatus* (Figure 3.79 - E).

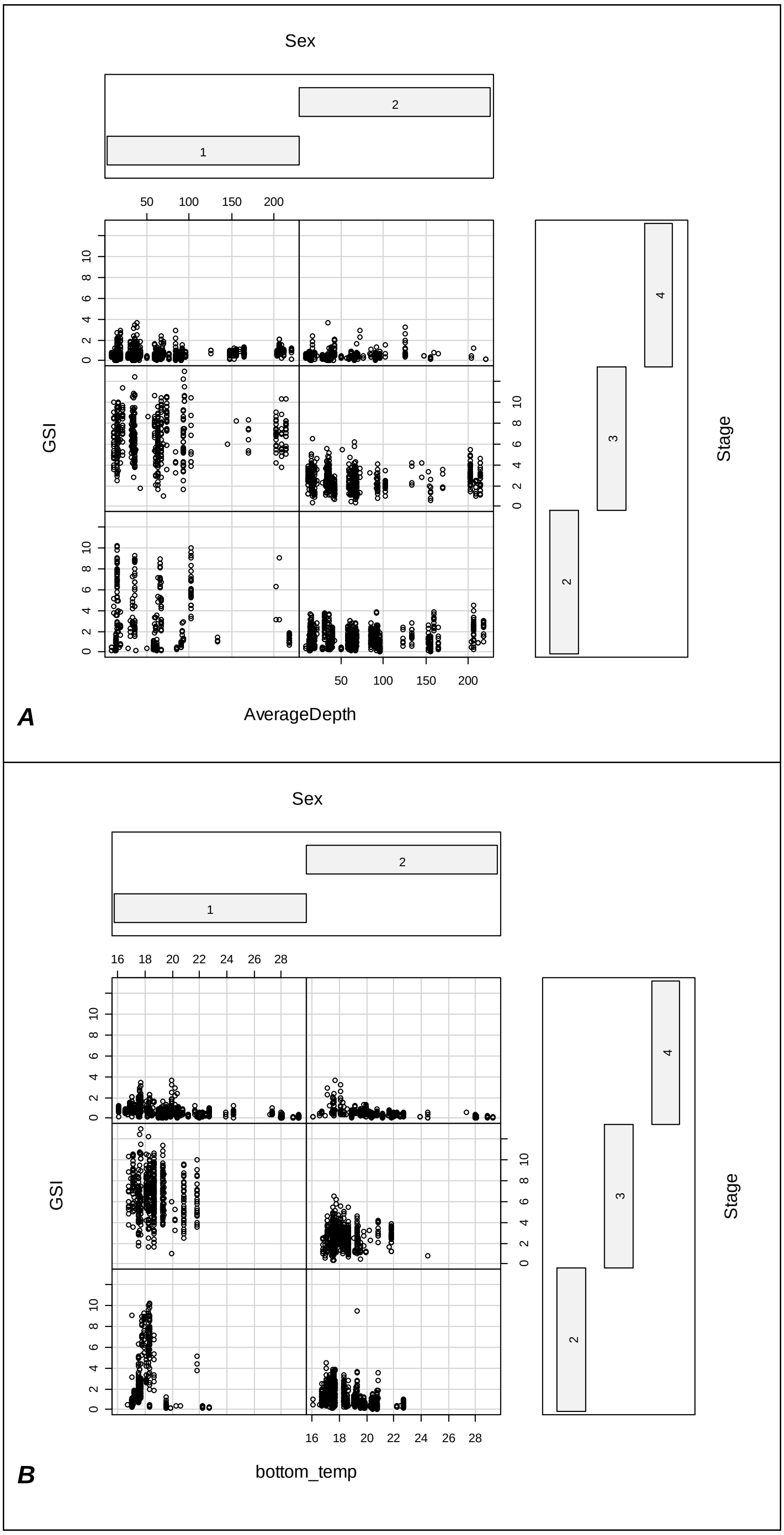


Figure 3.79. Coplot of GSI of *M. barbatus* versus explanatory variables. Upper panel is showing sex of M. barbatus as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage).

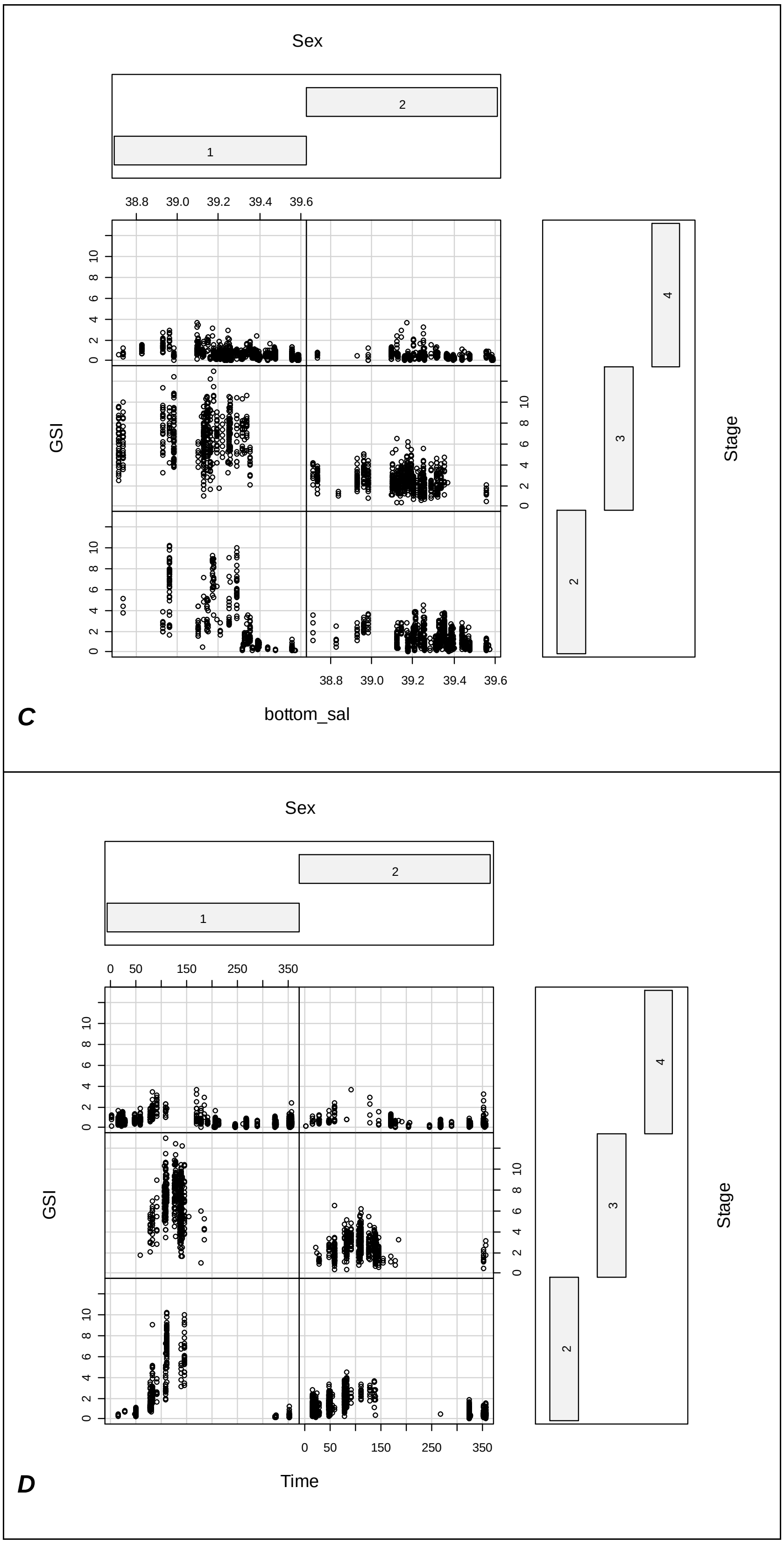


Figure 3.79. (continued). Coplot of GSI of *M. barbatus* versus explanatory variables. Upper panel is showing sex of M. barbatus as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage).

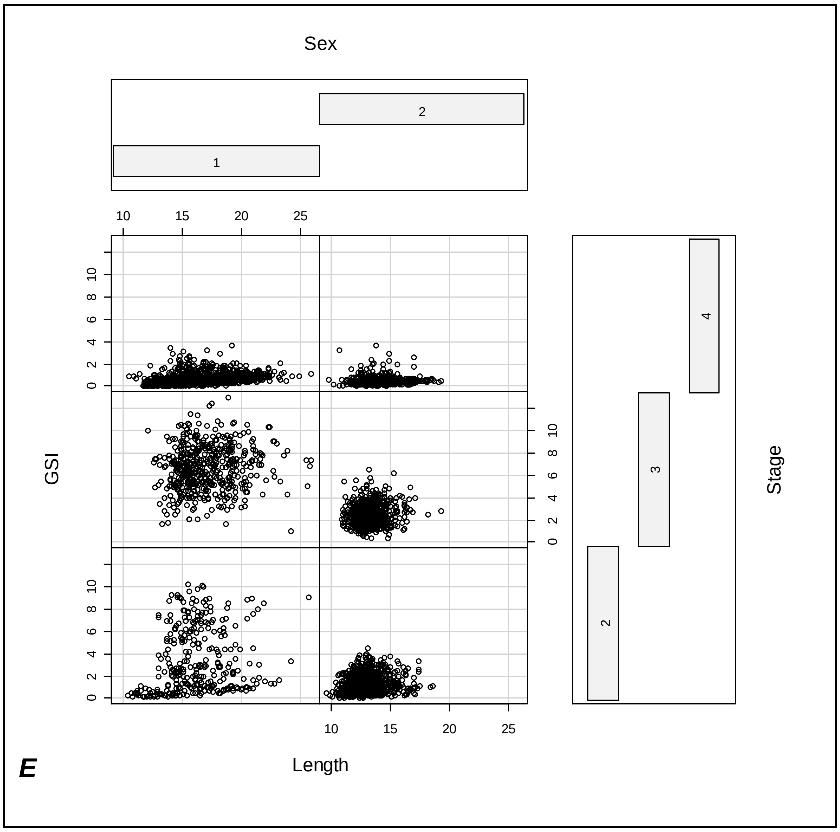


Figure 3.79. (continued). Coplot of GSI of *M. barbatus* versus explanatory variables. Upper panel is showing sex of M. barbatus as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage).

Figure 3.80 shows the sex and maturity stages as conditional variables on explanatory variables (depth, bottom temperature and salinity, time and length) suggested that there are no linear relationship between HSI of *M. barbatus* and all explanatory variables conditional on sex and stage.

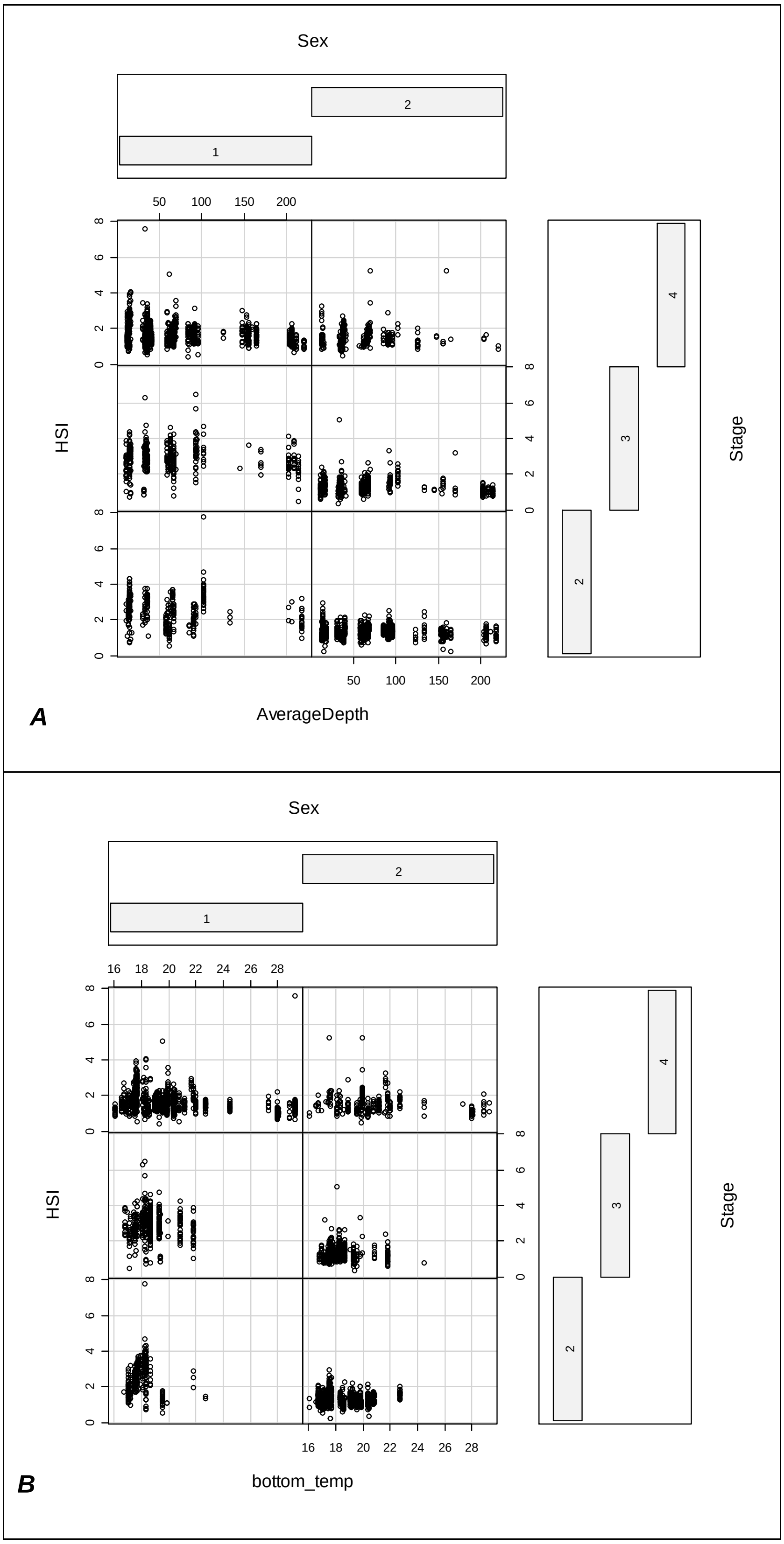


Figure 3.80. Coplot of HSI of M. barbatus versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of *M. barbatus* as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioni variable of reproductive stage.

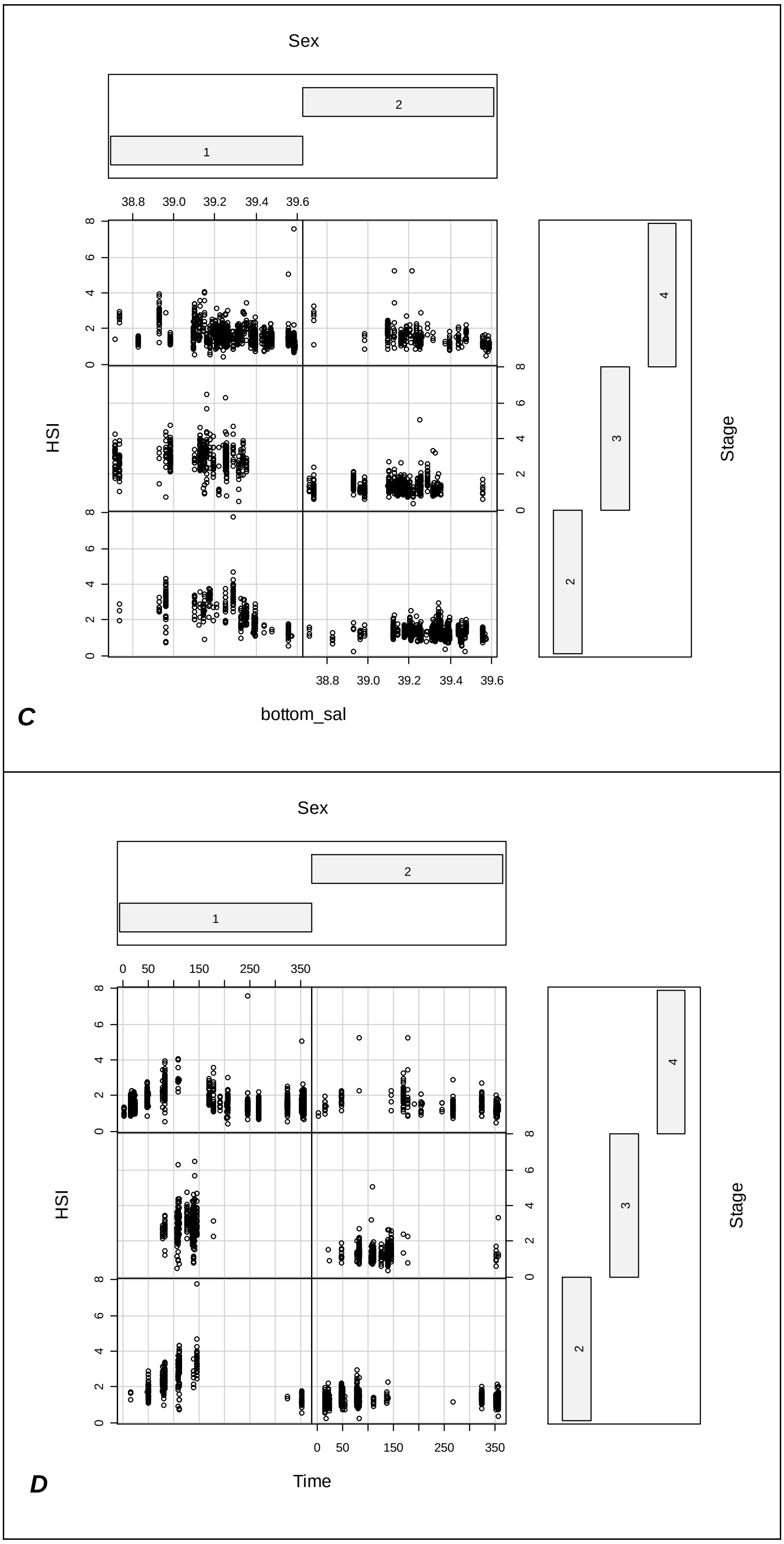


Figure 3.80. (continued). Coplot of HSI of M. barbatus versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of M. barbatus as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioni variable of reproductive stage.

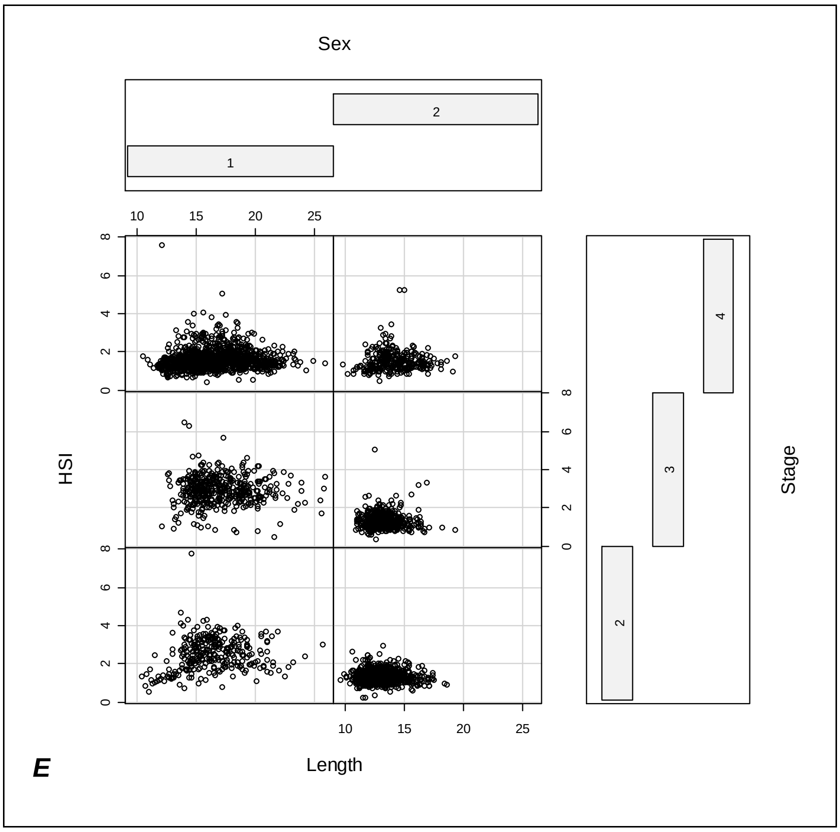


Figure 3.80. (continued). Coplot of HSI of M. barbatus versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of *M. barbatus* as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioni variable of reproductive stage.

Coplot of Somatic condition factor of *M. barbatus* indicated that the condition of males slightly decreased through increasing depth especially during post spawning periods (Figure 3.81 – A). Except individuals in post spawning period, condition factor of both males and female of *M. barbatus* slightly increased with increasing temperature (Figure 3.81 – B). Unsurprisingly, clear seasonal variations in condition factor of male and female *M. barbatus* were observed (Figure 3.81 – D). Bigger individuals seemed to have slightly better conditions than individuals in smaller sizes (Figure 3.81 – E).

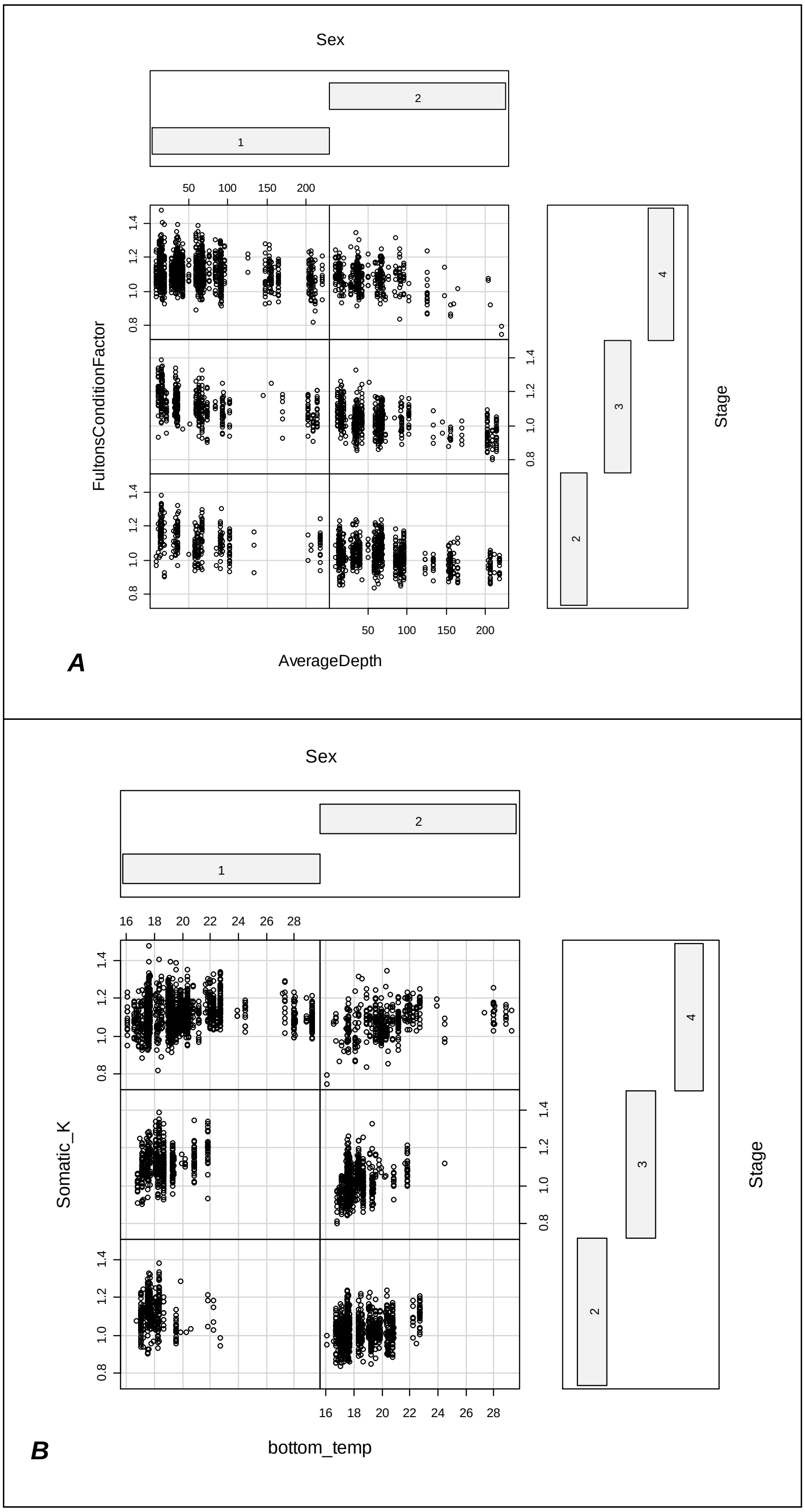


Figure 3.81. Coplot of Fulton's condition factor of *M. barbatus* versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of *M. barbatus* as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage.

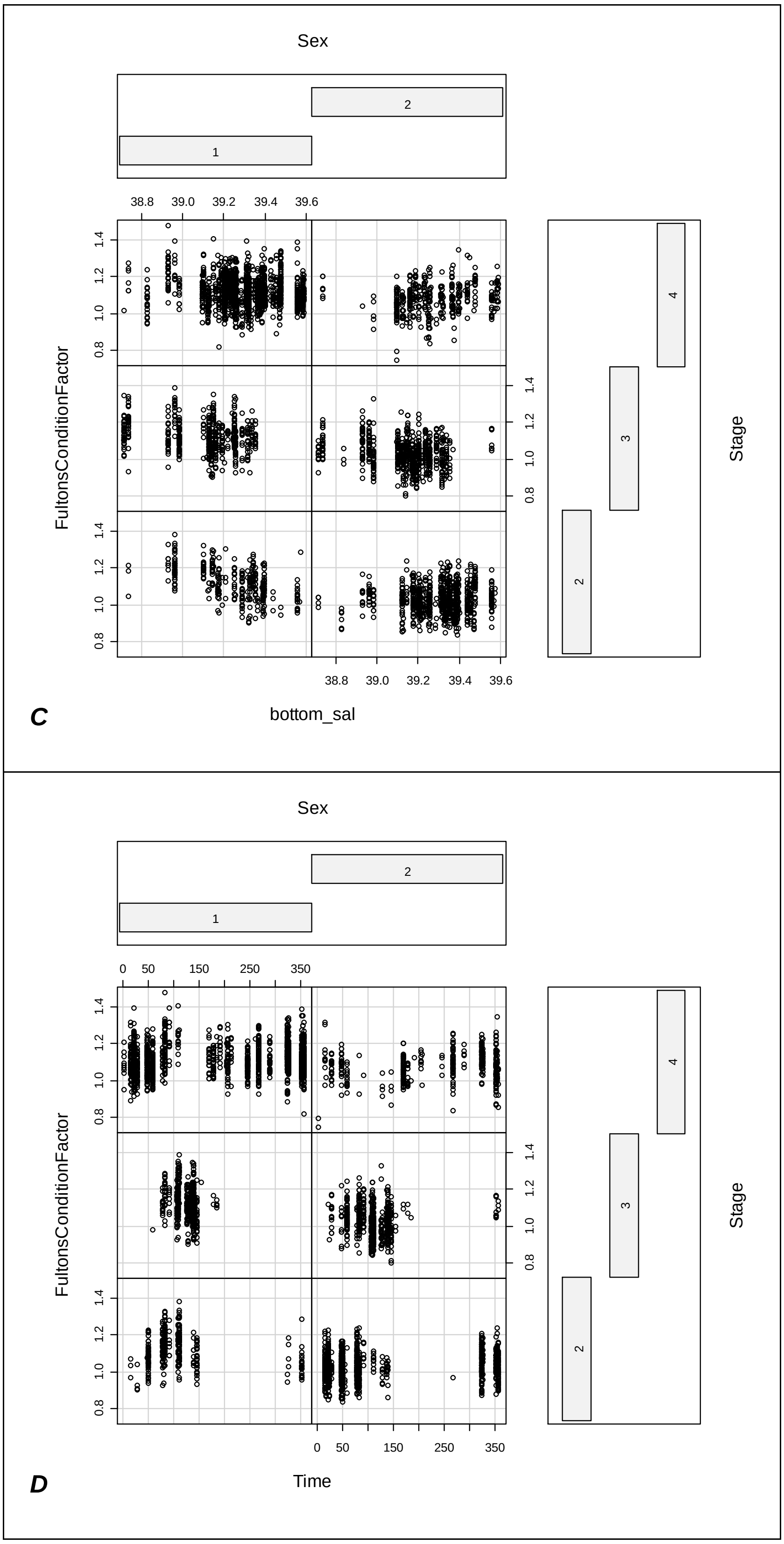


Figure 3.81. (continued). Coplot of Fulton's condition factor of *M. barbatus* versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of *M. barbatus* as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage.

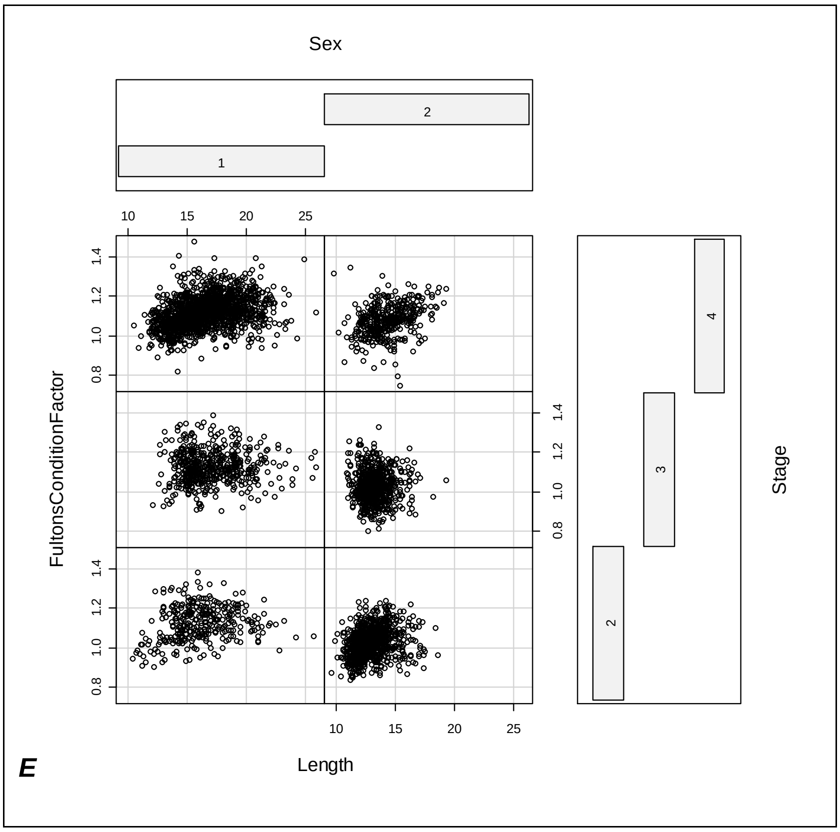


Figure 3.81. (continued). Coplot of Fulton's condition factor of *M. barbatus* versus explanatory variables conditional on sex and reproduction stage. Upper panel shows sex of *M. barbatus* as a conditioning variable (1 and 2 represent females and males respectively). Right panel is for the conditioning variable of reproductive stage.

3.7.2 Distribution through depth and environmental parameters

The relationships between abundance and biomass indices (response variables) of *M. barbatus* and explanatory variables were evaluated. A strong co-linearity exists between biomass and abundance (Figure 3.82) indicating that only one of the response variables would be enough to obtain meaningful results. Significance of the relationship between bottom temperature and mean length was also high however; this was not considered as collinearity since its biological meaning might be critical for the model. Another significant collinearity was observed between time and bottom temperature. Bottom temperature which has higher significance than time variable was retained while the latter was removed from the explanatory variables. Further, the correlation coefficient between explanatory variables having less than 0.5 was not considered collinear.

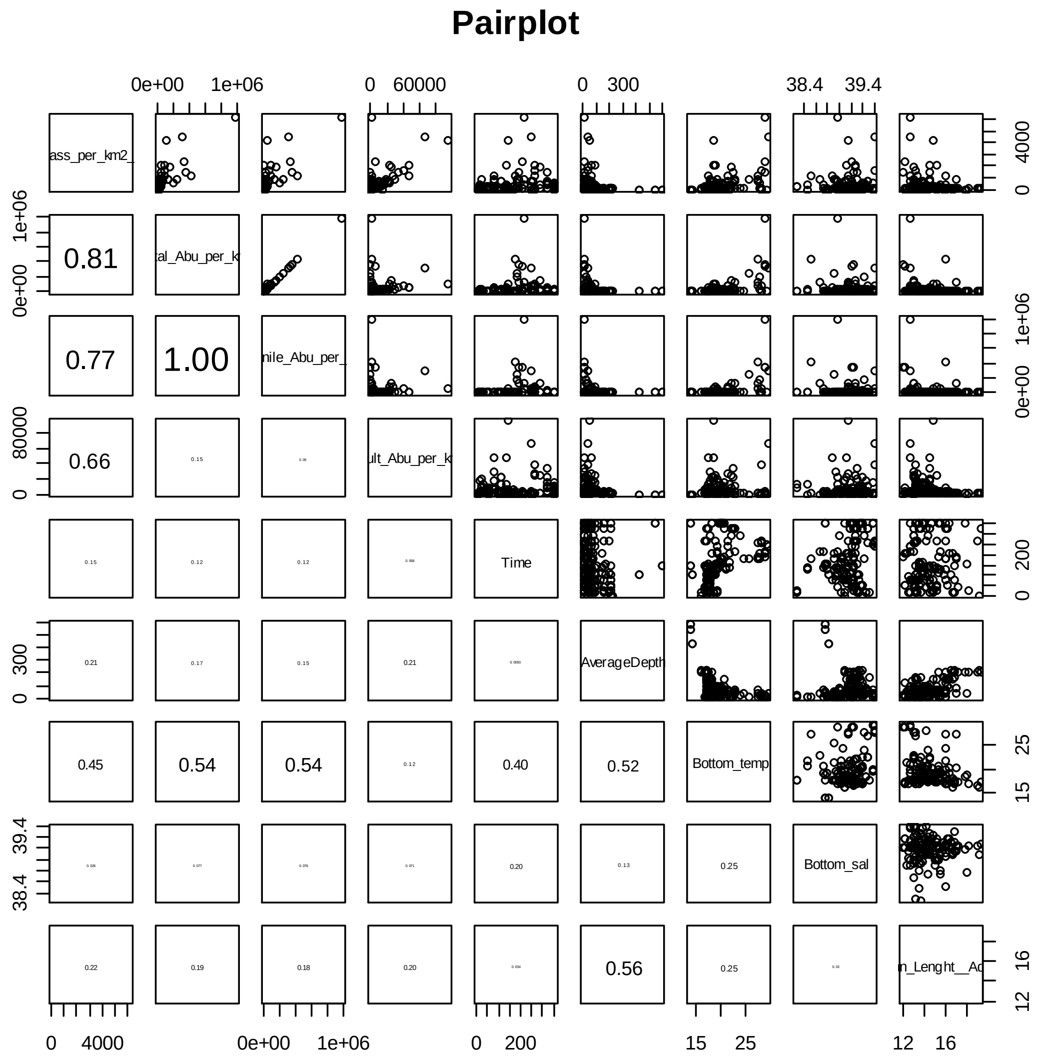


Figure 3.82. Pairplot of *M. barbatus* abundance and biomass indices vs. explanatory variables. Lower diagonal of the graph shows the Pearson correlation coefficients for corresponding variables and the font size of the value is proportional to its significance.

3.8 Statistical data analyses

Regressions of the GSI on *M. barbatus* size as a function of maturity stage by sex (Figure 3.83) showed that there is no correlation between these two variables. In other words, GSI is independent from body size in the *M. barbatus* so this index constitutes a good marker for sexual maturation.

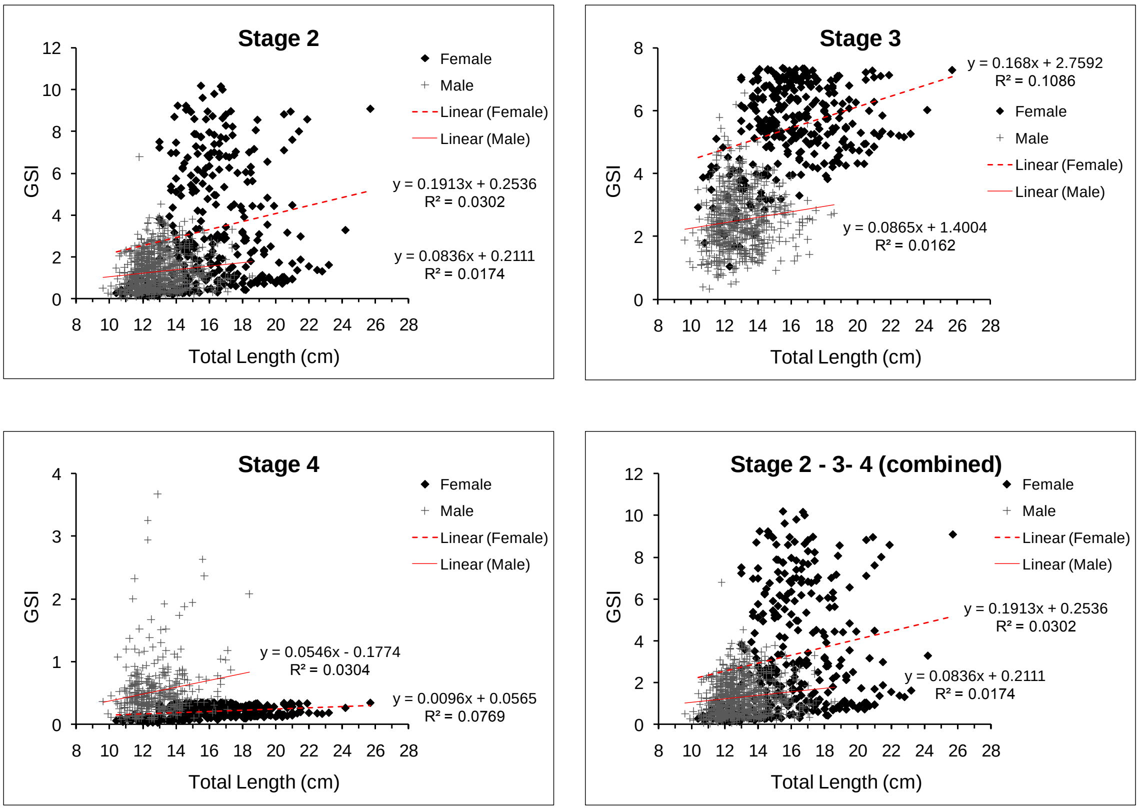


Figure 3.83. Gonadosomatic index of *M. barbatus* by sex and maturity stage as a function of size.

3.8.1 Influences of depth, environmental variables and time on biological Indices

Biological indices of male and female *M. barbatus* were compared statistically to investigate if there are any differences (Table 3.22). The normality tests indicated that the data of each index varied significantly from the pattern expected if the data was drawn from a population with a normal distribution. However, none of the variables was normally distributed even after transformation.

Table 3.22. Descriptive statistics of data on biological indices of *M. barbatus* by sex (F: female and M: male).

Sex_Index	Valid N	Mean	Median	Min	Max	Std.Dev.	Skewness	Kurtosis
F_GSI	1854	2.43	0.78	0.02	13.00	2.87	1.22	0.11
M_GSI	1601	1.56	1.34	0.04	6.78	1.12	0.80	0.32
F_HSI	1854	2.07	1.82	0.46	7.75	0.85	1.07	2.09
M_HSI	1601	1.39	1.33	0.23	25.62	0.72	23.84	785.70
F_Somatic	1854	1.12	1.12	0.82	1.48	0.08	0.22	0.27
M_Somatic	1601	1.03	1.03	0.74	1.35	0.08	0.19	0.13

Due to failure of normality, the difference between males and females were tested by non-parametric Mann-Whitney U test. Statistically significant difference was found between all indices of females and males of *M. barbatus* (P<0.001).

Table 3.23. Summary of the statistical tests (the non-parametric Mann Whitney U test) results showing if there is any difference between male and female *M. barbatus*.

Sex_Index	**Valid N**	**Median**	**Results**
F GSI	2261	0.72	P = <0.001
M GSI	1916	1.34	
F HSI	1854	1.82	P = <0.001
M HSI	1601	1.33	
F Somatic K	1854	1.12	P = <0.001
M Somatic K	1601	1.03	

3.8.1.1 Influences of depth, environmental variables and time on GSI

The results of generalized additive modeling of GSI are given in Table 3.24. Fitted contribution of all seven variables: depth, temperature, salinity, time, length, sex and stage were found highly significant (P<0.001). In overall, model with the given variable set explained 81.5 % of variance in GSI.

The difference in GSI of females and males found in statistical evaluation of data (Table 3.23) was also captured by the GAM (Table 3.24). Discrimination of sex suggested by the model was summarized in Figure 3.84.

Table 3.24. Significance values (p-values) for GAM covariates of the final model for GSI. Summary of parameter estimates applied to explanatory variables and statistical tests for generalized additive model (GAM) on *M. barbatus* GSI data.

GSI	**Df**	**F**	**p-value**
f(Average depth)	4	31.29	P < 0.001
f(Bottom temperature)	4	39.74	P < 0.001
f(Bottom salinity)	4	31.29	P < 0.001
f(length)	4	111.86	P < 0.001
f(Time)	4	332.75	P < 0.001
Sex	1	-	P < 0.001
Rep. stage	2	-	P < 0.001
Total % variation explained	**81.5**		

Statistical comparison gave highly significant differences among the GSI values at adult maturity stages greater than 1 (Table 3.25). The model significantly differentiated (P<0.001) the impact of this second categorical variable (Figure 3.84). The output of the model discriminating the differences in the maturity stages was summarized in Figure 3.85.

Table 3.25. Statistical comparison of maturity stages on GSI.

Kruskal-Wallis One Way Analysis of Variance on Ranks			
Group	**N**	**Median**	**P value**
GSI_Stage_2	1171	1.249	P < 0.001
GSI_Stage_3	1144	3.429	P < 0.001
GSI_Stage_4	1852	0.508	P < 0.001

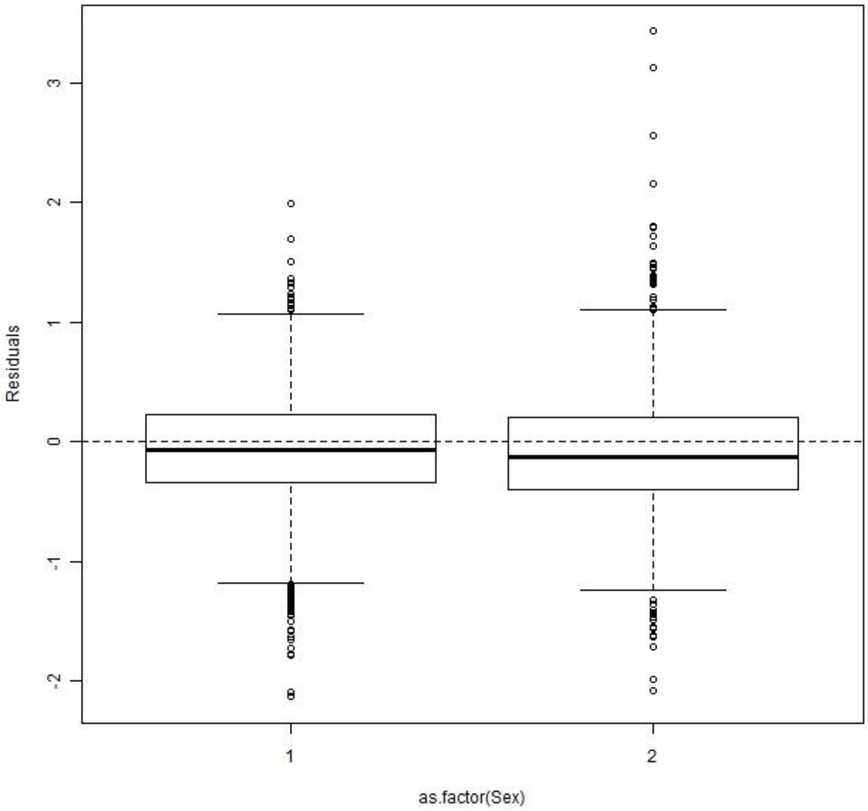


Figure 3.84. Whisker-Box Plot showing the effect of sex on GSI predicted by the GAM.

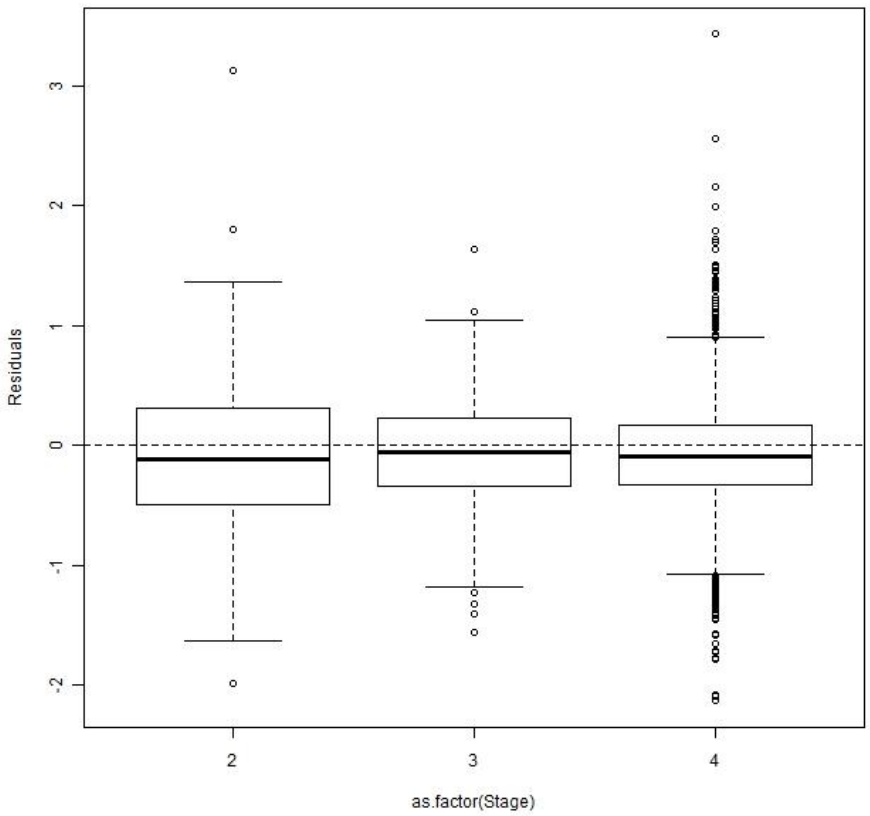


Figure 3.85. Whisker-Box Plot showing the effect of stage on GSI predicted by the GAM.

The seasonal variations of GSI depicted in Figure 3.10 and Figure 3.11 were converted into an annual scale (Figure 3.86). The figure showed one clear peak centered on day 126. Right after the peak, data aggregation showed a decline reaching a minimum around between day 260 and day 290. Later following day 300, aggregation again expanded and completed the cycle. The same data was classified based on sex and maturity stages and presented in separate plots. The reproduction cycle described above agreed well with each of the plots. Females at stage 3 exclusively occurred between day 50 and day 200, indicating that this stage has great importance in the formation of GSI peak mentioned above. Although males at stage 3 show very similar distribution confined day 25 to day 175, a secondary but lesser occurrence was observed through the end of the calendar year. Another important finding is that during the time slot at which individuals at stage 3 is confined none of the individual at stage 4 indicating that all individuals were reproductively active.

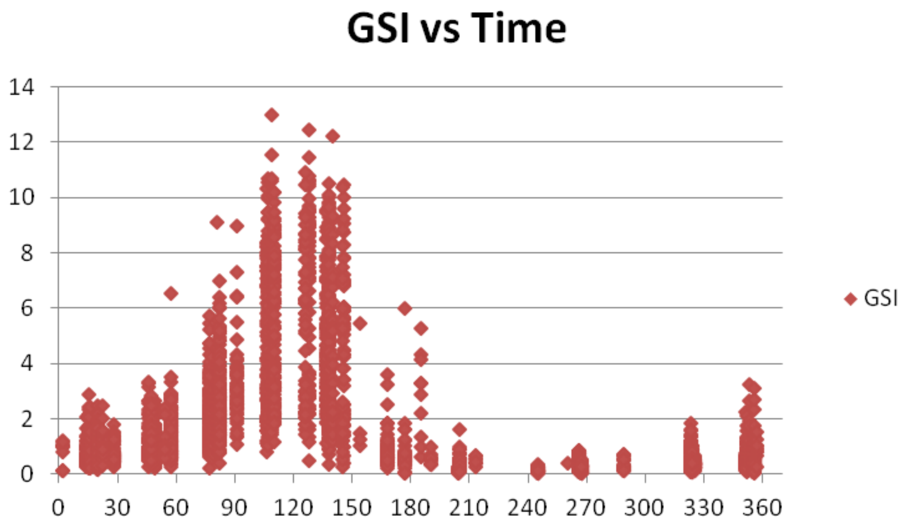


Figure 3.86. GSI variations in time (raw data include both females and males).

The time component in the GAM model captures the same cyclic pattern which affects GSI positively between day 50 and day 175 (corresponding to third week of February and third week of June, respectively). The highest effect is observed around day 125. Time has negative effect on GSI in the rest of the year. According to the model, the lowest effect is at day 250 (Figure 3.87).

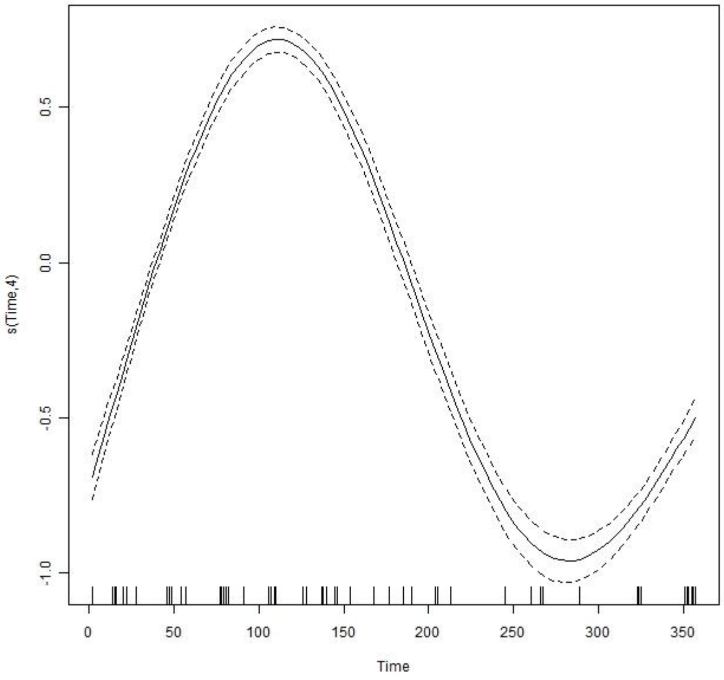


Figure 3.87. GAM smoothing curve fitted to partial effects of time on gonadosomatic index of *M. barbatus*. GSI is represented as a function of time in days. Dashed lines represent 95% confidence intervals around the main effects.

Temperature measured over the bottom where *M. barbatus* is distributed varied between 16 and 29.5 °C during the study period. The highest GSI values are restricted to a narrower range between 16 and 23 °C (Figure 3.88). However, the GAM results suggest that the highest GSI values associated with the bottom water temperature between 18 – 19 °C. Partial effect of temperature on GSI is negative bottom waters warmer than 20 °C (Figure 3.89).

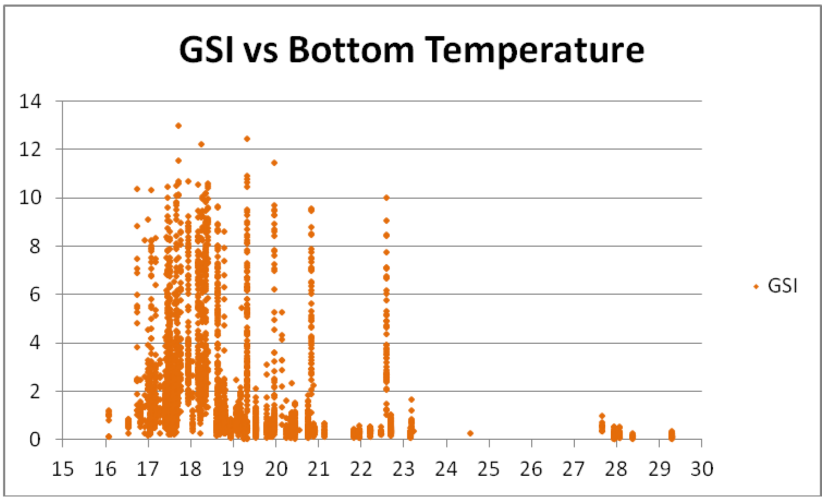


Figure 3.88. GSI variations through bottom temperature (raw data include both female and male).

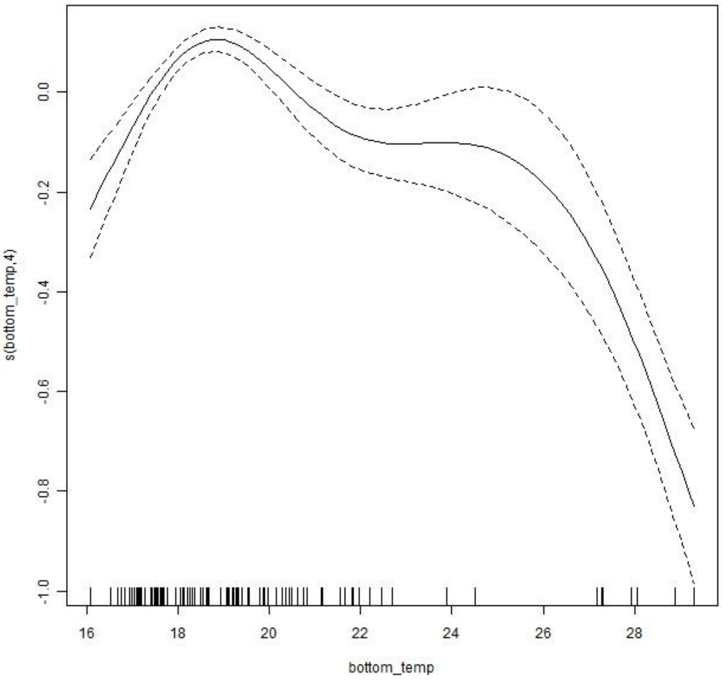


Figure 3.89. GAM smoothing curve fitted to partial effects of bottom temperature on gonadosomatic index of *M. barbatus*. GSI is represented as a function of bottom temperature. Dashed lines represent 95% confidence intervals around the main effects.

GSI plotted against depth does not show a clear pattern between these two variables (Figure 3.90). GAM smoother for the partial effect of average depth on GSI (Figure 3.91) shows that a positive effect of depth on GSI starts after 60 meters depth. Increasing trend continues until 125 meters depth and then decreases.

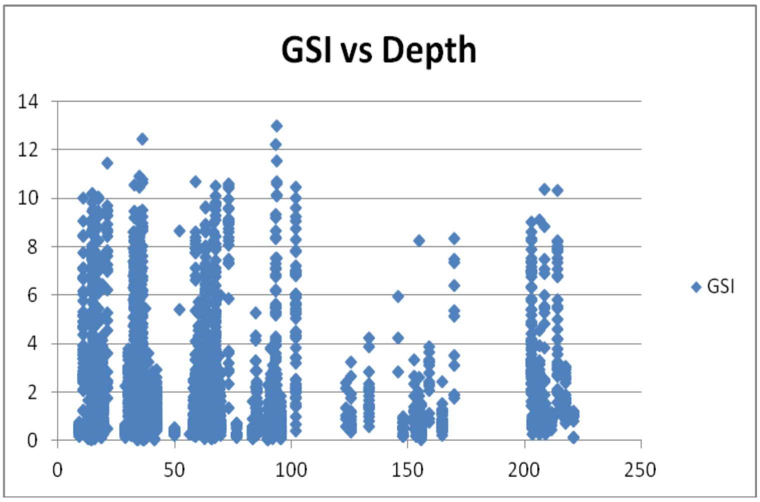


Figure 3.90. GSI variations along depth (raw data include both females and males).

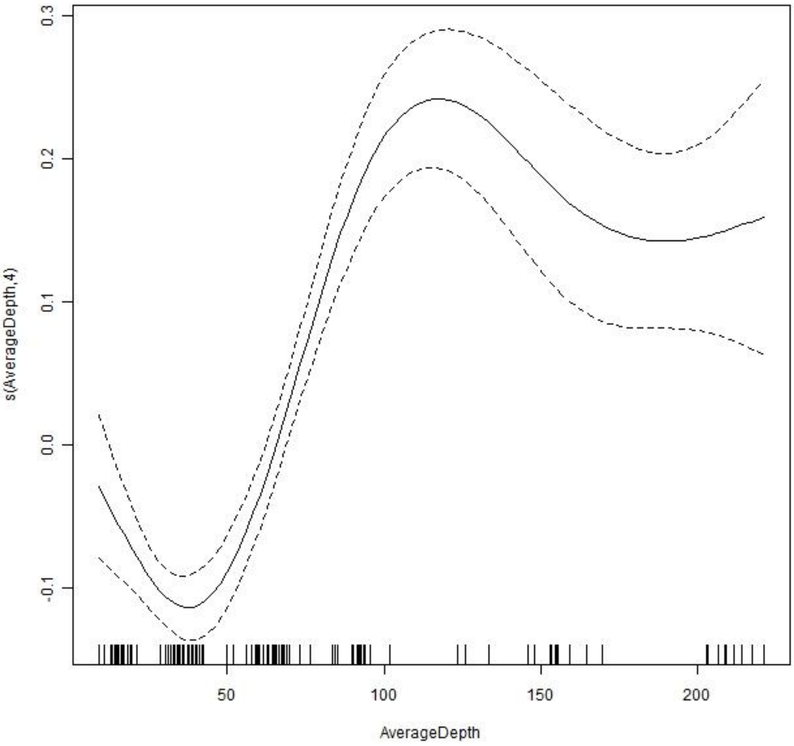


Figure 3.91. GAM smoothing curve fitted to partial effects of the average depth on gonadosomatic index of *M. barbatus*. GSI is represented as a function of average depth. Dashed lines represent 95% confidence intervals around the main effects.

Bottom salinity varied between 38.7 and 39.6 psu during the study period (Figure 3.92). The GAM results suggest that the partial effect of bottom salinity on GSI is negative below 38.3 psu and between 39.1 and 39.5 psu. The highest effect was observed at 38.7 psu (Figure 3.93).

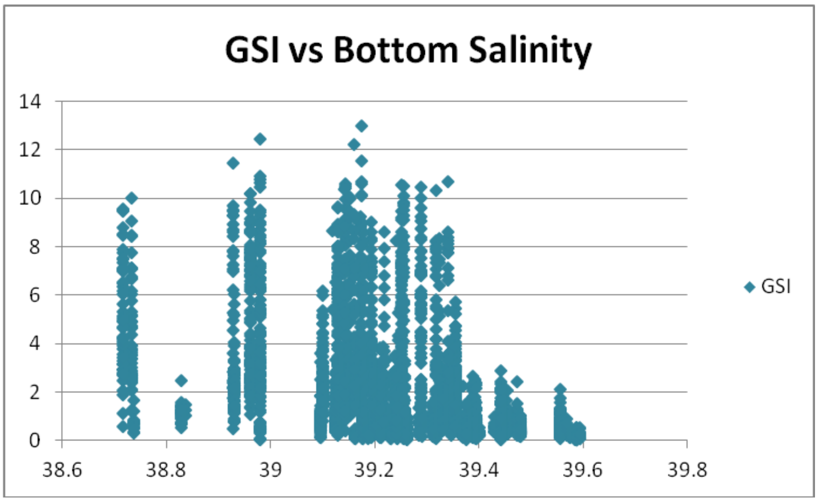


Figure 3.92. GSI variations through bottom salinity (raw data include both females and males).

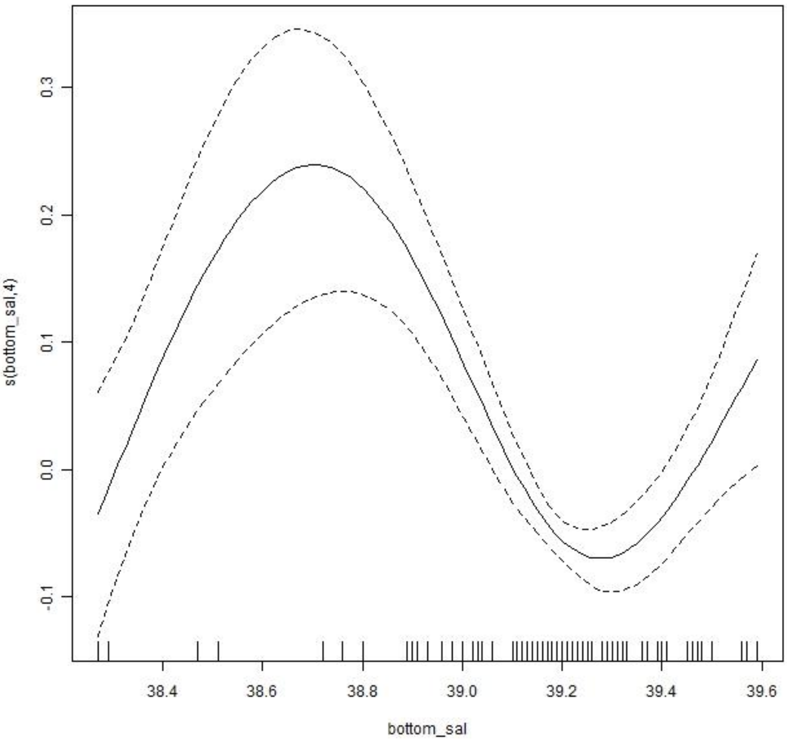


Figure 3.93 GAM smoothing curve fitted to partial effects of bottom salinity on gonadosomatic index of *M. barbatus*. GSI is represented as a function of bottom salinity. Dashed lines represent 95% confidence intervals around the main effects.

GAM result showing the partial effect of length on GSI indicated that positive effect of length over the GSI started after 15 cm length sizes and it had an increasing trend through larger sizes.

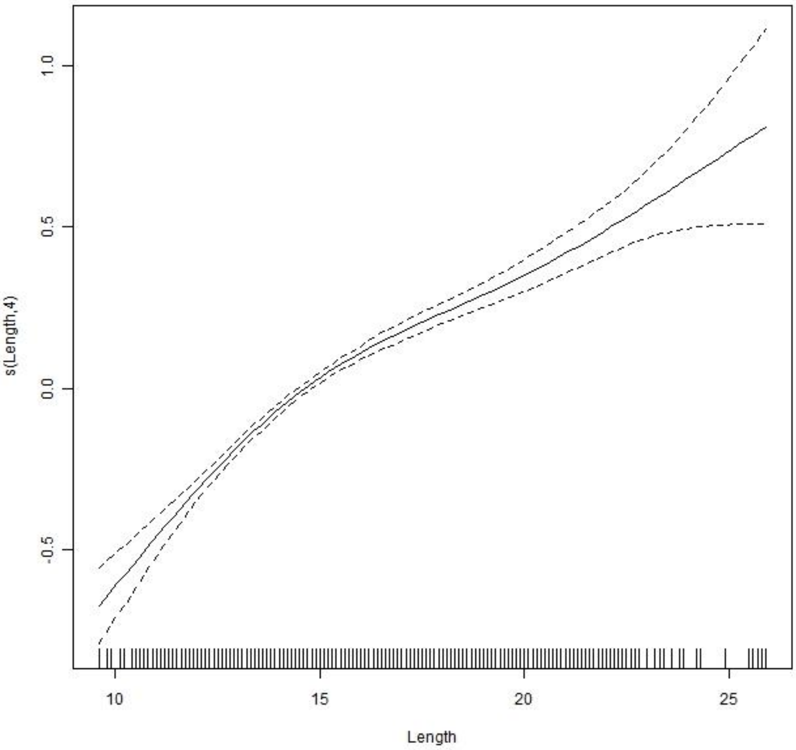


Figure 3.94. GAM smoothing curve fitted to partial effects of length on gonadosomatic index of *M. barbatus*. GSI is represented as a function of length. Dashed lines represent 95% confidence intervals around the main effects.

3.8.1.2 Influences of depth, environmental variables on HSI

All explanatory variables (depth, temperature, salinity, time, length, sex and stage) were found to be highly significant covariates ($P < 0.001$) in the statistical modeling of HSI. 55.2 % of variance in HSI was explained by the model with these variables (Table 3.26).

Table 3.26. Significance values (p-values) for GAM covariates of the final model for HSI. Summary of parameter estimates applied to explanatory variables and statistical tests for generalized additive model (GAM) on HSI data of *M. barbatus*.

HSI	**Df**	**F**	**p-value**
f(Average depth)	4	59.67	P < 0.001
f(Bottom temperature)	4	18.60	P < 0.001
f(Bottom salinity)	4	13.08	P < 0.001
f(Length)	4	42.53	P < 0.001
f(Time)	4	91.33	P < 0.001
Sex	1	-	P < 0.001
Rep. stage	2	-	P < 0.001
Total % variation explained	**55.2**		

Similar to the pattern observed in GSI, high seasonality in HSI occurs throughout the year. This species had highest HSI values during pre-spawning and spawning period. It decreased gradually during summer and again started to increase in fall (Figure 3.95).

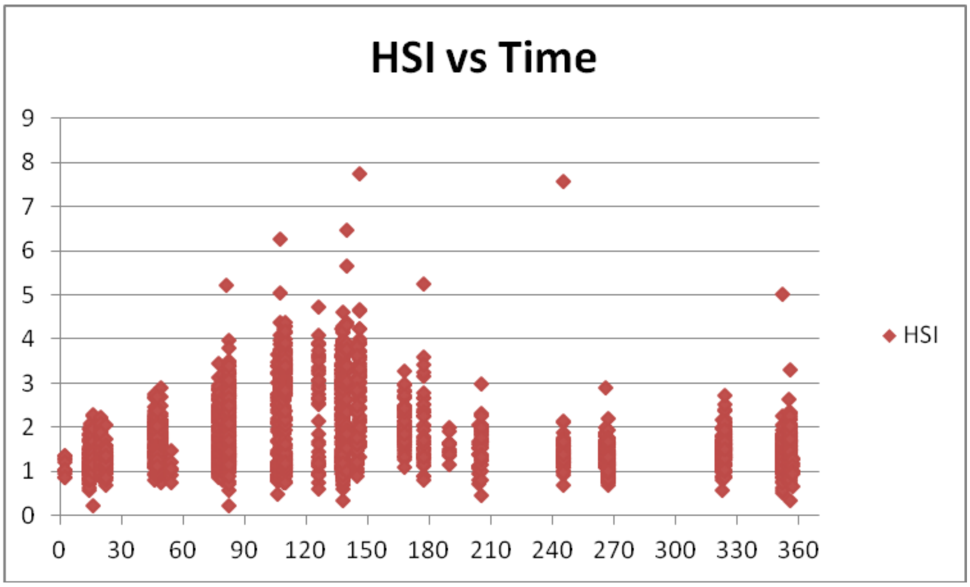


Figure 3.95.HSI variations in time (raw data include both females and males).

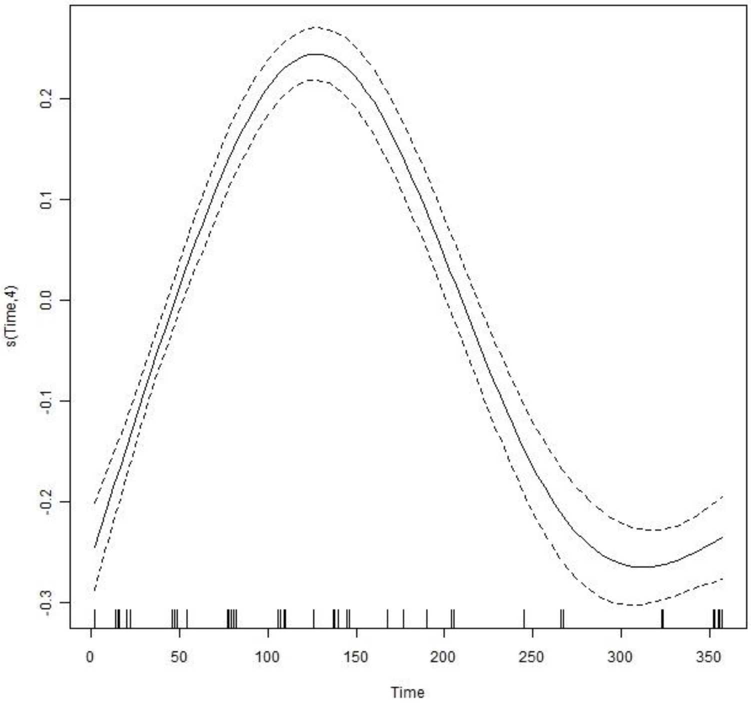


Figure 3.96.GAM smoothing curve fitted to partial effects of time on Hepatosomatic index of *M. barbatus*. HSI is represented as a function of time. Dashed lines represent 95% confidence intervals around the main effects.

Bottom water temperature lower than 20 °C and higher than 23 °C had negative effect on HSI of *M. barbatus*. Highest HSI values were observed bottom waters around 22 °C temperature values (Figure 3.97).

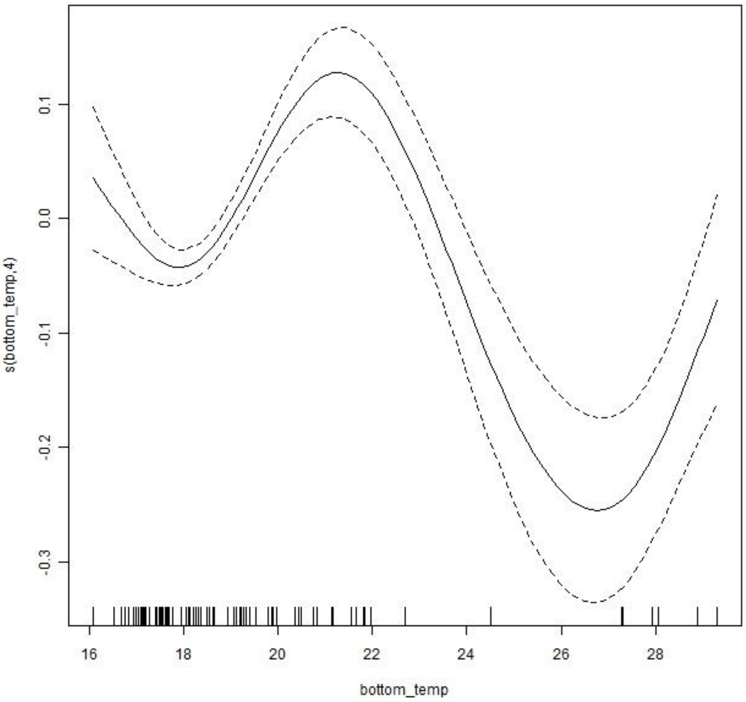


Figure 3.97.GAM smoothing curve fitted to partial effects of bottom temperature on Hepatosomatic index of *M. barbatus*. HSI is represented as a function of bottom temperature. Dashed lines represent 95% confidence intervals around the main effects.

The spline plot of HSI of *M. barbatus* showing the effect of average depth (Figure 3.98) indicated that individuals having highest HSI values occupied 125 meters and surrounding depths. Then it decreased sharply with decreasing depths. Below 60 m depth, HSI was negatively affected from this variable.

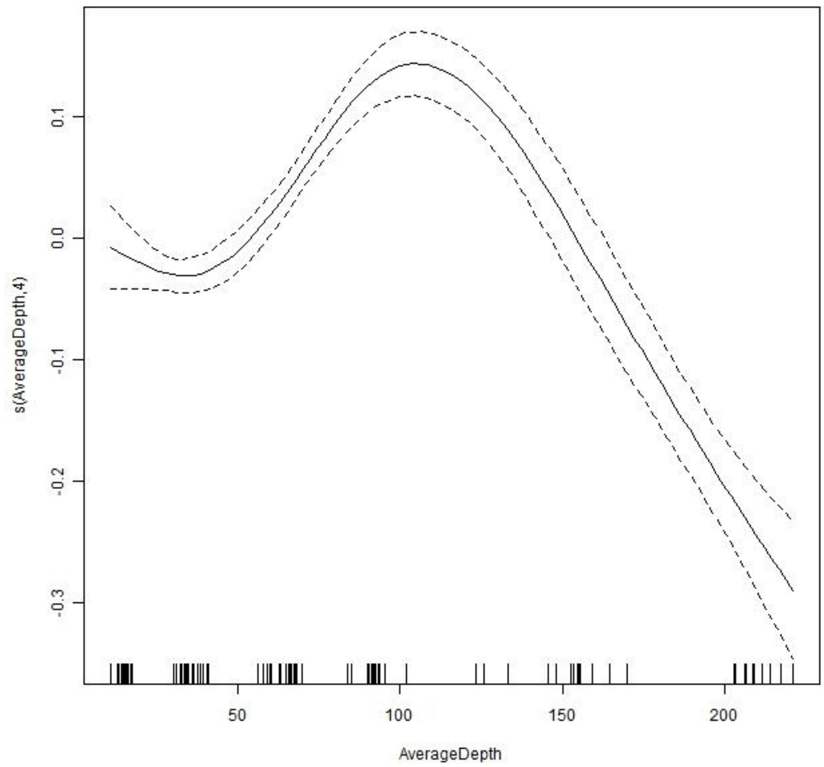


Figure 3.98. GAM smoothing curve fitted to partial effects of average depth on Hepatosomatic index of *M. barbatus*. HSI is represented as a function of average depth. Dashed lines represent 95% confidence intervals around the main effects.

The GAM smoothing curve showing the partial effect of bottom salinity on HSI showed that the highest HSI values associated with the bottom water salinity was around 39.0 psu. Partial effect of bottom salinity on HSI is negative below 38.9 psu (Figure 3.99).

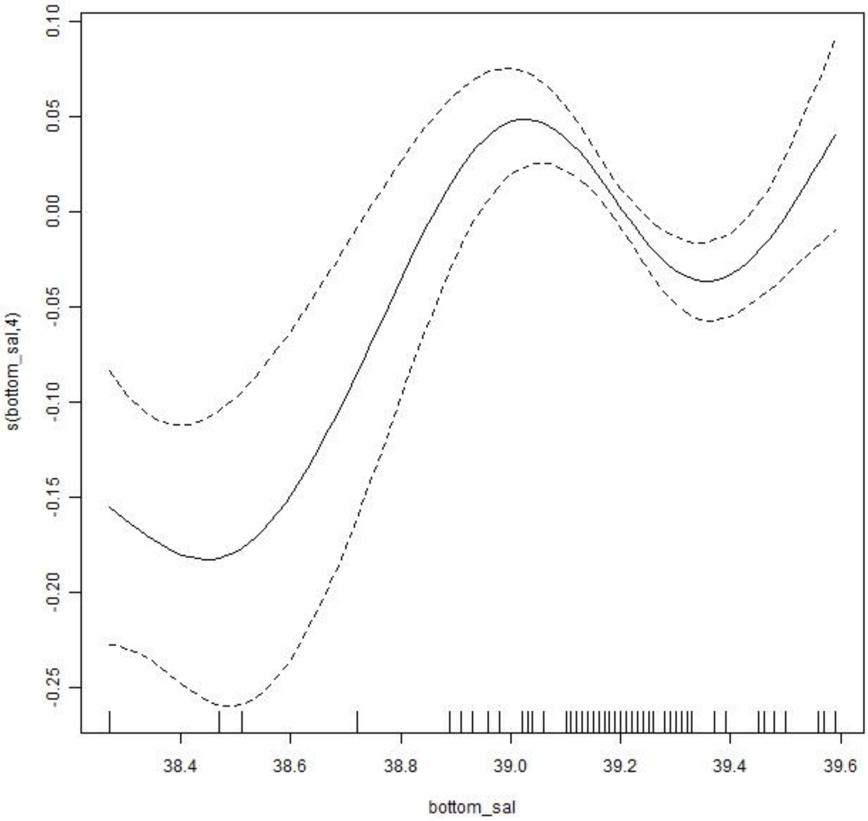


Figure 3.99. GAM smoothing curve fitted to partial effects of bottom salinity on Hepatosomatic index of *M. barbatus*. HSI is represented as a function of bottom salinity. Dashed lines represent 95% confidence intervals around the main effects.

As observed in GSI, length generally had positive effect on HSI. In other words, larger individuals have larger liver with respect to their size (Figure 3.100). The influence of size on HSI progressively increased towards the 16 cm length, levels off between 16 and 23 cm, and then increased again.

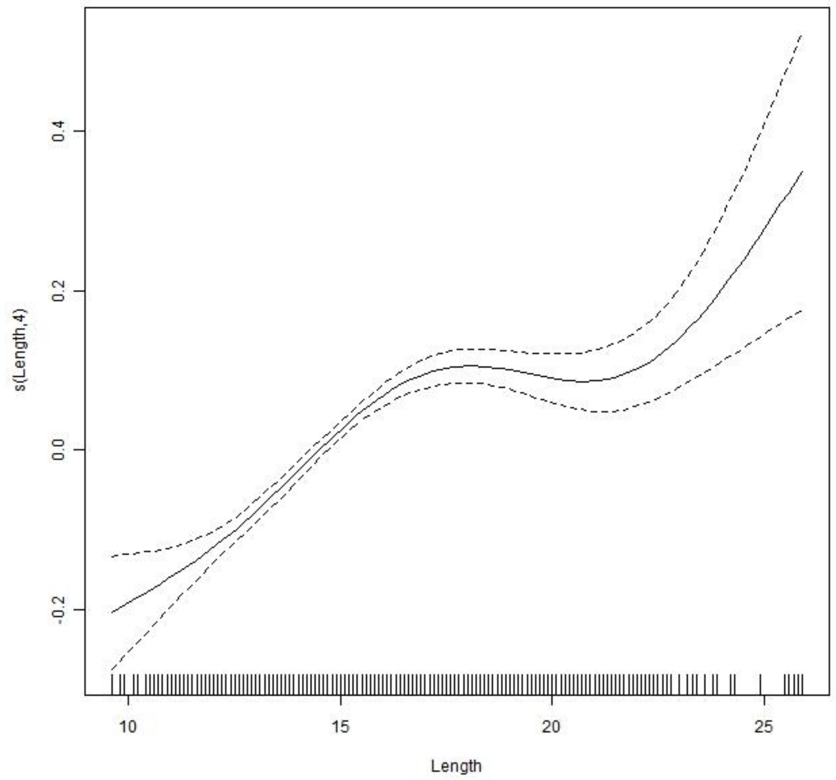


Figure 3.100. GAM smoothing curve fitted to partial effects of length on Hepatosomatic index of *M. barbatus*. HSI is represented as a function of length. Dashed lines represent 95% confidence intervals around the main effects.

3.8.1.3 Influences of depth, environmental variables on Somatic K

The results of generalized additive modeling of somatic condition factor are given in Table 3.27. Fitted contribution of all seven variables: depth, temperature, salinity, time, length, sex and stage were found highly significant (P<0.001). In overall, model with the given variable set explained 43.9 % of variance in somatic K.

Table 3.27. Significance values (p-values) for GAM covariates of the final model for Somatic K. Summary of parameter estimates applied to explanatory variables and statistical tests for generalized additive model (GAM) on *M. barbatus* Somatic K data.

Fulton's K	**df**	**F**	**p-value**
f(Average depth)	4	61.94	P < 0.001
f(Bottom temperature)	4	21.48	P < 0.001
f(Bottom salinity)	4	11.07	P < 0.001
f(Time)	4	36.04	P < 0.001
f(Length)	4	195.85	P < 0.001
Sex	1		P < 0.001
Rep. stage	2		P < 0.001
Total % variation explained	**43.9**		

As indicated by Figure 3.101, individuals were in better condition during pre-spawning (between February - mid April) and post-spawning period (between mid July-December). Bottom waters with temperature values between 18-24.5 ^{o}C associated with better conditioned fish (Figure 3.102). Although shallower waters hosted individuals having good condition, Somatic K of *M. barbatus* decreased with decreasing average depth and average depth has generally negative effect on Fulton's K (Figure 3.103). Somatic K gradually decreased through warmer waters. Individuals in better condition seemed to prefer generally bottom waters of 38.4 - 39.1 psu (Figure 3.104) but decreasing trend started in the bottom water salinity values greater than 38.7 psu. As observed in GSI and HSI, length generally had positive effect on Somatic K. In other words, influence of size on somatic K gradually increased towards the 16 cm length (Figure 3.105).

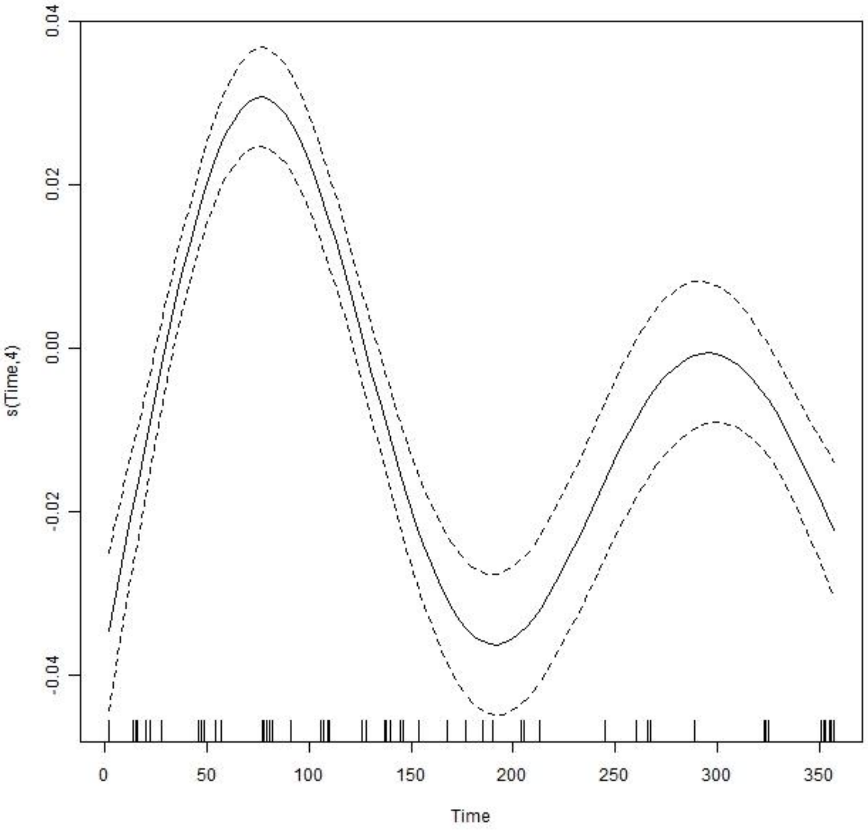


Figure 3.101. GAM smoothing curves fitted to partial effects of time on somatic K of *M. barbatus*. Somatic K is represented as a function of time. Dashed lines represent 95% confidence intervals around the main effects.

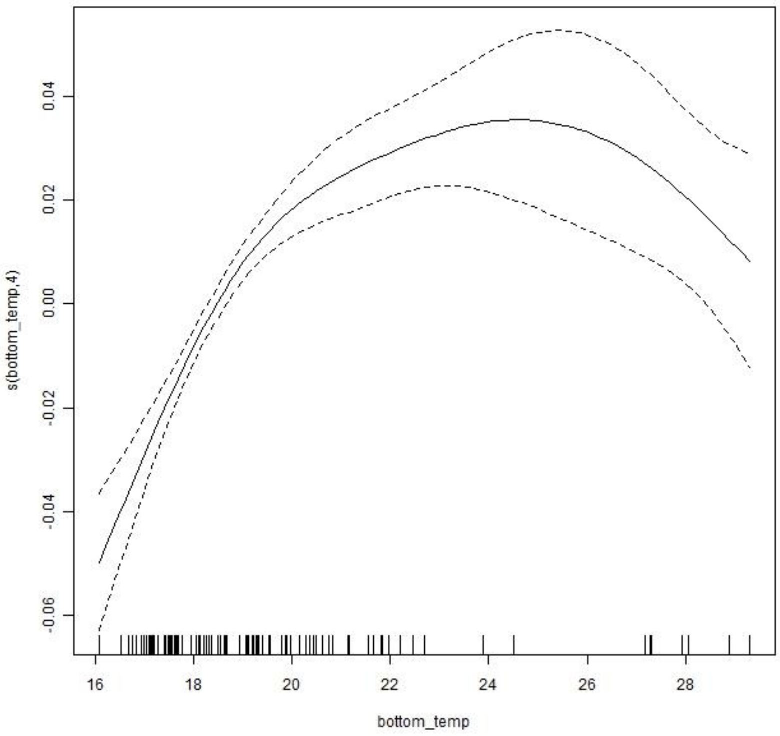


Figure 3.102. GAM smoothing curve fitted to partial effects of bottom temperature on somatic K of *M. barbatus*. Somatic K is represented as a function of bottom temperature. Dashed lines represent 95% confidence intervals around the main effects.

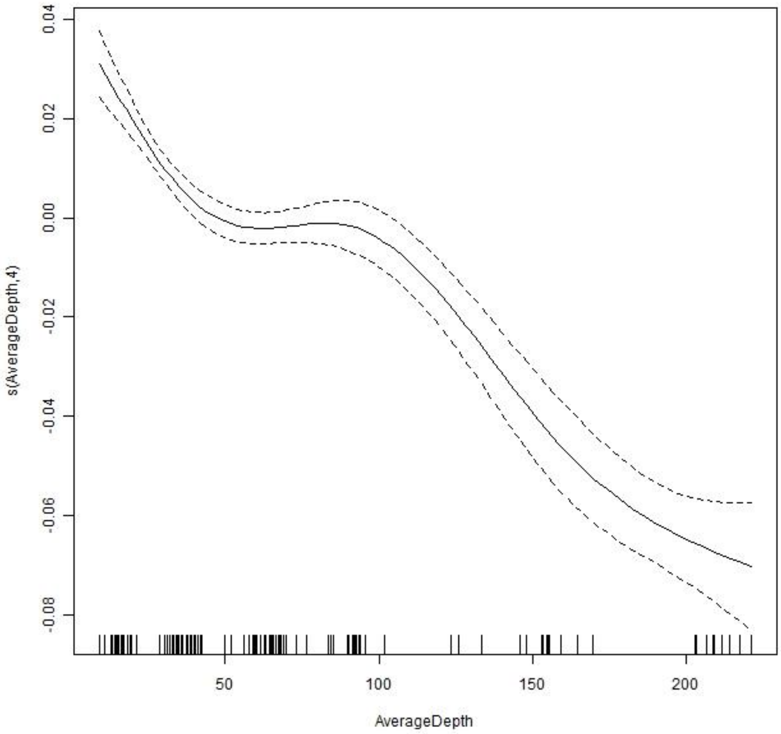


Figure 3.103. GAM smoothing curve fitted to partial effects of average depth on average depth of M. barbatus. Somatic K is represented as a function of average depth. Dashed lines represent 95% confidence intervals around the main effects.

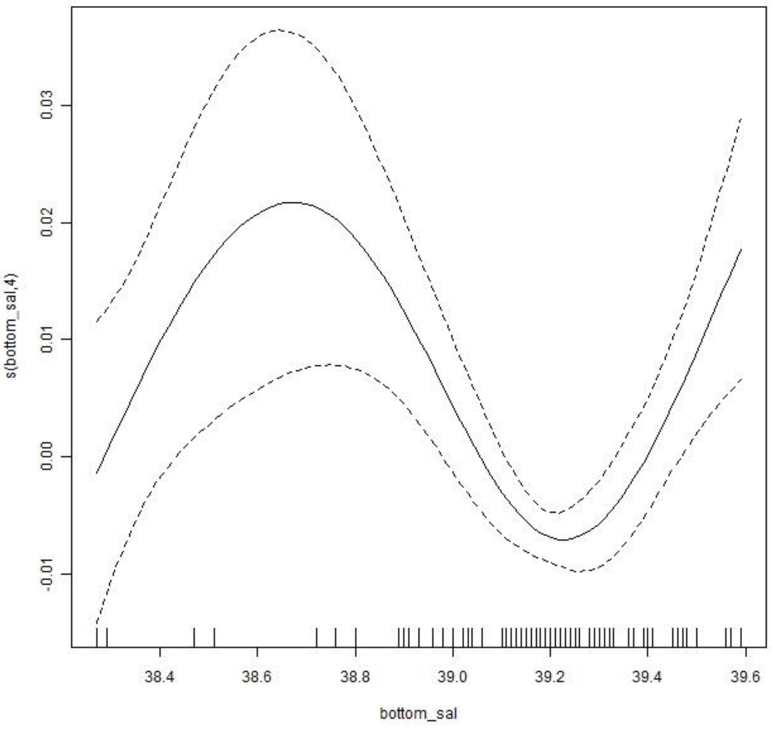


Figure 3.104. GAM smoothing curve fitted to partial effects of bottom salinity on bottom salinity of *M. barbatus*. Somatic K is represented as a function of bottom salinity. Dashed lines represent 95% confidence intervals around the main effects.

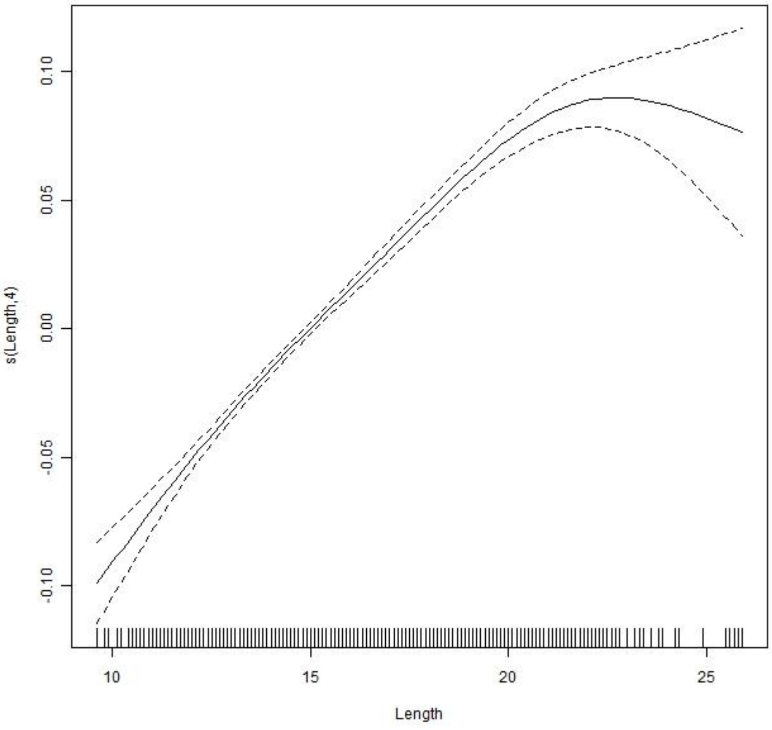


Figure 3.105. GAM smoothing curve fitted to partial effects of length on length of *M. barbatus*. Somatic K is represented as a function of length. Dashed lines represent 95% confidence intervals around the main effects.

3.8.2 Influences of depth and environmental variables on distribution of *M. barbatus*

It was assumed that due to the ontogenetic spatial shift, habitat preferences of juveniles and adults are different hence, influence of environmental variables on the abundance of juveniles and adults were analyzed separately.

Model results of bathymetrical distribution of juveniles are given in Table 3.28. All three explanatory variables (temperature, salinity and depth) were found highly significant. Overall, the model with the given variable set explained 83.5 % of variance in abundance variation of juvenile *M. barbatus.*

Table 3.28. Significance values (p-values) for GAM covariates of the final model for juvenile *M. barbatus* distribution.

Abundance Index	**df**	**Chi. Sq**	**p-value**
f(Average depth)	4	21.83	0.000217
f(Bottom temperature)	4	215.69	0.0000
f(Bottom salinity)	4	114.14	0.0000
Total % variation explained	**83.5**		

The spline plot of salinity of *M. barbatus* (Figure 3.106) indicated that salinity has positive effect between 38.3 psu – 39.1 psu with a peak value around 38.7 psu. At lower salinity values the effect turns into negative.

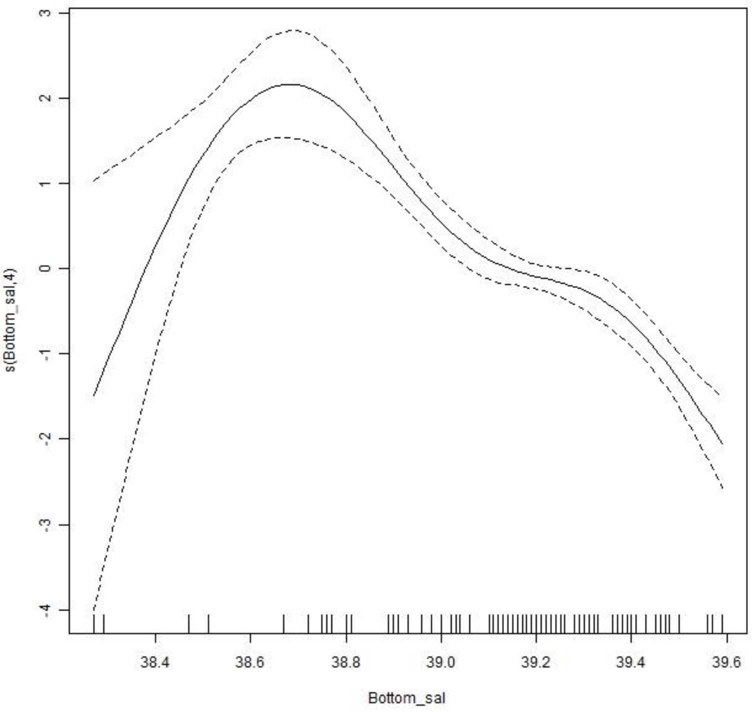


Figure 3.106.Partial effect of bottom salinity on distribution of juveniles. The dotted lines represent 95% confidence intervals.

In contrary to the two tailed effect of salinity, model suggested a gradually increasing almost linear effect on the abundance of juvenile *M. barbatus* above 20 °C with slight intensification after 26 °C. Below 18 °C, confidence interval gets wider indicating no significant contribution.

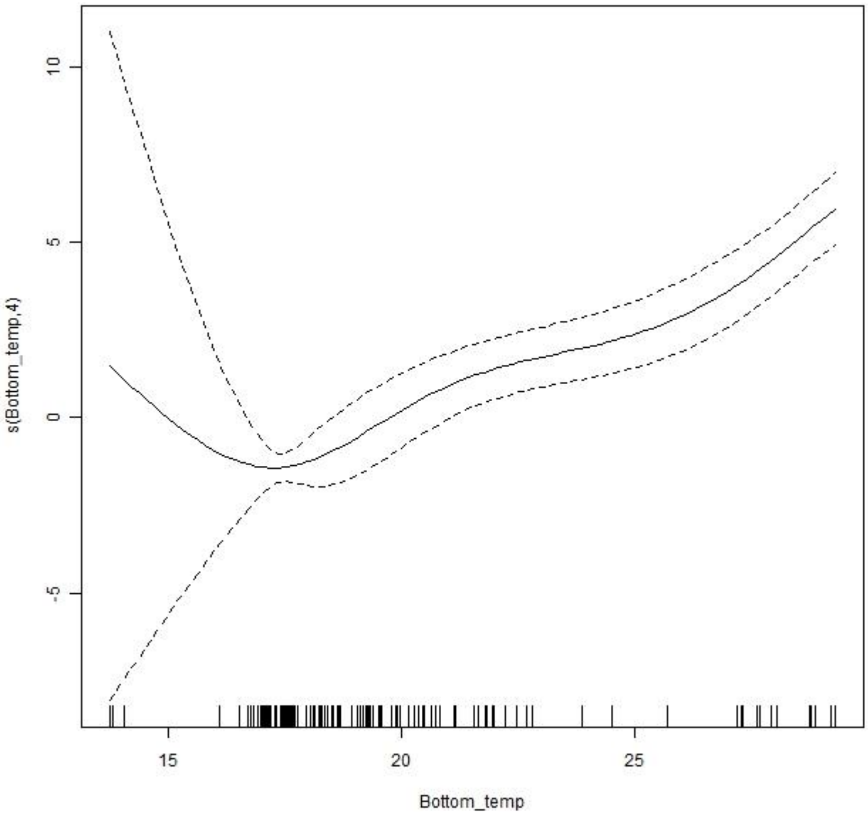


Figure 3.107. Partial effect of bottom temperature on distribution of juveniles. The dotted lines represent a 95% confidence intervals.

The depth has the least effect on the abundance (Table 3.28) among the explanatory variables. The model suggests a slightly positive and gradually increasing effect at depth down to 100 meters. At deeper depths, the affect turns to negative and confidence interval enlarges meaning that the impact of depth is idle.

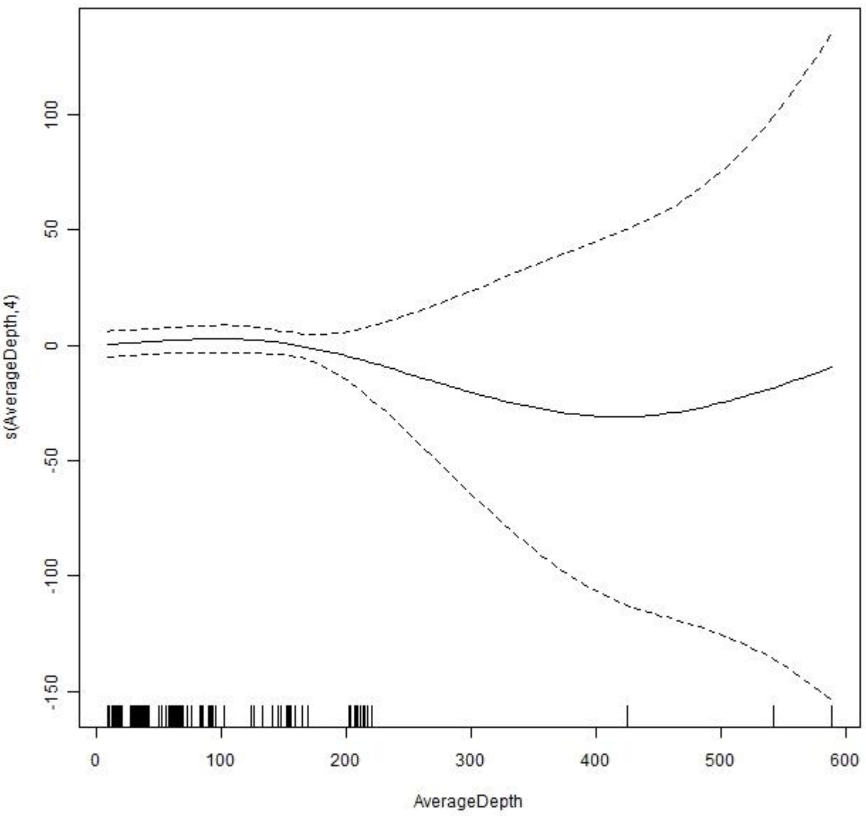


Figure 3.108. Partial effect of average depth on distribution of juveniles. The dotted lines represent a 95% confidence intervals.

As in juveniles, the adult abundance was modeled as a function of depth, temperature and salinity. However, none of the explanatory variable showed significant effect (Table 3.29). In contrary to the juveniles, the adult group is composed of at least 4 cohorts; each differs from the others. Therefore mean length at the stations were added to the model as an explanatory variable. However the outcome has not changed; the model explained zero variance.

Table 3.29. Significance values (p-values) for GAM covariates of the final model for adult *M. barbatus* distribution.

Abundance Index	**df**	**Chi. Sq**	**p-value**
f(Average depth)	4	7.085	0.1315
f(Bottom temperature)	4	1.940	0.7468
f(Bottom salinity)	4	1.427	0.8396
f(mean length)	4	8.315	0.0807
Total % variation explained	**N/A**		

4 DISCUSSION

4.1 Biological characteristics of *M. barbatus*

Being characterized by a considerably short lifespan and a very high population turnover, the knowledge on the population dynamics of *M. barbatus*, especially during its first year of life, is particularly important. Different results were reported on rate and pattern of growth of *M. barbatus* in the literature as indicated by Fiorentino et al. (1998). Some authors have considered that these differences reflect the existence of different stocks in the Mediterranean, while others believed that these are method-related differences (Levi et al., 1992; Fiorentino et al., 1998; Voliani et al. 1995 and 1998). Voliani et al. (1998) characterized the growth of *M. barbatus* during the first months of its life as an extremely fast, which later followed by a slower growth increment with time. They concluded that the growth of *M. barbatus* is hardly explainable with a single set of growth parameters in general. Growth of *M. barbatus* also varies between sexes; females are characterized by a faster growth rate and larger size reaching 28-29 cm TL, while males grow more slowly and seldom exceed 20 cm TL (Voliani, 1999). The males sampled in this study has a maximum size of 19.3 cm which agrees with the work done by Voliani (1998) however the largest female sampled was only 25.9 cm. Length-weight relationship is a useful tool for fisheries research since it allows i) the conversion of growth-in-length equations for estimation of biomass from length observations; ii) life-history and morphological characteristic of fish to be comparable for different regions; iii) the calculation of condition indices in the analysis of ontogenetic changes; and, iv) the comparison of populations from different regions (Goncalves et al. 1997; Moutopoulos and Stergiou, 2002; Froese and Pauly, 2010). Results of this study on LWRs of *M. barbatus* have been presented for a total sample including both sexes and immature specimens together and also for each sexed individual. The values of the constant (b) of length-weight relationship for combined data, males and females show that the growth of *M. barbatus* is slightly positively allometric, i.e. slightly faster growth in weight than in length so that large specimens is in better condition than small ones (Table 4.1). A comparison of b values between this study and those of available literature shows both inter-regional similarities and differences in (b) values (Table 4.1). This regional variation in the b exponents can be attributed to combination of one or more factors such as differences in sampling (i.e. frequency), sample size or length ranges obtained during sampling. Besides, Shepherd and Grimes (1983) and Wootton (1998) indicated that differences in stage of maturity, food (quantity, quality and size) and environmental conditions, such as temperature, salinity and seasonality, can also affect the value of b.

Table 4.1. Parameters of the length-weight relationship W=aL b [Weight (in g) and length (in cm)] of *Mullus barbatus* from the Mediterranean Sea. The significant figures of each a and b values were taken directly from the related articles without making any modification.

Area	**(a)**	**(b)**	**Reference**
Mersin Bay (Turkey)	0.005	3.260	Bingel, 1981
Aegean Sea (Greece)	0.0096	3.179	Vassilopoulou and Papaconstantinou, 1992
Mersin Bay (Turkey)	0.006	3.251	Gücü and Bingel, 1993
Gulf of Ewoikos	0.0145	3.085	Petrakis and Stergiou, 1995
Edremit Bay (Turkey)	0.0157	2.980	Çelik and Torcu, 2000
Black Sea (Turkey)	0.0063	3.180	Genc, 2002
Izmir Bay (Turkey)	0.0070	3.290	Kınacıgil et al., 2001
Ionian Sea (Greece)	0.0177	2.832	Moutopoulos and Stergiou, 2002
Izmir Bay (Turkey)	0.0102	3.176	Özaydin and Taskavak, 2006
Gulf of Tunis (Tunisia)	0.0055 0.0069 0.0072	3.215 3.122 3.105	M F F+M Cherif et al., 2007
Antalya Bay (Turkey)	0.0061	3.229	Özvarol et. al., 2006
Montenegrin Shelf (South Adriatic)	0.0077 30.007 29 0.0076	3.090 3.118 3.102	M F F+M Joksimovic´ et al., 2008
Black Sea (Turkey)	0,07 0,07 0,07	3,17 3,14 3,15	M F F+M Suer, 2008
Northeastern Levant sea (Turkey)	0.0063 0.0076 0.0067	3.188 3.137 3.178	M F F+M This study

The von Bertalanffy Growth Function (vBGF) parameters used to describe the growth of *M. barbatus* in the study area were compared with the other studies (Table 4.2). In general there are two approaches in the literature to estimate the parameters of vBGF. These are length and age based methods. Fiorentino et al (1998) has underlined earlier, different methods may produce different results even if the same dataset is used in the analyses. The comparison of these methods applied to *M. barbatus* in the Mediterranean Sea summarized in Table 4.2. The table suggests that Φ’, which was originally introduced as growth performance index (Munro, 1984), but later used as a method of validating growth parameters (Gayanilo and Pauly, 1996), is significantly different in age and length based analyses ($P<0.05$, Mann-Whitney U Test). Examination of the same list (Table 4.2) shows that K values estimated by length based models are significantly larger than those estimated by age based methods and significantly lower t_0 ($P<0.001$). This, especially very low t_0, is probably due to erroneous age interpretations regarding non-annual rings such as pelagic ring, spawning ring etc. (ICES, 2009). The growth parameters of *M. barbatus* in the present study falls within the range of the values estimated by the length based methods given in the literature and it is particularly close to those obtained in the previous studies carried out in the study region (Table 4.2).

Table 4.2. Literature on growth parameters (VBGP) of M. barbatus reported from different part of the Mediterranean.

Parameters of t Von Bertalanffy Growth Function (VBGF)						
Location and Author	**Sex**	**L_∞ (cm)**	**K (yr^{-1})**	**t_0 (yr)**	**Φ'**	**Method**
Mersin Bay (Bingel, 1981)	F	34.8	0.089	-1.32	2.03*	Age-Length Method
	M	24.9	0.104	-1.32	1.81*	
Mersin Bay (Bingel, 1987)	F+M	24.4	0.716	-0.45	2.63*	ELEFAN
Central Aegean Sea,(Vassilopoulou and Papaconstantinou, 1992)	F+M	25.5**	0.214	-2.133	2.14	Otolith
Mersin Bay (Gücü and Bingel, 1993)	F+M	24.2	0.63	-0.27	2.57	ELEFAN
Iskenderun Bay (Gücü, 1995)	F+M	24.2	0.63	-	2.57	ELEFAN
Elba Island (Voliani et al., 1998)	F	27	0.696	-0.39	2.71*	MULTIFAN
	M	20.6	0.697	-0.6	2.47*	
İzmir Bay (Kınacıgil et al., 2001)	F+M	19.04**	0.438	-0.777	2.20	Otolith
Edremit Bay (Çelik and Torcu 2000)	F+M	26.08	0.127	-3.535	1.94	Otolith
İzmir Bay (Özbilgin et al.,2004)	F+M	24.26	0.565	-0.305	2.52	ELEFAN
Antalya Bay (Özvarol et al., 2006)	F	30.3	0.104	-4.465	1.98*	Scale
	M	24.2	0.105	-5.618	1.79*	
Montenegrin Shelf (South Adriatic) (Joksimovic´ et al., 2008)	F	27.47	0.149	-2.688	2.05*	ELEFAN
	M	17.81	0.282	-3.013	1.95*	
	F+M	30.12	0.118	-3.182	2.03*	
	F	29.13	0.122	-3.013	2.02*	Least Squares of non-linear functions
	M	17.81	0.282	-3.013	1.95*	
	F+M	30.11	0.118	-3.181	2.03*	
Gulf of Castellammare, NW Sicily (Sieli et al., 2011)	F	22.1	0.38	-0.94	2.27	Otolith
Off Erdemli, Northeastern Levant Sea (this study)	F+M	26	0.56	-0.30	2.58	ELEFAN

* It was not provided in the original article so calculated by using L_{inf} and K value provided in the related article according to Pauly and Munro (1984).
** Fork Length

Seasonality in the monthly length frequency distributions necessitated use of seasonalized growth function (see Figure 3.2). The amplitude of growth oscillation (C) and the winter point (WP) are often related to the mean temperature of the habitat of a species (Pauly, 1998). Therefore, it is expected that the growth should slow down during the coldest period of the year (WP = 0). The oscillation value estimated (0.40) suggested a quite strong seasonal pattern. However WP (0.3) corresponds to April meaning that growth slows down during spring when the sea water begins to warm. Therefore the strong seasonality in the region is not fully controlled by the temperature of the habitat.

GSI estimates given for three successive years are quite consistent which possibly indicate that the species go through the same annual reproductive cycle at the same time of the year. As a rule a sharp decline in the GSI as in Figure 3.10 indicates release of gametes (Wootton, 1998). The sharp decline occurring between May and June imply that the spawning takes places within this period. As far as the onset of gonadal development is concerned, the dates proposed in this work is almost identical to those reported in the literature. For instance, in the Tunisian waters Cherif et al. (2007) proposed exactly the same time range for the gonad development. In another work carried out in a MPA in NW Sicily, gonadal development starts almost two months later however the reported spawning time matches with the present study (Sieli et al., 2011). Similarly, according to Metin (2005) the onset of gonad development is even earlier occurring in January in the Gulf of İzmir, Aegean Sea. Although duration and timing of gonad development of *M. barbatus* in different parts of the Mediterranean are more or less consistent, there are some differences in the timing of spawning and its duration. In this study the maximum GSI is followed by an immediate decline in the following month indicating that spawning is completed within a month. In the study of Cherif et al. (2007) once the GSI reached to the maximum, the subsequent decline occurs gradually showing that the duration of spawning is protracted lasting three months. This may be due to the gradient of environmental conditions, such as food availability and temperature, from west to east. Sonin et al. (2007) have recently discussed this issue within the scope of “Levantine nanism” (dwarfism) phenomenon suggested by Por (1989) and concluded that the low and unpredictable food supply in the eastern Mediterranean may favor r-strategy within the eastern populations. The individuals in the east should therefore accomplish reproduction in short period of time when environmental conditions offers sufficient energy to cover the cost of reproduction.

Another inconsistency is in the time of spawning. Although much of the work reviewed agrees that the spawning begins in May, there are few exceptions in which spawning takes places rather late. According to Çelik and Torcu (2000) spawning of *M. barbatus* occurs late between March and September in Edremit Bay, northern part of the Aegean Sea. Given that the temperature is primary factor regulating the onset of spawning, latitudinal differences in the sampling locations may explain differences in spawning time of *M. barbatus* in the study area and in the Edremit Bay.

Orsi-Relini and Arnaldi (1986 c.f. Sieli et al., 2011) reported two different peaks in GSI values implying existence of two spawning period within a year. According to the authors the first spawning period is between May and July, while second one occurs in November. In the present study, the analyses are based on almost entire size spectrum from 3 to 25 cm (≈ L_{inf}) of the species sampled monthly throughout three successive years but the secondary spawners have never been observed. Absence of secondary spawners may support narrow ecologically favorable window offered to the species in the eastern Mediterranean.

Several authors observed that the *M. barbatus* is a batch-spawner (Fiorentino et al., 2008 c.f. from Menini et al., 2001; Metin, 2005). The methodology used in this study (macroscopic observation) was not sufficient to detect multiple batches in the gonad. Therefore it is not possible to comment as to whether the species displays batch spawning. Batch spawning may possibly occur in protracted spawn such as observed by Cherif et al. (2007) in the Tunisian waters. However a population displaying short spawn occurring abruptly within a month such as the one observed in this study, the time given may not be sufficient to release eggs in different batches.

Biological indices used in the present study GSI, HSI and somatic K, may indicate the quantity of energy allocated in the gonads, liver (storage) and in the somatic volume of the fish, respectively. Usually a negative correlation is expected among GSI, HSI and somatic K since they compete for the same energy source (Lagler et al., 1977). In such a case reproduction is financed from stored energy capital. This reproductive strategy is called as capital breeding (Houston et al., 2007). If such an inverse correlation does not exist then situation points to alternative strategy in which energy used in reproduction is gained simultaneously through intensive feeding (income breeding strategy) (Houston et al., 2007).

Comparison of biological indices of females presented in Figure 3.10 display almost parallel fluctuations. These results show no sign of capital energy use, since all index values are well above their annual averages during gonad development. In other words, the food assimilated (energy intake) is used for the development of gonads between May-June. The energy taken during this period is apparently so high that it exceeds the utilization rate and a considerable part of it is stored in body (high HSI) and also used in the somatic growth (high somatic K).

In contrary to the females, fluctuations in biological indices of males do not follow a parallel pattern (Figure 3.11). Very low HSI and somatic K during winter indicate that the energy stored in the body of the males is exhausted throughout the winter. It is clear from the results that just before the activation of reproductive processes, stored energy are exhausted. Therefore it is very likely that the high energy cost of gonad development is fulfilled by the food taken simultaneously. The energy storage in the males begins only after the reproductive activity is completed.

A comparison of GSI of males and females displayed significant differences (Table 3.23). This is not surprising since there is a remarkable difference in the average weight of gonads in males and females, the latter being larger. This would eventually necessitate different energy demand for the development of reproductive material in different sexes (Wootton, 1998). The different levels of energy demand may shape energy intake pattern. The difference observed between males and females may also be resulted from differences in sizes of the sexes. As shown in Figure 3.3, the females are significantly larger than the males. It is well documented that being larger provides great advantage in reaching available (and limited) food.

Orsi-relini and Arnaldi (1986); Lalami (1971) and Hashem (1973) reported a shorter and earlier spawning period between April and June in the Ligurian Sea, the Algerian and Egyptian coasts, respectively. This period was extended from April to August in the Moroccan coast (Slimani *et al.,* 2003) and from April to September with an evident peak in May. Although onset and duration shift exist in reproduction period of *M. barbatus* through different regions, as stated by Cherif et al. (2007) all of these reported results indicate that *M. barbatus* prefer warm waters and seasons for spawning.

Differences observed in sex ratio at different length classes (Figure 3.3) have already been observed in various studies (Mamuris et al., 1998; Voliani et al., 1999; Sieli et al., 2011). It was also reported that the mean length also differs significantly between sexes (Mamuris et al., 1998). Previously, Županović and Jardas (1989) found that, males are dominant at lengths up to 17 cm, while females are present at greater lengths. Similarly, Vrgoč (2000) in the central and northern Adriatic found that males were dominant in the population up to 14 to 15 cm; above 15 cm, females were dominant. By the several authors, it has been mainly attributed to the faster growth of females, which can already be noticed in the first year of their life (Županović and Jardas, 1989; Fiorentino et al., 1998; Voliani, 1999; Dulčić et al., 2003) and these authors concluded that it was most probably because of different growth rates of males and females.

Županović (1963) reviewed the available literature in 60s and stated that females predominate in the eastern Mediterranean including the Adriatic Sea, while male dominance occurs in Western Mediterranean. Later, this statement was confirmed by means of the research performed within the framework of MEDITS (Voliani, 1999). The sex ratios of *M. barbatus* reported from the different areas in the Mediterranean are 68.78 % and 31.22 % in Aegean Sea (Çelik and Torcu, 2000); 63 % and 37 % in montenegrin waters (Joksimovic, 2005) and 68 % and 32 % in the gulf of Tunis (Cherif et al., 2007) for females and males respectively. The high ratio of females may be caused by several factors such as different growth rates between sex (Joksimović, 2005; Vrgoč, 2000) and a different catchability between the two sexes since a fishing effort more aimed to females than to males due to the body shape dimorphism; females are heavier and fatter than males (N’Da et al., 1993).

Vassilopoulou and Papaconstantinou (1992) reported that the length at first maturity is around 11-12 cm TL for both males and females. In the Italian waters, the first sexual maturity is reached for most of the population during the first year of life, at sizes of 11.9 cm TL for males and 13.4 cm TL for females (Fiorentino et al., 1998). According to Metin (2005), total length at first maturity of females and males of *M. barbatus* in Izmir bay are 14,2 and 12.4 respectively. The estimated mean size at which 50 % of females are mature was reported as 13.94 cm TL, whereas this was estimated 13.87 cm TL for males in the recent study carried out by Cherif et al. (2007) in Tunisian waters.

GSI versus length data for all *M. barbatus* captured throughout the study period is presented in Figure 4.1. Grey boxes represent the range of available values of L_m published in the literature. Different estimates of L_{50} may be due to the populations analyzed from distant basins having different environmental conditions (Basilone et al., 2006). For example, exceptional environmental conditions such as high salinity and temperature, low productivity may lead earlier sexual maturity as discussed by Sonin et al. (2007). Apart from the estimations of Haidar (1970) and Vrgoč (2000) from Adriatic Sea, Vassilopoulou and Papaconstantinou (1992) from Greek waters, length at first maturity for males and females in this study (11.6 cm TL and 12.6 cm TL respectively) is one of the smallest estimations among the reviewed literature in the Eastern Mediterranean suggesting the statement of Sonin et al. (2007).

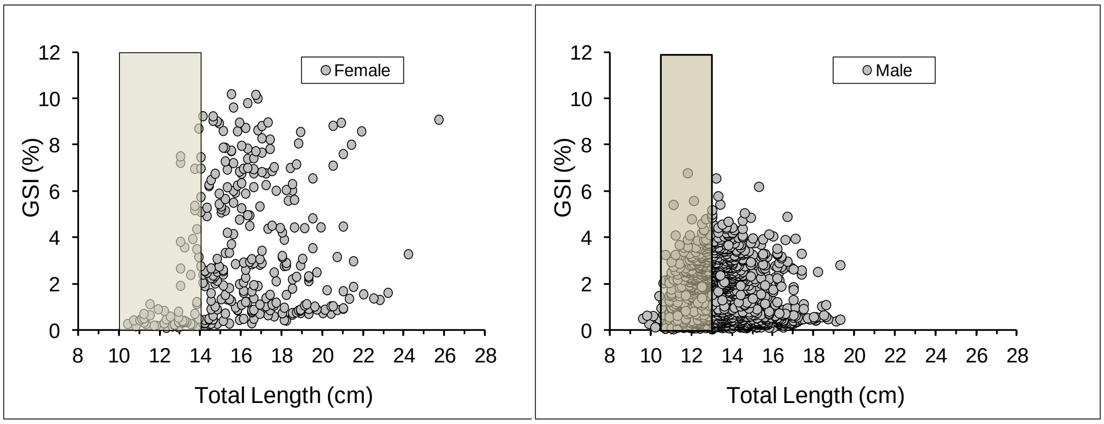


Figure 4.1. Individual distribution of female and male gonado-somatic index (GSI) according to the total length in *M. barbatus*. Grey colored areas represent published estimates of size at first maturity (L_m).

In the present study, statistically significant difference was found between HSI of female and male *M. barbatus*. The condition factor also differs significantly between females and males. HSI of *M. barbatus* show that females use their energy gained concurrently during gonadal development i.e. they do not store energy earlier than spawning implying income breeding in females. Lloret et al. (2007) have studied lipid reserves of *M. barbatus* (but only females) during pre-spawning in the northwestern Mediterranean and indicated that although *M. barbatus* allocates lipid reserves to the gonad during the reproductive period, it does not experience depletion in muscle lipids which is probably because it feeds intensely at that time (Bizsel, 1987). Similar pattern observed in HSI of female *M. barbatus* during reproduction period. On the other hand, dynamics of energy allocation in males are rather different. After beginning of spawning around March, energy intake exceed the rate of utilization together with the food supply available in spring so surplus energy is stored as reserves in males in contrast to females. These sex-specific differences in energy allocation may be responsible for the differences in the effect of condition on maturation as reported by Morgan (2004). Chellappa et al. (1995) have identified two periods of energetic stress for three-spined sticklebacks. These critical seasons are in winter when food supply and the time available for foraging are limited and the summer breeding season when energetic demands are very high. The critical season in terms of energy allocation of *M. barbatus* will be discussed in the following section.

4.2 Biological characteristics of *U. pori*

The constants (a and b) of length-weight relationships calculated in this study were given together with the other studies carried out in the region (Table 4.3). According to the results of this analysis, *U. pori* shows isometric growth which was also stated by İşmen (2006) and Çiçek and Avşar (2011). No further emphasis is given here to the differences in variations of b exponent between the studies since it may be due to the combination of several factors such as differences in sampling, sample size, differences in stage of maturity and food quantity, quality and prey size (Shepherd and Grimes, 1983; Wootton, 1998) which could not have been considered and so that reported.

Table 4.3. Parameters of the length-weight relationship $W=aL^b$ [Weight (in g) and length (in cm)] of *U. pori* from several studies. The significant figures of each a and b values were taken directly from the related articles without making any modification.

Area	**(a)**	**(b)**	**Reference**
Eastern Mediterranean (Turkey)	0.0050	3.25	Taşkavak et al., 2001
Iskenderun bay (Turkey)	0.0102	3.01	F+M
	0.0097	3.03	F
	0.0108	2.99	M İşmen, 2006
İskenderun bay (Turkey)	0.0107	2.9487	Çiçek and Avşar, 2011
Northeastern Levant sea (Turkey)	0.0067	3.1551	F+M
	0.0074	3.1083	M
	0.0071	3.1083	F In this study

VBGF parameters estimated in the eastern Mediterranean were given in Table 4.3. As it can be seen from the table, very few studies were carried out on the species and so the related literature is very limited.

The L∞ estimated in this study is between the values given in the previous studies conducted in the area. Estimated K in this study is the highest K value observed in the literature reported. At this point, it should be noted that K values estimated by length based models are significantly larger than those estimated by age based models. This may be due to inconsistency between the precision of the age readings (usually a year) and the short life span of the species; the great percentage of growth in length is achieved within the first year of life.

Table 4.4. Computed VBGP of this study and the previous studies.

VBGP	**Location and Author**	**Method**
L_∞=19.1 cm, K=0.360 yr^{-1}, t_0 = -0.812 yr.	İskenderun, İşmen (2006)	Otolith
L_∞=21.98 cm, K=0.194 yr^{-1}, t_0 = -1.168 yr.	İskenderun, Çiçek and Avşar	Otolith
L_∞ = 20, K = 0.45, C = 0.40, WP = 0.20	This study	Modal progression

As mentioned previously, the sex-ratio of sampled individuals was calculated as 0.55 (1.2:1) in a slight favour of females. İşmen (2006) calculated female to male ratio as 1.1:1.0 again in favor of females, while Çiçek et al. (2002) reported it for the individuals in the northeastern Mediterranean as 0.95:1.0. İşmen (2006) observed a significant increase in the number of males in autumn and attributed it to early departure of the females from the nursery grounds. The same author also concluded that seasonal variations in the sex ratio may possibly be due to the difference in the length (or age) of sexual maturity and the difference in length distribution in relation to depth. Although these factors may have influence on sex-ratio and size difference in sex of the species, it should be kept in mind that these ratios do not represent the actual sex ratio in the population; it is the sex ratio of the individuals sampled. Therefore non-biological factors (sampling location, time of sampling, sampling methodology, fishing gear used in data collection) may have remarkable influence on the determination of sex-ratio and size difference in the sex as does the biological characteristics. These non-biological factors should also be took into account while commenting on sex ratio and size different in sex of the species.

The length at first maturity (L_m) for males and females were estimated as 9.5 and 10.0 cm respectively. These results are very similar to the results of the study conducted by İşmen (2006). The author stated that males and females of *U. pori* mature at about 10 cm total length and about 1 year old. According to the results of Çiçek et al. (2002), the sexual maturation of females started at about 8 cm total length at age group 1 which is the smallest size class reported in the literature for length at first maturity of the females.

Figure 3.18 and Figure 3.19 showing the seasonal and annual variations in GSI of *U. pori* were evaluated together to investigate spawning season of the species. Variations in GSI indicated that the reproduction activity of *U. pori* takes places during two seasons starting from day 60 to day 185 (late February - early July) and after day 185 to day 355 (early July to late December). Moreover, comparison of the length distributions of these two groups indicated that individuals in autumn group were significantly larger in length than the spring group. Several studies investigated the reproductive biology of the *U. pori*. Golani et al. (2002) reported that the reproductive period of this species in the Mediterranean Sea is from April to September in Israeli waters while it was reported as March to August in İskenderun Bay by Çiçek (2002) and May to July again in İskenderun by İşmen (2006). Golani et al. (2002) also stated that settlement occurs 6-9 months after hatching, upon reaching length of 3-4 cm. İşmen (2006) also underlined that due to the presence of mature individuals in September reproduction may continue at a reduced rate during summer. HSI variations in females followed exactly the same pattern with the variation observed in GSI indicating that females do not store energy prior to the spawning season. Variation pattern in HSI of males seemed to be consistent with the fluctuations in GSI.

Somatic K plot showed that females seemed to be better conditioned during the spawning season. In adult fish, reproductive potential can be dramatically influenced by condition (Morgan, 2004). The egg production of fish in poor condition may decrease through lower potential fecundity, atresia, or even skipped spawning (Marshall et al., 1998; Rideout et al., 2000) Therefore, being in good conditioned during the spawning period may be advantageous for the species and one of the reason of successful colonization of *U. pori* in Northeastern Mediterranean Sea.

The *U. pori* is living mostly in sand, muddy sand or gravel bottoms at depths ranging from 20 m to 50 m (Golani, 1994). According to the result of this study, bathymetric distribution of the species (in terms of abundance) mainly concentrated shallower than 20 m depth. The biomass is always high at 0-25 m stratum as well but variation in biomass showed high seasonality. Golani (1994) studied resource partitioning between the two lessepsian goatfishes the Goldband Goatfish (*U. moluccensis*) and The Por's goatfish *(U. pori)* and the two indigenous goatfish, red mullet (*M. barbatus)* and striped red mullet (*M. surmuletus*) along the coast of Israel. The author concluded that rather than food preferences, niche partitioning was observed mainly on the bathymetric distribution axis, with the lessepsian migrants inhabiting shallower waters of 20-30 m while the native species occupies deeper grounds. Çiçek and Avşar (2011) also reported that majority of the *U. pori* samples (96.99%) were collected at depths between 0 and 20 meters.

4.3 Biological characteristics of *P. erythrinus*,

P.erythrinus is a hermaphroditic protogynous species so that first years of their life they are female (Bauchot and Hureau, 1986). As represented by Beverton and Holt (1957) the mean length in a stock decreases as the fishing pressure is increased. The fishing pressure over the demersal stocks in the study is already high (Bingel, 1981) and this may be the main reason why majority (94%) of the samples dissected were either juveniles or females.

The b-value in the length-weight relationship showed that although growth was negative allometric for males and females, calculation of combined data showed positive allometric growth (Table 4.5). There are various studies carried out in the Mediterranean on this species. The studies conducted in the eastern Mediterranean (Bingel, 1987; Özaydın, 1997; Hoşsucu and Çakır, 2003) indicated that the species show negative allometry; while in the western Mediterranean (Pajuelo and Lorenzo, 1998) the relation was reported as isometric. Also some authors reported both; negative allometry in females and isometry in males (Metin et al., 2011).

Table 4.5. Parameters of the length-weight relationship $W=aL^b$ [Weight (in g) and length (in cm)] of *P. erythrinus* from the different studies. The significant figures of each a and b values were taken directly from the related articles without making any modification.

Area	**(a)**	**(b)**	**Reference**
Mersin Bay (Turkey)	0.00072	2.202	Bingel, 1987
Canary Island	0.01279	3.013	Pajuelo and Lorenzo, 1998
Edremit Bay (Turkey)	0.00007	2.738	Hoşsucu and Türker, 2003
Izmir Bay (Turkey)	0.0121	2.998	Ilkyaz and Metin, 2007
İzmir Bay(Turkey)	0.0107	3.06	F
	0.0125	2.99	M,
	0.0143	2.95	F+M, Metin et al., 2011
Northeastern Levant sea (Turkey)	0.0199	2.834	F
	0.0024	2.760	M
	0.0109	3.053	F+M, This study

The von Bertalanffy Growth Function (vBGF) parameters used to describe the growth of *P. eryhtrinus* in the study area were presented with the other studies (Table 4.6). When compared the other studies, the growth parameters estimated during the present study are amongst the smallest L∞ and the highest k values. The small asymptotic length (L∞) estimated in this study may be due to the "Levantine nanism" phenomenon suggested by Por (1989), and so the occurrence of short length (dwarfism) in benthic invertebrates inhabiting the eastern Mediterranean may also be valid for fish species as indicated by Stergiou et al.(1997) and Somarakis and Machias (2002). K value estimated in this study was one of the highest in the related literature. Different estimation in K values may be attributed to several factors. This can be due to the methodology used in the parameters estimations; K values estimated by length based models are significantly larger than those estimated by age based methods due to erroneous age interpretations regarding the non-annual rings such as pelagic ring, spawning ring etc. (ICES, 2009). Besides, the ecological conditions in the areas of investigation may possibly cause differences in growth rate (Shepherd and Grimes, 1983). The oscillation value estimated (0.60) suggested a quite strong seasonal pattern but WP (0.5) corresponds to summer months meaning that growth of *P. erythrinus* in the region is not fully controlled by the temperature of the habitat.

Table 4.6. VBGP of *P. erythrinus* in the Mediterranean.

Location and Author	**Sex**	**L_∞ (cm)**	**K (yr^{-1})**	**t_0 (yr)**	**Method**
Mersin Bay (Bingel, 1987)	F+M	30.0	0.597	-0.273	ELEFAN
Iskenderun Bay (Gücü, 1995)	F+M	34.2	0.40		ELEFAN
Canary Islands (Pajuelo and Lorenzo 1998)	F+M	41.7	0.20	-0.550	ELEFAN
Cretan Shelf (Somarakis and Machias 2002)	F+M	27.8	0.317	-0.739	Scales
Edremit Bay (Hoşsucu and Türker, 2003)	F+M	24.0*	0.16	-2.6	Otolith
İzmir Bay (Ilkyaz and Metin, 2007)	F+M	26.7	0.22	-0.68	Otolith
Southern Portugal (Abecasis et al., 2008)	F+M	31.84	0.19	-2.86	Otolith
	F+M	34.27	0.16	-2.74	Scales
Izmir Bay (Metin et al., 2011)	F+M	30.7	0.16	-0.86	Otolith
Southern Portugal (Coelho et al., 2010)	F+M	47.14	0.084	-4.42	Otolith
Northeastern Levant sea (Turkey) (This study)	F+M	25	0.60	-	ELEFAN
*** Fork Lenght**					

The sex ratio in fish is generally close to 1:1 for the majority of species (Nikolsky, 1963). However several authors reported unbalanced sex ratio in favour of females in *P. erythrinus*. According to Pajuelo and Lorenzo (1998), the ratio of males to females was 1:2.63. In Edremit Bay, it was reported as 1: 3.16 and females predominated in 12.0-15.0 cm size intervals (Hoşsucu and Türker 2003). In İzmir bay, female to male ratio was reported as 1:0.08 (Metin et al., 2011) indicating again the female dominancy in samples.

The proportion of females is very high in small length classes of *P. erythrinus* and this proportion decreases in larger length classes so that males are dominant in larger length classes. In terms of size difference in sex, all of individuals at 8 cm and smaller length classes found as juveniles in this study. Females started to be dominant at 9 cm and larger length classes. Proportion of males increased gradually through larger lengths (>12 cm). Rijavec and Županović (1965, Adriamed 2010b cf.) reported similarly that males are dominant above 16 cm length class and their proportion is 100% over 23 cm length class.

The estimated length at first maturity (L_m) parameters in this study showed that the males of this species reach to maturity at slightly larger sizes than the females (14.6 cm for females and 15.01 for males). It was reported in the literature that females of *P erythrinus* becomes mature at earlier ages than males as well. Various estimations were reported in the literature; Pajuelo and Lorenzo (1998) showed that the total length at which 50% maturity is reached was 17.4 cm for females and 23.2 cm for males. Somarakis and Machias (2002) stated that first maturation occurred within 13.0-15.0 cm (age 1+ and 2+). Hoşsucu and Türker (2003) found it as 13.0 cm in females in Edremit Bay (Aegean Sea). Coelho et al. (2010) indicated that males of this species mature at 17.58 cm TL and at 1.15 years, while females mature at 17.29 cm TL and at age of 1.04 years. Recently, Metin et al. (2011) conducted a study in İzmir bay (Aegean Sea) and reported that 50 % of the individuals were found at 11.30 cm TL for females and 15.08 cm TL for males. The author also underlined that the sexual maturity age was found to be 2 for female, 3 for male. In summary all author mentioned above agreed that males are larger than the females due to reproductive strategy adopted by the species (protogonic hermaphrodity) and the length at first maturity ranges between 11.30 - 17.4 cm for females and 15.08 - 23.2 cm for males. It may be worthwhile to note that, frequency of sampling and the sample size has a remarkable influence on the estimation of maturity length.

There are different observations given by various authors for the spawning period of *P. erythrinus*. Spawning occurs between May-September according to the studies of Papaconstantinou et al (1988) and Livadas (1989), while it was reported observed an rather extended spawning season lasting from April to October in NE Aeagen Sea (Erdemit Bay) (Hoşsucu and Çakır, 2003). Pajuelo and Lorenzo (1998) reported that the GSI values of females were usually higher than those of males but both indices followed the same pattern. According to the authors, the highest values occurred between April and September, with a maximum in June-July. In another study carried out by Metin et al. (2011), the GSI in females reaches to the maximum in June; however males reaches to maximum a month earlier. In both sex the value remains high until October. In this study, the development of gonads began around January, the highest GSI values were reached in April indicating the onset of spawning and it gradually decreased until July. The same pattern was observed in the percentage distribution of maturity stages. The highest percentage of spawning females was observed in April that is a bit earlier as compared to the studies carried out in the Aegean Sea. The warmer nature of the study area associated with geographical differences may explain this variability. The relationship between reproduction period and ambient temperature was discussed by several authors. According to Valdés et al. (2004), *P. erythrinus* spawns in water temperatures between 22 and 24 °C and the spawning declines in periods with high water temperature as high temperature results in abnormalities in eggs. On the contrary, Pajuelo and Lorenzo (1998) underlined that this species reproduces in the period of the highest water temperature in the Canary Islands. Metin et al. (2011) reported the optimum sea surface temperature for the spawning of *P. erythrinus* as 22.6 °C. The author also stated that although spawning continued in July, it showed a significant decrease when the average temperature was 25 °C. In this study, individuals at spawning stage were distributed over the sea bottom temperature ranged between 17.9 and 20.5 °C. Temperature ranges given in the literature and in this study are rather different. This is most probably due to the vertical temperature gradient which was not taken into consideration by Valdés et al. (2004) and Metin et al. (2011) who used sea surface temperature instead of ambient temperature in their evaluations. It should be noted that the vertical gradient is very strong and particularly important in summer when thermocline develops.

Despite the general agreement in the findings of the studies on the timing of the spawning season, the secondary peak in the GSI and in the percentage of individuals at spawning stage observed in this study which possibly indicates the occurrence of autumn spawners conflicts with the other studies mentioned above. Unfortunately the second peak was observed during the period which the data was not available. Therefore the secondary spawners in *P. erythrinus* are an issue that requires further analysis.

P. erythrinus is generally distributed over the continental shelf but more abundant at depths between 22–110 meters in NW Mediterranean (Macpherson and Duarte, 1991), between 15 and 165 meters (mainly below 122 meters) in Aegean-Ionian seas (Katsanevakis and Maravelias, 2009); between 26 and 177 meters in Cretan Sea (Somarakis and Machias, 2002). In this study the deepest station where the species was observed was at 206 meters. However throughout the study, main bulk of the stock was observed at depths between 9 and 110 meters. One or very few individuals observed at 135 m to 206 m depth during winter expanded the bathymetric distribution range of the species.

A distinct seasonal bathymetric movement of P. *erythrinus* was reported in the Adriatic Sea. These movements are confined to 100 m isobaths. In winter (October to April) the species descends to deeper parts, mainly for reproductive reasons and in summer (May to October) they were found are shallower depths where food availability is higher (Županović and Jardas, 1989). The seasonal pattern in the bathymetric distribution given for the Adriatic Sea did not fully suit to the distribution pattern observed in this study. Here, at the core of the spawning season the shallow depths were deserted and individuals were accumulated between 50-75 meters, indicating that the spawning might possibly take place within these depth limits, as was in the Adriatic Sea. Later, the recruits first observed in July-August, are accumulated at 25-50 meters depth interval; however remarkable quantities of *P. erythrinus* was observed at the adjacent lower and upper depth strata. Therefore even if there is a seasonal bathymetric displacement; it is not as distinct as described in the Adriatic or the migration is masked by fishing pressure. The sharp decline in the abundance (Figure 3.42) and biomass (Figure 3.43) shows how fast the recruits are removed from the stock. The fisheries regulations applied in the area, i.e. trawl exclusion zone and offseason may, to an extent, explain the inconsistency in the distribution. The time when the recruitment take place, hence the highest biomass was observed, is a period banned to the trawlers. A month later, with beginning of the trawling season the fish distributed over the legal fishing grounds beyond the trawl exclusion zone are rapidly removed. The depths range where the highest biomass is observed is located at the outer edge of the trawl exclusion zone. While this area is fished the shallower zone located within the trawl exclusion zone remains almost intact. Therefore the part of the fishes moving towards the deep in the fishing ground might have been removed by the fishery and only those distributed over the trawl exclusion zone might have been remained.

4.4 Biological characteristics of *L. suezensis*

There are five species of pufferfish in the Mediterranean, and four of them are lessepsian immigrant (Golani et al. 2002). Two of them, in particular, are considered among the pests by the fishermen. They almost exclusively feed on fishes entangled in the fish nets or hooked in the long-lines (Michailidis, 2010) so they damage the fishing gears during feeding. On the other hand, although their first occurrence was rather new (it was from Lebonan in 1977 (Mouneimne, 1977)), they spread around the eastern Mediterranean very rapidly (Figure 4.2).

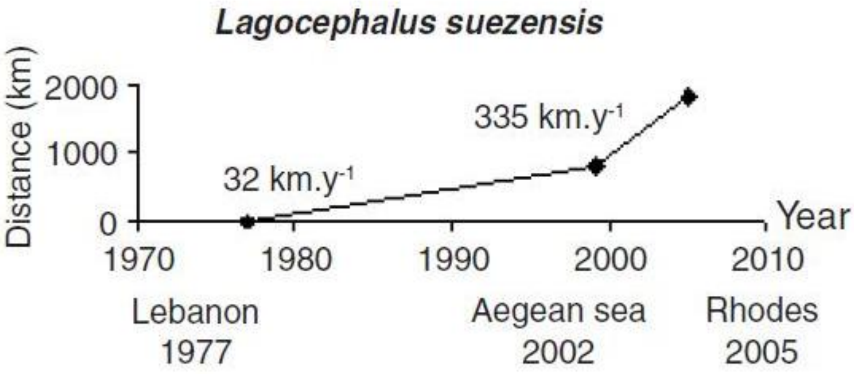


Figure 4.2. Dispersal of *L. suezensis*. Location of new records and average speed (km yr^{-1}) are indicated below the x-axis and within the curves, respectively (Taken from Lasram et al. 2010).

To understand the mechanism facilitating their fast expansion is very important. In the literature, information even on the basic biology and ecology of the species is very scarce. In the Mediterranean Sea, except for the study dealing with its LW relationship (Erguden et al., 2009), most of the work deal primarily with its first occurrence or range expansion (Bilecenoğlu et. al, 2002; Corsini et al., 2005; Katsanevakis, 2009; Ben-Abdallah, 2011). Therefore this study is the first detailed attempt to understand its fast expansion in the Mediterranean by investigating its biological characteristic and spatiotemporal distribution.

The rapid growth of the lessepsian species may be one of the factors responsible of their successful establishment and expansion in the Mediterranean and the issue has been long discussed by many authors (Golani, 1998; Lasram et al., 2007) within the context of theoretical ecology. Because of their ability for rapid population growth, species with an 'r-strategy' which is characterized by small body size, rapid growth, short longevity, early sexual maturity, high reproduction potential (Psomadakis et al, 2009). The VBGF parameters estimated for *L. suezensis* and particularly the growth constant K, is not very high compared to the native species occupying the same grounds. In contrary, the very high seasonality seems to play the role. Although the overall growth rate (increment in size per year) is not very high the specific growth rate (increment in size per day) at critical periods are extremely high. This feature perfectly fits to an r-strategist described above. The individuals waiting for the optimum conditions burst when the environment turns into their favor. When the condition is over, they become almost dormant. The period when the biological activities, including somatic growth spout in *L. suezensis*, coincides with the warmest period of the year.

The sex ratio of sampled *L. suezensis* indicated a dominance of female fish over male (0.58). The disparity in the sex ratio is generally attributed to the biological characteristics of the species (Joksimović, 2005; Vrgoč, 2000). However, as well as biological characteristics, non-biological factors (sampling location, time of sampling, sampling methodology, fishing gear used in data collection) may also have remarkable influence. For instance, if one sex is larger than the other and the sampling gear used is selective over a certain range, then one of the sexes not retained by the gear would have lesser presentation in the samples, hence lesser ratio. However as can be seen in Table 3.11, females are always greater presentation in all length classes. Therefore lower representation of a sex is the sample is not a matter of question. The inequality in the sex ratio may provide significant information on the species biology of the species, which actually fits to specialist (r-selected) nature of the species discussed above; in order to increase the overall fecundity of the population and so that to support bursting strength and speed when favorable conditions occurs, the most of the individuals may turn into females. However it may be worthwhile to add that out of 1060 individuals set aside for biometric examination and dissected; only ~300 individuals were used in the analysis. The body cavity and the internal organs of the rest of the individuals were so badly decomposed; it was not possible to determine sex so that discarded. However, by comparison, the females are relatively easy to recognize even when decomposed since they have larger gonads than the males (Figure 3.49 and Figure 3.50). Therefore it may also be possible that the unequal sex ratio is a result of sampling bias.

As shown in the four different set of figures, spawning takes place between April and August with a peak on July. The season of spawning, and especially the time of a peak is quite different than the other species spawning in the area. High temperature in summer appeared to be a limiting factor in the gonadal development for the native species, which are originated from temperate part of Atlantic and forced to adapt to the subtropical eastern Mediterranean, as well as some other lessepsian species, like siganids (Bariche et al., 2003). However it seems that *L. suezensis* use the high temperature disruption of the other species co-existing the same area for its benefit.

This argument is supported by biomass and abundance distribution of the species. In general, the abundance and biomass display parallel fluctuations. The minor differences observed are due to the variations in the mean size of the individuals. For instance, the highest abundance observed in September 2009 is three times higher than the next two highest abundances observed in November 2009 and January 2010. The biomass in September 2009 was still the highest value recorded throughout the study. However the difference from the next two highest values was not as pronounced as in the abundance. When the mean sizes are compared, the individuals in September 2009 (5.7 cm) are two times smaller than November 2009 (10.6 cm) and January 2010 (11.0 cm). Therefore although the abundance of the species decreases in time (probably due to mortality), the loss is compensated by very rapid growth. As given earlier (Figure 3.45), the period in question is the time when growth in *L. suezensis* is accelerated. After December the growth slows down (so that the mean length in November 2099 and January 2010 did not change much); abundance and biomass drop. As discussed above, this is also the period when the reproductive activities, from gonad development to spawning take place. It is worth to iterate that the spawning in this species occurs rather late compared to the other species. Also energy storage and somatic conditioning take place at the same period (Figure 3.49 and Figure 3.50). The fluctuation pattern in the mean length, particularly steady increase observed during the warm season followed by an abrupt drop. When this feature is associated with the increase in abundance, it marks the recruitment time of YOYs. Therefore Figure 3.55 suggest that the YOYs recruit to the stock almost a month later then they are spawned, so that the recruitment takes place within the same period. What are specific for this period are the very warm surface temperature and a very strong vertical temperature gradient Figure 4.7, which probably not welcomed by the native species. Besides, although period can slightly shift from one year to the another, trawl fishery in the area is banned between May and September when almost all biological activities of this species are hastened and within the 2 miles zones from the coast line which is the depth range preferred by the species. Therefore it seems that in addition to very high surface temperature triggering seasonal oscillation in the growth rate, the fisheries regulations applied in the area combined with coastal preference of the species facilitates successful establishment in the northeastern Mediterranean.

4.5 Biological characteristics of *S. undosquamis*

The parameters of length weight relation calculated in this study are given together with the previous studies carried out in the other regions of the Mediterranean Sea in Table 4.7. The value of the constant (b) of length-weight relationship for combined data, males and females of this study show that weight increases positive allometrically with length in all groups. The results given in Table 4.7 indicate that type of growth showed isometric or positive allometric growth in the previous studies, except for Bingel (1987), Can et al. (2002) and Çiçek and Avşar (2011). As mentioned previously, variation in the b exponents can be attributed to the combination of one or more factors. These can be technical (such as differences in sampling (i.e. frequency), sample size or length ranges obtained during sampling), biological (differences in stage of maturity, food (quantity, quality and size) and/or environmental such as temperature, salinity and seasonality) (Shepherd and Grimes, 1983; Wootton, 1998). Therefore no emphasis was given to the differences between the studies.

Table 4.7. Parameters of the length-weight relationship $W=aL^b$ [Weight (in g) and length (in cm)] of *S. undosquamis* from the Mediterranean Sea. The significant figures of each a and b values were taken directly from the related articles without making any modification.

Area	**(a)**	**(b)**	**Reference**
Göksu Region (Turkey)	0.0030	3.24	Bingel F., 1981
Tırtar Region (Turkey)	0.0035	3.19	Bingel F., 1981
Mersin Bay (Turkey)	0.000141	2.4501	Bingel F., 1987
İskenderun bay (Turkey)	0.0117	2.7971	Can et al., 2002
Babadıllimanı Bight (Turkey)	0.0047	3.086	Çiçek et al. 2006
Antalya Bay (Turkey)	0.004	3.240	Yılmaz and Hoşsucu 2007
Suez Channel (Egypt)	0.0038	3.16	El-Halfawy et al., 2007
İskenderun Bay (Turkey)	0.0083	2.789	Çiçek and Dursun, 2011
Northeastern Levant sea (Turkey)	0.0035 0.0029 0.0045	3.2032 3.2664 3.1235	M F F+M, This study

There are number of VBGF estimates given by various authors for eastern Mediterranean (Table 4.8). The L_∞ estimated in this study is beyond the values given in other studies and K is at the lower margin of the listed values. Among the studies listed in the table only one work takes the sex of the individuals into consideration (Golani, 1993), in which the females grow slightly faster and attain to larger size compared to males. The parameterization of VBGF is not clearly described in his work and the parameters particularly very low and negative K value is quite weird for such a species. As the age at length data given in Golani's (1993) work is used to recalculate the VBGF parameters for male and female the results (particularly those given for females) are almost identical to the value found in this study. The very broad length frequency distributions of the cohort observed at the early stages can therefore be explained by sex dependent growth rates; a cohort is formed by both, the slow growing females and the fast growing males which are lumped together in the size frequency distribution. This issue seems to be a significant artifact in growth estimation.

Table 4.8. Literature data about growth parameters VBGF of *Saurida undosquamis* in the Mediterranean Sea. The significant figures of each a and b values were taken directly from the related articles without making any modifications

Location and Author	**L_∞ (cm)**	**K (yr^{-1})**	**t_0 (yr)**	**Φ**	**Method**
Göksu (Mersin), Mediterranean Sea (Bingel, 1981)	46.70	0.133	-0.160	2.46	Otolith
Tırtar (Mersin), Mediterranean Sea (Bingel, 1981)	45.60	0.185	-0.007	2.58	Otolith
Mersin and İskenderun Bays, Mediterranean Sea (Bingel, 1987)	42	0.420	-0.360	-	ELEFAN
Mersin and İskenderun Bays, Mediterranean Sea (Bingel et al., 1993)	42	0.41975	-0.36	2.87	ELEFAN
İskenderun Bay (Gücü, 1995)	42.80	0.42	-	2.89	ELEFAN
İskenderun Bay, Mediterranean Sea (Türeli and Erdem 1997)	22.43	0.597	-1.365	2.47	Otolith
İskenderun Bay, Mediterranean Sea (İşmen, 2003)	42.00	0.178	-1.229	2.50	Otolith
İskenderun Bay, Mediterranean Sea (Gökçe et al., 2007)	42.00	0.510	-0.290	2.95	ELEFAN
Suez channel, Egypt (El-Halfawy et al. 2007)	35.56	0.26	-1.059	2.602	ELEFAN
Golani (1993) Females Males	 34.0 28.0	 0.033 0.036			Otolith
This study	57.3	0.14			ELEFAN

The sex-ratio found in this study (0.72 in favour to females) is the highest female to male ratio given in the literature. Bingel (1988a) reported that the sex ratio of *S. undosquamis* were 0.38 for males and 0.62 for females in Göksu region and 0.35 for males and 0.65 for females in Tırtar region. Golani (1993) found it as 0.41 for males and 0.59 for females in Israeli waters. Later İşmen (2003) found the sex ratios of *S. undosquamis* in İskenderun bay as 0.39 for males and 0.61 for females. Similarly, it was calculated as 0.39 for males and 0.61 for females at Fethiye and Mersin on the Mediterranean coast of Turkey (İşmen 2003 c.f. Torcu 1995). Yılmaz and Hoşsucu (2007) found this ratio as 0.41 for males and 0.59 for females in Antalya bay, Eastern Mediterranean. These ratios do not represent the actual sex ratio in the population; it is the sex ratio of the individuals sampled. The fishing gear(s) used to collect samples (mostly bottom trawl in the case of *S. undosquamis*) are size selective and effective over a limited length spectrum; i.e. smaller individuals are more likely to escape through the mesh. As presented in Figure 3.58Table 3.13 males of this species are significantly smaller than the females. Therefore, the size difference in the sex would eventually be reflected over the sex ratios and the females would dominate the samples since the catchability of the net over the relatively smaller males is lower (N'Da et al., 1993).

Length at first maturity analyses applied to the *S. undosquamis* indicated that length at first maturity (L_m) for males and females were 17.2 cm and 19.0 cm respectively. These values are slightly greater than the values reported by İşmen (2003) in Iskenderun bay (about 16 cm for males and about 16.5 cm for females). Zienab Abdel-Baki El-Greisy (2005) reported it for only males as 17 cm with a range of total length from 15 cm to 19 cm in the study conducted in the Egyptian waters of the Mediterranean Sea while Halfawy et al. (2007) presented it for only females as 18.1 cm in the Gulf of Suez. The previous studies performed in the Mediterranean Sea as well as this study, showed that size of the male *S. undosquamis* when they attain to sexual maturity lesser than the females. On the other hand the bimodal reproductive activity cycle presented in Figure 3.66 can only be achieved if the gonads in males and females are developed synchronously. With this respect the unequal maturity size may be explained by two possible situations; the first is the difference in gonad development time. For this species it seems that a male lizardfish requires more time to develop its gonad than does a female and therefore the onset of first maturation begins earlier. The second explanation is different growth rate presented by males and females; females grow faster than the males. As can be seen from eq. 9, the “r” value is the slope of the asymptotic maturation curve and may also signify how fast the individuals in a population attain to maturity. Comparison of males and females suggest that this period is actually shorter in males (greater “r” value). The methodology followed in the work does not allow comparison of growth rates in difference in sexes. Therefore it is not possible to see weather females grow faster than males; however Golani (1993) presented that the females are in fact grows faster than the males.

GSI values calculated in this study indicate that the reproduction activity of *S. undosquamis* takes places during two main seasons (May-early August and late November-late February). There are different observations on the reproductive cycle of *S. undosqamis*. According to Golani (1993) *S. undosquamis* reproduces year round in the tropical waters and to cope with the low winter temperature in the Mediterranean it has modified its life history in the Mediterranean by shortening the spawning season and by resting the gonads during winter in the Mediterranean Sea (see Figure 4.3).The same author use the data presented in Figure 4.3 and reports that the spawning season lasts from March to December. It may be worth noting that probably due to low sample size; the author disregards the slight increase in GSI in November (Figure 4.3).

On the other hand, other authors studied the reproduction cycle of the species in the other parts of the Mediterranean reported a prolonged reproduction period including two main spawning activities. Halfawy et al. (2007) underlined that the spawning season of *S. undosquamis* on Mediterranean coast of Egypt is prolonged, covering nearly all year round with two peaks in December and May. Zienab Abdel-Baki El-Greisy (2005) carried out a very similar study in the Egyptian Mediterranean waters and observed ripe males all year except in April. The highest percentage of ripe males was observed during the period extending from August to December. Similarly İşmen (2003) studies the same species around the Gulf of Iskenderun and reported that spawning of this species occurs in an extended spawning season over 12 months of the year with two slight increases in May-July and September-November.

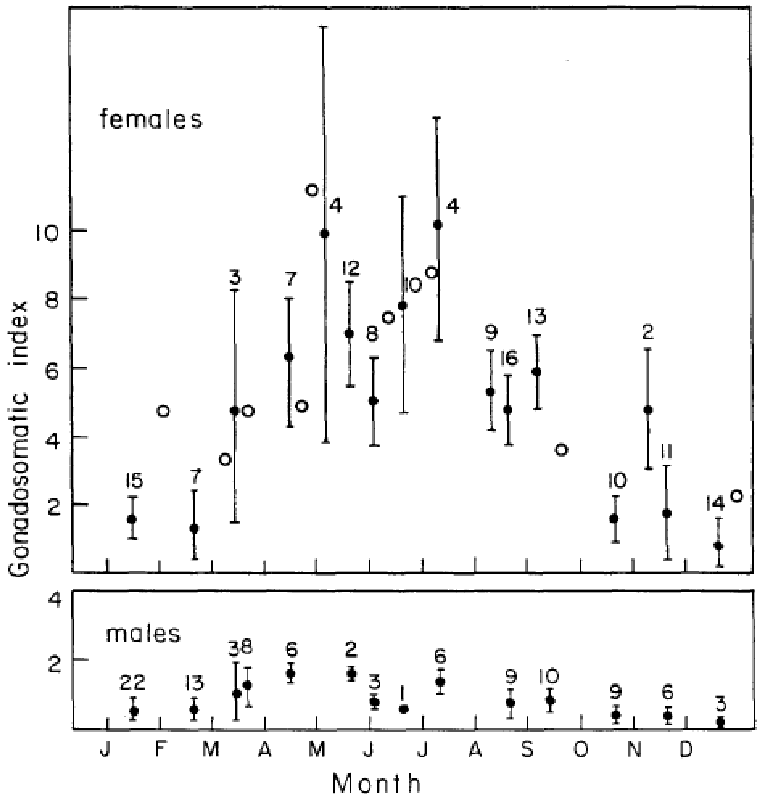


Figure 4.3. Year-round changes in GSI of Saurida undosquamis (black dots) and Synodus saurus (white dots) from the eastern Mediterranean coas of Israel. Numbers indicate sample size (taken from Golani, 1993).

According to Golani et al. (2002), this species found mostly at depth range of 30 to 70 m (rarely in 100 m. Ben-Yami and Glaser (1973) also underlined that it prefers rather shallow waters and it is caught in the cooler seasons at depths generally not exceeding 45 fm (=82.3 m) but found mostly at less than 35 fm (=64 m) in Levant Basin. These results are affirmative as 87.3 % of biomass of *Saurida undosquamis* was observed over the depths between 28 – 70 meters in this study. The vertical stratification in the area seems to play a role in the bathymetric localization of the species. The individuals are confined to the depth above the thermocline during summer and may descent to lower depths during the time of winter convection when all water column over the continental shelf is mixed (Figure 4.7 and 3.59). Thermocline might be a factor setting the lower vertical bathymetric limit of the distribution of the species. The upper limit, on the other hand, may be set by the food availability. There are several studies carried out on the diet of the species in the eastern Mediterranean. All these studies agree that *S. undosquamis* is a piscivorous fish and the main food items observed in its stomach are; *M. barbatus* small pelagics (mainly *Engraulis encrasicolus* and *Sardinella aurita*), and picarel, *Spicara* spp. As presented before (see Figure 3.12) the depth stratum preferred by *S. undosquamis* is the bathymetric region where largest accumulation of red mullet is observed. This region is also very rich in small pelagic (Gücü et al., 2011).

Annual changes in the biomass agrees with the estimated spawning season since the increase in the biomass which is mainly composed of smaller sized individuals Figure 3.69, is observed three months after the period when the highest GSI values were observed.

4.6 Biological characteristics of the other species

The vBGF parameters estimated for *U. moluccensis* and *M. merluccius* show the same strong seasonality observed among the other species. The length frequency distribution the limited samples of hake verified the vBGF parameters suggested for the species by Gucu and Bingel (2011) for the same area in the 1980's.

Hake in the study area was studies earlier by Gucu and Bingel (2011) based on historical data collected in 1980s when the species was very abundant in the region. In their work it was underlined that hake is a deep water species and the ascent of the species towards shallower depths where prey availability is higher was associated with the changing dietary requirements of the juveniles. Therefore the individuals observed in the continental shelf are, to a great extent, juveniles. In this study more than 90% of the samples were below the maturity size and therefore could not be sexed. The author also noted a dramatic decline associated with the temporal hydrographical changes and found that the occurrence of the species correlated with the presence of the modified Atlantic water in the basin. In the samples of this study the species was totally absent until 2009 and suddenly appears in the samples supporting the temporal occurrence in the region. During the period when the species was present on the continental shelf, the signature of Atlantic water (38.9 ppm salinity) was detected (Figure 4.4). However during the period of hake absence, there is no salinity measurement. The results showed that *M. merluccius* and *U. moluccensis* coexist indicating that both species respond to the same factor triggering biomass increase. Gucu and Bingel (2011) also reported that the species occurred on the shelf area only during the cold months, which is also the case for the period when hake was observed during this study.

L. mormyrus occurred only on the very shallow stations during autumn and winter and disappear during the warm season induced by summer warming. The interesting point here is, the spawning season suggested by annual GSI variation is the period when the biomass of this species was minimal. This indicates that the shallow waters are actually the nursery grounds for the species.

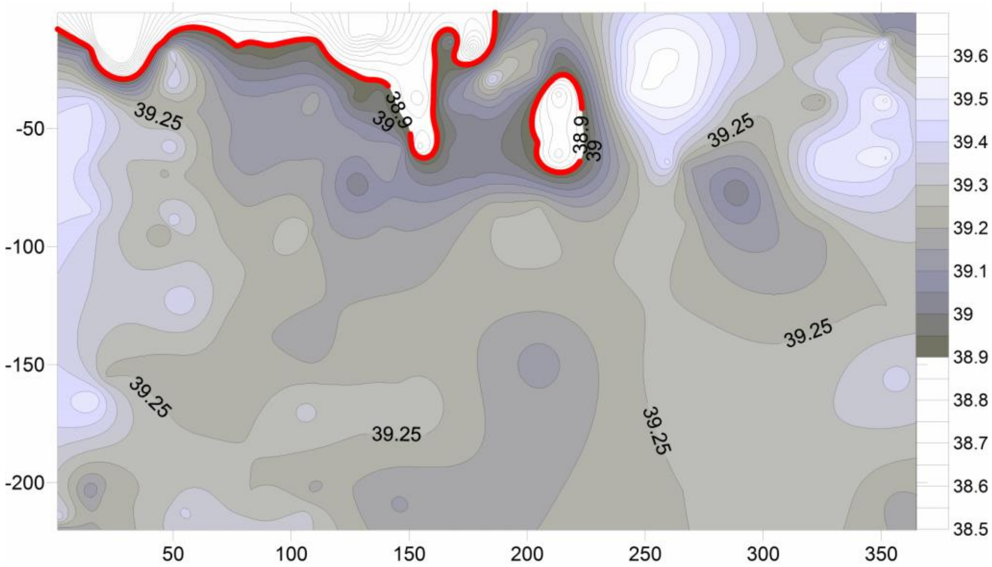


Figure 4.4. Time series of salinity changes over the sea bottom.

4.7 Statistical analyses

4.7.1 Influences of depth and environmental variables on condition of *M. barbatus*

The only study dealing with bathymetric and spatial variation in condition of several fish species including *M. barbatus* (without evaluating the influence of environmental parameters) was carried out by Lloret et al. (2002). Although Lloret et al. (2002) indicated that depth affects HSI but not K and GSI of *M. barbatus*, this could be due to the absence of evaluation of environmental factors since the significant relationships were found between depth and all these indices in this study.

In the GAM application on gonad development two hydrographical variables, temperature and salinity were considered. It was also assumed that depth, mean length and time have an impact on GSI. In general, the temperature drops with increasing depth and this may be seen as a type of co-linearity and in statistical sense should probably be excluded in order not to overemphasis the importance of temperature. However in a biological sense, depth is associated with other environmental parameters which were not included in this study. The food type and availability is the most crucial one of such. A species, developing gonad which requires very costly energy investment, demands continuous, appropriate and sufficient food supply. *M. barbatus* is benthic feeder and feeds mainly on polychaetes, also on crustaceans and, to a lesser extent, on mollusks (Ben-Eliahu and Golani, 1990; Golani, 1994; Labropoulou and Eleftheriou, 1997; Machias and Labropoulou, 2002). The diversity, availability and size in the benthic assemblages in the study area are strongly influenced by the bathymetry (Mutlu et al., 2010). Therefore despite statistical constraints, the depth is included in the GAM analysis as an indicator of unaccounted, bathymetry associated parameters, mainly food. The model results, in essence, showed that the depth has positive effect between 100-150 meters depth, when the effects of other explanatory variables are removed.

In the time variable, it was assumed that gonad development is triggered by an intrinsic biological clock and the gonad development begins when the biological time comes. Obviously this assumption has little biological support. The reason why it is included in the analysis is to emphasize inter-annual variability in timing of gonad development and that bring the other factors to forefront. However as can be seen from Figure 3.87 and Table 3.24, time has a highly significant influence on GSI variability and inter-annual variability is negligibly small. In this case, in addition to the discussion made in the previous chapter, time component smoothed by the model allowed to make better evaluation and comparison biological indices. That is; when the time factor and depth are considered alone (Figure 3.91) the highest effect of depth is at 100-150 meters depth at around May (day 120). In a benthic study carried out in the Levant coast, Mutlu et al. (2010) reported a significant increase in the benthic polychaetes biomass at the same time and bathymetric slot in which GSI is impacted most by time and temperature. This may be an indirect evidence of food influence on gonad development. The individuals are accumulated where the food availability, polychaete biomass in this case, is the highest.

As shown in Figure 3.83, the GSI is independent of size, since gonad weight is normalized to somatic weight. However in an additive model such as GAM, impact of a variable which could have been masked in a linear model, may become visible. Therefore mean length at each trawl station were added to the model. Surprisingly model suggested a very high effect of length on GSI. This may partly be a result of positive allometry observed between lengths and weight presented in Figure 3.1. Apart from normalization, this result may point to the fact that the fecundity increases exponentially with respect to size and that the size of the eggs produced are bigger in the large individuals than the smaller ones (Wootton, 1998).

The HSI results are almost identical to GSI outputs indicating that the effects of the parameters concerned act in a similar manner. The similarity may also signify almost simultaneous use of energy source for gonad and fat deposition. The slight shift in the position of the GSI and HSI curves suggested by the model (Figure 3.87 and Figure 3.96) may indicate that the priority in the energy allocation is given to gonad development and then comes the energy storage. The bimodal somatic K (Figure 3.10 and Figure 3.11) and the WP value of the estimated vBGF curve may signify that first somatic growth is ahead of gonad development and energy storage; however it seems that it is interrupted during gonad development phase and then resumed after the completion of spawning.

Figure 4.5 is the monthly chlorophyll variation incurred from satellite (Modis-Aqua) integrated for Mersin Bay (north of the line between Goksu/Incekum and Karatas capes). Despite inter-annual variability the productive period of a year begins in winter (December) and lasts until summer (June). Therefore it would not be speculative to assume that overall productivity in the region increases in spring and a part of the pelagic production are benefited by the bottom dwelling filter-feeders such as polychaets as already reported by Mutlu et al. (2010). Following the increase in the food availability, *M. barbatus* invests the assimilated energy into leverage of its somatic condition first (Figure 3.105). Then, from February onwards, they use the income energy for gonad development until May (Figure 3.101) and almost synchronously the excess energy is stored as fat (Figure 3.10 and Figure 3.11). As dictated by WP value (WP=0.3), with the start of gonad development, the growth in length slows down in mid April and remains until spawning is completed; (Figure 3.8). Finally in late summer, the part of the fat storage, and probably income energy is used for growth again while the other part is utilized to build up new tissue as pointed by the second peak in Figure 3.8.

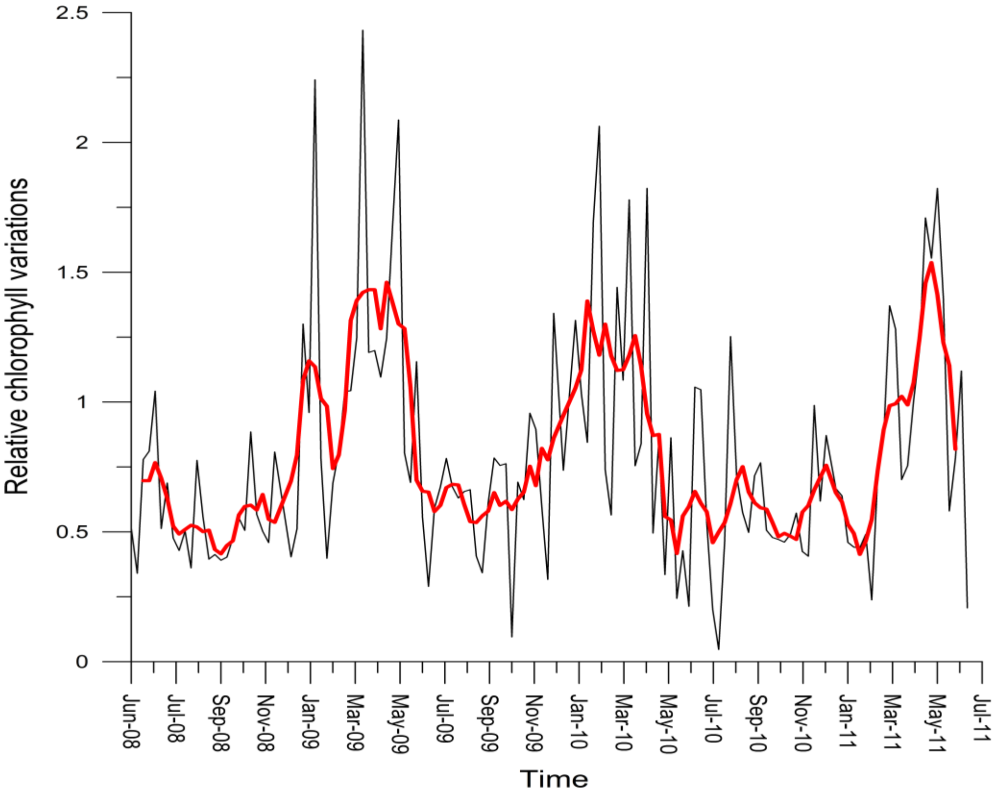


Figure 4.5. Monthly Chlorophyll variation at the surface layer over the continental shelf in Mersin Bay (computed from Modis-Aqua) (prepared by Serdar Sakınan)

4.7.2 Influences of depth and environmental variables on distribution of *M. barbatus*

The results of the GAM models failed to explain influence of environmental parameters on vertical and seasonal distribution of adult *M. barbatus* abundance. Apparently there are other forces determining the habitat preference; such as competition, predation pressure, food availability. However variances in the abundance of juveniles were explained with appreciable success. Among the parameters considered, salinity and temperature had the highest impact on the distribution. The salinity range preferred by the juveniles signifies two different water masses; the first occupies the surface layer down to 19 meters between January and May. This peculiar water mass originating from the Lamas River is located very close to the sampling area. The other one is the Atlantic water temporally intruding the area (Ozsoy et al., 1989). The latter, when occurring, is usually observed at depths between 50-80 meters while riverine input is confined to the near shore shallow waters. Figure 4.4 which shows the monthly salinity changes over the bottom, explains the occurrence depth and time of the both water masses. The surface layer observed until day 150 is the water mass influenced by the river water; and the intermediate layer observed around day 150 (June) and 210 (August) is the modified Atlantic water.

The second important parameter is the temperature (Table 3.28). Figure 4.7 summarizes the monthly temperature changes over the bottom. The most remarkable feature in the figure is the formation of the thermocline and the warming of the surface waters. The warming of the surface waters begins in April and progresses towards September. In October thermocline exceeds 70 meters. With the surface cooling in winter, the water column over the continental shelf is mixed up. A comparison of vertical abundance distribution of *M. barbatus* and the vertical temperature variations may indicate that this species can tolerate up to 27°C and they descent to cooler waters when the temperature exceeds the tolerance limit. Only after cooling they return to the surface waters.

In the study area the deepest trawl station where *M. barbatus* was observed was located at 220 meters depth. As also agreed by the local fishermen, this is the bathymetric limit of the species in the region. Although the GAM analysis suggested the least significance for depth among the explanatory variables, the bathymetric limit of the species is presented in the model outputs by wide confidence interval suddenly expanding below 200 meter depth (Figure 3.108). Maravelias et al. (2007) has observed a very similar bathymetric range in the Aegean Sea; however they attributed the limits to the temperature and stated that the highest abundance was found at bottom temperature around 19 °C and they avoid cold bottom waters below 16°C. The temperature has also a highly significant effect on the abundance of *M. barbatus* in the study area (Figure 3.107) and above 20 °C represents an steadily increasing positive effect. The negative impact below 20 °C may indicate that cold waters are not very much preferred by the species. The very broad confidence interval at even colder waters may signify avoidance at a temperature value very close to that suggested by Maravelias et al. (2007). Furthermore, as can be seen from the vertical temperature profiles at the deepest trawl station (Figure 4.6) the temperature at 200 meters depth is very close to 16 °C.

The combination of salinity and temperature preferences of *M. barbatus* (both mentioned and suggested by the GAM model also implies that modified Atlantic water (with 38.8-38.9 psu and 22°C) is a favorable for juveniles.

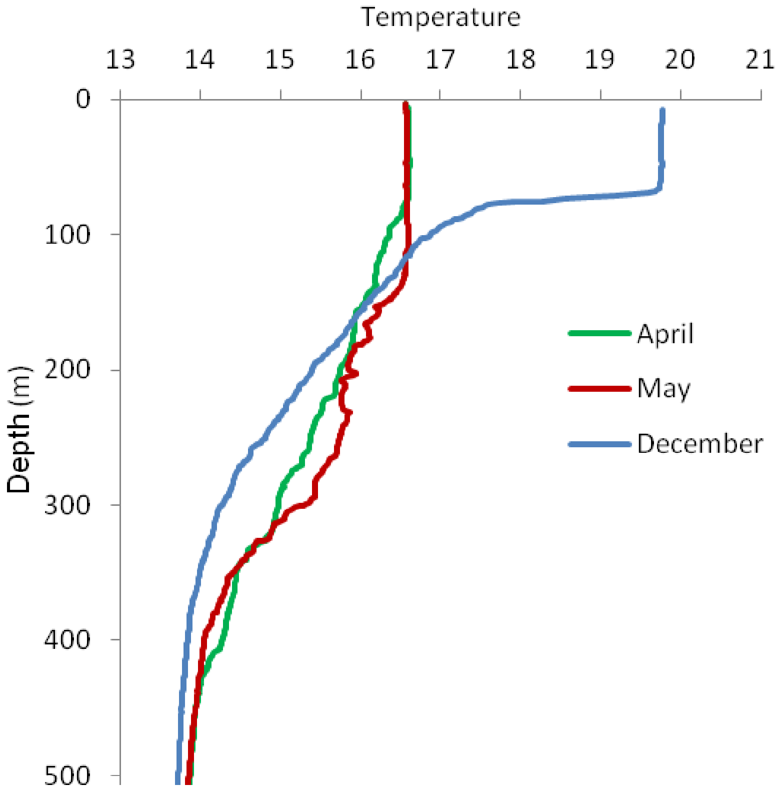


Figure 4.6. Temperature profiles at the deepest stations

M. barbatus prefer muddy and sandy bottoms, e.g. the regions with the highest availability of its food. *M. barbatus* and *M. surmuletus* showed spatial segregation in the western Mediterranean (Lombarte et al., 2000). According to results of the authors, *M. barbatus* shows a clear preference for the wider shelf areas, while *M. surmuletus* prefers narrow shelf areas with rocky or sandy bottoms. Besides, ecomorphological studies show that *M. barbatus* has the adaptive morphological and anatomical characteristics that allow it to use muddy and turbid bottoms better than its congeneric species, *M. surmuletus* (Lombarte and Aguirre, 1997). Machias and Labropoulou (2002) indicated that higher temperatures were preferred by small individuals, while larger fish were distributed over a wider temperature range. Authors also suggested that spawning occurs at 50–90 m depth during summer, and specimens move toward this depth to deeper waters.

An ontogenetic movement (after maturation) to deeper water might have the advantage of reducing inter-specific competition (Warburton and Blaber, 1992).

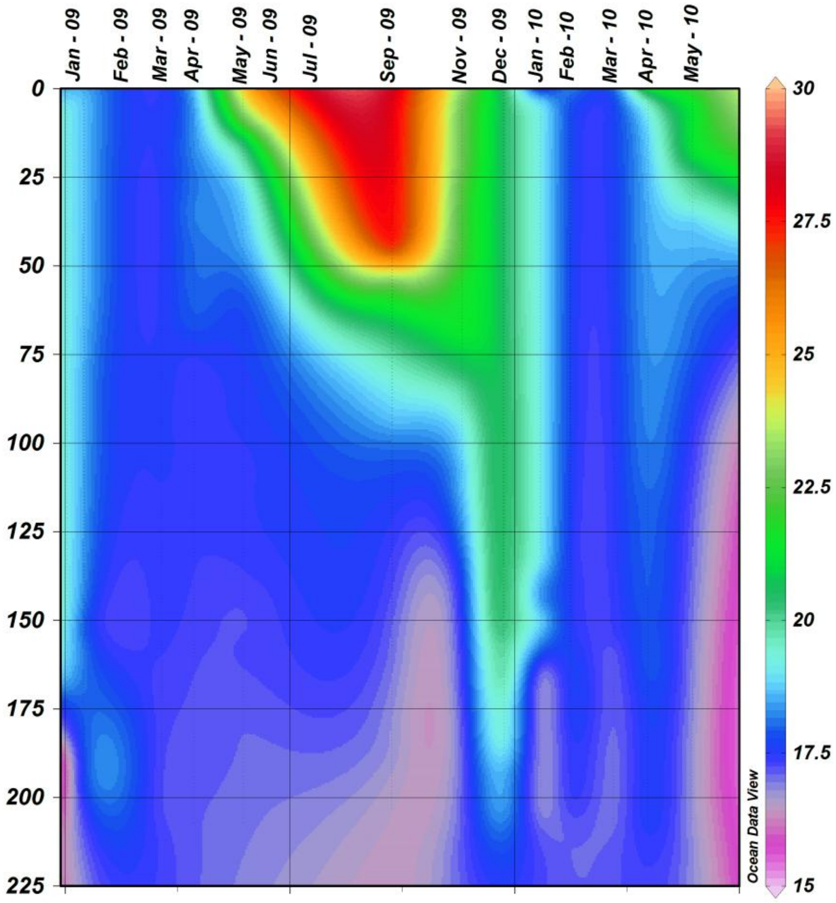


Figure 4.7. Time series of temperature variations over the sea bottom

4.7.3 Possible Outcomes of Temperature Increase on *M. barbatus* within the Context of Climate Change

Recalling the upper and lower limits of the ontogenetic bathymetry preference of *M. barbatus* are determined by summer surface temperature warmer than the tolerable limits and the bottom temperature lower than the bearable threshold, brings the possible effect of climate change on the species into question. The projections made by the experts of the Intergovernmental Panel on Climate Change (IPCC) of the scale of possible changes in temperature given by a climate model (multi-model data set, MMD) on three emission scenarios suggests that temperatures could rise by over 4°C by 2100 over the inland areas and by more than half of this over the Mediterranean Sea (Christensen et al., 2007) (Figure

4.8). As discussed before, the results of this study indicated that the *M. barbatus* and especially those at early life stages position themselves within the water column in a way to avoid excess conditions; by descending deeper when it is too warm at the surface and ascending when it is too cold at depths. As the results are considered a 2°C rise in the temperature would certainly affect the timing of the gonad development; which would occur earlier. It is hard to predict further consequences on the population however it could negatively influence the competition with the lessepsian mullids at the juvenile stage. The temperature rise would also taper the size of the distribution range of the species; since the excessively warm patch on the surface during summer that forces the *M. barbatus* move deeper, would be wider and deeper than today.

As far as the results of this study are concerned, another possible impact of temperature rise could be on the habitat partitioning. As Galil and Zenetos (2002) underlined before, the due re-colonization of the Mediterranean by Atlantic species after the Messinian crisis, present-day Levantine fauna is not truly representative of the hydrography of the region. The high temperature and salinity prevailing in the Levant made it unsuitable for many Atlantic-Mediterranean species. Many of the taxa present are believed to be at the limit of their ecological tolerance. The species which developed adaptations to fight against extreme conditions colonized in the Levant Sea. The temperature driven vertical movement is one of such adaptations and with further increase in the temperature would possibly leave this part of the Mediterranean even more vulnerable to further invasion by tropic oriented species.

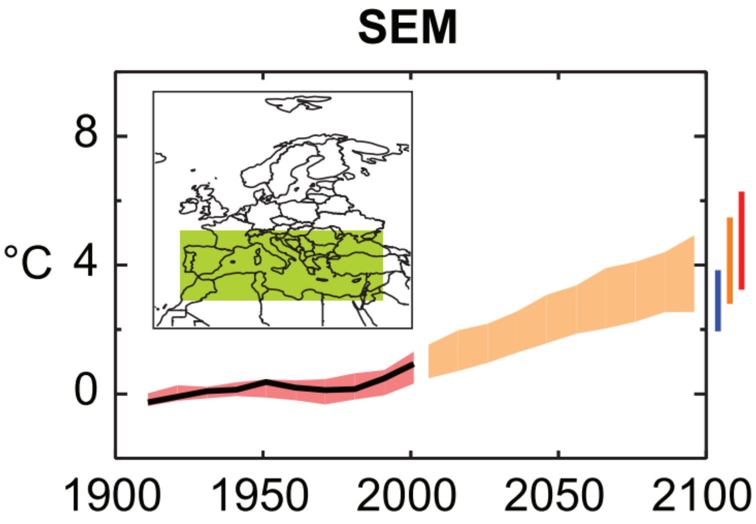


Figure 4.8. Temperature anomalies with respect to 1901 to 1950 for Mediterranean region for 1906 to 2005 (black line) and as simulated (red envelope) by multi-model data set models (MMD) incorporating known forcings; and as projected for 2001 to 2100 by MMD models for the IPCC-A1B scenario (balanced emphasis on all energy sources; orange envelope). The bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 under different scenarios (the B1 scenario (of a world more integrated, and more

ecologically friendly; blue bar), the A1B scenario (orange) and the A2 scenario (of a more divided world; red bar) (taken from Christensen et al., 2007).

The same ICCP report (Christensen et al., 2007) also projected that the annual precipitation is very likely to decrease in most of the Mediterranean area; the annual number of precipitation days is very likely to decrease in the Mediterranean area; and the risk of summer drought is likely to increase in the Mediterranean area. The ecologically optimum time and depth slot, in which *M. barbatus* accomplish its main biological needs to expand, is actually determined by food availability and temperature. Putting the temperature aside, the food availability of *M. barbatus* which mainly feeds on filter feeder polychaetes and molluscs, is determined indirectly by the organic matter carried into the shelf. The rain fall, therefore, has crucial effect and a decrease in the precipitation would certainly influence on the species. However it is hard at stage to predict whether competitors of *M. barbatus*, especially lessepsian mullids whose ecologically optimum window is opened towards summer would be more influenced by the summer droughts.

4.8 Limitations of the study

Generalized Additive Modeling

In general, models are inherently inexact and only approximate natural phenomena. The model description can be imperfect and/or our understanding of phenomenon may be incomplete. Parameters used in models to represent natural processes are often uncertain because they actually represent multiple processes. Statistical modelling tools are widely used in ecological studies to analyze relationships between the distributions and biology of species and their environment to predict species distributions across geographically extensive areas for conservation (e.g., Elith and Burgman, 2002) or resource management (e.g. Borchers et al., 1997). Such analyses are now widely used in terrestrial (e.g. Ferrier et al., 2002), freshwater (e.g. Olden and Jackson, 2001) and marine settings (e.g., Ysebaert et al., 2002). While the relationships between species and environmental variables are complex and often non-linear, earlier techniques such as generalized linear models (McCullagh and Nelder, 1989) were considered to be limited to explain these relationships (Austin et al., 1990). Various techniques are available in last years that allow more realistic description of these relationships. Generalized additive models (GAM, Hastie and Tibshirani, 1990) are perhaps one of the most widely used techniques, particularly in marine studies (e.g., Gregr and Trites, 2001). They provide a more flexible approach for analyzing non normal data when random effects are present. However, although their use of non-parametric smoothing functions allows flexible description of complex species responses to environment (Yee and Mitchell, 1991), their computational complexity makes cumbersome the generation of predictions for datasets. For example, GAM is described as a generalized linear model in which part of the linear predictor is specified as a sum of smooth functions of predictor variables. Finding suitable parametric representations for the smooth functions and controlling and choosing the degree of smoothness appropriately are the challenge and resulted in over and under estimate of degrees of the relationships between dependent and independent variables (Wood, 2006).

Interannual Variablity

It should be noted that the effect of temperature and salinity investigated in this study is based on CTD sampling carried out during the study. As given in the Appendices I and II, CTD sampling started a year after trawl sampling due to technical deficits. The gap is partly filled by the data collected in the other studies in the same area concurrently conducted. For the rest inter annual variability was disregarded and assumed that the bottom temperature does not change significantly from year to year. However there are some well reported evidences that the hydrography might change drastically by the existence of different water masses in the area. Although some of the main oceanographic features persist, the general circulation is subjected to remarkable inter annual variability (Ozsoy, et al., 1991 and 1993). A temporal and important variability is the geographical range achieved by the (modified) Atlantic Water (MAW). It is also reported that variability in the hydrography may have remarkable consequences on the species composition of fish assemblages (Gucu and Bingel, 2011). On the other hand, Sea Surface Temperature data collected from satellite (from Modis-Aqua 4km computed by using Giovanni online data system; Figure 4.9) did not show noticeable difference during the study period. Of course this is not necessarily proof that the surface layer perfectly represents the underlying water masses, particularly those lying below the thermocline.

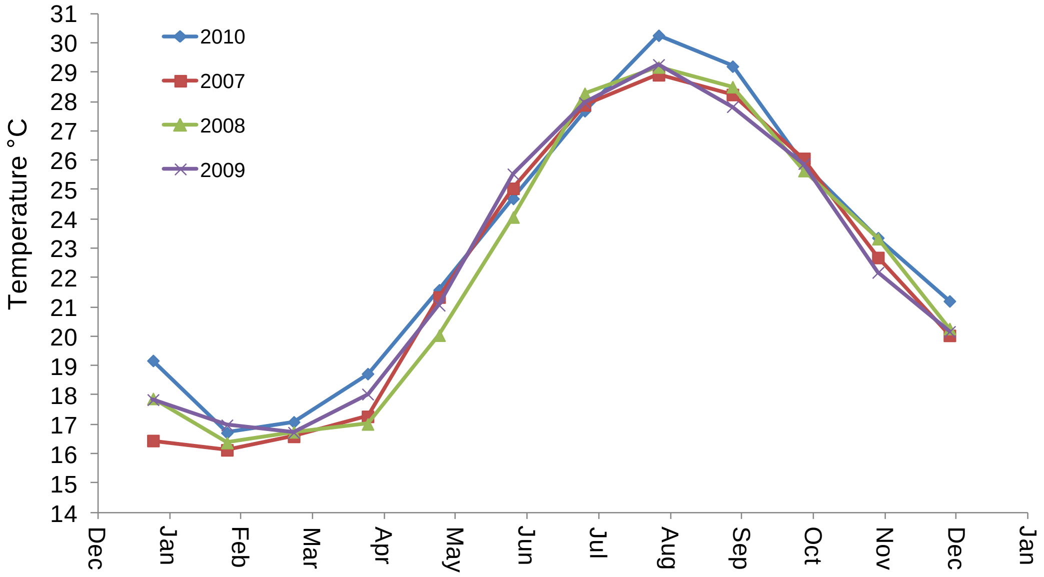


Figure 4.9. Monthly Sea Surface temperature variation (Modis-Aqua 4km) at the surface layer over the continental shelf in the study area (computed by using Giovanni online data system).

4.9 Implications to fisheries

M. barbatus is the target species of the trawl fleet and its stocks are heavily exploited since the 1980's (Gucu, 1995). However, very surprisingly, no significant reduction has been observed in the catch per unit effort of *M. barbatus* within last 30 years while several other species, which were once very abundant in the region, have declined severely (Gucu et al., 2010). One possible explanation for resilience of *M. barbatus* against heavy trawling pressure is possibly the perfection in the timing of biological activities and occupation of habitat. The models suggested that they make the best use of productivity as discussed before. Another possibility is the accordance between biologically active period and no trawling season. The time slot at which almost all biological requirements are accomplished or accelerated and when the main pulse of youngs (almost 74%) are recruited (Figure 3.7) are perfectly covered by the no-fishing season regulation enforced in the area. According to the fishing regulations applied in the region, demersal trawling is not allowed between mid April-May to mid- September. The lessening of fishing pressure over the *M. barbatus* stocks during the productive season enable species utilizes food that available through the food chain.

The result of this study indicated that the biological activities of all the other species are also concentrated on a certain period and that are within the trawl closed season. Therefore the fisheries regulations, particularly the time limits applied in the area are in favor of the species and should be continued within these time period.

It should be noted that there is a remarkable difference between species composition of landing statistics and species composition (order of abundance and frequency of occurrence) of this study. The reasons of this difference are due to the several factors: although several lessepsian species has long been exploited on commercial scale, not all of them are recorded separately in the Turkish landing statistics. Brushtooth lizardfish (*S. undosquamis*) and goldband goat fish (*U. moluccensis*) are the only two which are reported specifically in the statistics. Many others were combined with the native species; for example no distinction is made between *M. barbatus* and *U. pori*. Besides some species like *L. kluzingeri* (which form the 40% of the catch in this study) are discarded as they are not commercial for the fishing fleet so they are not registered officially as a catch so there is no information in the landing statistics.

Within the context of this study, length at first maturity (Lm) for each species was estimated to better understand and explain biology of each species. On the other hand, Lm is also useful tool for fish stock management. However, unless the status of stock is assessed which is beyond the research question of this study, this parameter alone should not be used for management purposes.

5 CONCLUSION

The flora and fauna characteristics of the Mediterranean Sea and particularly of its eastern half, is experiencing dramatic changes due to anthropogenic interferences and climate change. Tens of species from almost every taxonomic group drastically decline or disappear while tens of new ones appear. Some of the immigrants establish very successful colonies while some others just boom and bust. What controls the success of the species and what inhibits them is not known. There scientific literature is full of records reporting arrival of the new species, however there is only very little work concerning their impact on the other species and on the entire ecosystem. What is evident is that a new Mediterranean ecosystem is being shaped by the driving forces and the driver is the man. Therefore theoretically man can manipulate the any longer unstoppable process of metamorphosis from old to new Mediterranean ecosystem. However this utopic thought requires comprehensive understanding of the gears running the ecosystem. This work is a very humble attempt to serve this goal in a narrow perspective limited to time and area partitioning among the main demersal fishes occupying the continental shelf. The main instinct for a species is to survive and reproduce; therefore they are in continuous search for food to be utilized for synthesis of reproductive material. This thesis is concentrated on the annual patterns in the main energy allocation and utilization in some selected species. As the demersal fish assemblage occupying the soft bottoms over the continental shelf is characterized by *Mullus barbatus*, the emphasis was given to this species. Besides its importance in the assemblage, this species is a representative of the species enduring the changing conditions and withstanding its position against the pressure fostered by several new competitors.

The results points to a very strong seasonality in all biological functions dealt with in this study. Usually seasonality is associated with seasonal temperature variations. In this study temperature is found to be a significant factor for *M. barbatus*. It is the main factor determining vertical distribution of the species. The vertical distribution range is set by the high temperatures (>27 C) at the shallow depths during summer and the low temperatures on the shelf break zone (<16 C). However strong seasonality observed in the species did not show any relation to seasonal variations in the temperature. On the contrary, availability of utilizable energy in the environment (food) had a remarkable influence on the biological timing of the species. In the study area, which represents an oligotrophic sea; the primary production shows significant fluctuations which, in turn, induce the production in the next trophic levels. As the highest productivity is always reached in a few months in spring the species competing for the same food source are obliged to utilize the energy required to fulfill their biological activities within this short productive season. Those of which synchronize their needs in a way to fit to the ecologically optimum time window gain vital advantage over their competitors. *Mullus barbatus* seems to achieve this through a series of adaptations. These adaptations are; i) the energy taken during the productive season is used rapidly to develop their gonads while a part of the assimilated energy is also used for somatic growth and storage. Therefore when this short period is over, the individuals are spawned, well-conditioned and have enough reserves to survive in the rest of the year; ii) gonad development and spawning is tuned to the pulse of productivity and therefore the duration of gonad development and spawning is very short (one of the shortest reported in the literature); iii) some costly strategies, like batch spawning and secondary spawning, which are adapted by species elsewhere, are avoided to better allocate the energy; iv) very fast growth rate fueled by the reserved energy stored during productive season enables the YoY to attain larger size in a relatively short time.

In addition to the life history traits adopted by the species, there are some other factors providing advantages to the species. The fisheries regulations, particularly the time limits applied in the area are in favor of the species. The pre-recruits which tend to form dense nursery aggregations composed of small sized juveniles are extremely vulnerable to fishery. The YoY grow very fast (due to the reasons given just above) attain to enough size, leave the nursery aggregation, spread all over the fishing ground and so become less vulnerable to the fishery before the beginning of the fishing season.

The temperature at the surface rises during summer to extreme values above tolerable limits of the species during summer. The warming on the surface progresses towards the deep throughout the summer and forces the fishes to move deeper and abandon the shallow waters. This is the period when the recruits first appear on the fishing ground. On the other hand as the results indicated the occurrence of Atlantic Water in the area has a positive influence on *M. barbatus*, particularly on the recruits through either its low salinity or another factor associated with this water mass. The time of the occurrence of Atlantic water in the area and the bathymetric displacement of the juveniles driven by surface warming perfectly matches; so that the juveniles meet the Atlantic water mass.

In contrary to *M. barbatus*, another native species, *P. erythrinus*, formerly important for the area displayed differences in the adaptation developed to cope with the recent environmental and anthropogenic constraints. The cost of fast growth rate and strong seasonality, which are common strategies adopted by almost all species in the area, has been reduction in the first maturity size and the maximum size of *P. erythrinus*. Actually this is not an expensive cost for the species because the relatively high depth to length ratio (negative allometry) of its body reduces the minimum size of the individual retained in the nets, hence increases the vulnerability to fishery. By reducing the size of first maturity probability of reaching maturity before being caught, has increased.

Among the native components of the demersal fish assemblage *M. barbatus* seems to develop strategies to use environmental peculiarities of the region for its benefit and the successful exotic colonizers seems to use the time and space slot that *M. barbatus*, or generally speaking, the native species avoids. *L. suezensis* has adopted life history traits very similar to *M. barbatus.* This successful immigrant displays seasonality in growth even stronger than *M. barbatus* and it is biologically active during a narrower ecological window than that described for *M. barbatus*. The only difference which makes the species so successful may be that *L. suezensis* uses the shallow waters at the time slot during which *M. barbatus* is pushed towards deeper waters. Actually a similar strategy is used by the native species, such as *Lithognathus mormyrus*, which migrate to shallow depths over the thermocline during summer. However, this species did not show a sign of acceleration in the biological activities during this period.

U. pori, which is another successful colonizer, seems to use the space slot not preferred by *M. barbatus* rather than the time slot. In contrary to *L. suezensis*, the summer temperature at the shallow waters is apparently too high for the species to spawn. In addition to shallow water preference, another trait adopted by *U. pori* is the secondary spawners.

These traits listed above are typical characteristics of “r-selected” life history strategy and provides advantages to the species in question, during the rush to utilize the energy available for the ecosystem during the very narrow high productivity season. Moreover, some of the common features adopted by the species examined were explained within the “r-selected” context. For instance, a typical trait of this sort is increased fecundity. In all species examined (except for *L. suezensis*), a very significant variation in the sex ratios at size classes were observed and generally females attained to larger size, except for hermaphroditic protogynous *P. erythrinus*. This may be a strategy adopted by the species as the female fecundity exponentially increases with size and beyond a certain point there is no advantage to males accruing larger size. The other species, such as *P. erythrinus,* representing just the opposite in the size distribution of sexes due to their inherited genus characteristics, compensated their lost through secondary spawners. It was also found that secondary spawners in the population are a rewarding supplementary trait for the species which does not possess adaptations to utilize the energy during the high productivity season.

On the other hand the same trait may not be very successful for every species. There are not much piscivorous predators in the native demersal fish assemblage in the Mediterranean; therefore this formerly empty ecological niche has been filled by *S. undosquamis*. Despite its advantageous position in the ecosystem it was not as abundant as expected. It seems that in the case of this species small sized males escape through the meshes due to their slender body and therefore the fishing mortality over the sexes differs greatly altering the over-all sex ratio in the population. This, in turn, reduces the overall fecundity of the population.

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APPENDICES

Appendix 1: Number of trawl survey performed during the study period

#	Date	Starting Coordinates		Ending Coordinates		Depth	
1	9-May-2007	36°34.116’N	34°16.371’E	36°32.232’N	34°14.447’E	22.5	19.7
2	9-May-2007	36°32.985’N	34°17.521’E	36°31.513’N	34°15.106’E	70.8	75.3
3	9-May-2007	36°31.626’N	34°17.521’E	36°33.217’N	34°15.662’E	38.8	33.5
4	4-Jun-2007	36°34.286’N	34°16.542’E	36°32.451’N	34°14.575’E	21.0	12.7
5	4-Jun-2007	36°33.339’N	34°15.697’E	36°32.320’N	34°14.867’E	29.6	45.3
6	4-Jun-2007	36°32.307’N	34°15.352’E	36°33.168’N	34°16.455’E	60.0	55.4
7	5-Jul-2007	36°32.677’N	34°14.712’E	36°33.668’N	34°15.472’E	16.3	13.2
8	5-Jul-2007	36°31.673’N	34°16.077’E	36°30.696’N	34°15.221’E	80.6	88.6
9	5-Jul-2007	36°32.092’N	34°14.400’E	36°33.067’N	34°15.395’E	28.0	30.1
10	2-Aug-2007	36°32.624’N	34°14.780’E	36°33.635’N	34°15.477’E	23.3	14.8
11	2-Aug-2007	36°32.728’N	34°15.248’E	36°33.547’N	34°16.042’E	38.8	31.2
12	2-Aug-2007	36°32.244’N	34°15.658’E	36°33.108’N	34°16.539’E	64.8	58.0
13	18-Sep-2007	36°32.520’N	34°14.966’E	36°33.514’N	34°15.623’E	37.1	22.5
14	18-Sep-2007	36°33.189’N	34°17.241’E	36°32.388’N	34°16.326’E	60.2	69.0
15	18-Sep-2007	36°32.261’N	34°14.431’E	36°33.317’N	34°15.119’E	14.8	12.1
16	17-Oct-2007	36°33.292’N	34°15.940’E	36°32.451’N	34°14.984’E	37.6	42.1
17	17-Oct-2007	36°32.144’N	34°15.962’E	36°31.004’N	34°15.089’E	70.4	82.9
18	17-Oct-2007	36°32.238’N	34°14.426’E	36°33.059’N	34°15.107’E	15.8	21.3
19	22-Nov-2007	36°32.330’N	34°14.670’E	36°33.240’N	34°15.720’E	31.0	31.4
20	22-Nov-2007	36°34.090’N	34°15.940’E	36°33.050’N	34°14.950’E	13.0	13.7
21	22-Nov-2007	36°32.880’N	34°15.980’E	36°33.730’N	34°17.680’E	55.0	63.0
22	18-Dec-2007	36°31.179’N	34°13.193’E	36°34.235’N	34°16.999’E	9.4	9.0
23	18-Dec-2007	36°33.249’N	34°15.334’E	36°34.110’N	34°16.706’E	29.5	28.0
24	18-Dec-2007	36°33.586’N	34°16.662’E	36°32.617’N	34°15.553’E	45.1	54.8
25	29-Jan-2008	36°33.936’N	34°15.911’E	36°32.943’N	34°15.095’E	16.2	22.8
26	29-Jan-2008	36°32.910’N	34°15.369’E	36°31.889’N	34°14.557’E	33.2	51.2
27	29-Jan-2008	36°31.998’N	34°14.900’E	36°32.775’N	34°16.266’E	58.5	60.3
28	27-Feb-2008	36°32.827’N	34°14.852’E	36°33.655’N	34°15.647’E	15.0	17.7
29	27-Feb-2008	36°33.048’N	34°15.458’E	36°32.000’N	34°14.718’E	31.3	53.2
30	27-Feb-2008	36°31.764’N	34°14.831’E	36°32.084’N	34°16.445’E	62.1	76.0
31	1-Apr-2008	36°33.350’N	34°15.239’E	36°33.937’N	34°16.267’E	14.6	23.5
32	1-Apr-2008	36°33.578’N	34°16.163’E	36°32.755’N	34°15.292’E	32.1	38.0
33	1-Apr-2008	36°31.504’N	34°14.453’E	36°32.176’N	34°15.597’E	60.8	64.4
34	6-May-2008	36°34.237’N	34°16.055’E	36°33.216’N	34°15.005’E	11.1	10.1
35	6-May-2008	36°33.439’N	34°15.799’E	36°32.339’N	34°14.828’E	28.7	40.6

36	6-May-2008	36°32.099’N	34°14.753’E	36°32.987’N	34°16.004’E	51.3	52.5
37	25-Jun-2008	36°32.556’N	34°16.396’E	36°31.692’N	34°15.575’E	65.4	74.0
38	26-Jun-2008	36°34.385’N	34°16.479’E	36°33.472’N	34°15.430’E	15.1	17.1
39	26-Jun-2008	36°32.472’N	34°15.036’E	36°33.277’N	34°16.258’E	36.5	45.7
40	9-Jul-2008	36°34.077’N	34°16.229’E	36°33.157’N	34°15.173’E	18.4	19.0
41	9-Jul-2008	36°33.024’N	34°15.520’E	36°33.819’N	34°16.610’E	33.6	33.2
42	9-Jul-2008	36°32.049’N	34°15.564’E	36°32.713’N	34°16.748’E	66.9	65.8
43	18-Dec-2008	36°33.645’N	34°16.409’E	36°32.803’N	34°15.332’E	37.0	38.5
44	18-Dec-2008	36°31.953’N	34°15.061’E	36°32.754’N	34°16.201’E	63.5	61.8
45	18-Dec-2008	36°32.086’N	34°14.295’E	36°33.222’N	34°15.036’E	14.2	12.0
46	19-Dec-2008	36°31.905’N	34°21.585’E	36°30.409’N	34°20.262’E	118.0	133.5
47	2-Jan-2009	36°29.976’N	34°29.580’E	36°27.553’N	34°26.953’E	206.0	224.0
48	2-Jan-2009	36°27.216’N	34°25.614’E	36°26.550’N	34°22.895’E	224.0	218.0
49	14-Jan-2009	36°33.567’N	34°16.404’E	36°32.725’N	34°15.236’E	39.7	38.7
50	14-Jan-2009	36°31.902’N	34°14.151’E	36°32.816’N	34°14.797’E	18.6	15.6
51	14-Jan-2009	36°33.387’N	34°17.386’E	36°32.859’N	34°16.040’E	62.2	57.2
52	15-Jan-2009	36°32.049’N	34°17.249’E	36°31.350’N	34°16.023’E	84.4	85.9
53	15-Jan-2009	36°28.901’N	34°28.677’E	36°28.987’N	34°25.839’E	210.0	196.6
54	16-Jan-2009	36°30.787’N	34°24.944’E	36°29.535’N	34°22.561’E	160.0	169.0
55	18-Feb-2009	36°33.270’N	34°16.372’E	36°32.273’N	34°15.366’E	28.5	33.9
56	18-Feb-2009	36°31.993’N	34°14.414’E	36°33.034’N	34°15.183’E	20.5	14.1
57	18-Feb-2009	36°31.861’N	34°19.830’E	36°31.256’N	34°18.396’E	58.7	57.3
58	18-Feb-2009	36°29.596’N	34°22.108’E	36°29.081’N	34°20.636’E	90.7	84.4
59	23-Feb-2009	36°27.408’N	34°24.032’E	36°26.608’N	34°21.162’E	215.0	209.0
60	18-Feb-2009	36°29.198’N	34°18.252’E	36°31.401’N	34°19.228’E	138.2	108.8
61	18-Mar-2009	36°34.065’N	34°16.754’E	36°33.293’N	34°15.634’E	31.2	29.4
62	18-Mar-2009	36°33.147’N	34°16.840’E	36°32.476’N	34°15.528’E	61.6	59.0
63	18-Mar-2009	36°32.962’N	34°14.958’E	36°33.976’N	34°15.699’E	18.9	10.1
64	19-Mar-2009	36°31.549’N	34°17.291’E	36°30.717’N	34°16.187’E	91.5	93.8
65	19-Mar-2009	36°30.289’N	34°19.142’E	36°30.496’N	34°21.181’E	126.6	140.0
66	20-Mar-2009	36°27.363’N	34°25.688’E	36°26.900’N	34°22.976’E	221.0	214.0
67	14-Apr-2009	36°17.834’N	34°29.581’E	36°16.249’N	34°27.574’E	390.0	460.0
68	16-Apr-2009	36°36.200’N	34°36.518’E	36°35.865’N	34°34.960’E	91.0	96.0
69	16-Apr-2009	36°31.337’N	34°34.731’E	36°30.863’N	34°32.309’E	163.9	175.6
70	16-Apr-2009	36°28.304’N	34°31.042’E	36°28.608’N	34°27.888’E	218.1	209.9
71	17-Apr-2009	36°33.847’N	34°16.392’E	36°32.896’N	34°15.351’E	30.5	35.1
72	17-Apr-2009	36°32.018’N	34°14.898’E	36°32.847’N	34°16.111’E	59.5	58.6
73	17-Apr-2009	36°34.202’N	34°16.260’E	36°33.320’N	34°15.206’E	17.9	16.2
74	18-May-2009	36°33.585’N	34°16.099’E	36°32.692’N	34°15.061’E	31.7	32.7

75	18-May-2009	36°33.039’N	34°14.877’E	36°33.999’N	34°15.730’E	11.3	10.3
76	18-May-2009	36°33.079’N	34°17.121’E	36°32.253’N	34°15.965’E	65.8	69.1
77	20-May-2009	36°29.603’N	34°20.209’E	36°30.706’N	34°20.972’E	148.6	133.9
78	25-May-2009	36°15.362’N	34°20.388’E	36°15.433’N	34°17.567’E	592.0	435.0
79	26-May-2009	36°33.015’N	34°21.850’E	36°32.694’N	34°20.423’E	105.0	99.1
80	26-May-2009	36°33.792’N	34°17.671’E	36°32.601’N	34°15.864’E	57.1	60.49
81	1-Jun-2009	36°28.280’N	34°19.684’E	36°27.520’N	34°18.437’E	167.6	170.3
82	17-Jun-2009	36°39.412’N	34°26.709’E	36°38.614’N	34°25.383’E	39.7	37.6
83	17-Jun-2009	36°34.485’N	34°19.435’E	36°33.904’N	34°17.984’E	61.0	58.0
84	17-Jun-2009	36°34.394’N	34°16.654’E	36°33.601’N	34°15.266’E	19.8	6.7
85	23-Jul-2009	36°33.455’N	34°15.769’E	36°33.118’N	34°15.374’E	27.7	27.4
86	23-Jul-2009	36°31.745’N	34°14.568’E	36°32.689’N	34°15.646’E	58.3	54.3
87	23-Jul-2009	36°33.644’N	34°15.565’E	36°32.666’N	34°14.610’E	17.8	10.8
88	24-Jul-2009	36°29.270’N	34°19.513’E	36°28.553’N	34°18.197’E	148.0	148.1
89	24-Jul-2009	36°29.775’N	34°13.917’E	36°31.019’N	34°14.800’E	88.7	78.5
90	2-Sep-2009	36°33.518’N	34°18.129’E	36°32.792’N	34°16.627’E	66.3	64.6
91	2-Sep-2009	36°32.561’N	34°19.222’E	36°31.904’N	34°17.809’E	90.0	90.0
92	2-Sep-2009	36°33.944’N	34°16.880’E	36°33.145’N	34°15.553’E	36.3	31.8
93	3-Sep-2009	36°33.980’N	34°15.891’E	36°32.909’N	34°14.803’E	16.1	12.8
94	23-Sep-2009	36°26.422’N	34°19.621’E	36°25.105’N	34°16.744’E	204.5	202.1
95	23-Sep-2009	36°26.414’N	34°14.968’E	36°27.897’N	34°17.277’E	154.0	153.0
96	23-Sep-2009	36°30.056’N	34°14.308’E	36°30.972’N	34°15.535’E	90.5	90.0
97	24-Sep-2009	36°33.040’N	34°17.166’E	36°33.765’N	34°18.611’E	66.0	65.8
98	24-Sep-2009	36°34.720’N	34°18.277’E	36°34.044’N	34°16.990’E	37.7	35.0
99	24-Sep-2009	36°32.507’N	34°14.609’E	36°33.628’N	34°15.428’E	17.6	13.2
100	19-Nov-2009	36°26.272’N	34°20.377’E	36°25.020’N	34°17.350’E	213.0	210.0
101	19-Nov-2009	36°26.903’N	34°15.663’E	36°27.648’N	34°17.127’E	153.7	153.0
102	19-Nov-2009	36°30.426’N	34°15.709’E	36°31.182’N	34°17.197’E	95.0	96.0
103	20-Nov-2009	36°32.578’N	34°16.600’E	36°33.389’N	34°17.838’E	69.0	66.0
104	20-Nov-2009	36°32.803’N	34°15.636’E	36°31.967’N	34°14.386’E	39.0	36.0
105	20-Nov-2009	36°32.668’N	34°14.649’E	36°33.897’N	34°15.679’E	13.0	13.0
106	21-Dec-2009	36°33.930’N	34°16.837’E	36°33.030’N	34°15.411’E	36.6	32.0
107	21-Dec-2009	36°33.891’N	34°15.740’E	36°32.681’N	34°14.674’E	14.6	14.0
108	22-Dec-2009	36°33.813’N	34°18.909’E	36°33.110’N	34°17.465’E	67.5	67.0
109	22-Dec-2009	36°31.527’N	34°27.012’E	36°31.034’N	34°25.349’E	157.0	154.0
110	22-Dec-2009	36°34.975’N	34°24.597’E	36°34.555’N	34°22.913’E	92.7	91.0
111	23-Dec-2009	36°25.557’N	34°18.793’E	36°24.337’N	34°15.872’E	212.0	206.0
112	23-Dec-2009	36°16.884’N	34°22.616’E	36°17.770’N	34°24.598’E	618.0	467.0
113	20-Jan-2010	36°33.560’N	34°18.000’E	36°32.758’N	34°16.550’E	65.0	65.0

114	20-Jan-2010	36°34.159’N	34°17.215’E	36°33.217’N	34°15.733’E	37.0	35.0
115	20-Jan-2010	36°31.472’N	34°17.166’E	36°30.760’N	34°15.591’E	92.0	91.0
116	20-Jan-2010	36°32.507’N	34°14.564’E	36°33.681’N	34°15.594’E	12.7	13.0
117	22-Jan-2010	36°27.312’N	34°22.360’E	36°26.186’N	34°19.539’E	207.0	206.0
118	22-Jan-2010	36°30.227’N	34°22.143’E	36°30.510’N	34°23.568’E	153.0	156.0
119	15-Feb-2010	36°33.197’N	34°17.760’E	36°33.963’N	34°19.146’E	69.3	67.1
120	15-Feb-2010	36°28.190’N	34°24.859’E	36°27.004’N	34°21.932’E	205.6	207.2
121	15-Feb-2010	36°31.302’N	34°25.274’E	36°31.551’N	34°26.771’E	151.0	154.5
122	16-Feb-2010	36°33.290’N	34°16.128’E	36°32.341’N	34°14.753’E	44.0	36.8
123	16-Feb-2010	36°31.873’N	34°18.325’E	36°31.342’N	34°16.653’E	94.0	90.8
124	16-Feb-2010	36°33.972’N	34°15.796’E	36°34.921’N	34°17.257’E	14.0	15.0
125	22-Mar-2010	36°27.509’N	34°23.987’E	36°26.798’N	34°20.851’E	210.0	203.0
126	22-Mar-2010	36°29.238’N	34°19.798’E	36°29.596’N	34°21.451’E	159	159.5
127	22-Mar-2010	36°32.637’N	34°19.670’E	36°32.049’N	34°18.131’E	92.7	90.0
128	23-Mar-2010	36°33.294’N	34°17.849’E	36°32.548’N	34°16.339’E	68.0	67.2
129	23-Mar-2010	36°33.580’N	34°16.295’E	36°34.395’N	34°17.601’E	36.2	36.2
130	23-Mar-2010	36°34.750’N	34°17.060’E	36°33.955’N	34°15.804’E	16.8	14.4
131	19-Apr-2010	36°27.435’N	34°23.539’E	36°26.953’N	34°20.389’E	209.0	196.8
132	19-Apr-2010	36°29.990’N	34°21.496’E	36°30.973’N	34°22.583’E	151.0	140.4
133	19-Apr-2010	36°33.130’N	34°20.477’E	36°33.594’N	34°22.006’E	91.4	96.3
134	20- Apr-2010	36°33.509’N	34°18.267’E	36°34.167’N	34°19.462’E	68.0	65.0
135	20- Apr-2010	36°35.063’N	34°18.746’E	36°34.235’N	34°17.340’E	35.7	36.3
136	20- Apr-2010	36°34.5700’N	34°16.746’E	36°33.695’N	34°15.493’E	16.4	13.2
137	17-May-2010	36°33.722’N	34°16.493’E	36°34.506’N	34°17.757’E	36.2	35.6
138	17-May-2010	36°34.973’N	34°17.372’E	36°34.195’N	34°16.094’E	15.8	14.6
139	18-May-2010	36°33.959’N	34°18.437’E	36°33.141’N	34°17.148’E	62.2	64.5
140	20-May-2010	36°33.305’N	34°21.190’E	36°32.681’N	34°19.671’E	94.8	92.0
141	25-May-2010	36°28.117’N	34°25.343’E	36°27.360’N	34°22.389’E	211.0	206.0
142	25-May-2010	36°29.008’N	34°19.544’E	36°29.596’N	34°20.998’E	154.0	156.0

Appendix 2: Summary of CTD probe sampling performed during the study period

#	Date	Time	Latitude	Longitude	Depth
1	19-Dec-2008	11:00	36°30.409’N	34°20.262’E	110.0
2	2-Jan-2009	11:00	36°29.546’N	34°30.251’E	200.0
3	15-Jan-2009	12:30	36°28.902’N	34°29.009’E	215.0
4	16-Jan-2009	10:55	36°31.199’N	34°25.612’E	155.0
5	20-Mar-2009	11:20	36°28.055’N	34°26.248’E	205.0
6	15-Apr-2009	10:40	36°27.461’N	34°25.248’E	220.0
7	25-May-2009	15:30	36°624.23’N	34°17.197’E	225.5
8	1-Jun-2009	15:44	36°28.852’N	34°16.947’E	131.0
9	17-Jun-2009	10:12	36°43.837’N	34°33.676’E	22.2
10	17-Jun-2009	12:09	36°38.616’N	34°24.979’E	29.0
11	24-Jul-2009	9:32	36°31.308’N	34°419.04’E	107.8
12	2-Sep-2009	11:57	36°632.77’N	34°16.329’E	62.0
13	2-Sep-2009	13:25	36°31.904’N	34°17.809’E	85.0
14	3-Sep-2009	8:30	36°32.909’N	34°14.803’E	12.0
15	3-Sep-2009	8:40	36°32.625’N	34°15.106’E	38.0
16	23-Sep-2009	12:45	36°24.802’N	34°16.625’E	207.0
17	23-Sep-2009	14:55	36°27.683’N	34°17.275’E	157.0
18	23-Sep-2009	16:38	36°3631.1’N	34°15.448’E	86.0
19	24-Sep-2009	11:05	36°33.991’N	34°18.716’E	63.0
20	24-Sep-2009	12:15	36°33.948’N	34°16.988’E	38.9
21	24-Sep-2009	15:50	36°33.862’N	34°15.713’E	15.0
22	19-Nov-2009	11:27	36°24.836’N	34°16.893’E	208.0
23	19-Nov-2009	11:55	36°26.258’N	34°15.034’E	157.8
24	19-Nov-2009	13:30	36°30.112’N	34°15.429’E	96.0
25	20-Nov-2009	10:08	36°33.448’N	34°17.905’E	65.7
26	20-Nov-2009	11:24	36°31.878’N	34°14.351’E	40.5
27	20-Nov-2009	14:18	36°33.897’N	34°15.679’E	16.0
28	21-Dec-2009	11:40	36°32.796’N	34°415.31’E	38.6
29	21-Dec-2009	13:10	36°32.415’N	34°14.576’E	22.7
30	22-Dec-2009	10:13	36°633.16’N	34°17.283’E	65.5
31	22-Dec-2009	11:31	36°31.808’N	34°27.853’E	154.0
32	22-Dec-2009	13:12	36°35.146’N	34°25.061’E	93.0
33	23-Dec-2009	11:30	36°624.18’N	34°415.77’E	206.0
34	20-Jan-2010	10:25	36°632.62’N	34°16.461’E	67.0
35	20-Jan-2010	10:50	36°34.352’N	34°17.514’E	36.0
36	20-Jan-2010	13:46	36°31.624’N	34°17.599’E	93.0
37	20-Jan-2010	15:42	36°33.782’N	34°415.72’E	18.0

38	22-Jan-2010	10:16	36°27.914’N	34°23.319’E	202.0
39	22-Jan-2010	10:35	36°27.312’N	34°422.36’E	155.0
40	15-Feb-2010	9:40	36°33.035’N	34°17.257’E	67.7
41	15-Feb-2010	11:40	36°28.562’N	34°25.688’E	202.4
42	15-Feb-2010	14:00	36°30.533’N	34°23.301’E	155.0
43	15-Feb-2010	15:56	36°33.245’N	34°21.048’E	95.0
44	15-Feb-2010	16:30	36°33.788’N	34°16.661’E	39.0
45	15-Feb-2010	16:45	36°33.879’N	34°15.755’E	16.0
46	22-Mar-2010	10:19	36°28.136’N	34°24.656’E	204.0
47	22-Mar-2010	12:31	36°28.826’N	34°19.437’E	156.0
48	22-Mar-2010	14:10	36°32.954’N	34°20.291’E	93.7
49	23-Mar-2010	9:10	36°33.475’N	34°18.049’E	66.9
50	23-Mar-2010	10:19	36°633.43’N	34°16.158’E	38.0
51	23-Mar-2010	12:30	36°3635.1’N	34°17.691’E	16.5
52	19-Apr-2010	9:47	36°27989’N	34°24.292’E	205
53	19-Apr-2010	12:08	36°29.679’N	34°20.865’E	151.9
54	19-Apr-2010	13:53	36°32.743’N	34°19.991’E	93.9
55	20-Apr-2010	9:05	36°33.347’N	34°17.759’E	66.6
56	20-Apr-2010	10:08	36°35.310’N	34°19.287’E	36.2
57	20-Apr-2010	11:03	36°34.660’N	34°16.964’E	17.8
58	17-May-2010	9:06	36°33.521’N	34°16.266’E	36.3
59	17-May-2010	10:05	36°35.114’N	34°17.62’E	14.1
60	18-May-2010	10:13	36°32.991’N	34°17.132’E	67.0
61	20-May-2010	9:45	36°33.875’N	34°20.342’E	96.0
62	25-May-2010	10:21	36°28.670’N	34°26.100’E	204.0
63	25-May-2010	12:27	36°28.709’N	34°19.401’E	156.0

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Ok, Meltem
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Marital Status: Single
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Languages: Turkish (Native), English (Advance)
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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU Institute of Marine Sciences	2006
BS	Ege University, Faculty of Fisheries	2002
High School	Deneme High School, Ankara	1996

WORK EXPERIENCE AND PROJECTS INVOLVED

2011 –2012	Project Assistant, Stock Assessment Of Black Sea Anchovy Using Acoustic Method And Establishing A Monitoring Model For National Fisheries Data Collection Program
2012	Project Assistant, Viability assessment of northeastern Mediterranean Monk seal (*Monachus monachus*) population (TBAG-111T681, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin, Turkey.
2008 – 2012	Project Assistant, Investigations on the changes in small pelagic fish stocks of the northeastern Mediterranean. (TOVAG-108O566, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin, Turkey.
2007 – 2008	Project Assistant, Mediterranean Monk Seal Research Project on habitats of Mediterranean Monk Seals in Antalya-Ucadalar (TBAG-107T598, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin, Turkey.
2007 – 2008	Project Assistant, Monitoring the changes in demersal fish stocks of the northeastern Mediterranean. (Scientific Research Project of METU-2007-07-01-01). METU/IMS, Mersin, Turkey.

2007 – 2008	Project Assistant, SESAME (Southern European Seas: Assessing and Modelling Ecosystem changes) Integrated Project supported by the European Commission's Sixth Framework Programme, Sustainable Development, Global Change and Ecosystems.
2007 – 2008	Project Assistant, Promoting Mediterranean Monk Seal Friendly Traditional Fishing in Samandag (Hatay) (TUR/SGP/OP3/07/2/08, supported by United Nations Development Program (UNDP) The Global Environment Facility/Small Grants Program (GEF/SGP)). Levant Nature Conservation Society, Mersin, Turkey.
2006 – 2007	Project Assistant, Mediterranean Monk Seal Research Project in Northern Cyprus (YDABAG-106T166, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin, Turkey.
2006 – 2007	Project Assistant, Sea-friendly fishing in Antakya-Samandag Meydan Village (Supported by United Nations Development Program (UNDP), BTC Environmental Investment Program, Small Investments Fund Project). Levant Nature Conservation Society, Mersin, Turkey.
2005 – 2006	Project Assistant, Investigations on the reasons of absence of *Posidonia oceanica* meadows in Levant Sea (Eastern Mediterranean) (CAYDAG-105Y023, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin,Turkey.
2004 – 2005	Project Assistant, Investigations on the changing impacts on Kizilliman Marine Protected Area and responses of the ecosystem (YDABAG-104Y028, supported by The Scientific and Technological Research Council of Turkey). METU/IMS, Mersin, Turkey.
2003 – 2005	Project Assistant, Mediterranean monk seal research project in Gulf of Iskenderun, Turkey (supported by BTC Co. - Environmental Investment Program). METU/IMS, Mersin, Turkey.

INSTRUMENTAL SKILLS AND COMPUTER EXPERTISE

SBE 19*plus* SEACAT Oceanographic CTD Profiler, Scientific purposed trawling, scientific scuba diving, Vigil P-Box infrared wildlife monitoring system, Bushnell wildlife monitoring systems. Advance knowledge of Microsoft Office package (i.e. MS Word, MS Excel, MS Access, MS PowerPoint) and Adobe Acrobat Applications. Knowledge of Surfer 8, Grapher

8, Ocean Data View 4, CorelDraw Graphic Suite 14, FISAT II, FishStat Plus, Statistica 8, Brodgar V2.6.6, Biodiversity Pro, SBE Data Processing 7, Photomodeler 5.

AWARDS

- Best Student Poster Presentation award in 22nd Annual Conference of European Cetacean Society, 10-12 March 2008 Egmond Aan Zee, Netherlands.

- Travel grant in 22nd Annual Conference of European Cetacean Society, 10-12 March 2008 Egmond Aan Zee, Netherlands.

- Full grant for the attendance of the Sixth European Seminar on Marine Mammals: Biology and Conservation organized by University of Valencia, 11-15 September 2006, Valencia, Spain.

RESEARCH CRUISE PARTICIPATION

Date	Vessel	Location	Total Duration (days)
Sep 2003 – Sep 2012	*R/V Lamas-1*	Mediterranean Sea	240 (62 cruises)
Sep 2008 – Sep 2012	*R/V Bilim-2*	Black Sea	45 (3 cruises)
May 2008 – Sep 2012	*R/V Bilim-2*	Mediterranean Sea	32 (8 cruises)

PUBLICATIONS

Peer Reviewed

Ok M., and Gucu A.C., 2012 (in prep). Reproductive cycle, condition and energy allocation of Red Mullet *Mullus barbatus* (Linnaeus, 1758) in relation to the environmental variables and depth in the northern Levantine basin.

Gucu, A.C, **Ok, M.** and Sakınan, S. 2010. Past and present of fish fauna in the NE Levant Sea and factor facilitating the colonization by Lessepsian fishes. EastMed Report of the Sub-Regional Technical meeting on the Lessepsian migration and its impact on Eastern Mediterranean fishery. GCP/INT/041/EC – GRE – ITA/TD-04, pp. 88-108.

Gucu A.C, **Ok M.,** and Sakinan S., 2009. A survey of the critically endangered Mediterranean monk seal, *Monachus monachus* (Hermann, 1779) along the coast of Northern Cyprus. Israel Journal of Ecology & Evolution, Vol. 55, 2009, pp. 77–82.

Gucu A.C, Sakinan S. and **Ok M.,** 2009. Occurrence of the Critically endangered Mediterranean Monk Seal, *Monachus monachus*, at Olympos-Beydağları National Park, Turkey (Mammalia:Phocidae). Zoology in the Middle East, Vol. 46, 2009, pp. 3–8.

Ok M., 2006. Past, Present Status and Future of The Mediterranean Monk Seal (*Monachus monachus*, Hermann 1779) in The Northeastern Mediterranean. M.Sc. Thesis, METU Institute of Marine Sciences, Mersin-Turkey, September 2006. 114p. (Thesis Supervisor: Assoc. Prof. Ali Cemal Gucu).

Celebi B., Gucu A.C., **Ok M.,** Sakinan S., and Akoglu E., 2006. Hydrographic indications to understand the absence of *Posidonia oceanica* in the Levant Sea (Eastern Mediterranean). Proceedings of the Mediterranean Seagrass Workshop 2006, Malta, Biologia Marina Mediterranea, 13 (4) p: 34-38.

OK M., 2002. Population status of the critically endangered Nile soft shelled turtle (*Trionyx triunguis* Forskål, 1775) along the Mersin coast. B.Sc. Thesis, Ege University Faculty of Fisheries, Izmir-Turkey, June 2002. (Thesis Supervisor: Prof. Dr. Ertan Taskavak).

Non-Reviewed

Gucu A.C., Erbil E., **Ok M.,** Sakinan S., Celebi B., 2007. Pup Rescue in Samandag. The Monachus Guardian Vol. 10 (1): June 2007.

Ok, M. and Gucu, A.C., 2006. To what extent can the Cilician monk seal colony recover under existing regulations? The Monachus Guardian Vol. 9 (2): November 2006.

Gucu, A.C., **Ok, M.,** Sakinan, S., Celebi, B., Akoglu, E., 2006. Seals of Northern Cyprus. The Monachus Guardian Vol. 9 (2): November 2006.

Gucu A.C. and **Ok M.,** 2004. Arab the Pilgrim. The Monachus Guardian Vol. 7 (1): June 2004.

Gucu A.C., **Ok M.** and Örek H., 2003. Seeking Answers In The Gulf of Iskenderun: Do Eastern Mediterranean Monk Seals Migrate?. The Monachus Guardian Vol. 6 (2): December 2003.