CHANGES IN THE BIOLOGY AND THE PRODUCTION OF *MELICERTUS KERATHURUS*: THE CASE STUDY IN AMVRAKIKOS GULF (WESTERN GREECE)

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Summary

The paper presents the results of a review of scientific information regarding the biological and population data on the species *Melicertus kerathurus* in Amvrakikos Gulf (Western Greece). The existing historical data indicate significant changes in the state of the population which are attributed to the environmental degradation of the gulf mainly due to agriculture, overfishing and illegal fishing.

Introduction

The shrimp Melicertus kerathurus is a species with high commercial value in the North Mediterranean region and mainly in Italy and Greece. Despite the excellent climatic conditions, coastal fish and shrimp are considered to be poor in condition and largely affected by over-fishing, fishing with illegal methods and pollution.
In Greece the species can be found in Amvrakikos Gulf (Western Greece). Smaller populations inadequate to support a target fishery can be found along the Ionion Sea coast of Greece and the North Aegean Sea (from the Gulf of Thermaikos to Alexandroupolis). It is commonly accepted that scientific knowledge of the coastal ecosystems is still limited. Additionally, there are no reliable data regarding the fish and shrimp yields in most lagoons, especially in the case of multi-species fisheries. A matter of similar importance is the fisheries and environmental data collection process applied in these areas today. In the case of a closed gulf, such as the Amvrakikos Gulf, the pollution and the other coastal human activities apply significant stress on the population of the shrimp. The isolation of the species population in the gulf combined with the facts that this population has never been studied before and that it is considered as the most valuable commercial product of the whole region, makes the need for a thorough study imperative.

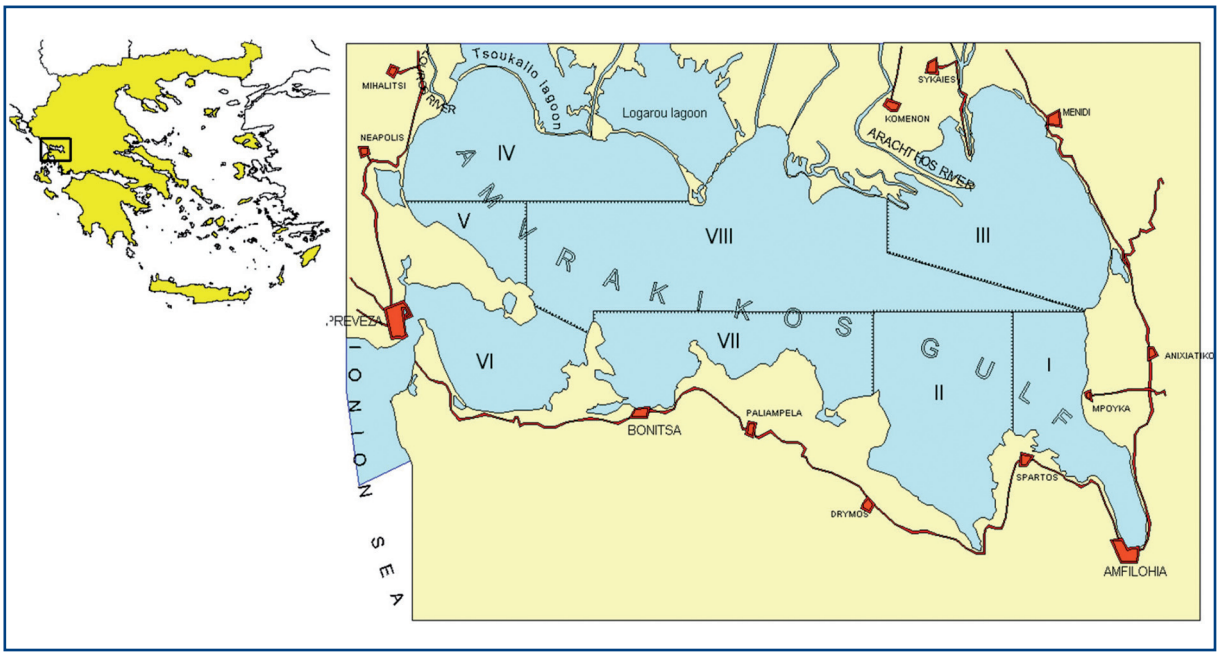
Materials and Methods

1. Area Description

The Amvrakikos Gulf is located on the west coast of Central Greece between 38°55′ and 39°05′ N and 20°45′ and 21°10′ E (Fig. 1). It covers an area of 530 km^2 with a maximum length of 35 km and maximum width 20 km. The maximum depth of the gulf is approximately 63 m at the centre according to the maps but bathymetric study during research projects (H.C.M.R. 2001) showed a maximum depth of 58 m indicating an approximate 30 cm decrease of depth per year since the last mapping of the area. The Gulf is connected with the open sea (Ionion Sea) through a narrow channel located at the west side. The width of the channel is about 600 m and the maximum depth is 7 m. There are 2 rivers: the Louros and Arachthos rivers that flow into the gulf from the North side creating a multiple habitat that sustains aquatic ecosystems locally. The flow of the rivers is constant at 32.9 and 15.5 m^3/sec respectively.
The rivers have created over the years, a series of lagoons at the North side. These 4 lagoons are named Rodia, Tsoukalio, Avleri and Logarou. These lagoons can be organized in two distinct areas - the Tsoukalio complex (composed of the lagoons of Tsoukalio, Avleri and Rodia, which are interconnected with canals) with an area of 6000 Ha and the Logarou complex with an area of 4000 Ha. The Tsoukalio complex is connected with Amvrakikos Gulf through one main canal located at the south side of the Avleri lagoon. From this canal, the seawa-

ter is transferred to the Rodia lagoon through the Tsoukalio lagoon and therefore, both Rodia and Tsoukalio lagoons are considered isolated. The Logarou lagoon is interconnected with the Gulf through four openings on its southern levees. Most of the fisheries production of Amvrakikos area originats from these lagoons but the pollution (agriculture chemicals) and the use of freshwater flows for irrigation, has caused the dramatic decrease of water quality, increase of salinity and reduction of the fisheries production.

Figure 1. G.I.S. map of the Amvrakikos Gulf area (Central-Western Greece).



2. Sources of data

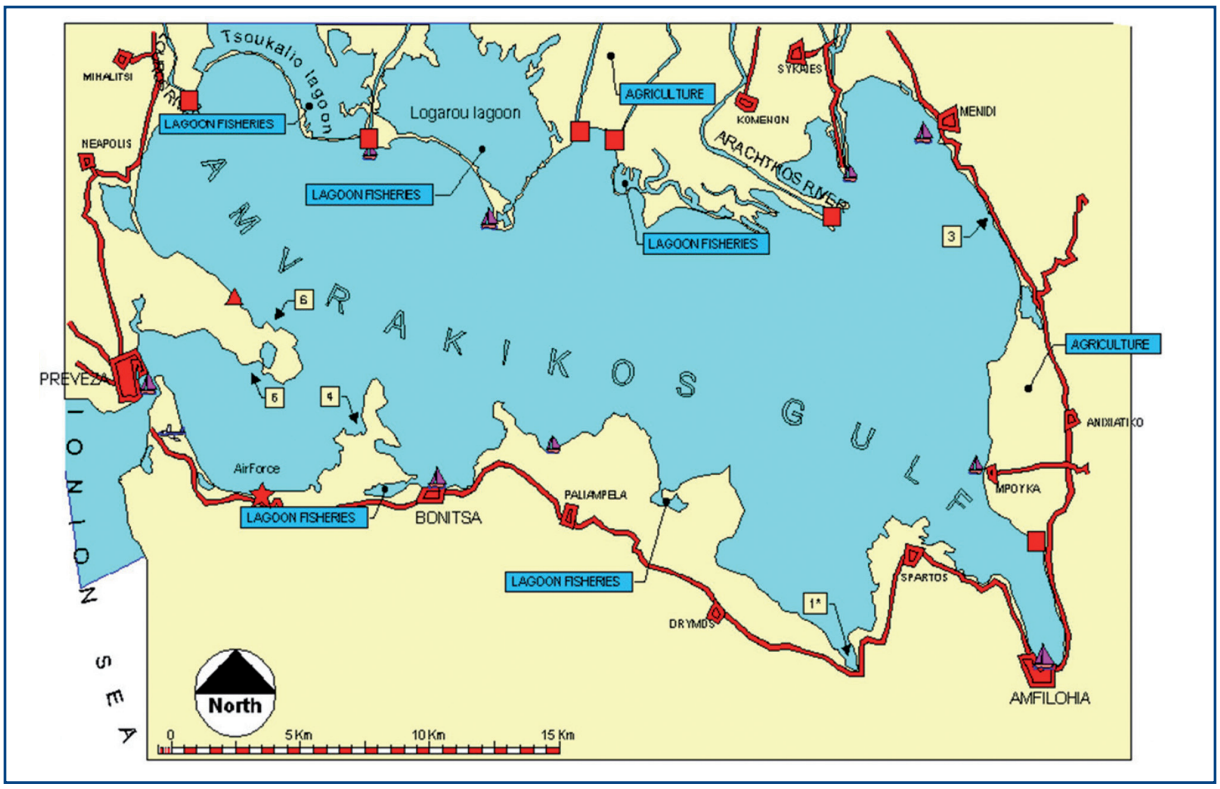
The review is based on fishing, environmental and socioeconomic data collected during research projects in the area of Amvrakikos Gulf. Until today there have been 2 recent projects in the area targeting the karamote shrimp (Klaoudatos, 1984; HCMR, 1989; 2001).

Results and discussion

1. Uses and sources of conflict

The area of Amvrakikos Gulf is characterised by intensive uses along the coastal zone as well as the surrounding land. North shoreline exhibits 2 groups of large lagoons which are exploited for lagoon fisheries using traps. Further to the north (a distance of 1-2 km from north shoreline bordering the lagoons), an extensive irrigation and drainage system for agriculture is in operation with an area of 100 km^2 approximately.
The system outflows at the north shoreline of the gulf through 2 rivers (Louros and Arachthos) and a few irrigation canals (Fig. 2). Livestock is greatly developed in the surrounding lands. Also there exist 3 major commercial harbours and 7 small fishing vessel refuges (Fig. 2). The commercial harbours are used for transportation of agriculture materials (mainly chemicals) and fuel. In a few areas organised camping can be found and small scale tourist activities take place. However, most tourist activity is transferred to the Ionion islands and especially Lefkada (20 minutes from the Gulf region on average). On the south-east shoreline, 2 fuel depots can be found (SHELL and MAMIDAKIS) and on the south-west shoreline, one air force fuel depot can be found. Finally, 21 cage fish farms, 3 eel farms (land based) and 2 hatcheries operate in the area (Fig. 2. yellow arrow-boxes).

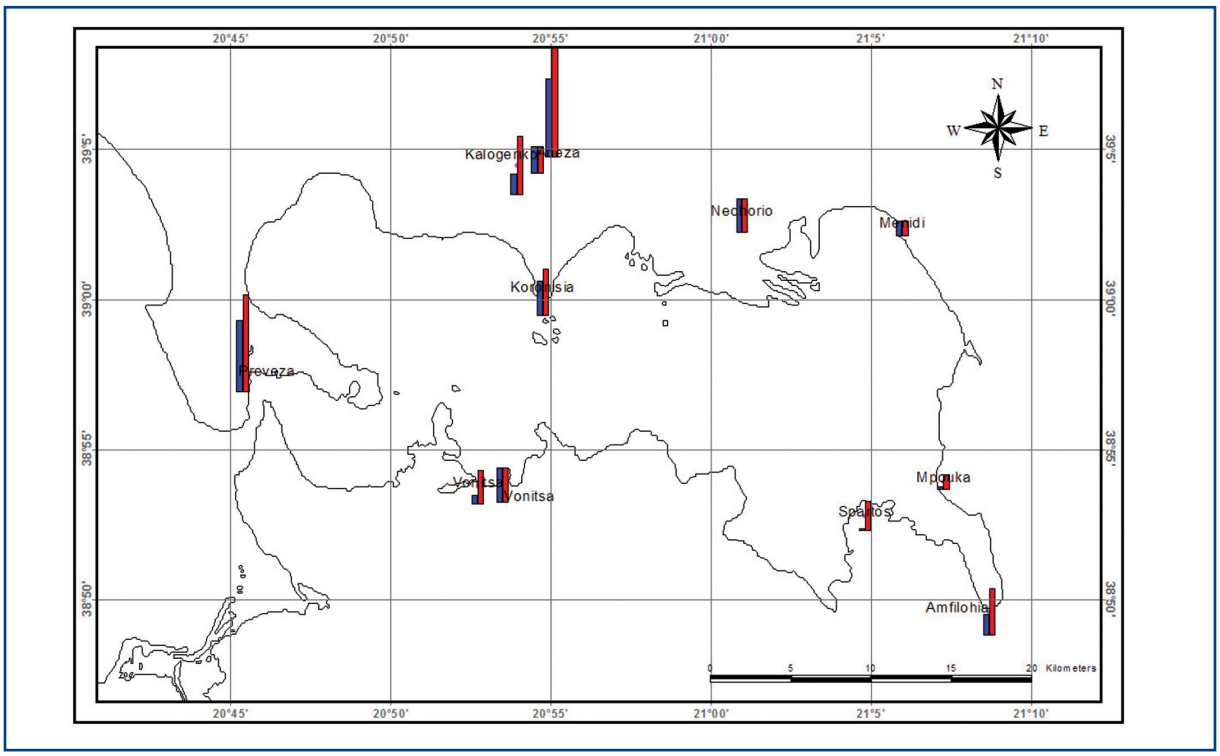
Figure 2. Distribution and location of the major coastal zone uses in Amvrakikos Gulf.



2. Fleet and professional fishermen

Survey of the local fishermen unions and vessel counting in harbours and fishing refuges showed the following results (Fig. 3).

Figure 3. Distribution of fleet and professional fishermen.



There are:
- 12 official and registered cooperatives of professional fishermen
- 604 fishermen with professional licenses issued by the local Coast Guard Authority
- 435 fishing vessels operating in the Gulf

Most fishermen and unions are located on the north parts. Harbours located on the western shoreline also exhibit high numbers of registered vessels and fishermen but care should be taken to distinguish the fleet segment which operates out of the gulf (Ionion Sea coasts). Those vessels are purse and beach seiners mainly which are not allowed to operate in the gulf.

3. Vessels and fishing operations

Fishing of shrimps is carried out using trammel nets with internal mesh of 22 mm and external of 110 mm. Today this is the only allowed gear in Amvrakikos gulf according to the legislation in effect. The nets are deployed usually at depths between 5 and 16 m in various areas of Amvrakikos Gulf. The nets that are used in the area, in general, have a length of 500-600 m and a height of 1.5-4 m. The nets are deployed either parallel or perpendicular to the coastline depending from the coast morphology and previous experience. The nets remain in the water for 2 to 12 hours depending to the season and the existence of large schools of other non-commercial species as anchovies and sardines or large animals (dolphins and turtles) that may destroy the net.

The boat used locally is called "priari" (Fig. 4) and is a small wooden craft with a length between 4-8 m and a small inboard petrol engine (5-15 HP in most cases).

The technical characteristics of the local traditional fishing vessel are:
- LOA 6-9 m, average 7 m
- no keel, wooden, traditional ship building technique unique in the region
- facilities for net lifting are rarely installed as in the picture on the left; hand lifting of nets limits the depth of deployment at depths above 10 m
- engine: inboard, petrol, 5-25 HP, average: 15 HP
- trammel nets and long lines only
- one or rarely two fishermen per boat (owner/captain and worker)

Figure 4. Typical fishing vessel.

4. Fishing grounds evolution

Previous studies undertaken in the area of Amvrakikos Gulf, have shown that there has been a dramatic change in the distribution and migration patterns of the species in Amvrakikos Gulf.

The results have shown that the fishing grounds have been reduced almost to 50% and are today located along the south shoreline only (Figs. 5 & 6). Traditional fishing grounds (and also reproduction grounds where adult shrimps gather) around the river deltas have been eliminated due to agro-chemical pollution (Louros river; north-west shoreline) and water management for upstream hydro-electric power production (Arachthos river; north-east shoreline).

The use of old and traditional fishing vessels in the gulf as well as the extremely low financial strength of fishermen – which hinders their ability to modernise the vessels or buy more nets - does not allow them to operate far from their home ports. The average fishing trip is 2-3 hours (one way) until the selected area for net deployment and is highly affected by the weather (especially the winds coming from the west).

Fishermen from the north shoreline need to cover long distances in order to reach the rich south fishing grounds (Fig. 7). Fishermen from Amfilohia city (south-east area) usually operate within the Amfilohia gulf. The low financial strength of the fishermen does not allow them to invest in nets and on average each fishermen owns 800-1200 m of trammel nets. Because of this, the fishermen cannot exploit more than one fishing ground per day (only one location). Only a few fishermen with large vessels (coastal vessels, 8-10 m in total length, 30-60 HP) which are registered in west harbours (Preveza city) exhibit the appropriate power to cover within one day all the area of Amvrakikos Gulf and therefore, these vessels can exploit more than one fishing grounds simultaneously.

Figure 5. Distribution of the main shrimp fishing grounds in Amvrakikos Gulf (1980-1984).

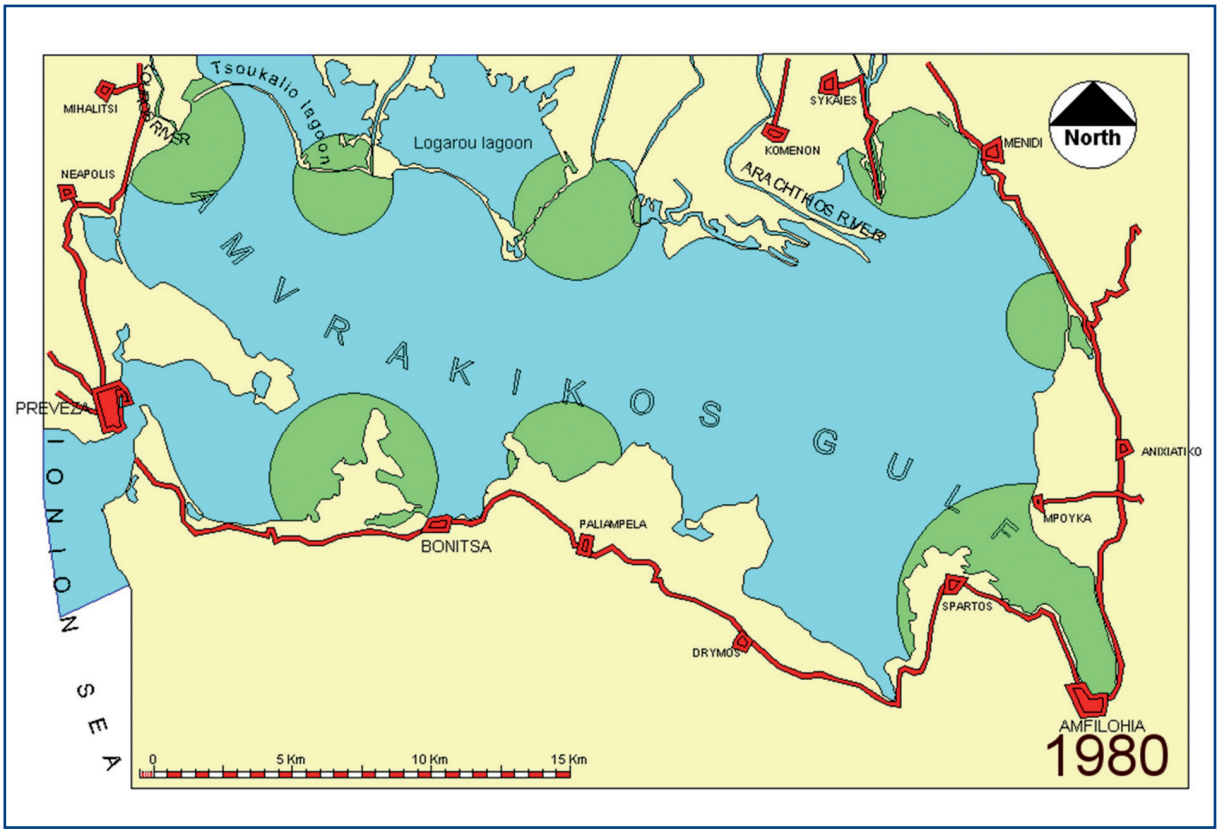


Figure 6. Distribution of the main shrimp fishing grounds in Amvrakikos Gulf (2000).

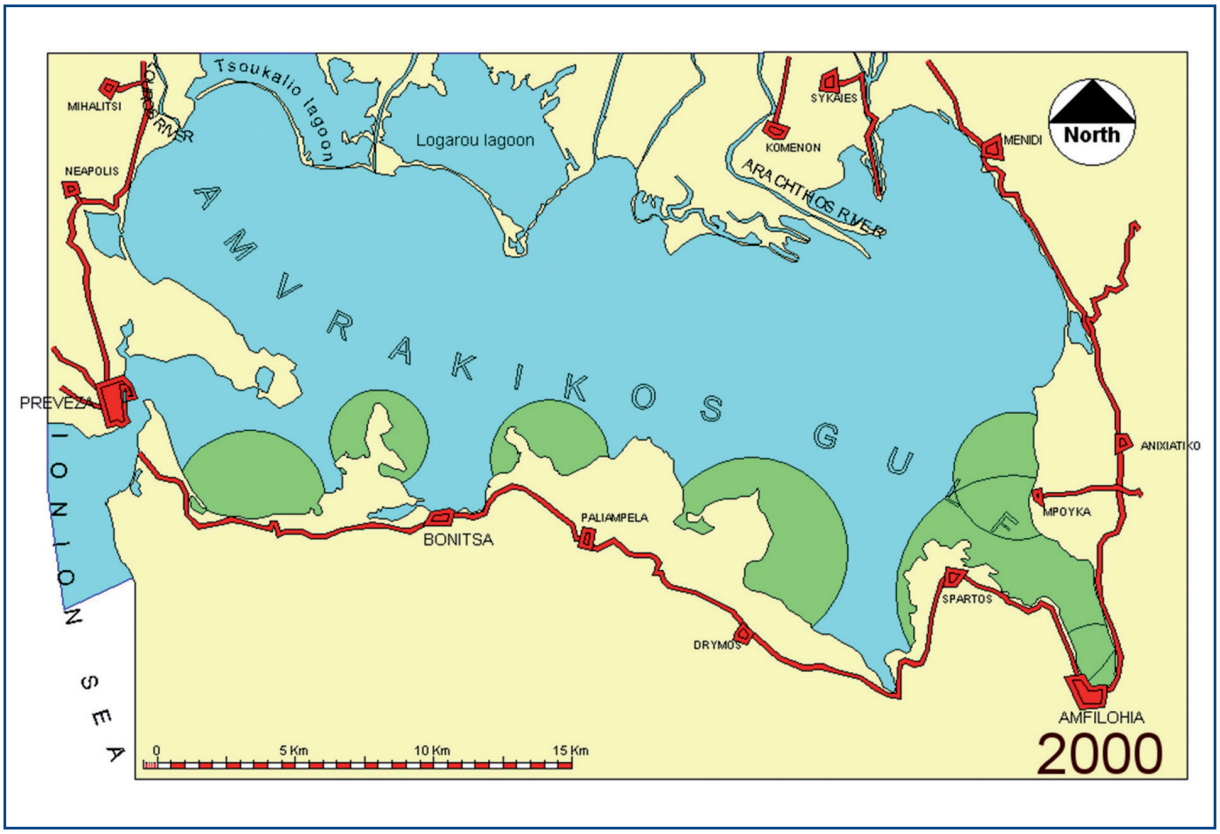
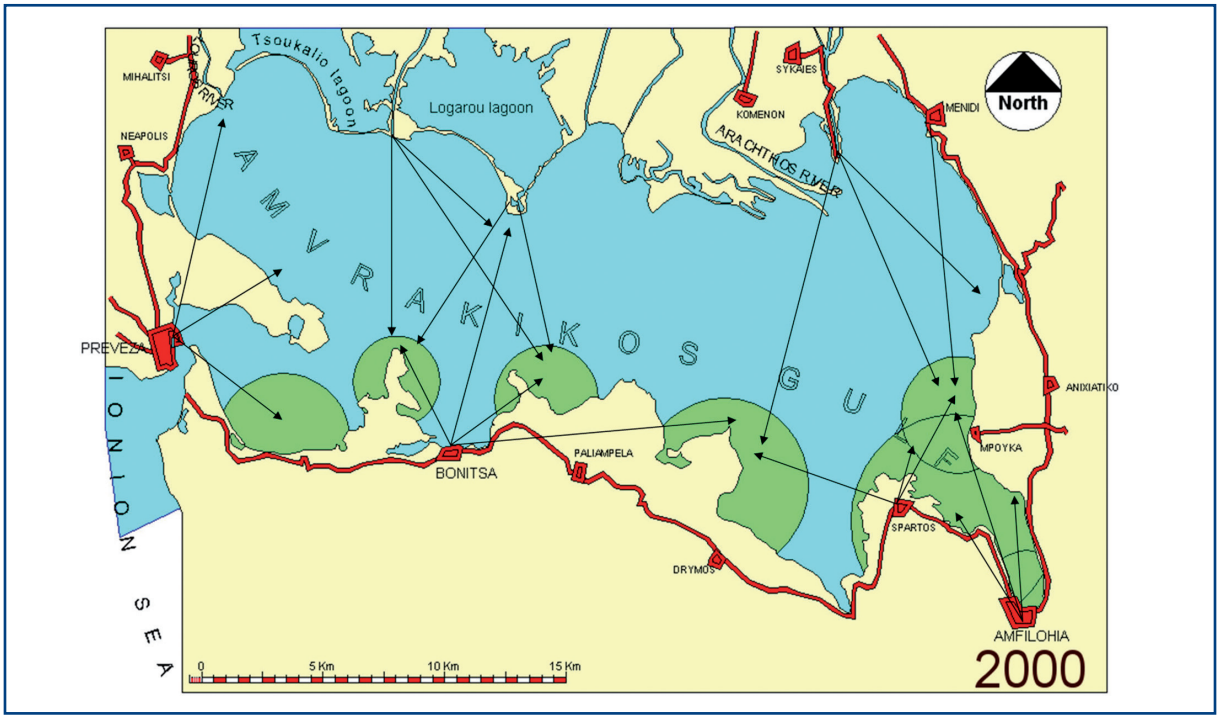


Figure 7. Relationship between fishing grounds and fishing harbours/refuges in Amvrakikos Gulf (arrows: daily fishing trips).



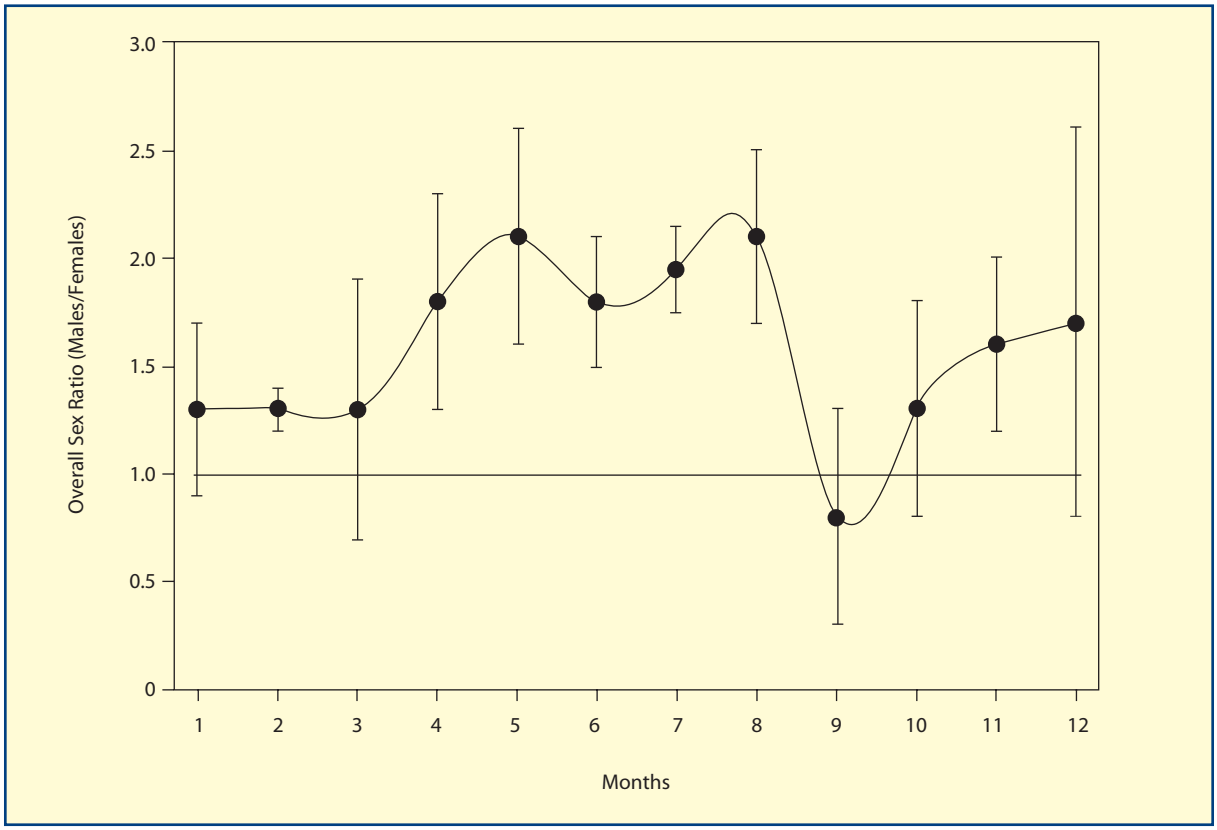
5. Trends in reproduction

The onset of gonad maturation and the stimulus for the reproduction maturation is the rapid increase of the temperature during March and half April, by 7.7 °C in average. It has been implied that this increase of temperature by 7.7 °C in a period of 35-40 days during spring is not possible, since the amounts of energy required are tremendous considering the fact that the temperature of the water was very low (around 10-12 °C) for a long time before (since November; Koutsikopoulos, personal communication). However, this seems to be a common situation in the coastal waters. Klaoudatos (1984) reports for the period of 1974-1980 in Amvrakikos Gulf, that there exists a rapid increase of temperature by 4-6 °C (depending the area of the gulf). N.C.M.R. (1989) reported a similar increase by 4-5 °C in the same period and finally, ETANAM (1999) reported a similar increase by 5-6 °C in surface waters and 4-6 °C increase of temperature close to the sea bottom in the gulf. The thermal stimulus has been recognised as the main stimulus (together with photoperiod) for the initiation of reproduction (maturation of gonads and migration to the reproduction grounds for copulation) and it is intensively used in intensive aquaculture practices (Lumare, 1979; Klaoudatos, 1984; Laubier-Bonichon and Laubier, 1976; Beard et al., 1977; Laubier-Bonichon, 1978; Shigueno, 1975; Lumare, 1976; San Feliu et al., 1976).
An important finding of the GSI analyses in the present study is that as the GSI increases, the range of values and deviation increases significantly. The average values and ranges of GSI are 0.77% (0.23-2.94) for stage I, 2.1% (0.72-5.96) for stage II, 3.95% (1.07-6.08) for stage III, 9.62% (4.20-21.98) for stage IV and 2.51% (0.61-4.92) for stage V females. Earlier studies (Klaoudatos, 1984) showed that the respective values of GSI per stage are 2%, 2-7%, 7-12%, 12% and 3% respectively. The difference between these 2 reports maybe owed to the fact that the GSI values reported by Klaoudatos (1984) originate from cultured shrimps and not from the wild stock directly and there has been reported great difference in the GSI values between reared and captured *Melicertus kerathurus* shrimps (Medina et al., 1996). Moreover, the reported ranges are different. In the 2000-2001 study, the maximum GSI (peak of reproduction) was evident during May and reached 6.9%, which is very low in comparison with other authors. There is evidence from this study that the reproductive performance of the shrimps has been lowered significantly (less females than before) and the reproduction peak has shifted by one month (from June to May). Klaoudatos (1984) working in Amvrakikos Gulf found that the GSI reaches a maximum of 11.73% during June. Medina et al., (1996) reported that GSI in July reached 11.3% in *Melicertus kerathurus* in the Gulf of Cádiz (Spain). Earlier, Rodríguez (1985) found for the same region and species, maximum values of 10.52%.

6. Trends in sex ratios

The sex ratios obtained in this study can be considered as skewed. In most cases, the sex ratios (expressed as males/females in numbers) are rarely close or equal to the – generally considered as normal – 1:1 ratio. In most cases, the males are far more than females and in some case they are 2 or 3 times higher in numbers than females. Total monthly sex ratio (all population pooled) is illustrated in Fig. 8.

Figure 8. Overall monthly sex ratios of *Melicertus kerathurus* population in Amvrakikos Gulf (Vertical limits; standard deviation).



This result leads to the following 2 conclusions:

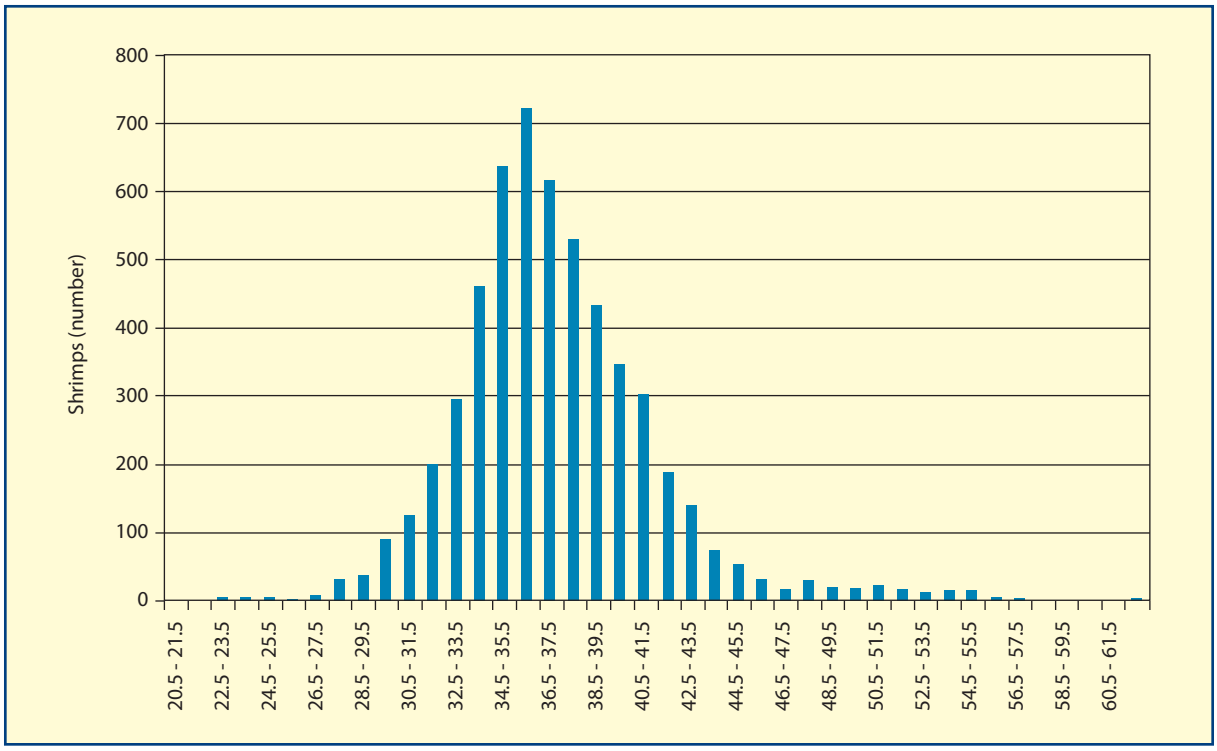
- The males show different distribution and migration pattern from females, in other words, males and females do not appear in the same area in the same time and,
- The female part of the population has been affected by fishing more than the males since females are always larger than males.

Earlier studies (Klaoudatos, 1984) have shown that overall sex ratio is close to 1 (51.53% males/48.47% females).

7. Length-frequency distributions

The size distribution of the shrimp Melicertus kerathurus in Amvrakikos Gulf reflects clearly the effects of low environmental quality and over-fishing/illegal fishing. The population length-frequency diagram (all samples pooled) shows only one (1) mode indicating that, regardless any problems in shrimp ageing methodologies, the population is composed of 1-year-old individuals by 98% and a few older individuals by 2%. The size distribution ranged from 20 mm to 62 mm (CL), which equals to a Total Length range between 89 mm and 250 mm (TL; Fig. 9).

Fig 9. Total carapace length frequency distribution of the shrimps *Melicertus kerathurus* in Amvrakikos Gulf (2000-2004).



An older study on aquaculture (fishing of live shrimps for lab experiments) of the species in the area (Klaoudatos, 1984) showed that the size distribution of the shrimps was greater and covered all 3 years of longevity of the species in Amvrakikos Gulf. Using the same traditional nets operated also today (shrimp trammel net, 22 mm internal net mesh and 110 mm outer nets), the size distribution ranged between 110 and 230 mm with one, two or three (depending on the month) separate and almost equal modes. In addition, the males and females always showed a slight difference between the modes of similar age class by approximately 10 mm (the females were larger than the males of similar age). This gives a clear indication that the effects of human activities on the population have shrunken the population over the last 15-20 years. This further indicates that reproductive performance has decreased since the age classes which can give a good output in terms of both number of eggs and quality (>2 years of age) are now absent from the population, while all the population disappears during one year and the stock of the next year is produced by the reproduction during the previous year. This also indicates that the population is extremely sensitive since even a natural problem caused during the reproduction period, may result to the elimination of the population in the Gulf.

8. Trends in morphometry

Earlier studies in the area of Amvrakikos Gulf (Klaoudatos, 1984) produced the following TL-W, CL-W and TL-CL relationships (overall, males and females). In the case that an overall relationship is not provided by the authors, the un-weighted geometric mean relationship was estimated[1]:

♀: logW=-2.301 + 3.180 logTL
♂: logW=-1.537 + 2.503 logTL
Overall : logW=-3.824 + 2.421 logTL

♀: logW=-0.567 + 2.683 logCL
♂: logW=-0.123 + 2.042 logCL
Overall: logW=-0.345 + 2.363 logCL

[1] Weights in g; lengths in cm.

The equations obtained in 2000 for *Melicertus kerathurus* in Amvrakikos Gulf, are:

♀: logW=-3.691 + 2.369 logTL
♂: logW=-3.472 + 2.251 logTL
Overall : logW=-1.767 + 2.037 logTL

♀: logW=-1.870 + 2.105 logCL
♂: logW=-2.042 + 2.212 logCL
Overall: logW=-3.824 + 2.421 logCL

It is clear from the above results, that there is a significant difference between the population of Amvrakikos Gulf today in comparison with the same population 20 years ago and other populations of the shrimp in the Mediterranean (Ishak et al., 1980; Rodrigues, 1987; Ben Mariem 1995). The power coefficient, b, of the overall TL-W relationship in almost all previous studies is between 2.7 and 3.1 which indicates mostly isometrical growth for the shrimps while the 2000 data show that it has been lowered to 2.04.

9. C.P.U.E. and spatial distribution of C.P.U.E.

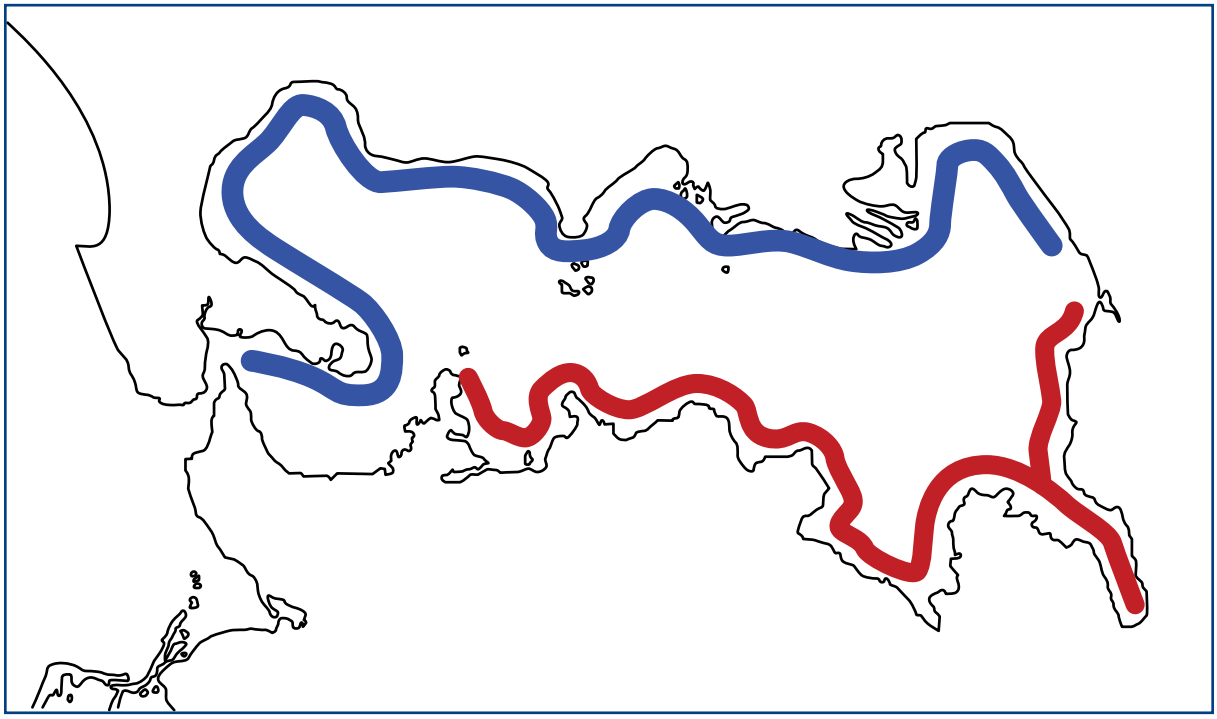
The results from the experimental fishery showed that high C.P.U.E. values can be obtained from the south fishing grounds, hence the fishermen preference for these areas and very low or 0 values, from the north grounds (Fig. 10). This result is explained by the distribution patterns of the shrimps: abundance is higher in the south ground and very low in the north grounds due to agriculture pollution.

The results were:

- Average fishing days per year = 225
- Average C.P.U.E. per day (g 1000 m of net^{-1} day^{-1}) = 3421 ± 354 g

C.P.U.E. values also fluctuate on a monthly basis significantly with higher values in winter and lower values in summer. At this point, however, the effects of sport fishing on the lowering of C.P.U.E. during summer cannot be assessed because sport fishing in Greece is completely uncontrolled by all authorities and the fact that this fishery is "open access" without any limitation at all limits the capacity and the benefits from the further analysis of C.P.U.E.

Figure 10. Spatial distribution of C.P.U.E. values (red: high values; blue: low values).



10. Trends in habitats

In terms of numbers, the areas VII and I are the most abundant for shrimps. The smaller individuals appear in zones I, V and VII, indicating that these may be the main recruitment areas (Fig. 11). However, these zones do not exhibit exactly similar geomorphology. Zone V is near the Louros river delta and the physical conditions gradients are evident (freshwater flow). In zone VII, there are some underwater springs as well as small lagoons that create similar gradients. Zone I exhibits only some underwater springs and it is highly eutrophic. The above observations indicate a pattern of recruitment, which is governed mainly by the search for food and for favourable physical conditions (mainly salinity gradients; Dall et al., 1990; Klaoudatos, 1984). Salinity and temperature are two of the most important abiotic factors affecting the growth and survival of aquatic organisms.

Figure 11. Map of small individuals appearance patterns. (with "?" the areas of older appearance reports are shown).

Certain habitats are difficult to recognize in Amvrakikos Gulf. The pollution from land activities and the freshwater flow regulation is such that most of the traditional habitats identified in earlier studies (Klaoudatos, 1984; N.C.M.R., 1989) have been eliminated and the shrimps cannot utilize them today. Therefore, size/age specific habitat preferences were not recognized in 2000 except for the seasonal preference of the young shrimps, before recruitment, to enter the eutrophic seawater gradients of the north Amvrakikos lagoons. In addition, small lagoons at the east coast of Amvrakikos Gulf have been destroyed by human landscape alterations and reproduction grounds disappeared (Katafourko lagoon, Agrilos lagoon, Arachthos river delta).

11. Management options

From the results of the research study on the fishery of *Melicertus kerathurus* in Amvrakikos Gulf and the difficulties encountered during the study, the following information are fundamental for shrimp fishery management in the area and which do not exist today:

- ***Detailed study of the environment*** – the state of pollution, existence of endangered species, monitoring and detailed databases
- ***Fisheries assessment studies*** – to assess the status of the resources
- ***Detailed study of the economic sector*** (all economic activities) to reveal the importance of the various sectors (including fisheries) for the local economy – description of market, prices and elasticities of prices, demand and supply of products, fishing cost. Also include Infrastructure – fleet, distribution of fleet, age of fleet, processing sector, fishing routes and distances plus built new; Legislation and environmental protection schemes – the balance between the natural and human environments has to be maintained.

In order to support any shrimp fishing management plan, the following actions are required:

- ***Establish a basic monitoring system*** – Production time series, Fleet, Fishermen, Data Bases
- ***Enforce a basic management framework*** – size limitation, gear, licenses, TAC/QUOTA
- ***Support fisheries by development of Infrastructure*** – Processing and packaging, whole sale and retail markets
- ***Funds for reimbursement of damage***s – Special bank loan schemes
- ***Legislation enforcement to prevent illegal fishing***.

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