Spatial Analysis of Fish Farming in the Gulluk Bay (Eastern Aegean)

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Abstract

Marine aquaculture in Turkey has been rapidly growing during the last two decades in the coastal zone. This growth has led the government to take measures to reduce environmental degradation. After the new regulation for aquaculture, in 2007, most sea farm cages were relocated from shallow water to relatively deeper areas in Gulluk Bay. In this study a spatial analysis of marine fish farming was performed, using several GIS data layers to assess Allocated Aquaculture Zone (AZA) and to monitor operations. A spatial analysis of fish farming the Gulluk Bay in the context of the other major sea users and their relative percentages in the sea use pattern were determined. The Allocated Aquaculture Zone (AZA) amounted to 20.8 % of total water surface area; licensed cage areas occupied 0.45%, trawl areas 34.4%, important natural areas 35.4% and multi-usages zones the rest. The study used water quality index (TRIX) data for evaluation in conjunction with GIS. The study shows how different terrestrial and marine activities interact with each other, and that certain areas are subject to layers of multiple usages and water quality index (TRIX) data was evaluated by using a GIS.

Keywords: Marine aquaculture, GIS, TRIX.

Güllük Körfezi’nde Balık Çiftliklerinin Alansal Analizi (Doğu Ege)

Özet

Türkiye’de deniz yetiştiriciliği kıyısal alanlarda son 20 yıl boyunca hızlı bir şekilde artış göstermiştir. Bunun sonucu olarak hükümet, çevrede oluşan negatif etkilerin azaltılması yolunda önlemler almıştır. 2007 yılında yayınlanan yönetmelikten sonra birçok balık çiftliği Güllük Körfezi’nin kıyı sularından daha derin sulara taşınmıştır. Bu çalışmada, balık çiftliklerinin alansal analizleri ve izleme çalışmaları CBS veri katmanları kullanılarak yapılmıştır. Güllük Körfezi’nde balık çiftliklerinin alansal analizi, diğer deniz kullanıcıları ve kullanım alan yüzdeleri ile birlikte tanımlanmıştır. Deniz yetiştiriciliğine ait alan körfezin %20.8 (yeterli kültür için kiralanan alan körfezin %0.45’i), trol alanı %34.4, önemli doğal alanı %35.4’ünü kapsamaktadır, kalan deniz alanının ise birden fazla kullanıcılığı ait olduğu belirlenmiştir. Çalışmada kullanılan su kalite indeksi (TRIX) değerlendirmelemesinde CBS kullanılmıştır. Bu çalışmada farklı karasal ve denizsel kullanıcıların birbirile ilişkileri, bazı alanların çoku kullanıcı olduğu ve su kalite indeksinin CBS ile değerlendirilebileceği gösterilmiştir.

Anahtar Kelimeler: Deniz yetiştiriciliği, CBS, TRIX.

Introduction

It is the rapid growth of the aquaculture sector within the overall Mediterranean economy which makes it remarkable. There has been a 7% growth over the past ten years; total production reached 2 million tons in 2010 (FAO, 2012). Consequently there is a need for expansion space. This, together with the actual and potential conflicts with other users (e.g. fishery, tourism) of the Maritime Zone, has drawn the attention of the GFCM (General Fisheries Commission for the Mediterranean) towards development of the concept of Allocated Aquaculture Zones (AZA) to help member countries with the planning and sustainable development of aquaculture. AZAs are areas in which there is no interference with other activities or users; environmental conditions allow for the development of the activity and the minimization of impacts. It is proposed by the FAO that in AZAs the development of aquaculture is to be granted priority (FAO, 2012). AZAs are designed for the planning of finfish marine aquaculture activities and for their establishment within local and national plans for aquaculture. These should be drawn up by
the competent Mediterranean and Black Sea area authorities to ensure that aquaculture development is sustainable within the context of Integrated Coastal Zone Management (ICZM).

Coastal aquaculture along the Eastern Aegean coasts has been going through a period of unprecedented growth over the past ten years. Turkish aquaculture production has increased from 34,000 tons in 2000 to around 75,000 tons in 2009 (TURKSTAT, 2010). The actual production for Gulluk Bay was 67,000 tons in 2011, making it the premier production area in Turkey. Furthermore this growth has led to the drafting and implementation of new planning and management policies by the Turkish government. Coastal planning was realized by the inter-ministry committee. There was no broad-based “Integrated Coastal Management Board” with inputs by the mayor, non-governmental organizations and so on. Gulluk Bay is the most important area for sea bass and sea bream production. Gulluk contributes about 70% of total Turkish aquaculture production. Its expansion in coastal waters has not only added more pressure to marine and coastal ecosystems, but has also created conflicts among existing users of coastal resources. In a process that increased the pressure on fish farming in the coastal zone, the Ministry of the Environment amended existing environmental legislation. It was now obligatory for the farms to be moved from the shallow shoreline waters to the deeper areas. These comprised a newly defined AZA at the center of Gulluk Bay (MEF, 2007). According to this new legislation specific criteria were laid down for marine aquaculture site selection and monitoring. With regard to this law, water quality status was to be identified by the trophic index (TRIX), which is used to monitor fish farms established in enclosed bays and gulfs.

Rapid urban development has taken place in Gulluk Bay and created much conflict. A Master Plan for the Mugla Province was developed (MEF, 2010) but it was primarily a land use plan. The goal of this study was to create for the first time a spatial analysis, using Geographic Information Systems (GIS), integrated with the adjoining sea area (IMST-DEU/BAP, 2012). This would help in the planned integration of marine aquaculture within the range of activities of Gulluk Bay. TRIX and GIS analysis define a better spatial planning of aquaculture in a sensitive area.

Materials and Methods

Study Area

The Bay of Gulluk is located in Mugla Province on the southeastern Aegean Sea coast (Figure 1), and is formed of four large natural coves and many smaller bays and inlets. The rapid growth of fish farming and tourism has been paralleled by the very rapid urbanization of the coastal zone at Gulluk. The area has a winter population of approximately 21,000 (TKDK, 2013). However during the summer the population increases by tens of thousands due to tourism. Gulluk Bay is famous as a luxury cruise transit feature along the blue voyages between Kusadasi and Fethiye. This increases pressure on water usage.

Various pollutants in the Bay of Gulluk are the result of anthropogenic activity including domestic waste water, agriculture runoff, tourism, aquaculture
GIS Analysis

To construct zone map for Gulluk Province, basic cartographic data was obtained from the General Command of Mapping of the Turkish Navy Department of Navigation, Hydrography and Oceanography at a scale of 1:100,000 in connection with the Master Plan created by the Ministry of the Environment and Forestry (MEF, 2010). Fish farm coordinates were obtained from the Ministry of Agriculture and Rural Affairs. TRIX data was obtained from the national projects (IMST-165 2008).

A spatial analysis of fish farming within ICZM required several GIS data layers to assess Allocated Aquaculture Zone (AZA) and to monitor operation. To fulfill all these expectations, the data covered a broad range of information, from hydrological data to environmental data.

A list of the metadata properties of the primary data set is given in Table 1. Other state-generated land use maps of Gulluk were assembled, and then put into a GIS program (MapInfo) to provide spatial analysis and facilitate the display of data. Before creating the GIS datasets, all spatial data was manually verified and corrected. Remote sensing data from the archive of Landsat/TM and Landsat/MSS images of the whole coastline of Turkey, and from field research archives, kept at IMST was then converted into a standard GIS format. This was used together with other data coming from different sources, especially official documents in the public domain in the construction of the new map.

Several valuable paper maps without any coordinate system or geo-referencing information were scanned or digitized and then converted to forms suitable for analysis. GIS layers, for fish farming, marine transport zones and fisheries were generated, based on the coordinate information. A new digital coastline map was generated based on the existing 1:25,000 scale military topos map and on the navigation charts of Gulluk Bay. Because all this data came from a variety of different sources, before creating the final GIS datasets, all spatial data was again verified and small discrepancies and omissions were corrected by reference to the draft base map, before a final conversion into a standard GIS format calculated in terms of the Turkish Coordinate System (UTM 6 Degree, k=0.9996, ED50 Datum, Zone35 Central Meridian 27).

Trophic Index (TRIX)

Data was collected in 2008 in summer at sampling stations (G1-G8), which represent all the bay, at the surface, middle and at the bottom of the bay, at the surface, middle and at the bottom of the bay.
water column, giving a total of 24 samples (IMST-165, 2008). According to MEF (2007), TRIX monitoring should be performed in the summer period, when nutritional needs were highest for raising a stock of fish in the cages. In this study summer period was considered to determine impact of fish farming activity using TRIX. The impact of fish farming activity on the ecosystem can be interpreted using TRIX. This determined the eutrophication status in Gulluk Bay. The eutrophication scale for TRIX was defined in the Turkish legislation for application to marine aquaculture in Table 2.

Following Vollenweider et al, 1998, the TRIX index was used to give numerical trophic levels to the coastal waters of Gulluk Bay using the formula:

\[
TRIX = (\log_{10}[\text{Chl-a} \times \text{DIN} \times \text{TP}] + 1.5) \times 0.833
\]

Chlorophyll-a (Chl-a µg/l), oxygen as absolute (aDO%), where DIN is total dissolved inorganic nitrogen (NO\(_3^-\)+NO\(_2^-\)+NH\(_4^+\)) and TP is total phosphorus as µg/l. Chl-a and aDO% components were direct indicators of productivity. They occur respectively, in terms of both the amount of phytoplankton biomass produced and the dynamic of that production.

Since the TRIX data were collected only at eight stations, the data was inadequate for the creation of visual representation of the distribution of data over the entire bay. An interpolation method together with GIS was used to create a better visualization of the distribution of the TRIX data. MapInfo Vertical Mapper was used to build the distribution map of TRIX data, by selecting the simple natural neighborhood option for the interpolation method.

**Result**

The prime aim of this research was to produce an integrated land-sea map of Gulluk Bay for discussion among the stakeholders and coastal management community. This initiative has been unique for Turkey and fulfills a need. For that, ecological and socio-economical criteria should be taken into account, and then aquaculture management can search for suitable space that minimizes conflict with other stakeholders.

Figure 2 shows sea and land uses and enables users to share information that minimizes conflict within coastal waters. The GIS work, shows that Gulluk Bay has a surface area of about 670 km\(^2\) and a coastline of around 262 km, running from Yalikavak to Akbuk. This line extends from a point at latitude 37° 20’ 21.42” N; as far as a point at longitude 27°14’ 27.00” E; to the point at latitude 37° 5’ 4.11” N; longitude 27° 14’ 28.04” E.

Sea utilization patterns in Gulluk Bay were given in Table 3. Major uses of the Bay were defined as aquaculture, trawling and the definition and maintenance of important natural areas. As is clearly seen in this table, although the AZA covers 20.8% (139.8 km\(^2\)) of the bay, licensing for cage areas was only taken up for 0.45% (3.03 km\(^2\)) of this area. This has now been confirmed as the maximum limit useable of the total water-surface area.

Figure 3 shows the position of licensed farming facilities before and after relocation according to the provisions of the Environmental Laws (MEF, 2007). Before relocation 127 fish farms, had been working close in-shore. These had a reported 52,000 tons production capacity in 2007.

Figure 4 shows the TRIX values in 2008 at the surface only, before the fish farms were moved to the new AZAs. Water quality monitoring parameters as TRIX values from 8 stations were represented from G1 to G8, in Figure 4. Calculated TRIX values ranged from 3 to 5 at surface in Gulluk Bay. This status was further considered to have a “high eutrophication risk” in terms of Turkish legislation (Table 2). This result, showing eutrophication risk in the coastal area, has to be attributed to the affect of aquaculture together with all other coastal activities. To this end we recommend legislation to compel all stakeholders to undertake TRIX examination of their facilities.

**Discussion and Conclusion**

This research has applied GIS technology widely so as to better explore relationships between the distribution of resources and their users, so as to prioritize resource management.

Over the last 20 years, due to the increase in use of the coast areas around Gulluk Bay by fish farming enterprises there has been extra conflict with other coastal users especially with tourism, fisheries and marine transportation. The development of Turkish marine aquaculture site selection and zoning should address all the issues through a participatory process involving stakeholders, scientists and government. It is necessary to find acceptable solutions for site selection and zoning. Agreements must be negotiated on the most cost-effective and socially-acceptable mechanisms for mariculture development. These should be integrated into the coastal development program to reduce negative effects. A Road Map for Marine Aquaculture was jointly launched by MARA and FAO (2009). The key output from this project was an increased awareness of the possibilities of applying coastal zone management techniques in the Gulluk Bay situation (MARA-FAO, 2009). This event arose directly from discussion between the FAO, Turkish Ministries, the Aquaculture Union, fish
Figure 2. Sea/Land use plan of Gulluk Bay.
Table 3. Sea utilization pattern in Gulluk Bay

<table>
<thead>
<tr>
<th>Sea utilization class</th>
<th>Area (km²)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture Allocated Areas</td>
<td>139.8</td>
<td>20.8</td>
</tr>
<tr>
<td>Aquaculture Licensed Areas</td>
<td>3.03</td>
<td>0.45</td>
</tr>
<tr>
<td>*Trawl</td>
<td>230.5</td>
<td>34.4</td>
</tr>
<tr>
<td>Important Natural Areas</td>
<td>236.7</td>
<td>35.4</td>
</tr>
<tr>
<td>Multi-usage zones</td>
<td>59.97</td>
<td>8.95</td>
</tr>
</tbody>
</table>

*Deep trawling is prohibited within 1.5 miles from the coast in Aegean Sea (MARA, 2008)

Figure 3. Gulluk Bay before and after the relocation of the fish farms.

Figure 4. TRIX values interpolated from modeled outputs and old fish farming areas in Gulluk Bay.
farmers and scientists at the European Aquaculture 2007 Conference in Istanbul. At this time marine aquaculture was under considerable pressure from media and other sources. In 2007, new legislation was enacted in Turkey related to the protection of coastal waters, especially those of enclosed bays and gulfs, from pollution by fish farming (MEF, 2007). This legislation imposed 3 main relocation criteria. Fish farms were required to move beyond a minimum distance from the land of 0.6 miles; beyond the minimum depth of 30 meters, and within the acceptable TRIX value of less than 4. Accordingly the legal framework, in Gulluk Bay comprises two large AZAs, one for the Milas Zone and the other for the Bodrum Zone as defined by a Turkish Inter-Ministerial Consortium in 2007 (Figure 2). An appropriate Environmental Impact Assessment (EIA) was performed at the time of the establishment of these AZAs (EIA, 2008). The movement of farms to these AZAs took place from 2009 to 2011. After relocation a total number of 81 new larger fish farms began to operate in Gulluk Bay and planned production capacity was increased to 88,000 tons 48 of these fish farms have a capacity of between 300 and 1000 tons (EIA, 2008). As an economic consequence the small scale fish farm has disappeared.

Many other coastal activities have recently developed in sectors such as recreation, tourism, holiday homes and fisheries, together with marine transportation in Gulluk Bay. These activities will continue to expand. A further important economic activity in the Bay is focused on Gulluk Port, (Fig 2). There are now considerable marine transportation activities as well as cruise boat traffic which makes it essential to define maritime route ways so as to avoid accidents. It is now necessary to print this route way on all legal documents. There are 8 small scale traditional fisher-cooperatives and fisheries whose welfare needs to be considered (Tokac et al., 2010) in this context.

In Figure 2, two major Gulluk Bay wetlands are shown. Gulluk Delta (2,500 ha) and Metruk Tuzla (2,000 ha), are both classified as "Wetlands of International Importance" according to Ramsar criteria (MEF, 2011). Wetlands are ecological treasures in terms of the background “goods and services” of the Bay and also act as wild fish nurseries. In Gulluk Delta sea bass, sea bream, carp, eels and mullet are targets for small scale commercial fishing (MARA Report, 1988). In Figure 2, Posidonia oceanica meadows are shown. These need better mapping and proper conservation. In the future these data elements need to be completely researched.

Also rapid urban development connected with tourism, recreation and urbanization on the coastline of Gulluk Bay needs constant monitoring and updating. Figure 4 shows how GIS applications were used to obtain environmental information. The TRIX data as given in the GIS map is easier to understand. On the basis of this map it is to be hoped that other maps will be constructed over time in order to monitor every sector of economic development of the coastline. Current pollution originates from remnants of previous fish farming activity, inadequately treated sewage, run-off from agricultural facilities or uncontrolled coastal development. Several papers about TRIX and its relation to water quality show eutrophication in the coastal waters of the Turkish Mediterranean originate from sources other than aquaculture supporting the results of this study (IU 2006; MEDPOL 2009; Yucel-Gier et al., 2011). TRIX currently is only applied to AZAs. Sadly, the old fish farming areas, which are now the preserve of holiday homes, are no longer tested. Further monitoring is necessary so as to show whether or not a sustainable improved environmental quality has resulted from the moved fish farms. Gulluk Bay provides a case study with a combination of parameters that have to be carefully identified and precisely monitored.

The study deals with the selection of the appropriate locations for aquaculture units within designated areas a critical issue for the development of aquaculture in terms of AZAs. It is a question with wider interest in the Mediterranean coastal areas and beyond. Governments, entrepreneurs and scientists are all keen to address this difficult problem. The setting of sea farms requires the evaluation of many different and often controversial parameters. The establishment of AZAs should be considered within the framework of this ICZM. This study is intended to be useful for similar case studies and in general planning throughout the Mediterranean.

This paper, using GIS as a tool to examine the spatial development of sea and land uses as well as the sea water quality, may offer the necessary legitimacy to the final decisions.

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