www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 13: 737-744 (2013) DOI: 10.4194/1303-2712-v13_4_19

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

Guzel Yucel-Gier[1,*], Idil Pazi[1], Filiz Kucuksezgin[1]

[1] Dokuz Eylul University, Institute of Marine Sciences and Technology, Inciralti, Izmir, Turkey.

* Corresponding Author: Tel.: +90.232 2785565; Fax: +90.232 2785082;
E-mail: yucel.gier@deu.edu.tr

Received 2 May 2013
Accepted 13 December 2013

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-usage 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 ayrılan alan körfezin %20.8 (yetiştiricilik için kiralanan alan körfezin %0.45'ini), trol alanı %34.4, önemli doğa alanı %35.4'ünü kapsamakta olup, kalan deniz alanının ise birden fazla kullanıcıya ait olduğu belirlenmiştir. Çalışmada kullanılan su kalite indeksi (TRIX) değerlendirilmesinde CBS kullanılmıştır. Bu çalışmada farklı karasal ve denizel kullanıcıların birbiriyle ilişkileri, bazı alanların çoklu kullanıcıları 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

Figure 1. Location of study area.

and Gulluk Port activities. There is currently no industry in the area surrounding the Bay of Gulluk and only a few small settlements. Fishing and maritime transport, including the loading port, are other types of coastal use (MEF, 2010). However, year by year the surroundings of Gulluk Bay are developing and this exponentially increases pressure on its total environment.

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 transportation 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 topographic 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

Table 1. The primary data sources used for the development of GIS, original data format and other data properties

Sources	Feature	Format	Date	Scale, Resolution, Accuracy	Coordinate System
IMST and Engineering Faculty Archive	Base Maps (Coastline, Rivers, Lakes, Freeways, Roads, Railroads)	Hardcopy (Paper Map) & Digital; Vector	2000-2009	±10-100m	Lat/Long
Turkish Navy Department of Navigation, Hydrography and Oceanography	Bathymetry	Hardcopy	---	1/25,000 scale 1/50,000 scale 1/100,000 scale	Lat/Long
	Marine Transport Route	Hardcopy	2010	1/25,000 scale	Lat/Long
	Lighthouses	Attribute Data	2006	±10m	Lat/Long
General Command of Mapping	Topography	Hardcopy & Digital (Raster & Vector)	1990-2005	1:25,000 scale	Turkish Coordinate System
Ministry of the Environment and Forestry & State Agency of Environment and Forestry	Archeological site, Urban Site, Natural SIT, Special Environmental Areas, , Wetlands, Tourism Zone, Urban Areas, Recreation Zone,	Spatial data; Digital; Vector	2010	±10m	Lat/Long
Ministry of Agriculture and Rural Affairs	Fish Farming	Attribute Data	2007-2010	---	Lat/Long & Turkish Coor. System
Ministry of Agriculture and Rural Affairs & Ministry of Transportation DLH	Fishing Harbors & Ports	Attribute Data & Hardcopy	2004	±10m	Lat/Long
General Directorate Landsat/TM & Landsat/MSS	Remote Sensing Data	Digital Image Raster, Geotiff	1999	30x30m	UTM, WGS84 Zone35N
Google Earth	Wetlands	Digital Image	2012	±10 - 50m	Lat/Long; WGS84
IMST	Water quality Index (TRIX)	Attribute Data	2008	---	Lat/Long

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}[Chl-a * a D%O * DIN * TP] + 1.5) * 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)-N as µg/l and where 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.

Table 2. Eutrophication scale for TRIX as defined in Turkish legislation for application to marine aquaculture (MEF, 2007)

TRIX	Trophic status
TRIX < 4	No eutrophication risk
4 ≤ TRIX ≤ 6	High eutrophication risk
TRIX > 6	Eutrophic

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

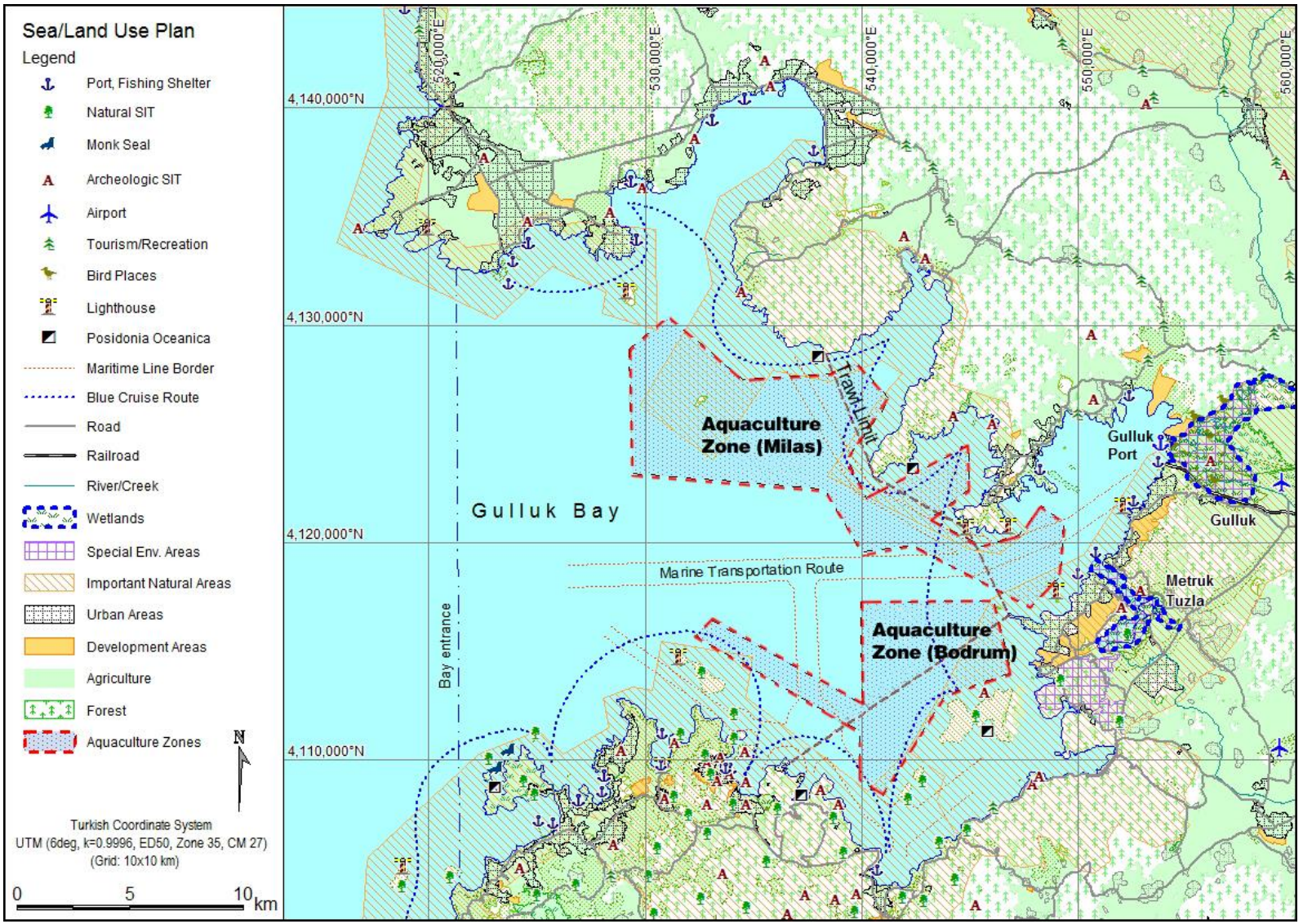

Figure 2. Sea/Land use plan of Gulluk Bay.

Table 3. Sea utilization pattern in Gulluk Bay

Sea utilization class		Area (km^2)	Percentage
Aquaculture	Allocated Areas	139.8	20.8
	Licensed Areas	3.03	0.45
*Trawl		230.5	34.4
Important Natural Areas		236.7	35.4
Multi-usage zones		59.97	8.95

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

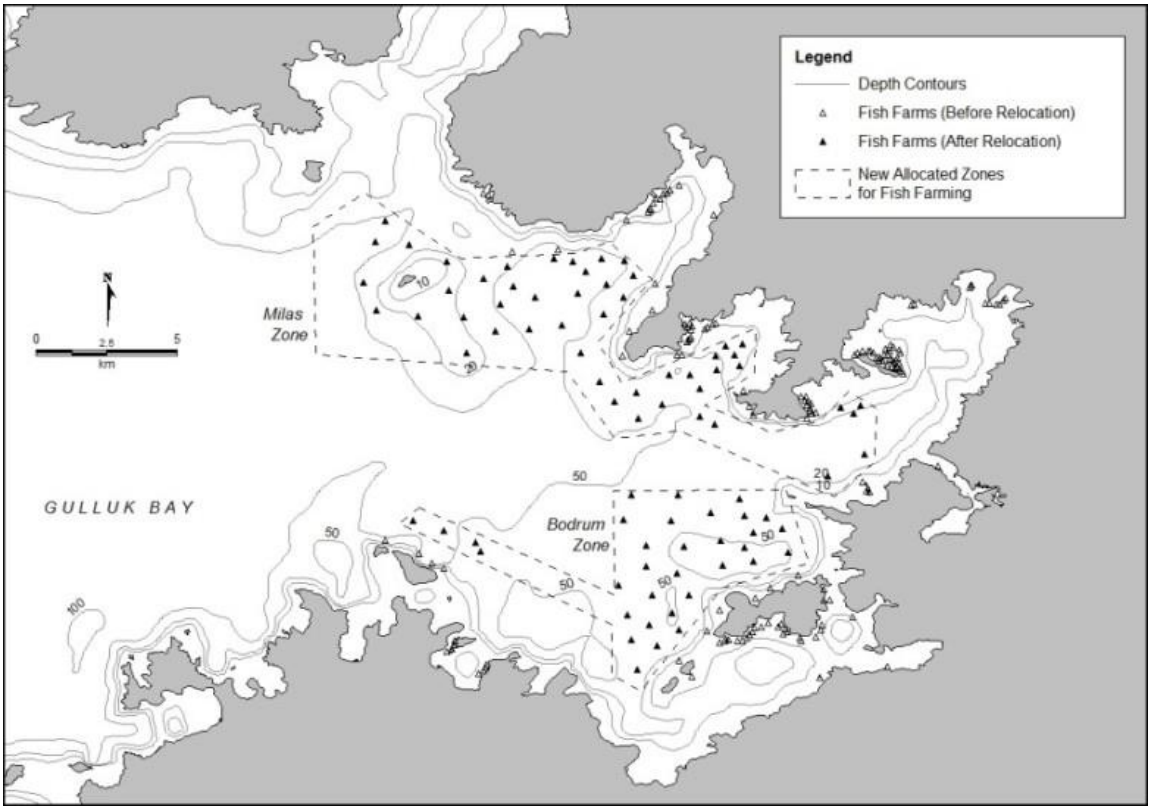

Figure 3. Gulluk Bay before and after the relocation of the fish farms.

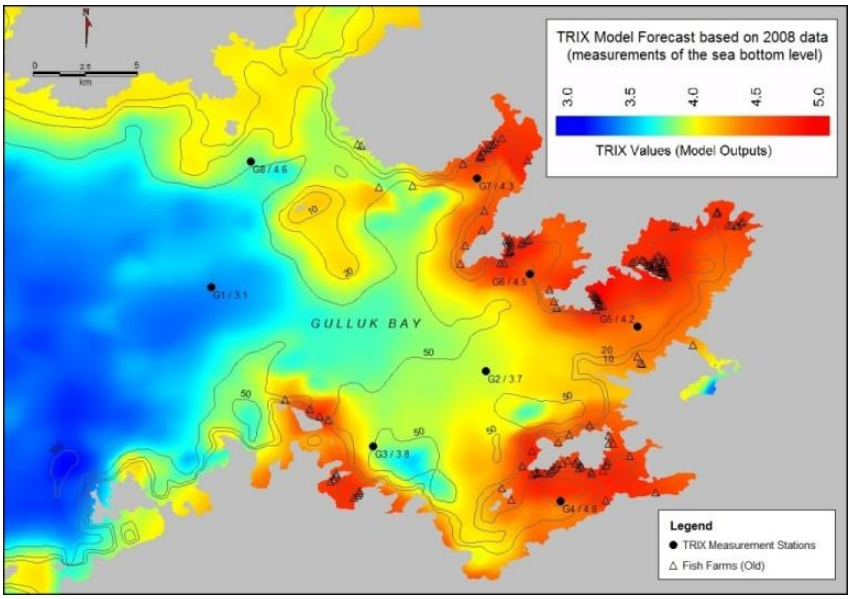

Figure 4. TRIX values interpolated from modeled outputs and old fish farming areas in Gulluk Bay.

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 (Figure2). 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 planed production capacity was increased to 88,000 tons 48 of these fish farms have a capacity of between 500 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 sitting 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.

Acknowledgements

This study was supported by the IMST-DEU/BAP (Project no. 2011.KB.FEN.025). For valuable help and information, we would like to thank Ufuk Akbıyık Mugla Aquaculture Association, to Safak Agacdiken, General Director of Environmental Impact Assessment and Planning/MEF, to Turker Kutlu the President of Gulluk Harbor Authority. We wish to say an especial thank you to Prof. Dr. Yalcin Arisoy for all his valued and excellent help with the GIS section of this study.

References

EIA, 2008. Mugla-Milas Fish Farming Environmental Impact Assessment Report. Mugla, Turkey, 126 pp, (In Turkish).

FAO, 2012. Draft of Guidelines for establishment of Allocated Zones for Aquaculture (AZA) in the Mediterranean countries. General Fisheries Commission for the Mediterranean Studies and Reviews No. 93, 35 pp.

IMST-165, 2008. MED POL PHASE IV Long term

biomonitoring, trend and compliance monitoring program in coastal areas from Aegean Northeastern Mediterranean and Eutrophication monitoring in Mersin Bay Final Report. Izmir –Turkey, 257 pp.

IMST-DEU/BAP, 2012. Project no.KB.FEN.025. GIS for Integrated Coastal Management in the Bayof Gulluk and for the Determination of Marine and Coastal Areas of Use, Final Report. Izmir –Turkey, 19 pp.

IU, 2006. Project to determine possible parameters and of pollution for Sensitive Areas of Mugla Province in relation to proposed new Aquaculture Areas, 94 pp (In Turkish).

MARA (Ministry of Agriculture and Rural Affairs) Report, 1988. Research project of Gulluk Lagun. Institute of Fishery in Bodrum, Turkey, 41pp (In Turkish).

MARA, 2008. Notification of Fishery Regulation. Turkish Official Gazette No. 26974, (In Turkish)

MARA-FAO, 2009. Report Developing a Roadmap for Turkish Marine Aquaculture Site Selection and Zoning Using an Ecosystem Approach to Management Project TCP-TUR-3101, 44 pp.

MEDPOL, 2009. MED POL PHASE IV Long term biomonitoring, trend and compliance monitoring program in coastal areas from Aegean Northeastern Mediterranean and Eutrophication monitoring in Mersin Bay Final Report, 396 pp.

MEF, 2007. The notification to identify the closed bay and gulf qualified sensitive where fish farms are not suitable to be established in the seas. Turkish Official Gazette No. 26413 (In Turkish).

MEF, 2009. The notification to monitor of fish farming facilities. Turkish Official Gazette No. 27257 (In Turkish).

ÇOB, 2012. Aydin-Mugla-Denizli Planning Region 1/100 000 Scale Environment Master Plan Information Report. General Directorate of EIA and Planning. 141 pp (In Turkish).

MEF, 2010. Aydin-Mugla-Denizli Planning Region 1/100 000 Scale Environment Master Plan Information Report. General Directorate of EIA and Planning. 141 pp (In Turkish).

MEF, 2011. General Directory of Nature Protection and National Parks. (http://gis2.cevreorman.gov.tr/mp/)

Tokac, A., Unal, V., Tosunoglu, Z., Akyol, O., Ozbilgin, H. and Gokce, G. 2010. Aegean Sea fisheries. DTO Izmir Publications, Izmir, 390 pp (In Turkish).

TURKSTAT, 2010. Fishery Statistics Prime Ministry Republic of Turkey Turkish Statistical Institute Fishery Statistics in 2009. ISSN 1013-6177 (In Turkish) (http://www.turkstat.gov.tr)

TKDK, 2013. Official web page of Republic of Turkey Ministry of Food, Agriculture and Livestock http://www.tkdk.gov.tr/BasvuruFiles/BasvuruPaketiHazirlamaDokumanlari/KirsalAlan/KirsalAlan.xls, (Accessed date, Jan18, 2013) (in Turkish).

Volleinweider, R.A., Giovanardi, F., Montanari, G. and Rinaldi, A. 1998. Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics, 9: 329–357. doi: 10.1002/(SICI)1099-095X (199805/06)9:3<329::AID-ENV308>3.0.CO;2-9

Yucel-Gier, G., Pazi, I., Kucuksezgin, F.and Kocak, F. 2011. The composite trophic status index (TRIX) as a potential tool for the regulation of Turkish marine aquaculture as applied to the eastern Aegean coast (Izmir Bay) J. Appl. Ichthyol., 27: 39–4. doi: 10.1111/j.1439-0426.2010.01576.x