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RESEARCH PAPER

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Analysis of Long and Short Terms Fishery Landings of Köyceğiz Lagoon (Turkey)

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Abstract

In the present study, we analysed long and short terms fishery landings of Köyceğiz Lagoon recorded by Dalko (Dalyan Fishery Cooperative) for sustainable fishery. These time series are long-term (1974-2016) data which include monthly short-term (2012-2016) in the more recent years. A combination of Principal Component Analysis (PCA) and Hierarchical Clustering Analysis (HCA) were used to determined characteristics of the lagoon. Grey mullets are the most abundant species accounting for 86% of the total biomass of the landing for the 43-year period, followed by Common carp, European eel, Sea bass, Gilthead sea bream and others. PCA values are highly correlated grey mullets, European eel and Sea bass for P1, Striped sea bream, Gilthead sea bream, Carp and other for PC2, respectively. The first discernible cluster comprised Gilthead sea bream, Striped sea bream, Sea bass, other and European eel. The second included carp and the third cluster was represented by Grey mullets. Köyceğiz Lagoon is the only lagoon where landings did not show a decreasing trend for a long time in Turkey due to the fact that lagoons have been strictly protected by special rules and owing to the fishing strategies developed by Dalko.

Introduction

Coastal lagoons are defined as shallow coastal lake or wet land, which is separated from sea by a sand barrier, usually has brackish water characteristics and also has connection with the sea through one or more inlets (Joyeux & Ward, 1998). These fragile ecosystems are sensitive to climate changes and influenced by the marine and terrestrial environments (Katselis, Moutopoulos, Dimitriou, & Koutsikopoulos, 2013) which lead to highly variable abiotic condition. The highly variable abiotic conditions create nutritionally rich habitats for a number of fish species in juvenile and adult stages. However, many Mediterranean lagoons have recently disappeared due to severe anthropogenic pressures and climate change (Moutopoulos, Katselis, Kentrou, & Koutsikopoulos, 2007; Cataudella, Crosetti, Ciccotti, & Massa, 2015). Anthropogenic impacts such as fishing, pollution, eutrophication, habitat loss, introduction of non-indigenous species, and climate change and their natural consequences are the pressing problems to the Mediterranean lagoons. These impacts together with the influence of environmental variables, lead to changes in spatial and temporal distribution of fish species and/or to significant habitat losses for the aquatic organisms.

In the beginning of the 1990s, there were 72 coastal lagoons that covered 36000 ha along the coast of Turkey (Anonymous, 1997). The numbers of lagoons, their surface area, and ecological functions have been reduced due to various reasons including climate change, urbanization, land reclamation, and pollution (Tosunoğlu, Kaykaç, & Ünal, 2017). At present, thirteen lagoons are used for fishing with various types of gears along the coast of Turkey. The physical characteristics, management authority, and type of fishery vary among the lagoons. The main fishing gear in all these lagoons is barrier traps various shape and size.

Köyceğiz Lagoon is different its geomorphology and ecology from the other lagoons in Turkey as well as Mediterranean. The lagoon complex ecosystem consists of Lake Köyceğiz (freshwater), Dalyan Channel, Meander Bed and Lake Sülüngür (brackish) which display various water characteristics such as salinity, turbidity. Because

its location is in a very important touristic area with rich ecological value, Lake Köyceğiz was declared as Köyceğiz-Dalyan Specially Protected Environmental Area (SPEA) in 1988. For this reason only barrier traps are used for the exploitation of the fish assemblages from that date in the protected area.

Many studies were performed about water quality (Ekdal, 2008; Özçelik, 2015), dynamics (Bayarı, Kurttaş, & Tezcan, 2001; Gönenç, *et al*., 2004; Stumpp, Ekdal, Gönenç, & Maloszewski, 2014) and biodiversity (Kazancı, Oğuzkurt, Girgin., & Dügel, 2003; Akın, Buhan, Winemiller, & Yılmaz, 2005; Balık, Ustaoğlu, Sarı, İlhan, & Topkara, 2005; Saygılı, Yiğit, & Bulut, 2011) of Köyceğiz Lagoon. However, limited studies on fishes inhabited the ecosystem and fishing practised, are available. Although there is no detailed study on fish taxonomy in Köyceğiz Lagoon, totally 50 fish species were revealed by a few studies (Bilecik, *et al*., 1994; Buhan, 1998; Akın *et al*., 2005; Bilecenoğlu, 2007). Some biological characteristics of European eel (Anguilla Anguilla) and Thinlip grey mullet (Liza ramada), which are the most important commercial species in Köyceğiz Lagoon, were studied between 1986 and 1988 by Yerli (1991, 1992). Spatial and temporal variation in fish assemblage structure of Köyceğiz Lagoon Estuarine System (KLES) was investigated during October 1993-September 1994 by Akın *et al*., (2005). In this study eighteen species were determined in trammel net samplings in the lagoon. Only five different grey mullet species Mugil cephalus, Liza aurata, Liza saliens, Liza ramada and Chelon labrosus have been caught in Köyceğiz barrier traps (Alparslan, Baygar, Cerim, Metin, & Ateş, 2016).

The fishing access of the Köyceğiz Lagoon by private enterprises continued to 1970s when the Ministry of Rural Affairs and Cooperatives was established. After that date, the ministry engaged the lagoon to the nearest fishery cooperatives with a statute. Dalko (Dalyan Fisheries Cooperative) is the only cooperative that leased and operates the Köyceğiz Lagoon for a long time (43 year) without interruption and has landing records regularly in Turkey since the establishment. Therefore, this study is based on the landing records of the cooperative.

In the present study, annually long term (period 1974-2016) and monthly short term (period 2012-2016) fishery landings of the Köyceğiz Lagoon were analysed in detail and discussed for sustainable fishery.

Materials and Methods

Köyceğiz Lagoon is a complex ecosystem that consists of Lake Köyceğiz, Dalyan Channel and Meander Beds, Lake Alagöl, Lake Sülüngür, Lake Sülüklü and Iztuzu Beach (Figure 1). Lake Köyceğiz has nearly 5500 ha surface area and the length and width of the lake is 12-13 km and 5-6 km, respectively. The lake is formed by two basins as Köyceğiz Basin (north side) and Sultaniye Basin (south side). Köyceğiz Basin is bigger but shallower (24 m average depth) than Sultaniye Basin (28-30 m). The two basins are connected with a quite narrow and shallow passage having an average depth of 4 m. Dalyan Channel, which is a bridge between the Mediterranean Sea and Lake Köyceğiz, has a length of 10 km. Its width and depth varies between 5 and 70 m and 1 and 6 m, respectively. The outflow of Lake Köyceğiz, which is commonly called Dalyan River, follows a meandering bed, which enlarges into a labyrinth-like channel system

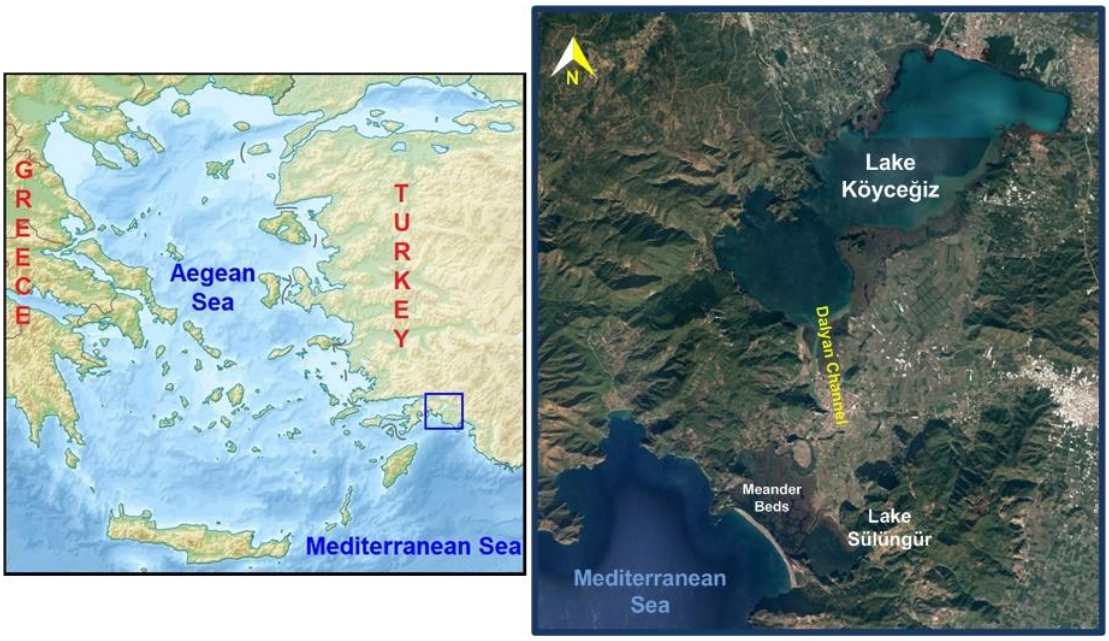

Figure 1. Köyceğiz Lagoon and its components (Google Earth, 2017).

discharging into the Mediterranean Sea at Dalyanağzı (Kazancı *et al*., 2003). Dalyan Channel has a delta area (meander bed) with approximately 1150 ha and it merges with the sea with a 100 m width and nearly 4 to 5-km long beach. Lake Alagöl, located at the mouth of the channel, Lakes Sülüngür and Sülüklü located near Lake Iztuzu are three major mesohaline lakes in Köyceğiz Lagoon system (Kazancı, İzbırak, Çağlar, & Gökçe, 1992). Lake Köyceğiz is fed by a lot of creeks with different sizes and flows into the Mediterranean Sea through Dalyan Channel. Namnam and Yuvarlakçay are the main creeks that feeds the lake. In addition, there are many medium scaled creeks, seasonal creeks and ten drainage channels contributing to the lake. Flowrate of Namnam and Yuvarlakçay Creeks decreases in summer months due to the Mediterranean climate effect and irrigation (Özçelik, 2015).

In Köyceğiz Lagoon, there are four traditional barrier traps. The largest of these traps is Convex barrier exposed to the freshwaters of the Lake Köyceğiz and supply the majority of the landings. The other three small size barriers near the Lake Sülüngür consist of salty waters supply approximately 5-10% percent of total landings. While Convex barrier is run all year round, the small ones are opened along the two periods (beginning of September to mid of October and from mid of March to end of April) to enter the principal fish species into the Sülüngür Lake part of the Köyceğiz Lagoon. Traps are built up on the two sides of Convex barrier to catch various fish species in certain periods of the year by means of the current and tidal effects. Fishes are gathered in Convex by the six V type passages to the four confined barrier backyards. The backyards of the Convex barrier can easily stock approximately one thousand tonnes alive fish.

The usage of the any type of fishing gear such as trammel net, gillnet, longline and fyke nets is forbidden in Köyceğiz lagoon for a long time according to Turkish Fisheries Regulations since 2000.

Dalko (Dalyan Fisheries Cooperative) is the only cooperative that leased and operates the Köyceğiz Lagoon for a long time (43 year) without interruption. The cooperative, about 600 members (65 working personnel), has leased the lagoon from the ministry concerned for a period of five years to 80000 Euro per year. However, none of these members catch in the lagoon. All lagoons in Turkey including Köyceğiz are government property and managed by Ministry of Food, Agriculture and Livestock, General Directorate of Fisheries and Aquaculture.

Fisheries data of the Köyceğiz Lagoon consist of time series annual landings according to species based on the records of the lagoon exploiter Dalko. These time series are long-term (1974-2016) data which include monthly short-term (2012-2016) data in the more recent years. In addition to the landing data, production data from intensive mariculture for gilthead sea bream and sea bass are available for the period from 2003 to 2014. However, mariculture production has ended by a regulation implemented by related ministry since 2014.

The landings of the species used in this study were computed by the sum of the landings of all the commercial categories defined by the different size ranges of the species. Species were categorized according to the commercial group. Grey mullets included all the commercial sizes of flathead grey mullet, golden grey mullet, thick-lipped grey mullet, leaping mullet and thin-lipped grey mullet. Gilthead sea breams *Sparus aurata*, Sea bass *Dicenrtatchus labrax*, Common sole *Solea solea*, European eel, Common carp *Cyprinus carpio* are also commercially exploited important fish species. The category 'others' included the low quantities of different commercial fishes and invertebrates as bycatch; striped bream *Lithognathus mormyrus*, Atlantic bonito *Sarda sarda*, Bluefish *Pomatomus saltatrix*, white sea bream *Diplodus sargus*, white grouper *Epinephelus aeneus*, Marbled spinefoot *Siganus rivulatus*, bogue *Boops boops*, sharp snout sea bream *Diplodus puntazzo*, Blue crap *Callinectes sapidus* and Cuttlefish *Sepia officinalis*.

All landing characteristics in terms of total and species categories were illustrated by various graphics for the annually long term period between 1974 and 2016 and monthly short term period between 2012 and 2016. Descriptive statistics of the landings was also given. The confidence intervals calculated for the landing data were estimated by multiplying the mean ± 2*SD.

The main purpose of this study is to find an effective, quantitative approach to species landed emerging in Köyceğiz Lagoon by basic component analysis and hierarchical cluster analysis methods. PCA is a multivariate statistical method to reduce the size of data without losing important information. This is uncontrolled neutral classification method of data classification. PCA, multidimensional data reflect a new sub-dimension subspace. When the variance % of the principal components is greater than 5% (eigenvalue value) or 80% (total variance) these values are considered to have significant influence (Jackson, 2005). Using this rule, the first two PCs are sufficient because they described 90.00% of the sample variability. This is in accordance, which suggests rejecting those PC having eigenvalues <0.7 (Jolliffe, 1973). Principal components (PCs), known as the new sub axes, multidimensional linear combinations of original variables in the formula. The first principal component (PC1) corresponds to the large main variant of the data. The second base component (PC2) is first guided by the second largest variation of the data and so on.

In addition to PCA, to find the Hierarchical Clustering Analyse (HCA) compounds parties have used as a supervised classification method. HC calculations are based on the multidimensional space of the variables and similarity in clusters. Hierarchical clustering on the main components, using methods Ward extent with the Euclidean distance as a measure of similarity between individuals was carried out on the

basic components. The results of cluster analysis, to represent the compounds of the horizontal axis and vertical axis of individuals have been proposed as dendrogram represents the degree of similarity. The SPSS 15.0 software was utilized in all these analyses.

Results

Although total annual landing in the Köyceğiz Lagoon is as high as mean 300 (133-575) tons in the long-term period between 1974 and 2016, there have been major fluctuations over the years (Table 1; Figure 2). These fluctuations were also seen in each species that landed. Despite these fluctuations total landing amount has not declined for a long time. Grey mullets are the most abundant species accounting for 86% of the total biomass of the landings for the 43-year period, followed by Common carp (5), European eel (4), Sea bass (2), Gilthead sea bream (1), and Striped sea bream (0.5). The highest landing was obtained with 568 tonnes for Grey mullets in 2010 and recently these species have constituted almost all landings (over 95%). The mean annual landing of the latest period (2012-2016) were higher than the previous years for grey mullets and the total landings ($p<0.05$). Common carp and European eel landings, which were higher after Grey mullets, ended in 1994 and 2008, respectively (Figure 2). While Sea bass landings have decreased along the years ($p<0.05$), Gilthead sea bream's is the same level with a higher variability ($p>0.05$). In addition to the fisheries landings, over 100 tonnes gilthead Sea bream and Sea bass were totally produced in the first year of the mariculture practices in Köyceğiz Lagoon. Mean total production of the last three years was about 35 tonnes. Gilthead sea bream and Sea bass productions were approximately 20 and 10 tonnes, respectively, in the last production year 2014. A substantially higher fluctuation among the years is also seen in mariculture production in Köyceğiz Lagoon (Figure 3).

PCA analysis (for 7 fish species) on the Köyceğiz Lagoon was grouped using 43 year landing data so that the best model with the least number of dimensions defining the data structure can be selected (Table 2). The first two functions of the species landed and the relative weight are given in Figure 4. Furthermore, Figure 4 is a graph of the weights of the original set of variables in the plane of the first two PCs of production. Also, these values are highly correlated grey mullets, European eel and Sea bass for P1, Striped sea bream, Gilthead sea bream, Carp and other for PC2, respectively (Figure 4).

Hierarchical Cluster Analysis (HCA) was performed

Table 1. Descriptive statistics of Köyceğiz Lagoon landings in the period of 1974-2016

Species	Count	Min	Max	Range	Mean ± (2*SD)
Grey mullets	43	79,600.0	567,582.0	487,982.0	252,070.1 ± 33,147.2
Seabass	43	1,685.1	24,090.0	22,405.0	6,846.1 ± 1,274.8
Gilthead bream	43	306.0	14,819.0	14,513.0	3,867.2 ± 827.8
European eel	42	8.0	27,589.0	27,581.0	11,048.9 ± 2,174.6
Common carp	21	1,786.0	61,186.0	59,400.0	30,108.8 ± 6,699.2
Striped bream	19	41.0	2,286.3	2,245.3	824.1 ± 304.2
Other	40	314.0	28,708.0	28,394.0	5,310.8 ± 1,537.4
Total	43	133,242.0	574,806.0	441,564.0	293,044.5 ± 31,580.6

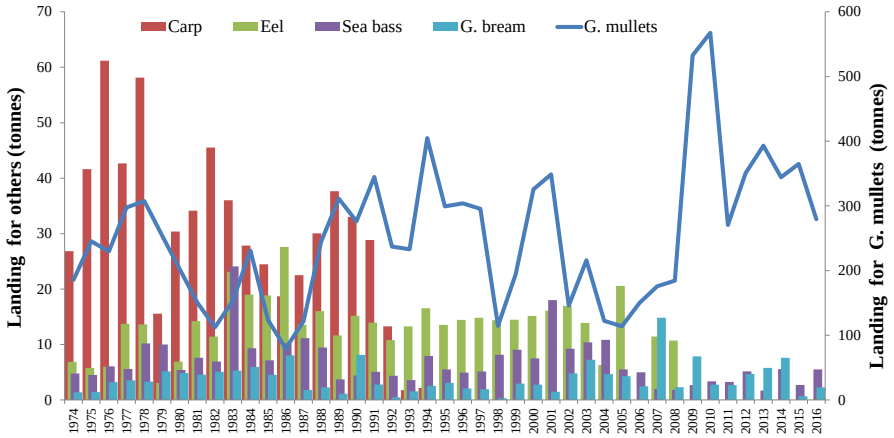

Figure 2. Species which are landed from Köyceğiz Lagoon period of 1974 to 2016.

to analyse the landing composition of species caught in Köyceğiz Lagoon. The dendrogram resulting from the CA analysis together with the AU (Approximately Unbiased), p-values and BP (Bootstrap Probability), shows three main groups, significant at least at the 95% confidence interval ($p<0.05$) (Figure 5). The first discernible cluster comprised Gilthead sea bream, Striped sea bream, Sea bass, other and European eel. The second included carp and the third cluster was represented by Grey mullets.

Two different catching incidents were observed in Köyceğiz Lagoon barriers. The first one was ontogenetic migrations of grey mullets in summer and autumn/winter months and the second one concerned offshore migration of the species linked to their reaction to the environmental changes in winter months. However, landings from Köyceğiz Lagoon barrier backyards extend to March sometimes even April due to marketing conditions (Figure 6). The highest landings period of Grey mullets start from June, prolonged to April in barrier traps of Köyceğiz Lagoon. Percentages of the grey mullet species for the last five years were estimated as 85-90 thin-lipped, 8-12 flat-head, 1-3 leaping, 0.3-0.7 thick-lipped and 0.2-0.6 golden grey. In general, species of grey mullets have landed from the

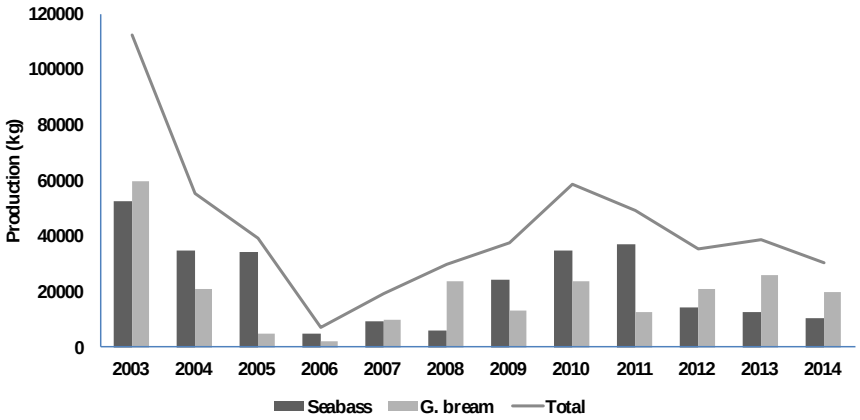

Figure 3. Annual mariculture production of Köyceğiz Lagoon for sea bass and gilthead sea bream.

Table 2. Variance values explained by the principal components for landings of seven species in Köyceğiz Lagoon

Component	Eigenvalues	% of Variance	Cumulative %
Grey mullets	2.284	32.631	32.631
European eel	1.323	18.905	51.537
Sea bass	1.115	15.935	67.472
Gilthead bream	0.861	12.294	79.765
Carp	0.717	10.236	90.001
Striped bream	0.477	6.814	96.815
Other	0.223	3.185	100.000

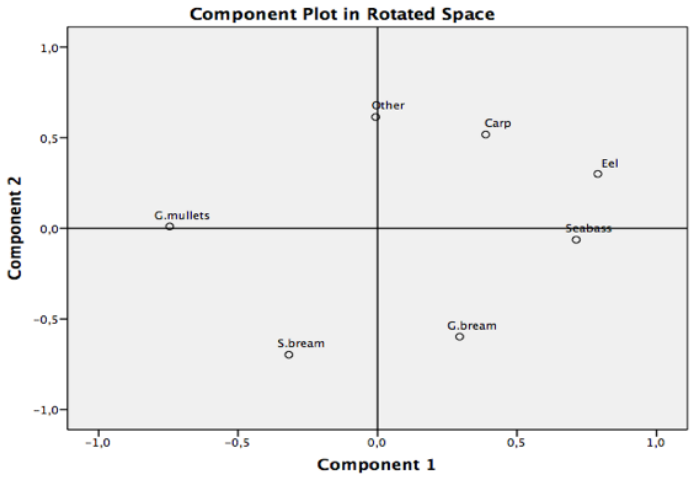

Figure 4. PCA for species landings.

barrier traps in Köyceğiz Lagoon within two periods. Flathead grey mullet and also Golden grey mullet are the first comers also called summer Grey mullet, and caught and landed densely between July and August. Thin-lipped grey mullets called winter mullet enter into the barrier trap only in November with higher amounts at two or three batches (each batch about 100 tonnes). However, their landings that begin as from November extend to March according to the market requirements. Leaping and thick-lipped grey mullets are the other winter Grey mullets caught in very small quantities compared to the Thin-lipped ones.

The major landings of Gilthead sea bream is seen in two periods as April-May and November-January (Figure 6) similar to the Thin-lipped grey mullet. Landings of the Sea bass start in December and it is prolonged to May. The months of May and June are the highest landings for Striped sea bream. Other species (Atlantic bonito, Blue fish, Red mullet, and Breams) landed every month with small quantity in Köyceğiz Lagoon. Although Grey mullets roe market data were seen in each month, higher amounts of roe obtained from thin-lipped Grey mullet between November and December. In addition to this, the most invaluable roe production from Flathead grey mullet started in July, as prolonged to end of the August.

Discussion

In Köyceğiz Lagoon barrier traps, five Mugilidae members, *M. cephalus*, *L. aurata*, *L. saliens*, *L. ramada* and *C. labrosus* were detected by many researches

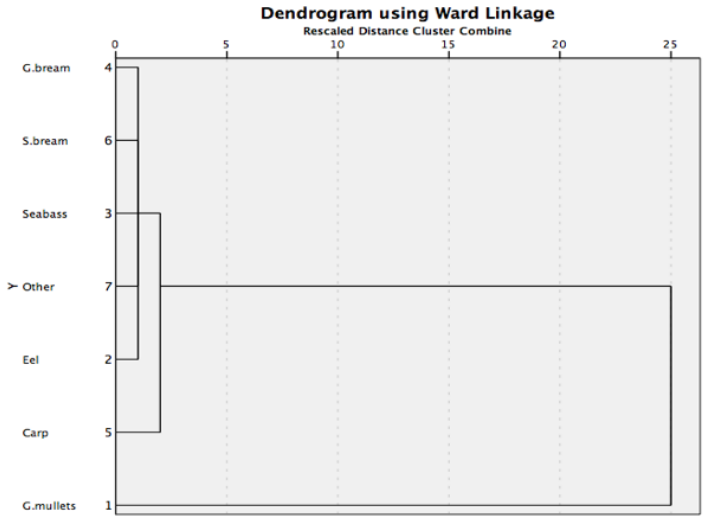

Figure 5. HCA for species landings.

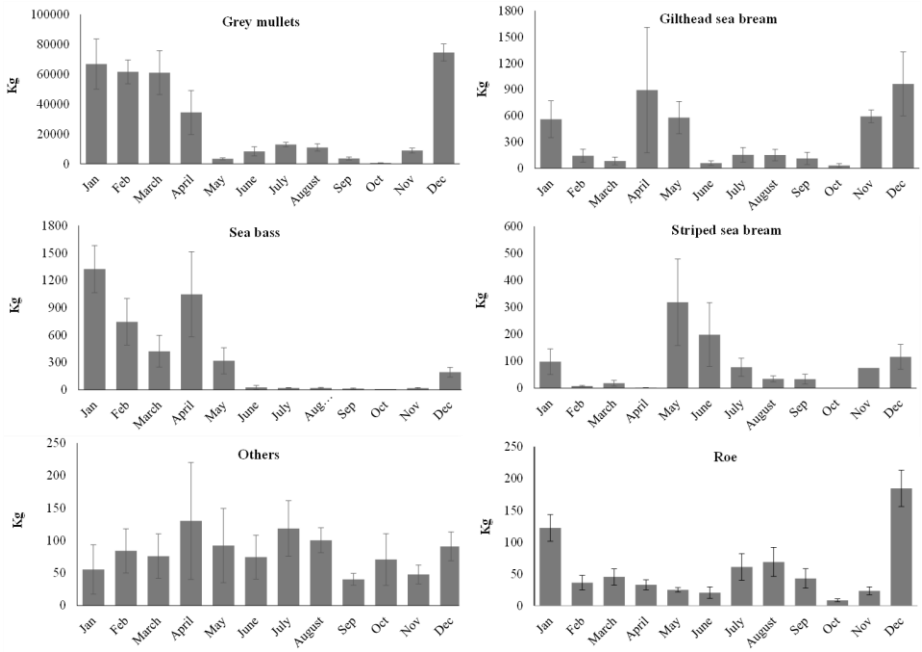

Figure 6. Average monthly landings with standard error bars in Köyceğiz Lagoon between 2012 and 2016.

(Yerli, 1992; Bilecik *et al*., 1994; Buhan, 1998; Akın *et al*., 2005; Alparslan *et al*., 2016). Yerli (1992) and Bilecenoğlu (2007) found that *L. ramada* was the most landed species after *M. cephalus*. Contrary to the abovementioned findings, Bilecik *et al.* (1994), Buhan (1998) and Akın *et al.* (2005) determined that *L. aurata* was the most landed species after *M. cephalus*. According to Buhan (1998), the percentage of Mugilidae species in Köyceğiz Lagoon is as follows; 35 for *M. cephalus*, 33.5 for *L. aurata*, 13.5 for *L. saliens*, 12.5 for *L. ramada* and 5.5 for C. *labrosus*. However, the percentage of *L. ramada* among the five landed Grey mullet species was found substantially higher (nearly ninety) in this study. Recently, fertilizer contribution induced by agricultural practices around Köyceğiz Lagoon may result in a higher *L. ramada* abundance depended to algae biomass. Mugilids microalgae and detritus feeders are more common in the muddy inland areas with higher abundance of detritus and algae in Köyceğiz Lagoon (Akın *et al*., 2005). Moreover, juvenile or larvae fishes use the ecosystem not only for feeding but also for predator avoidance (shelter area).

The fish populations of Köyceğiz Lagoon are mostly migratory fishes of marine origin. The Grey mullet landings are different from other species due to inhabited the Lake Köyceğiz and their ontogenetic migrations (Figure 4-5). Köyceğiz Lagoon system shows significant spatial and temporal differences in hydrologic gradients (Gönenç *et al*., 2004). According to Buhan (1998), salinity of Köyceğiz Lagoon system varied as 5.3‰ (2.8-8.2) for the Lake Köyceğiz, 5.7‰ (4.2-5.9) for the Dalyan Channel, 8.6‰ (5.4-14.3) for the Meander Beds (Convex weirs), 18.5‰ (9.2-32.8) for the Lake Sülüngür and 40‰ for the Iztuzu Beach (seaward). Salinity and turbidity were found to be the most important environmental parameters affecting fish distribution in the lagoon ecosystem. The sites near the sea were associated with high salinity and low turbidity, and the sites in upper reaches had low salinity and high turbidity (Akın *et al*., 2005). The other marine originated species were grouped regarding the choice of Lake Sülüngür and their migrations caused by environmental changes and feeding habits. Gilthead sea bream and sea bass, follower of the winter grey mullets, were also caught in the barrier traps from November to March (Figure 6). The reason of the follow-up is to feed by eggs hanging from the ovaries of the winter grey mullets in that period. In addition to the feeding behaviour in the lagoon, gilthead sea bream, sea bass and striped sea bream are oriented to the lagoon by the freshwater surface current in the channel in certain times of the year. Ontogenetic migration of grey mullets, and tidal flow and surface currents orientate the gilthead and striped sea bream from the lagoon to the seaward, supplying bulges of catch in the barrier traps easily prolonged the spring season (Moutopoulos *et al*., 2007).

A concern with use of the strategies is that while each has its own set of inter-ventions that address a particular problem or set of problems, they are often not utilized together in an integrated manner to address the complex web of issues and solutions that are necessary to deal with insecurity and build resilience in coastal communities (Pomeroy, 2016; Stephenson, *et al*., 2016). Dalko is a good example for the greatest potential for contributing to the solution of problems facing the traditional fisheries and their communities. Köyceğiz is the one of the most productive lagoon in terms of commercial landings among the Turkish as well as Mediterranean lagoons and total landing amount has not declined for a long time. Sustainability of the landings can be explained by the protection of the lagoon environment by special rules since 1988 and implementations of the strategies launched by Dalko. For instance, approximately 30 percent of mature fish release or escape from the gates and inlets of the lagoon according to the administrative board of the lagoon. The board and master fishermen of the lagoon also claim that this application is the guarantee of the upcoming year production. Released fish populations from the lagoon will become the spawning stock biomass for the next year recruitments. Notwithstanding the landing percentage of grey mullets highly increased during the recent years due to the extinction of fresh water species such as Common carp and Cat fish, and low abundance of other marine originated fish species by overfishing in adjacent marine areas. As a result, grey mullets have shown time-dependent increase in landing values with percentages of 70-80 in 1974-1990, 80-90 in 1991-2008 and over 95 in the last eight years.

The rich fish assemblages found in lagoons have always represented a source of income and livelihood for human settlements throughout the Mediterranean basin (Cataudella, *et, al.,* 2015). These activities play an important role in both socio-economic and cultural aspects of the people of coastal communities (Malouli, Zahri, Houssa, Abdelaoui, & El Ouamari, 2002; Lloret, Marin, Velasco, & Bello, 2015) as shown in Köyceğiz lagoon. For instance, Blue crap (*Callinectes sapidus*) landing in Köyceğiz Lagoon started firstly in 2017 tourism season. A total of 45,637 individuals with a mean weight (se) 210.34 (6.28) gr were marketed to the tourists with cooked as fast food and alive to the restaurant in the vicinity between May and November. The minimum and maximum weight of the marketed blue crap (n=81) were between 83 and 373 gr, respectively. It is thought that this overfishing carried out during the seasons will have a negative impact on the species stock next year. For this reason, agreements have already been made regarding the purchase of blue crabs from other nearby lagoons for the upcoming tourist season.

The complex character of lagoon system makes it difficult to predict how the system will respond. Complex policy problems are characterized by the systemic and persistent character of the environmental problem, many interdependencies, a diversity of

stakeholder interests, and many different views on the problem (Zaucha, Conides, Klaoudatos, & Norén, 2016a, Zaucha, *et al*., 2016b). Freshwater species Common carp, *Silurus glanis*, and European eel were captured in Köyceğiz Lagoon and its channels by trammel nets and fyke nets, respectively before 2000s. Tilapia species *Tilapia zilli*, *Oreochromis aureus* and *Oreochromis mossambicus* inhabited Köyceğiz Lake. The reason of ending the carp fishing is related to increasing tilapias populations (Bilecik *et al*., 1994), because these fishes have the ability to strong competition. They are higher feeder individuals and show higher growth performance and reach sexual maturity size quickly (Howard, 2002; Bilecenoğlu, 2007). Therefore, their population doubled in one-year period. Buhan (1998) also claimed that lower hatching rate of the carp eggs due to unsuitable water quality of the lake and overfishing on the species might be the reasons of the decreased carp population. One of the solutions to cope with the problem of ended landing is restocking or stock enhancement which is the practice of putting artificially reared young fish into their natural environment to let them grow (Cooke, 1984). Recently, administrative board of Köyceğiz Lagoon has requested restocking of Common carp fry into Lake Köyceğiz from the related Ministry. Restocking applications with Flathead grey mullet, European sea bass, and Gilthead sea bream fry were carried out in many lagoons in Mediterranean (Ardizzone, Cataudella, & Rossi, 1988; Franzoi, Trisolini, & Rossi, 1999; Koutrakis, Conides, Parpoura, Van Ham, Katselis, & Koutsikopoulos, 2007).

European eel landings have not been observed in Köyceğiz Lagoon along the last ten years. Because the export ban on the species has prevented the caught by fyke nets and the barriers. This species is not also preferred for domestic consumption. Turkey's export quota for this species has been identified as 70 tons in 2017. According to the administrative board of Köyceğiz Lagoon, about 20 tonnes European eel can be exploited each year. The board also claim that remarkable amount of eel escaped from the lagoon barrier to the seaward each year. As it was found a region-wide decline in eel catch, beginning in the mid-1970s and lower productivity in larger lagoons and those in the southern Mediterranean (Aalto, *et al*., 2017), the European Union issued the Regulation EC 1100/2007 (Council of the European Union, 2007) to reduce anthropogenic mortalities so as to permit the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of pristine escapement in 2007. However, the protected nature of the Köyceğiz Lagoon is still considered to provide pristine biomass level of eel stocks.

Recently, new administrative board of Köyceğiz Lagoon investigates methods of sustainable fish production and increases fish productions by intensive culture or *Valliculture*. For these reasons *Mariculture* in earth ponds or *Valliculture in the lagoon* area is their priority area of investment to diversify production methods. Sea bass mariculture in earth ponds is rather common around the Güllük lagoon area which is very close to Köyceğiz Lagoon. Therefore, if the permissions are taken/given for mariculture in earth ponds from the related ministries, we believe that this production will be launched successfully in a short time in Köyceğiz Lagoon and this production model may spread rapidly over other lagoons in Turkey.

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References

Aalto, E., Capoccioni, F., Terradez Mas, J., Schiavina, M., Leone, C., De Leo, G., & Ciccotti, E. (2016). Quantifying 60 years of declining European eel (*Anguilla anguilla* L., 1758) fishery yields in Mediterranean coastal lagoons. *ICES Journal of Marine Science, 73*, 101-110. https://doi.org/10.1093/icesjms/fsv084

Akın, S., Buhan, E., Winemiller, K.O., & Yılmaz, H. (2005). Fish assemblage structure of Köycegiz Lagoon Estuary, Turkey: Spatial and temporal distribution patterns in relation to environmental variation. *Estuarine, Coastal and Shelf Science, 64(4)*, 671-684.

Retrieved from https://ac.els-cdn.com/S0272771405001290/1-s2.0-S0272771405001290-main.pdf?_tid=3c3bef08-da8b-11e7-b53d-00000aacb35f&acdnat=1512567901_f41e53a24fbee447e6fe937945f90a7a

Alparslan, Y., Baygar, T., Cerim, H., Metin, C., & Ateş, Ü. (2016). Detection of nutritional compositions and meat quality aspects of grey mullet species (*Mugilidae*) in Köyceğiz lagoon (*in Turkish*). TUBİTAK Project Final Report No. 115O839, Muğla, 51 p.

Anonymous (1997). Management and Development Strategies, and Reclamation of Coastal Lagoons along the Coast of Turkey (in Turkish). Volume I-II. Republic of Turkey, Ministry of Agriculture and Rural Affairs, General Directorate of Agricultural Production and Development. ST Servizi Tecnici in Maricultura. *Vol I.* 579 pp.

Ardizzone, G.D., Cataudella, S. & Rossi, R. (1988). Management of coastal lagoon fisheries and aquaculture in Italy. FAO Fisheries Technical Paper, *No. 293*, Rome, 103 pp.

Balık, S., Ustaoğlu, M.R., Sarı, H.M., İlhan, A., & Topkara, E.T. (2005). The fish fauna of Yuvarlakçay (Köyceğiz, Muğla) (*in Turkish*). *Ege Journal of Fisheries and Aquatic Sciences, 22(1-2)*, 221-223. Retrieved from https://www.researchgate.net/publication/307643220_The_fish_fauna_of_Yuvarlakcay_Koycegiz_Mugla

Bayarı, C.S., Kurttaş, T., & Tezcan, L. (2001). Dynamics of Lake Köyceğiz, SW Turkey: An environmental isotopic and hydrochemical study. *In:* Use of isotope techniques in lake dynamics investigations, IAEA-TECDOC-1206, Vienna, Austria. Retrieved from http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/32/018/32018313.pdf

Bilecenoğlu, M. (2007). Fishing and Fisheries. *In* Project on Köyceğiz-Dalyan Specially Protected Area Determination of Biological Richness and Preparing Management Plan. Republic of Turkey Ministry of Environment and Forestry. Authority for Protection of Special Areas. 363-379 pp.

Bilecik, N., Ezer, N., Buhan, E., Morkan, Y., Erol, G., Topgül, M., … Dinçer, S. (1994). Fishery Project on Köyceğiz-Dalyan Specially Protected Area (*in Turkish*). Ministry of Environment, Authority for Protection of Special Areas (SPAA), Final Report, 117 p.

Buhan, E. (1998). Development of Lagoon Management of Köyceğiz Lagoon System by Researching Present Situation and Grey Mullet Populations (*in Turkish*). Ministry of Agriculture and Rural Affairs, Bodrum Fishery Research Institute Press, Serial B, Publish No. *3*, 347 p.

Cataudella, S., Crosetti, D., Ciccotti, E., & Massa, F. (2015). Sustainable Management in Mediterranean Coastal Lagoons: Interactions among Capture Fisheries, Aquaculture and the Environment. In S. Cataudella, D. Crosetti & F. Massa (Eds.), Mediterranean Coastal Lagoons: Sustainable Management and Interactions among Aquaculture, Capture Fisheries and the Environment (1-49 pp). FAO Studies and Reviews *No. 95*, Rome, Italy, 278 pp.

Cooke, J.G. (1984). Glossary of Technical Terms. In R.M. May (Edt.), Exploitation of Marine Communities. Springer-Verlag. New York NY, 348 pp.

Council of the European Union. (2007). Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Brussels, 7 p.

Ekdal, A. (2008). Water Quality Modeling of Köyceğiz- Dalyan Lagoon. Ph.D. Thesis. Istanbul Technical University, Istanbul, 236 p.

Franzoi, P., Trisolini, R. & Rossi, R. (1999). La pesca del novellame di pesce bianco da semina in Italia. La pesca del novellame, *Laguna (suppl.), 6*, 38-58.

Gönenç I.E., Beler Baykal B., Tanık A., Şeker D.Z., Gürel M., Ekdal A. ve Ertürk. A. (2004). Ecosystem modeling for the sustainable management of lagoons. Final Report. TUBITAK-YDABCAG Project No. 100Y047, Ankara.

Howard, G. (2002). Invasive species in water dependent ecosystems. Worldfish Center Scientific Reports, 22-26 pp. Retrieved from http://pubs.iclarm.net/Pubs/alien_species/pdf/04.pdf

Jackson, J. E. (2005). *A user's guide to principal components* (Vol. 587). John Wiley & Sons.

Jolliffe, I. (1973). Discarding Variables in a Principal Component Analysis. II: Real Data. *Journal of the Royal Statistical Society. Series C (Applied Statistics), 22(1)*, 21-31. https://dx.doi.org/10.2307/2346300

Joyeux, J.C., & Ward, A.B. (1998). Constraints on coastal lagoon fisheries. *Advances in Marine Biology, 34*, 73-199. https://doi.org/10.1016/S0065-2881(08)60211-4.

Katselis, G.N., Moutopoulos, D.K., Dimitriou, E.N., & Koutsikopoulos, C. (2013). Long-term changes of fisheries landings in enclosed gulf lagoons (Amvrakikos gulf, W Greece): Influences of fishing and other human impacts. *Estuarine, Coastal and Shelf Science*, 131, 31-40. http://dx.doi.org/10.1016/j.ecss.2013.07.004.

Koutrakis, E.T., Conides, A., Parpoura, A.C., Van Ham, E.H., Katselis, G., & Koutsikopoulos, C. (2007). Lagoon Fisheries Resources in Hellas. In C. Papaconstantinou, A. Zenetos, V. Vassilopoulou & G. Tserpes (Eds.), State of Hellenic Fisheries (pp. 223-233). Hellenic Centre for Marine Research Institute of Marine Biological Resources, Athens, HCMR Press., 466pp. Retrieved from https://www.researchgate.net/profile/Emmanuil_Koutrakis/publication/235285394_Lagoon_fisheries_resources_in_Hellas/links/02bfe510b93fcb1ca9000000/Lagoon-fisheries-resources-in-Hellas.pdf

Kazancı, N., İzbırak, A., Çağlar, S., & Gökçe, D. (1992). A Hydrobiological research on Köyceğiz-Dalyan Specially Protected Area. Özyurt Press, Ankara, 165 p.

Kazancı, N., Oğuzkurt, D., Girgin., S., & Dügel., M. (2003). Distribution of benthic macroinvertebrates in relation to physico-chemical properties in the Köyceğiz-Dalyan estuarine channel system (Mediterranean Sea, Turkey). *Indian Journal of Marine Sciences, 32(2)*: 141-146. Retrieved from http://nopr.niscair.res.in/bitstream/123456789/4257/1/IJMS%2032%282%29%20141-146.pdf

Lloret, J., Marin, A., Velasco, J., & Bello, C. (2015). The management story of Mar Menor. In A.I. Lillebø, P. Stålnacke & G.D. Gooch (Eds.), *Coastal Lagoons in Europe: Integrated Water Resource Strategies* (pp. 49-56). Water Research Series. IWA Publishing, London, UK, IWA Press., 223 pp.

Malouli, I.M., Zahri, Y., Houssa, R., Abdelaoui, B., & El Ouamari, N. (2002). Pêche artisanale dans la lagune de Nador: Exploitation et aspects socio-économiques. Retrived from http://webco.faocopemed.org/old_copemed/vldocs/0000762/case_std_nador.pdf

Moutopoulos, D. K., Katselis, G., Kentrou, A., & Koutsikopoulos, C. (2007). Indications of a possible change in the fishery exploitation pattern in Ionian Sea lagoons. In CIESM Congress Proceedings (*No. 38*). CIESM, Monaco.

Özçelik, O. (2015). Assessment and Prediction of Water Quality Parameters in Lake Köyceğiz Using Artificial Neural Network Approach. Master of Science Thesis. Middle East Technical University, Graduate School of Natural and Applied Sciences, Ankara, 148 p.

Pomeroy, R. (2016). A research framework for traditional fisheries: Revisited. *Marine Policy, 70*, 153-163. https://doi.org/10.1016/j.marpol.2016.05.012

Saygılı, F., Yiğit, N., & Bulut, Ş. (2011). The spatial and temporal distributions of waterbirds in Lakes Akşehir-Eber and Lake Köyceğiz in western Anatolia, Turkey-a comparative analysis. *Turkish Journal of Zoology, 35(4)*, 467-480. Retrieved from http://dergipark.gov.tr/download/article-file/134584

Stephenson, R. L., Paul, S., Pastoors, M. A., Kraan, M., Holm, P., Wiber, M., ... Benson, A. (2016). Integrating fishers' knowledge research in science and management. *ICES Journal of Marine Science*, *73(6)*, 1459-1465. https://doi.org/10.1093/icesjms/fsw025

Stumpp, C., Ekdal, A., Gönenç, E.I., & Maloszewski, P. (2014). Hydrological dynamics of water sources in a Mediterranean lagoon. *Hydrology and Earth System Sciences, 18*, 4825-4837. https://doi.org/10.5194/hess-18-4825-2014.

Tosunoğlu, Z., Kaykaç, M.H., & Ünal, V. (2017). Temporal

alterations of fishery landings in coastal lagoons along the Aegean coast of Turkey. *Turkish Journal of Fisheries and Aquatic Sciences, 17*, 1441-1448. https://doi.org/10.4194/1303-2712-v17_6_38

Yerli, S. (1991). Investigations on the stocks of *Anguilla anguilla* (Linnaeus, 1758) in Köyceğiz lagoon system (*in Turkish*). *Doğa Turkish Journal of Veterinary and Animal Sciences, 15*, 421-462.

Yerli, S. (1992). Investigations on the stocks of *Liza ramada* (Risso, 1826) in Köyceğiz lagoon system (*in Turkish*). *Doğa Turkish Journal of Veterinary and Animal Sciences, 16*, 103-120.

Zaucha, J., Conides, A., Klaoudatos, D., & Norén, K. (2016)a. Can the ecosystem services concept help in enhancing the resilience of land-sea social-ecological systems?. *Ocean and Coastal Management*, *124*, 33-41. https://doi.org/10.1016/j.ocecoaman.2016.01.015

Zaucha, J., Davoudi, S., Slob, A., Bouma, G., van Meerkerk, I., Oen, A. M., & Breedveld, G. D. (2016)b. State-of-the-lagoon reports as vehicles of cross-disciplinary integration. *Integrated environmental assessment and management*, *12(4)*, 690-700. https://doi.org/10.1002/ieam.1802