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RESEARCH PAPER

Temporal Alterations of Fishery Landings in Coastal Lagoons Along the Aegean Coast of Turkey

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Abstract

In the present study, we analysed the temporal changes of fisheries landings in the six coastal lagoons (Enez, Homa, Karina, Akköy, Güllük, and Köyceğiz) along the Aegean coast of Turkey. The data are based on the records of the lagoon cooperatives and previous related studies. The total annual fish landing from the lagoons, with a total area of 11300 ha, in 2015 was 530 tonnes. The landings trend from all lagoons except Köyceğiz and Karina was declining. The possible factors decreasing production include mismanagement, anthropogenic and climatic impacts. These factors can lead to changes in temporal distribution of fish species and total landings, which results in significant economic impacts. We suggest that the effects of harvesting and fishing are minimized by implementing appropriate management strategies developed together with the interested parties who highly invest in the lagoon productivity.

Keywords: The Aegean Sea, coastal lagoon, fishery landings, sustainability.

Introduction

Coastal lagoons are usually oriented parallel to the coast and separated from the sea by a sand barrier and connected to the sea by one or more communication channels or inlets with shallow waters (Kjerfve, 1994). Salinity varies from fresh water of the source streams and rivers to highly saline water of the associated sea, depending on their geomorphology. Lagoons have high productivity maintained by large nutrient inputs and play an important role as nursery areas for numerous invertebrate and fish species. Many fish species use coastal lagoons at some phases of their life cycles (Kapetsky, 1984). The essential elements of a lagoon are the brackish water that is important habitat for the juveniles migrating from the sea into the lagoon and the juveniles and adults migrating from the lagoon to the high salinity sea (Ardizzone, Cataudella, & Rossi, 1988).

The rich fish assemblages found in lagoons have always represented a source of income and livelihood for human settlements throughout the Mediterranean basin (Cataudella, Crosetti, Ciccotti, & Massa, 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).

Many Mediterranean lagoons have recently disappeared due to severe anthropogenic pressures and climate change (Cataudella *et al*., 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. In addition to aforementioned impacts, coastal lagoons are influenced by both the marine and the terrestrial environments (Katselis, Moutopoulos, Dimitriou, & Koutsikopoulos, 2013). These influences lead to highly variable abiotic conditions and are sensitive to climate changes. The lagoons are also vulnerable to human disturbance and that can create eutrophic habitats with low dissolved oxygen concentrations. Fishing (commercial/ recreational), mariculture, tourism and urban, industrial and agricultural discharges are the main human activities that affect the lagoon ecosystems. 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). Nineteen of the lagoons along the Aegean coast were leased in 1975

(Sarıkaya, 1980) while today there are only six (Tosunoğlu, Ünal, Kaykaç, Mermer, & Önem, 2015). 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 *et al*., 2015). At present, thirteen lagoons are used for fishing with various types of gears along the coast of Turkey. Six of them are on the Aegean coast, and seven are on the Levantine coast of Turkey. The physical characteristics, management authority, and type of fishery vary among the lagoons.

The traditional exploitation of all the Aegean lagoons is culture based on the seasonal migration movements of fry and adult fish between the sea and the lagoons. In Turkey, the lagoons are primarily exploited by barrier traps and nets. The basic principle of fishery exploitation of the lagoons is based on seasonal ongoing migrations of fish species from lagoon to the sea (offshore fish migration). In the Aegean coastal lagoons, fish can enter the lagoons by the way of opened barrier traps (weir) and inlets (canals) from February to June for feed and shelter. The barrier trap, constructed on the inlets of the lagoon, makes it possible to catch and harvest the migrant fish assemblages during their movement from lagoon to the sea at the rest of the year. Depending on the weather conditions, inlets of the lagoon are closed by construction of barrier traps and a kind of fence (tonoz) during the first week of June. Inlets remain closed (active) until January or February when the lagoon fishing period ends. Tonoz, usually made from reed plants, separates the lagoon from the sea and is traditionally used in the Karina, Akköy, and Güllük lagoons.

In addition to traditional harvesting practices, intensive aquaculture is only practised in the circular net cages in the Köyceğiz Lagoon. In all of the coastal lagoons, gillnets and trammel nets (rarely with reeds) with an 80 mm mesh size in the inner panel and 280 mm in the outer panels are also used for catching grey mullets (*Mugilidae spp*.). In addition, single, double and triple fyke nets specifically for European eel (*Anguilla anguilla*) and thick longline (a specific diameter of monofilament) for European sea bass (*Dicentrarchus labrax*) are preferred (Tosunoğlu *et al*., 2015).

In the Aegean coastal lagoons, flathead grey mullet (*Mugil cephalus*) and gilthead sea bream (*Sparus aurata*) are caught in large numbers in barrier traps between July-August and in September, respectively. Other fishing gears are generally used in the winter months for grey mullets (gillnets and trammel nets), European eel (fyke nets), and European sea bass (thick longline) (Kaykaç & Tosunoğlu, 2105). Flathead grey mullet is a commercially and highly important species because of the high value of the dried and salted mature ovaries. In practice, the fishing period starts in July and continues until the beginning of February of the next year, so the annual landings considered in the study correspond to this period.

Important fishing rules have been implemented for Turkish lagoons. It is compulsory that the lagoon inlets have to be open in a certain time of the year, and a minimum 10 % of the mature mullets must be realesed from the lagoons to the seaward side from the barrier traps. The distance between the barrier trap reeds (stick) should not be less than 30 mm (Anonymous, 2016).

In Turkey, all the coastal lagoons are public domain. A five-year license for fishing rights is given to the local fisheries cooperative or a private company through an agreement with the Directorate General for Fisheries and Aquaculture, Ministry of Food, Agriculture, and Livestock. One exceptional example is the Homa lagoon which has been allocated to the Ege University Faculty of Fisheries for education and research and run with joint venture system with local fishery cooperative (Tuzçullu Fishery Cooperative).

In the present study, a long-term time series data of fisheries landings and species availability in the six coastal lagoons along the Aegean coast of Turkey was analysed in relation to the changes observed in the anthropogenic impacts and environmental variables.

Materials and Methods

The six coastal lagoons along the Aegean coast of Turkey (Figure 1) were monitored in 2014 and 2015 to collect landings data and other parameters related to temporal changes. In addition to the records of the lagoons, data derived from face to face interviews with the managers and master fishers of the lagoons were used.

The species landings 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. Fisheries data consisted of the annual landings (total/species) based on the records of the lagoon cooperatives and previous studies.

Species were categorized according to the commercial group. All the commercial sizes of flathead grey mullet, thick-lipped grey mullet (*Chelon labrosus)*, leaping mullet (*Liza saliens)*, golden grey mullet (*Liza aurata)*, thin-lipped grey mullet (*Liza ramada)*, gilthead sea bream, European sea bass, common sole (*Solea solea)*, European eel, common carp (*Cyprinus carpio)* are important commercially explotited fish species. The category ‘others’ included the low quantities of different fish as bycatch; ceramote prawn (*Melicertus kerathurus)*, bluefish (*Pomatomus saltatrix)*, blue crap (*Callinectes sapidus)*; a few sparidae including bogue (*Boops boops)*, striped bream (*Lithognathus mormyrus)*, and sharp snout sea bream (*Diplodus puntazzo)*.

Two landing data sets were analyzed in the study. The first one is the landings data by species, which is based on the latest fishing season in 2015. The second one is the time series landings data, which

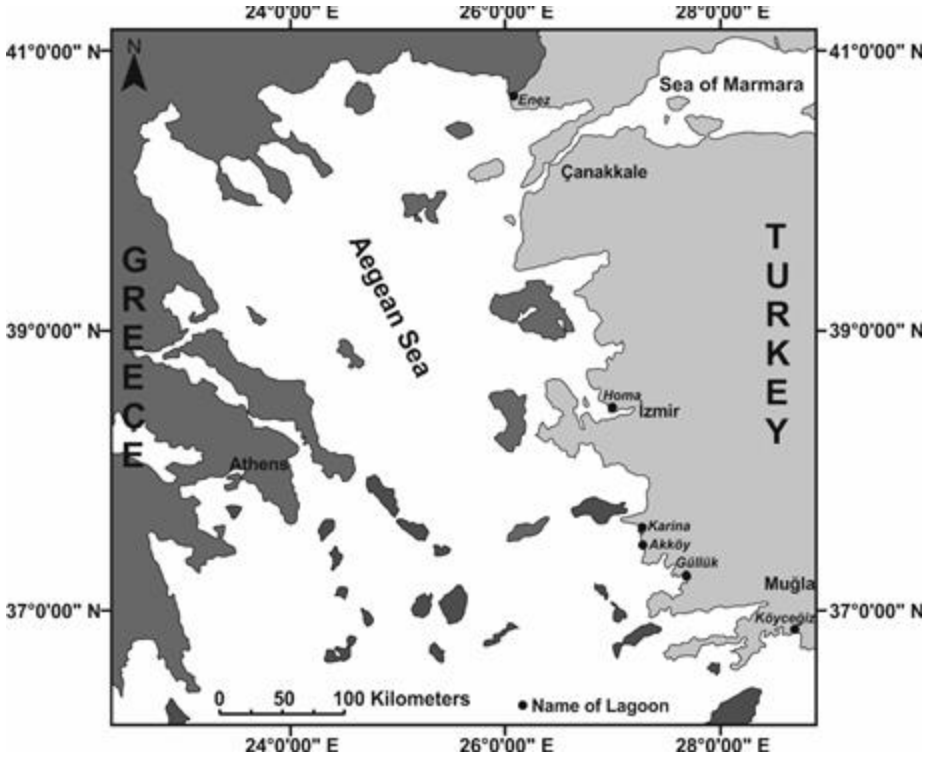

Figure 1. Coastal lagoons located along the Aegean Sea coast of Turkey.

cover the years between 1970 and 2015. However, the time series data are not suitable for the trend analysis due to discontinuities and great fluctuations between the years. For comparison, continuous (period from 2000 to 2015) landings data were firstly transformed into Log_{10} and then an independent One-way ANOVA with Tukey's HSD post-hoc test classified the lagoons according to mean total landings (kg/ha/year). In addition, the Two-way ANOVA with Tukey's HSD post-hoc test was used to compare the mean differences of the groups with each other, and these groups have been split on two independent variables (lagoon and species). For all the statistical analysis SPSS Version 18.0 statistical software program was used.

The annual landings data from the lagoons were not analysed by trend analysis for extracting an underlying pattern of behaviour in a time series, since the time series data are not suitable for analysis due to discontinuities and variability.

Results

Total landing of the Turkish lagoons exploited by mainly barrier traps and other fishing gears, trammel net, fyke net and long line was nearly 900 tonnes in 2015 (Table 1). The Köyceğiz lagoon has the largest surface area and the highest contributer to overall total landings of all the Turkish lagoons. However, the Güllük lagoon is the most important one in terms of productivity followed by Enez and Köyceğiz ($t=3.542$; $p=0.017$). Two state owned lagoons, Homa and Beymelek are the poorest lagoons regarding their landings and productivity.

Considering only the Aegean lagoons, two third of the total landings come from Köyceğiz (Figure 2a). In terms of species, Mugilidae accounted for the majority of the total landing with 447.9 tonnes (84%) followed by gilthead sea bream, European sea bass, European eel, and common sole (Figure 2b). The percentage of other commercial species was quite low.

The data, period between 1970-2015, show that the Mugilidae group of species and gilthead sea bream represent the vast majority of all total fishery landings for all the Aegean lagoons (Figure 3a-b). Grey mullets and gilthead sea bream were the most important species represented in almost all the total landings. Although grey mullets represented nearly all the lagoon Enez landings, blue crab landings (*Callinectes sapidus*) increased in recent years. Grey mullets and European eel are the most important species for the Güllük lagoon. Although sea bass and gilthead sea bream landings reached also considerable amounts in certain years, there has been no stability on their landings by years in the Güllük lagoon. As for the Köyceğiz lagoon, grey mullet species represented almost all the landings in recent years (Figure 3b). While common carp landings were considerably high prior to 1994, they disappeared after 1994. Other species such as a few sparids, blue fish, and marbled spinefoot (*Siganus rivulatus*) were caught by the barrier traps close to the sea.

Landings between the years 1970-2015 in all

Table 1. Landing and productivity of Turkish lagoons in 2015*

Lagoons	Location	Province	Surface area (ha)	%	Landing (kg)	%	Productivity (kg/ha)
Enez	Aegean	Edirne	520	2.4	40067	4.5	77.1
Homa		Izmir	1470	6.7	3105	0.3	2.1
Karina		Aydın	2460	11.3	66242	7.4	26.9
Akköy		Aydın	1200	5.5	23800	2.7	19.8
Güllük		Muğla	250	1.1	27500	3.1	110.0
Köyceğiz		Muğla	5400	24.8	368812	41.3	68.3
Beymelek	Levantine	Antalya	250	1.1	3000	0.3	12.0
Akgöl		Mersin	1410	6.5	45000	5.0	31.9
Tuzla		Adana	800	3.7	40000	4.5	50.0
Akyatan		Adana	5000	22.9	150000	16.8	30.0
Ağyatan		Adana	1100	5.0	45000	5.0	40.9
Yelkoma		Adana	640	2.9	30000	3.4	46.9
Çamlık		Adana	1300	6.0	50000	5.6	38.5
Total			21800	100	892526	100	40.9

*Data belongs to own records of the lagoons.

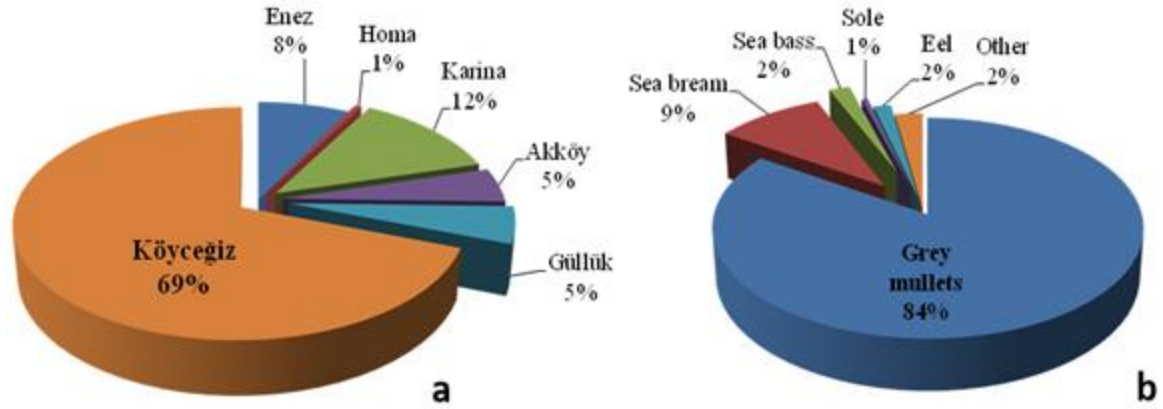

Figure 2. Percentages of total landings contribution by (a) lagoon and (b) species.

lagoons, except Köyceğiz's, showed a decreasing trend (Figure 4). However, quadratic trend model gave the best fit for the raw data in the analysis and decomposition fits for each lagoon show that the trends of landings for all the lagoons except Köyceğiz and Karina are decreasing.

In addition to time series analysis, mean landings per hectar for the Aegean lagoons were estimated for the period between 2000 and 2015 (Table 2). Four different groups of means were determined by the One-way Anova test ($F=61.655$ $P=0.000$). While the mean production of the Güllük lagoon (110 kg/ha/year), with the smallest surface area, is higher than that of all others, the Köyceğiz lagoon which has the largest area has moderate mean production with 57.5 kg/ha/year like the Enez lagoon has. The Homa and Akköy lagoons landings decreased substantially compared to previous years (Figure 4). These lagoons belong to the lowest mean production group (Table 2).

The effect of two independent variables lagoon and species on dependent variable of mean landing per ha was also examined by Two-way ANOVA test for a period from 2000 to 2015. According to the analyses, three different groups of means were estimated (Lagoon $F=12.026$ $P=0.000$; Species $F=124.218$ $P=0.000$). The Akköy and Homa lagoons were lower means group followed by Karina, Köyceğiz, and Güllük with moderate and Güllük, Köyceğiz, and Enez are a group of higher production (Table 2).

Discussion

We have observed a dramatic decrease on landings of the Aegean lagoons compared to the last three decades. It has decreased from 1500 tonnes in the 1980s (Geldiay & Balık, 1988) to 530 tonnes in recent years. There may be many reasons for this three-fold decline on total production. One of them is that there were twenty actively working lagoons in the 1980s while there are only six today in the Aegean coast of Turkey. Therefore, a comparison of productivity (kg/ha/year) would make sense if relevant data existed. In 2015, mean productivity of the Turkish lagoons was 40.9 kg/ha/year. This is not

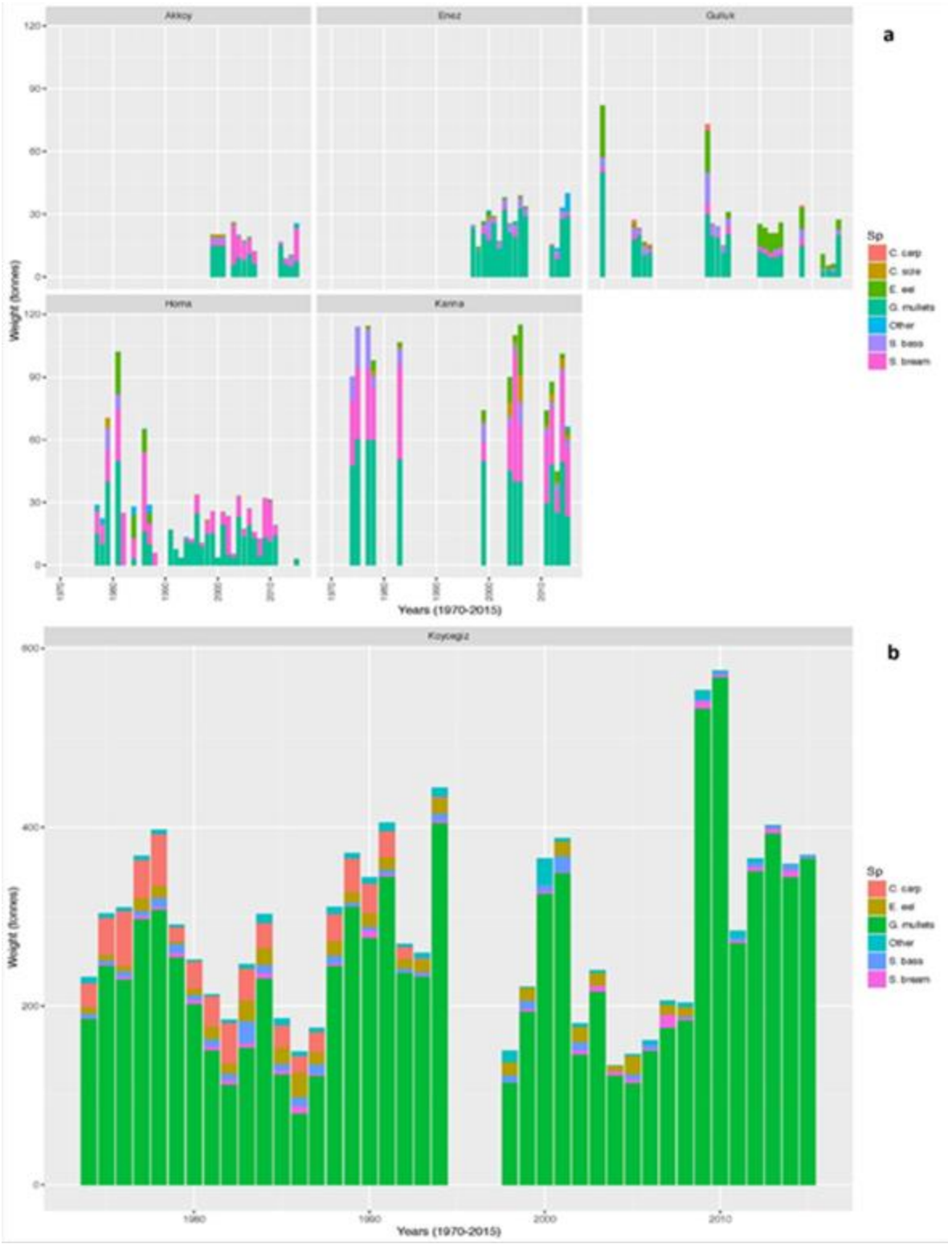

Figure 3. Annual landings of (a) Enez-Homa-Karina-Akköy-Güllük and (b) Köyceğiz lagoons in terms of species exploited for the period 1970-2015.

very low compared to the mean productivity of Italian lagoons, which is about 50 kg/ha/year (Cataudella, Tancioni, & Cannas, 2001; Cataudella *et al*., 2015). While, it is higher than the Greek lagoons with a mean productivity of 32 kg/ha/year (Reizopoulou, 2011).

There has also been a long-term shift in species composition (e.g., disappearance of common carp and European eel) and a significant decrease in the landings of the most important fish species in the six lagoons located on the Aegean coast of Turkey. These show similarity to other Mediterranean (Cataudella *et*

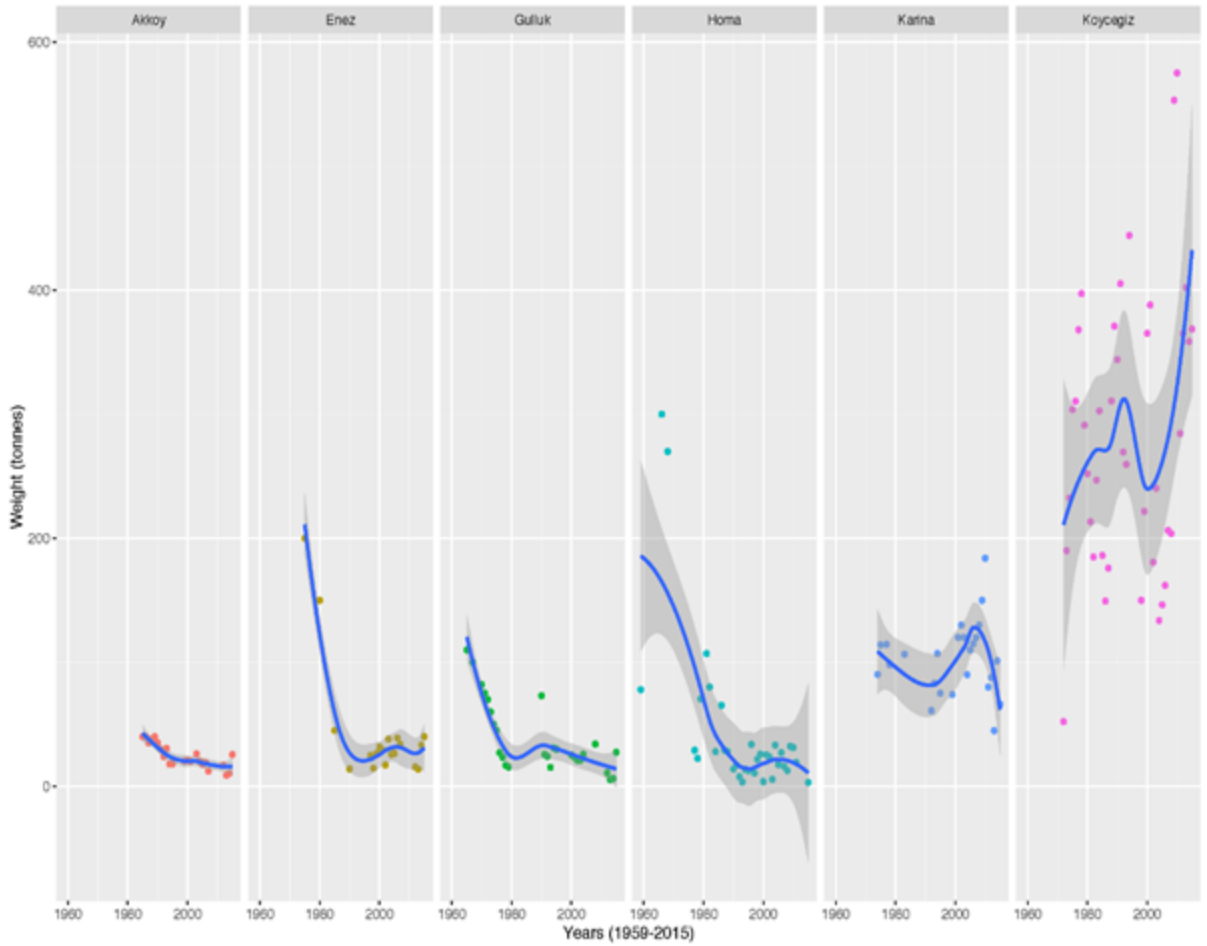

Figure 4. Annual landings of Aegean lagoons with 0.95 confidence interval (grey dashed area).

Table 2. Comparison of mean and standard deviation (SD) landings per hectare (kg) in terms of total (One-way ANOVA with Tukey's HSD post-hoc test) and lagoon-species (Two-way ANOVA with Tukey's HSD post-hoc test) for the Aegean lagoons in the period of 2000 to 2015

Lagoons	Species	Mean (kg)	S.D.	Group/s
Enez	Grey mullets	45.7	13.69	c
	G. Sea bream	2.0	1.53	
	Total	59.4	13.43	C
Homa	Grey mullets	8.0	4.23	a
	G. Sea bream	5.9	4.45	
	Total	14.0	6.78	A
Karina	Grey mullets	15.9	3.24	b
	G. Sea bream	13.2	3.48	
	Total	39.7	6.09	B
Akköy	Grey mullets	7.7	2.54	a
	G. Sea bream	4.8	4.11	
	Total	14.0	3.84	A
Güllük	Grey mullets	38.4	18.15	bc
	G. Sea bream	6.2	3.56	
	Total	93.3	21.57	D
Köyceğiz	Grey mullets	46.4	18.89	bc
	G. Sea bream	0.9	0.64	
	Total	57.5	24.97	C
Total	Grey mullets	26.6	20.63	
	G. Sea bream	5.4	5.05	
	Total	45.2	31.22	

*Letters indicate different groups of mean landing per ha (capitals for total, lowercases for lagoon-species.

al., 2015) and world (Pérez-Ruzafa & Marcos, 2012) lagoons. The reasons for the changes can be explained through climate change, anthropogenic effects (domestic, industrial, and agricultural pollution), and shifts in hydrology. Besides, the reasons for reduced landings include overfishing in and around the lagoons, reduced recruitment, and mismanagement of the lagoons. A reduced carrying capacity of the lagoons, temporal distribution of fish species and landings, and significant habitat losses reduce the productivity of fish and other organisms.

One of the solutions to cope with the problem of reduced landing is restocking or stock enhancement (a rising phenomenon in the Mediterranean lagoons) which is the practice of putting artificially reared young fish into their natural environment to let them grow (Cooke, 1984). For instance, according to Koutrakis *et al*. (2007), restocking with flathead grey mullet, European sea bass, and gilthead sea bream fry was carried out in many lagoons in Grecee. However, it has not been practiced any restocking in Turkish lagoons so far. Collection of all kinds of juvenile fish from coastal areas and lagoons was prohibited in 2000 according to Turkish Fisheries Regulations (Anonymous, 2000). Recently, resource users and relevant authorities have taken interest in some restocking practices from hatchery to wintering channels or net cages. Our observation in this study supports the existence of that kind of interest because restocking of common carp into the Köyceğiz lagoon is on the near future plan of the lagoon management board.

Overfishing and pollution problems were not reported in the lagoons located along the Aegean coast of Turkey until the 1980s (Balık & Ustaoğlu, 1984). The landings of all of the lagoons reached the maximum level during the 1980s. However, after that time total landings of these lagoons have decreased year by year. Therefore, year is the most important variable to describe species availability and landing amounts in each lagoon. Apart from these, thanks to its strictly protected environment by special codes as well as successful fishery management and strategies (for instance, self-regulation on releasing about 30% of adult fish species from the lagoons), Köyceğiz managed by Dalyan Fishery Cooperative is the only lagoon whose landings data has not changed for a long time. Recently, total landings from this lagoon have turned into almost only grey mullet species due to extinction of freshwater species, export ban for the European eel, and overfishing on marine fish in vicinity.

In the present study, the rivers Gediz and Great Meander (Büyük Menderes) and their surrounding lagoons have been subjected to a high degree of human impacts. Moreover, during the last 30 years there has been a significant climate change in the western Turkey (Kazancı, Girgin, & Dügel, 2008; Yeşilırmak, 2010). The Homa, Karina, and Akköy lagoons have seriously had the natural and anthropogenic impacts over time. Coastline destruction, siltation, and a reduced volume of water in the lagoons due to a lack of fresh water input after mid of 1980s are the main problems affecting lagoon survival and fish production. These negative events have reduced not only the number of active lagoons but also the amounts of commercial and other aquatic species. Koutrakis, Tsikliras, & Sinis (2005) also reported similar reduced production problems in the other Mediterranean lagoons.

In view of the dramatic decrease overtime of landings experienced in the studied lagoons, it is crucial to implement monitoring and appropriate management strategies for the fishing activities occurring not only in the Aegean Sea but also in all other Turkish lagoons. As a start, an initiative should be launched to explore the feasibility of management practices in a way that ensures social, economic, and environmental sustainability of the Turkish coastal lagoons.

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