

Observations on the increase of wild gilthead seabream, *Sparus aurata* abundance, in the eastern Adriatic Sea: problems and opportunities

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Abstract The recent increase of the local population of gilthead seabream, *Sparus aurata*, in three areas along the southeastern Adriatic Sea: Malostonski Bay (Croatia and Bosnia and Herzegovina), Neretva Estuary (Croatia) and Boka Kotorska Bay (Montenegro) and its adverse effects on shellfish culture by preying on Mediterranean mussels, *Mytilus galloprovincialis*, and the European flat oyster, *Ostrea edulis*, are studied. The results from the analysis of the existing information show that the main reason for the recent increase is the escapes from local fish farm which enrich the local population constantly with new gilthead sea bream. The existence of practically endless food in the area of the shellfish farms allows the concentration of the population in the region instead of its dispersion along the Adriatic coast. Moreover, ecological analysis indicates that the gilthead seabream is facing a very low competition from other local species which enhances its capacity to further populate the region. While the impact on the ecosystem is not yet known, the socio-economic impact of the increase of the gilthead seabream population is evident today. Many shellfish farms are closing today in the region since the damages may reach over 90 % of the production.

Keywords Gilthead seabream · *Sparus aurata* · Abundance increase · Croatia · Bosnia and Herzegovina · Montenegro · Damages

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Introduction

The gilthead seabream (*Sparus aurata* Linnaeus 1759, Sparidae) is a euryhaline and eurythermal perciform fish that inhabits the Atlantic European coast from Portugal to the United Kingdom, the Mediterranean and the Black Seas (Jardas 1996). Commercial farming started in the 1980s, spreading from Italy and France to Croatia and Greece and afterwards to the rest of the Mediterranean countries. Today, gilthead seabream is the most important finfish aquaculture product in the Mediterranean with a total production of 136,000 t in 2010 (<http://www.feap.info>). Croatia has a relatively small gilthead seabream production which reached 2,200 t in 2010, while Bosnia and Herzegovina produce approximately 90 t of seabream (<http://www.feap.org>).

The gilthead seabream inhabits mostly coastal waters and estuaries. The fish recruit in lagoons and estuaries and later spread along the coast and islands. It feeds mainly on molluscs and crustaceans (Jardas 1996). The historical abundance of gilthead seabream in the Adriatic, based on data of composition of catch by different fishing gears, was low. In the period 1960–1988, the gilthead seabream represented only 0.2–0.5 % of the catch with gillnets (Jardas and Pallaoro 1993). Cetinić and Pallaoro (1993) reported a similar low frequency (0.05 %) of gilthead seabream in catches of traditional rope-tramata nets. These results pointed to the conclusion that gilthead seabream was rare in catches along the Eastern Adriatic coast in the period 1960–2000, with an average annual catch of 58 t in whole Croatia (Kraljević 2010).

In the last decade, a significant increase in wild gilthead seabream populations has been documented and linked to climate change in some coastal zones such as the northeast Atlantic (Coscia et al. 2011). In other Mediterranean locations such as Messolonghi lagoon in Greece, this phenomenon was related to the farming of large mature specimens in commercial aquaculture farms which spawned in the sea cages (Dimitriou et al. 2007). In addition, this phenomenon has been attributed to escapes from fish farms (Jensen et al. 2010).

Considering the observed increase in *Sparus aurata* populations in the areas of Malostonski Bay (Croatia and Bosnia and Herzegovina), Neretva Estuary in Croatia and Boka Kotorska Bay in Montenegro in the last 3 years, this article discusses the facts and reasons regarding the recent propagation and the current status of gilthead seabream populations in the study areas, their impacts on local fisheries and the shellfish culture having consequently a strong influence on the socio-economy of the region.

Materials and methods

The study was based on data originating from three areas: Malostonski Bay (belonging to Croatia and Bosnia and Herzegovina) and Neretva Estuary (Croatia) and Boka Kotorska Bay (Montenegro). The Neretva Estuary is a nursery area for gilthead seabream, while Malostonski Bay and Boka Kotorska Bay is known for the farming of fish and shellfish (Fig. 1).

Sampling of juveniles was performed during the period between May and September 2012 in Neretva river estuary using wire traps which were checked every 3 days. All caught juveniles were frozen and measured for weight and length using digital balance and caliper. The age of available fish was determined using the scale reading method, while data on fish weight obtained from fishermen, restaurant owners, and fish farmers were calculated according to age classes using the weight-age scale determined by Kraljević (2010).

Additional information sources used in this study were collected from local professional fishermen who use gillnets (100 m length, 3 m height, 48 mm mesh), long lines (100 m length, 50 hooks) in the mouth of Neretva river and spear gun divers in the areas of shellfish culture in Malostonski Bay and Boka Kotorska Bay. The spear gun divers also provided visual information. Finally, information was collected from retailers and restaurants.

Information on escapes from aquaculture activities was collected from two private fish farms in Croatia, two farms in Bosnia and Herzegovina and one farm in Montenegro for the last 10 years as well as estimates by fish farm owners of sporadic escapes through damaged net cages was also used.

The damages of gilthead seabream predation on flat oyster, *Ostrea edulis* were studied on a newly established oyster farm in Boka Kotorska Bay (Montenegro) from the start of production in 2010 to December 2011. In 2010 the production cycle started with 300,000 spats (3–4 cm length) purchased from Croatia, and a similar number was stocked during spring 2011. During this period monitoring of dead or eaten flat oysters

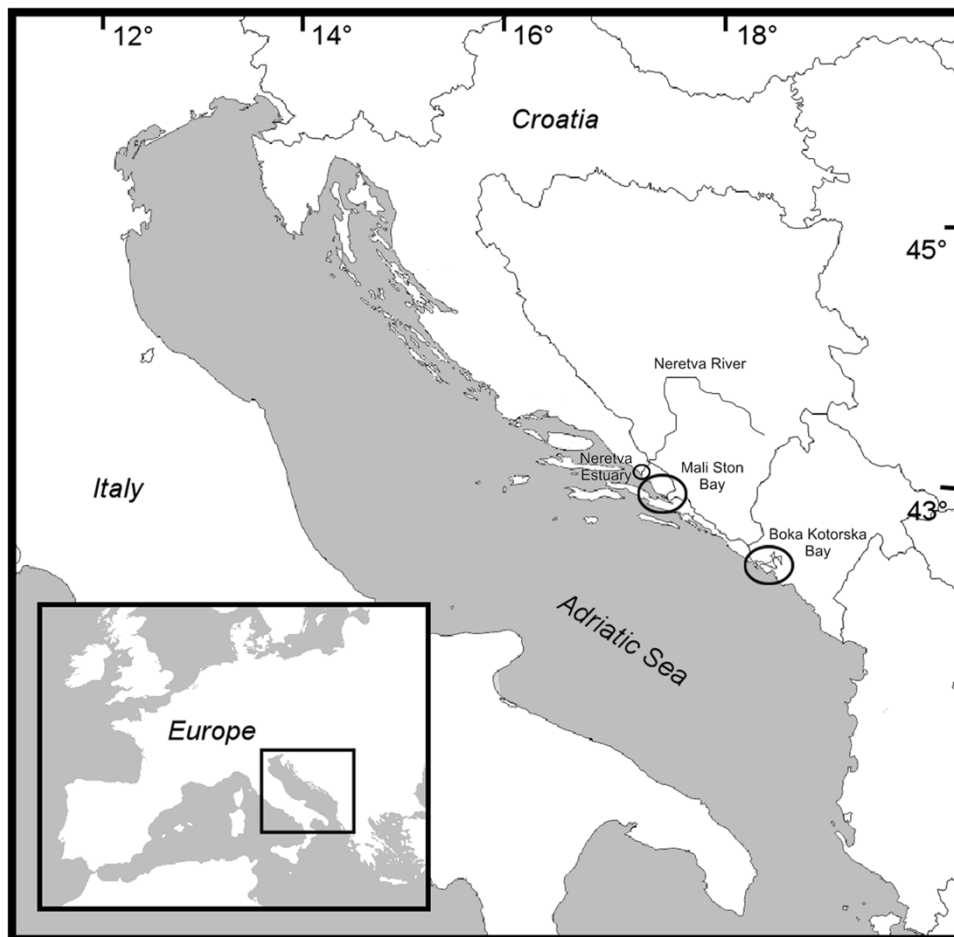


Fig. 1 Map of the study areas

was performed, while final counting was made in December 2011. Dead oysters were classified into two groups: group with visible bite or lacking part of the shell and group of oysters with unbroken shell.

Species association and species overlap analyses were carried out in accordance to traditional statistical ecology methods (Ludwig and Reynolds 1988).

Results and discussion

Composition of catches

A total of 1,429 individuals from 31 fish families were caught from May to September 2012 (Table 1) in the area of Neretva estuary. The species *Sparus aurata* was found the third dominant species in numbers (11.2 %) after *Atherina boyeri* (23.6 %) and *Sardina pilchardus* (21.6 %). Among other Sparidae species, *Diplodus annularis* and *Sarpa salpa* were represented both with low 2.8 %. The other two species *Diplodus puntazzo* (0.2 %) and *Lithognathus mormyrus* were rare (0.5 %). Gilthead sea bream individuals were mostly caught in traps during September (56.3 %) indicating strong late summer tendency to enter these nurseries. Individuals ranged from 6.1 to 25.8 cm (14.33 ± 2.79 cm) in total lengths and from 1.91 to 263.82 g (42.16 ± 31.69 g) in total weight. Most of the specimens belonged to 13–17 cm length classes (80.3 %). Age structure revealed that most of the sample is immature and aged 0^+ (86.7 %).

At the same time, at the Neretva Estuary, a total of 234 adult gilthead seabreams were caught by gillnets and long lines. It was found that 63.4 and 33.2 % of the specimens were aged 1^+ and 2^+ years, respectively.



Table 1 Monthly catch composition of fish in Malostonski Bay and Neretva estuary in the period May–September 2012

Species	Numbers						Percentage (%)				
	May	June	July	August	September	Total	May	June	July	August	September
<i>Sparus aurata</i>	0	1	18	51	90	160	0.0	0.6	11.3	31.9	56.3
<i>Anguilla anguilla</i>	0	7	8	4	9	28	0.0	25.0	28.6	14.3	32.1
<i>Atherina boyeri</i>	0	95	52	117	73	337	0.0	28.2	15.4	34.7	21.7
<i>Carassius gibelio</i>	0	0	0	0	3	3	0.0	0.0	0.0	0.0	100.0
<i>Dicentrarchus labrax</i>	0	0	0	1	0	1	0.0	0.0	0.0	100.0	0.0
<i>Diplodus annularis</i>	1	1	4	16	18	40	2.5	2.5	10.0	40.0	45.0
<i>Diplodus puntazzo</i>	0	0	1	0	1	2	0.0	0.0	50.0	0.0	50.0
<i>Engraulis encrasicolus</i>	0	7	39	10	8	64	0.0	10.9	60.9	15.6	12.5
<i>Gambusia affinis</i>	0	0	0	65	0	65	0.0	0.0	0.0	100.0	0.0
<i>Gasterosteus aculeatus</i>	0	0	0	2	0	2	0.0	0.0	0.0	100.0	0.0
<i>Gobius geniporus</i>	0	21	8	10	11	50	0.0	42.0	16.0	20.0	22.0
<i>Gobius niger</i>	0	0	3	2	0	5	0.0	0.0	60.0	40.0	0.0
<i>Ictalurus punctatus</i>	0	1	0	0	3	4	0.0	25.0	0.0	0.0	75.0
<i>Knipowitschia croatica</i>	0	0	0	3	0	3	0.0	0.0	0.0	100.0	0.0
<i>Labrus merula</i>	0	0	1	2	0	3	0.0	0.0	33.3	66.7	0.0
<i>Lichia amia</i>	0	0	0	0	1	1	0.0	0.0	0.0	0.0	100.0
<i>Lithognathus mormyrus</i>	1	1	1	4	0	7	14.3	14.3	14.3	57.1	0.0
<i>Liza aurata</i>	0	0	0	0	14	14	0.0	0.0	0.0	0.0	100.0
<i>Liza ramada</i>	18	27	36	10	26	117	15.4	23.1	30.8	8.5	22.2
<i>Mugil cephalus</i>	0	0	0	0	1	1	0.0	0.0	0.0	0.0	100.0
<i>Mullus barbatus</i>	0	0	1	5	3	9	0.0	0.0	11.1	55.6	33.3
<i>Parablennius gattorugine</i>	0	0	1	0	0	1	0.0	0.0	100.0	0.0	0.0
<i>Platichthys flesus</i>	0	1	3	3	0	7	0.0	14.3	42.9	42.9	0.0
<i>Rutilus basak</i>	0	1	0	2	0	3	0.0	33.3	0.0	66.7	0.0
<i>Sardina pilchardus</i>	5	29	64	110	101	309	1.6	9.4	20.7	35.6	32.7
<i>Sarpa salpa</i>	0	0	0	40	0	40	0.0	0.0	0.0	100.0	0.0
<i>Scardinius plotizza</i>	0	0	0	0	2	2	0.0	0.0	0.0	0.0	100.0
<i>Solea vulgaris</i>	14	21	14	46	14	109	12.8	19.3	12.8	42.2	12.8
<i>Sprattus sprattus</i>	1	8	0	0	0	9	11.1	88.9	0.0	0.0	0.0
<i>Syngnathus acus</i>	0	0	0	32	0	32	0.0	0.0	0.0	100.0	0.0
<i>Tinca tinca</i>	0	0	0	1	0	1	0.0	0.0	0.0	100.0	0.0

The rest were 3⁺ (2.3 %) and 4⁺ years (1.1 %) individuals. Two spear gun fishermen were questioned and they caught approximately 570 kg of adult gilthead seabreams together (360 and 210 kg each fisherman, respectively). The structure of their catches was not completely scientifically verified and thus we relied on their estimation. Moreover, this estimation is also biased by the preference of spear divers for larger fish. This was reflected in the structure of the catches: over 840 specimens with an individual weight of 300–500 g range (age 2⁺ and 3⁺ years) and 75 fish with weight between 1,500 and 2,100 g (age 5⁺ and 6⁺ years). These cohorts also dominated in the purchasing records of local restaurants at the estuary.

In shellfish culture farms of Malostonski Bay, the dominant weight of fish caught by three spear gun divers was in the range of 1–1.5 kg. The daily landings on average were such 5–6 specimens per diver. The biggest reported gilthead was 5.4 kg, while specimens of 2.5 to 4 kg were usual daily catch. But from the visual survey, arising the fact that younger age classes (from 0⁺ to 2⁺ years), live in the shellfish culture area and they are visible on a daily basis during the autumn season. These cohorts also dominated in the purchasing records of two local restaurants.

The usual catch of gilthead seabreams in Boka Kotorska Bay varied from fish of 300 g or 3⁺ years fished by hook at the coast by sports fishermen to fish of 0.8–1 kg or 4⁺ and 5⁺ years to 7 kg. The daily catch of one

spear gun fishermen located at a shellfish farm as prevention against fish predation during the summer season is usually 10–15 kg of gilthead seabream composed of specimens from 300 to 6 kg. Furthermore, five local sport fishermen reported “great” (not possible to quantify) increase in abundance of gilthead seabream in the last 2–3 years.

As recently in the same areas similar research has not been conducted, at this point it is impossible to make comparison that might provide us answers regarding abundance increase in percentage, but it is clear from current results that the gilthead seabream is gradually becoming the dominant species in the study areas. It is estimated that the recent increase of the population in Malostonski Bay and Neretva estuary is close to 50 t (2011) when the previous reported catches for the whole Croatia were around 58 t (Kraljević 2010).

The aquaculture production of gilthead seabream, European flat oyster and Mediterranean mussel in Malostonski Bay and Boka Kotorska Bay are presented in Table 2. The data show that the increase of the landings of the gilthead seabream in both areas coincides with the decrease of shellfish farming production of both shellfish species. During this period no significant shellfish mortalities due to diseases or parasites was reported and, therefore, it is considered that predation from gilthead seabreams is the main reason for the losses. Recently, Šegvić-Bubić et al. (2012) reported that gilthead seabream was extremely abundant at the vicinity of a mussel farm in Malostonski Bay representing almost 80 % of the landings and a maximum concentration of 285 individuals per 5,000 m³. Moreover, stomach content analysis of specimens from the area revealed the presence of mussel *Mytilus galloprovincialis* as the dominant prey and confirmed *Sparus aurata* as their main predator. In relation to Montenegro fishery sector, the situation is complicated due to scarcity of information and questionable validity of the data. Reliable national statistics for artisanal, recreational and sports fisheries landings is missing (Matić-Skoko et al. 2011). However, reported landings for *S. aurata* in 2010 with 59 t show increasing of 30.5 % in last 15 years (FAO 2012).

Species affinities and overlap

It is interesting to investigate as far as the available data allow the conditions by which this increase in gilthead seabream abundance in the study area occurred and how it can be explained. It is obvious that the rapid increase of abundance of a single species in an established ecosystem without changing its balance is not possible unless there are some conditions met. According to the data in Table 1, 31 species were recognized in the samples. Species niche overlap analysis (based on abundance data; Table 1; Petraitis 1985) showed that overall, the level of overlap among the 31 species identified is small (41.7 %; $P < 0.001$). Moreover, it revealed that all the species have 0–1 % specific overlap with gilthead seabream while for the opposite, gilthead seabream overlaps significantly with only a few of them. In particular, gilthead seabream overlaps mostly with *Rutilus basak* (62.6 %), *Ictalurus punctatus* (23.4 %) and *Mullus barbatus* (23.4 %). It is interesting to note that all of them are benthopelagic and the first two species are freshwater fish, while the third is a marine species. This overlap results clearly show that gilthead seabream as a broad euryhaline species can affect both freshwater and marine species along the coastal areas. Moreover, it is also interesting to see that the diets of all four species include zoobenthos among others (Fishbase). The two freshwater

Table 2 Commercial aquaculture production (in t) of gilthead seabream (*Sparus aurata*), European flat oyster, (*Ostrea edulis*) and Mediterranean mussel (*Mytilus galloprovincialis*) in Malostonski Bay (Croatia) and Boka Kotorska Bay (Montenegro) during 2000–2011 period

Area/species	Year (t)						
	2000	2006	2007	2008	2009	2010	2011
<i>Croatia and Bosnia-Herzegovina (Maliston Bay)</i>							
Gilthead seabream, <i>Sparus aurata</i>	130	170	310	320	340	350	350
Mediterranean mussel, <i>Mytilus galloprovincialis</i>	1,111	4,000	4,000	4,000	3,000	2,000	2,000
Flat oyster, <i>Ostrea edulis</i>	50	150	150	120	100	100	70
<i>Montenegro (Boka Kotorska Bay)</i>							
Gilthead seabream, <i>Sparus aurata</i>	35	50	50	50	50	90	90
Mediterranean mussel, <i>Mytilus galloprovincialis</i>	50	70	100	120	150	200	120
Flat oyster, <i>Ostrea edulis</i> (no of specimens)	–	–	–	–	–	60,000	15,000



species are practically omnivorous while the two marine species are carnivorous and all prey on zoobenthos among others. This explains the very low overlap of these species with the gilthead seabream since they can utilize a broad range of food items (plankton, benthos, plants, nekton etc.) which the gilthead seabream cannot. Therefore, if there is a competition for zoobenthos with the gilthead seabream, these species may rely on other food items. On the other hand, gilthead seabream since it feeds solely on zoobenthos, it is obvious that competes aggressively with other species that also prey on zoobenthos, hence the large overlap values. Another observation which was made is that the gilthead seabream and the other three species (*Rutilus basak*, *Ictalurus punctatus* and *Mullus barbatus*) have similar trophic levels (3.3, 3.2, 3.9 and 3.3, respectively; see also Stergiou and Karpouzi 2002). The identified species (Table 1) exhibit a trophic level between 3 and 4, while only a few such as the *I. punctatus* exhibit values close to 4 since they are known also to prey on fish. This indicates that the gilthead seabream interacts with a small number of species at the top of the food web of the area and thus, the competition is much less in relation to other species belonging to lower trophic levels.

Species association analysis (based on monthly presence–absence data from Table 1; Schluter 1984) showed overall that the 31 species identified are not associated [VR index = 0.26, $1.14 < \text{Chi square } W \text{ statistic } (=1.299) < 11.07$]. This means that they compete for their habitat which may be in the form of mutualism (competition for resources exclusively used by the species), competition (interference among species may cause occasional exclusion from the habitat) and predation (when there is a prey–predator relationship between species). The results show that the gilthead seabream shows negative association with 12 of the 31 species (Table 1). These species are: *Anguilla anguilla*, *Diplodus puntazzo*, *Gambusia affinis*, *Gobius geniporus*, *Gobius niger*, *Knipowitschia croatica*, *Labrus merula*, *Lithognathus mormyrus*, *Liza aurata*, *Liza ramada*, *Mugil cephalus* and *Scardinius plotizza*. Again both marine and freshwater fish are identified as competitors for the gilthead seabream. In addition, all these species prey on zoobenthos among others and this fact is considered as the main reason for competition with the gilthead seabream. In favor of the gilthead seabream is the fact that the competition is small in terms of abundance of most of these 12 species in the samples. The most important in terms of abundance are the *Liza ramada* and *Liza aurata* which, however, are omnivorous and, therefore, can utilize a broad range of prey (zooplankton, zoobenthos, plants, detritus, etc.) minimizing their competition with the gilthead seabream for zoobenthos.

Commercial fish farm escapes

Gilthead seabream escapes have been sporadically reported by fish farmers and they are usually related to cage net damages in the area of Malostonski Bay and Neretva estuary. The overall number of escapes from these farms is estimated to be 0.1 % of the purchased fry number after mortalities, based on the average weight of sold fish and the purchase records. However, we were able to locate at least one escape record of almost 2 t of 2-year-old gilthead seabreams from one single cage in 2004 (estimated 9,000 fish of 230–280 g). The origin of this batch of fish was a hatchery in France, according to an invoice document. Research on the genetic origin of the present wild gilthead seabream populations in Malostonski Bay and Neretva Estuary has revealed “French” origin and this proves that the increase of the population of wild gilthead seabreams in the area is contributed by escaped juveniles or adults from aquaculture farms (Šegvić-Bubić et al. 2011).

The farming of gilthead seabream in Montenegro waters started over 10 years ago with an initial annual production of 35 t, increasing to around 90 t of gilthead seabreams in the last few years (Simović 2006). The farm owners officially do not admit significant escapes but they have reported cases of damages to the cage nets due to which fish could potentially escape.

The observed increase of gilthead seabream population in the area of Malostonski Bay and Neretva Estuary creates two effects: on the professional artisanal and sport fishery sectors and the commercial shellfish aquaculture production sector. The increase of abundance provided approximately 50 t annually of additional resource for commercial exploitation for the fishermen (Glamuzina 2010). However, in relation to the local shellfish farmers, this increase resulted to significant losses estimated at around 1,000 t of shellfish in 2011 due to predation. This was clearly reflected in official statistics for shellfish production in Croatia through the decrease of the production over the period 2009–2011, from 4,000 to only 2,100 t (Croatian Trade Chamber 2011). The role of gilthead seabream propagation in this decrease is considered significant (Šegvić-Bubić et al. 2012). Furthermore, in the last 2 years the decline in shellfish production has forced dozens of smaller shellfish farmers to abandon their farms and their licenses for shellfish culture. This in turn could generate more



problems in the future by impacting the socio-economy of rural areas, because mariculture is a traditional activity.

During 2011 and 2012, the situation in the Boka Kotorska Bay was similar with a significant increase in the local seabream population. The estimated annual landings of gilthead seabream in 2011 were 25 t compared to 5 t 10 years ago according to local statistics (Institute of Marine Biology, Montenegro: unpublished results). In the case of the studied newly established shellfish farm, the seabreams have been preying on oyster juveniles and adults with a size of 4–7 cm. The total damage in terms of dead flat oysters was 94.85 % of the stocked juveniles and after 2 years of culture only around 15,000 specimens remained untouched and marketable. A very small percentage of the stocked spat equal to 2.65 % was found dead with unbroken shells indicating that this mortality was attributed to other reasons such as diseases or parasites.

Socio-economic valuation

On the basis of monetary values of the resources in Croatian waters, it can be estimated that the increase of the local landings of gilthead seabream population by 50 t annually corresponds to a gain for the local fisheries equal to 750,000.00 € (at 15 €/kg) while the damages due to the predation, equal to 1,000,000.00 €. Though both values are of similar scale, the socio-economic effects are negative due to the losses of income and job security of these fisheries-dependent communities of the area. In a similar way in Montenegro, the damage shall likely lead to the closing of flat oyster farms and stopping of oyster production. Without doubt, in the short term this will result in a loss of employment for the local inhabitants and shortages of shellfish in local market while the value of the shellfish for tourism as a traditional local delicacy should not be underestimated. In addition, the damages of predation exceed by far the above estimated value of 1 mill € since the cost of the abandoned infrastructure invested in the sector is considered as well.

Consequently, the artisanal fishermen can benefit from the previously presented situation. Some of the shellfish farmers compensate their income losses by catching giltheads on their farms. However, it should be stated that most of them abandon the shellfish farming business in spite of everything. In general, the positive effects are not clear in the light of rural development of these areas, while the tradition of shellfish culture is in danger and may need to be rebuilt. Furthermore, strategic planning for the zones in both Croatia (Glamuzina 2009) and Montenegro (Simovic 2006) has proposed significant development of shellfish farming as a crucial economic activity for these areas. These plans are now threatened and extensive research and future control of gilthead seabream populations are needed to execute these developments. However, this situation will surely persist and slow down these developmental plans in both states.

Conclusions

The recent trend of gilthead seabream expansion and their invasions and damage to shellfish culture facilities can be attributed to two main reasons:

First and most important reason is the escapes from fish farms as evident from the records of cage net damages and the results of genetic similarities between the local population and French strains of gilthead seabream (Šegvic-Bubic et al. 2011). These escapes provide constantly the local population with new fish which due to the existence of vast amounts of food in the area in the form of shellfish aquaculture farms is concentrating in the region instead of distributing along the Adriatic coastline. To make the situation more complicated, ecological analysis of the existing data revealed that the gilthead seabream is not facing a strong competition from local species and, therefore, the establishment of its population is successful.

A second reason should be the effects of global warming (Coscia et al. 2011), as described earlier for other fish species in Adriatic such as groupers (Glamuzina and Skaramuca 1999) and bluefish (Dulčić and Glamuzina 2010). Neretva estuary plays a very important role as the main nursery ground for gilthead seabream (Glamuzina 2010). The gilthead seabream is a thermophilic species and an increase in sea water temperature as a result of climate change, could potentially enhance spawning and recruitment success, both in natural waters and fish farms (Somarakis et al. 2013). The high number of shellfish farms in the immediate vicinity of the estuary is obvious feeding grounds for the juveniles and adults of the species.

The main result of gilthead sea bream abundance increase, from the social point of view, is the closure of shellfish farms in all three states. This has negative effects especially if we consider the invested capital to these farms along with the losses of the production. Furthermore, the plans to develop modern and industrial shellfish industry in these states are now seriously endangered.

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