Máster Internacional en
GESTIÓN PESQUERA SOSTENIBLE
(7ª edición: 2017-2019)

TESIS
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Potential interaction between meagre (<u>Argyrosomus regius</u> Asso, 1801) aquaculture and fisheries in the Mediterranean Sea

ARTURO SCOPECE
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CIHEAM
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a 27 de Septiembre de 2019

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Trabajo realizado en Alicante en la *Universidad de Alicante, España*, bajo la dirección de Dr. Pablo Sánchez Jerez y Dr. Kilian Toledo-Guedes

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Alicante, a 27 de Septiembre 2019

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Abstract

Argyrosomus regius (Asso, 1801) is a species of particular interest for aquaculture, actually, it is a relatively new breeding species, but for its characteristics, it is one of the most promising. For aquaculture management and farming, meagre is generally considered an autochthonous Mediterranean species, however, there is evidences to support the thesis that meagre is a locally absent species across many areas of the Mediterranean Sea, because its presence is not homogeneous in all areas and over time. Consequently, the general aim of the present thesis was to evaluate the potential interaction of aquaculture and fisheries in relation to natural distribution of meagre.

The distribution of three species of sciaenids was obtained through a review of scientific papers on fish assemblages, while to evaluate the relation between aquaculture and fishery, Mediterranean production data from the FishStatJ database and catches data from fisherman associations in the Comunidad Valenciana were used for a local analysis. Finally, the aquaculture production data of the Comunidad Valenciana were related to the historical hydrodynamic data of the Altea area.

The study found that of the three species of sciaenids *S.umbra* is the most widespread in the Mediterranean, while *U.cirrosa* and *A.regius* less, in particular meagre, was found only on the coasts of Egypt.

The analysis of fishing and aquaculture data did not reveal a statistical relation, while a linear regression between fishing data and hydrodynamics was identified, indicating that the largest fishing is due to the breakage of floating cages for bad weather. Finally, the possible consequences of escapes have been discussed and some measures to be taken to reduce the impact are proposed.

Resumen

Argyrosomus regius (Asso, 1801) es una especie de particular interés para la acuicultura, en realidad, es una especie relativamente nueva en acuicultura, pero por sus características es una de las más prometedoras. Para la gestión en acuicultura, la corvina se considera generalmente una especie mediterránea autóctona, sin embargo, hay pruebas que apoyan la tesis de que la escasez es una especie localmente ausente en muchas zonas del Mar Mediterráneo, ya que su presencia no es homogénea en todas las zonas y a lo largo del tiempo. En consecuencia, el objetivo general de la presente tesis es evaluar la interacción potencial de la acuicultura y la pesca en relación con la distribución natural de la corvina.

La distribución de tres especies de scianidae se obtuvo a través de una revisión de trabajos científicos sobre ensamblajes de peces, mientras que para evaluar la relación entre acuicultura y pesca se utilizaron datos de producción mediterránea de la base de datos FishStatJ y datos de capturas de asociaciones de pescadores de la Comunidad Valenciana para un análisis local. Finalmente, los datos de producción acuícola de la Comunidad Valenciana se relacionan con los datos hidrodinámicos históricos de la zona de Altea.

El estudio reveló que de las tres especies de scianidae, *S.umbra* es la más extendida en el Mediterráneo, mientras que *U.cirrosa* y *A.regius* menos, en particular la corvina, se encuentra sólo en las costas de Egipto.

El análisis de los datos de pesca y acuicultura no reveló una relación estadística, mientras que se identificó una regresión lineal entre los datos de pesca y la hidrodinámica, lo que indica que la mayor parte de la pesca se debe a la rotura de las jaulas flotantes por mal tiempo. Por último, se han discutido las posibles consecuencias de las fugas y se proponen algunas medidas para reducir el impacto.

1. Introduction

Mediterranean mariculture started in the 80's with the culture of European sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*) and shellfish. During the 90's, Atlantic bluefin tuna (*Thunnus thynnus*) rearing and the farming of other sparids was introduced. More recently other species, mainly from Scienidae and Carangidae families entered the industry with the most promising including meagre (*Argyrosomous regius*) and greater amberjack (*Seriola dumerilii*). The last three decades, following the global trend, Mediterranean mariculture has experienced a rapid growth. In particular, while total production accounted for 90 000 tonnes in 1985(CAQ-GFCM, 2008, 2009; FAO, 2008; Barazi-Yeroulanos, 2010), the 2016 figures have grown to 423 103 tonnes for marine fish. (data from fishstatJ, 2016)

Among the fish mentioned above *Argyrosomus regius* (Asso, 1801) is a species of particular interest for aquaculture, actually, it is a relatively new breeding species, but for its characteristics, it is one of the most promising. In fact, it can reach big dimensions, is easy to process, has a good yield in fillet and a good taste. It also has a very fast growth (up to one kilogram per year) and an excellent conversion index. Additionally, the larval and weaning phase is not very different from sea bass and sea bream. In the larval phase, it exceeds the weight of the sea bream larva by four times, and in the ongrowing phase, it grows much faster than any other marine aquaculture fish. (Monfort, 2010) . The first time it was produced in France in 1997 and since then it has spread to various Mediterranean countries with different ups and downs in the quantities produced. (Cárdenas S. et al., 2014).

It is not yet an important species in the market. However, certainly a point in favour of this fish is that the organoleptic characteristics show that the farmed meagre develop unusually low amounts of mesoenteric and muscular fat compared to other farmed species. It also allows a long period of conservation in refrigeration conditions. These characteristics makes meagre a product of excellent quality. Another feature that makes meagre interesting is its suitability for processing, both in terms of meat yield and the ease with which it can be filleted. In addition, as consumers demand more and more processed products, these characteristics become very important. (Duncan et al., 2013). For now, the only limitations in the spread of meagre are some problems in breeding techniques, but especially a market not yet ready to accept them in a massive way. Despite this, it is certainly a species that is slowly becoming known and will probably soon become one of the most bred species in the Mediterranean.

1.1. Argyrosomus regius

fig 1. Estavez et al., Technical Manual-Meagre (*Argyrosomus regius*)

1.1.1 Biology

Meagre (*Argyrosumus regius*) [fig.1] belongs to the family Sciaenidae (Order Perciformes, Class Actinopterygii). Sciaenidae includes about 70 genera and 270 species that are distributed in temperate and tropical regions around the world. The members of this family are commonly called "snorers", this name comes from the fact that the fish has the ability to produce noise through muscles connected to the swim bladder that acts as a sounding board (Griffiths et al., 1995).

The genus *Argyrosomus* is characterized by large fish with elongated bodies and with 3-5 small upper pores present at the tip of the snout. Caudal fin is S-shaped cut in adults. The swim bladder is carrot-shaped, with 36-42 pairs of complicated arborescent appendages, unlike *U.cirrosa* and *S.umbra*, with a simple swim bladder. A typical characteristic of the family is the presence of large, oval and thick otoliths (sagittae) [FIG2], with a tadpole-shaped furrow on its inner surface, which in the case of *Argyrosomus* has a granular outer surface. (Griffiths et al., 1995). The trophic level of meagre is 4.29, feeding on fishes and swimming crustaceans with a maximum length of 230 cm, and a growth coefficient (K) of 0.09 (Froese et al., 2019).

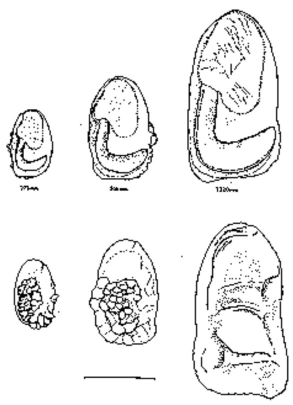


Fig 2. Proximal side (above) and distal side (below) views of sagittae of *Argyrosomus regius*. Scale bar = 10 mm. (Griffiths et al., 1995).

The species inhabits coastal waters near the bottom, as well as surface and intermediate waters 15 to 200 meters deep (Whitehead et al., 1986). During breeding, adults arrive at estuaries to spawn (anadromous migration) (Monfort, 2010) and form large reproductive aggregations in certain localities, well known to fishermen. It should be noted that the main breeding areas of the species are within or near estuaries and mouths of rivers with brackish water. Therefore, it could be considered an anadromous species that usually enters estuaries at the end of May to spawn. It remains in coastal waters (estuaries and along the coast) until late summer and then migrates to the sea during the winter period (Monfort, 2010).

Meagre has a relatively large head with an elongated body, mouth in terminal position without chin [fig.3]. Inside the mouth, there are narrow bands of viliform teeth in the upper jaw with the outer row enlarged. In the lower jaw, the teeth form 2 or 3 irregular rows, one of them enlarged. The eyes are quite small. The lateral line is evident, extending towards the caudal fin. The first dorsal fin has 9-10 spines and the second dorsal fin has 1 spine and 26-29 soft rays. The anal fin has a short first spinous ray and a very thin second with 7-8 soft rays afterwards. The size can range from 40-50 cm to 2 m long, with weights of up to 55 kg. The body is covered with very large cenoid scales, except for some cycloid scales on the chest, snout and under the eyes. The body colour is silver grey, with bronze marks on the dorsal part. The base of the fin is reddish brown and the mouth cavity is yellow gold. Post-mortem has a brown color.

It is an iteroparous, monomorphic and gonochoristic species with asynchronous ovarian development (García-Pacheco et al., 2009). The only estimates of maturity size described in the literature were 61.6 cm in males and within the range of 70-110 cm in females in the Cadiz population (González-Quirós et al., 2011), 60 cm in males and more than 80 cm in females in the Gulf of Gascony population (Sourget et al., 2009), and more than 72 cm in males and more than 82 cm in females in the Mauritanian population (Tixerant, 1974). The very plastic spawning period ranges from 15 days in the Gironde estuary (early June) to 8-9 months in Mauritania (October to June; Quéro, 1989). In the Gulf of Cadiz, the spawning period is 5 months, from March to August (González-Quirós et al., 2011). At the mouth of the Nile River, spawning occurs from October to December and lasts 3 months (Quéro, 1985).

Recent research on age determination based on otolith readings has shown that the maximum age for meagre was 36 years (LT=182 cm), as demonstrated in Portugal. (Prista, 2013). However, González-Quirós et al. (2011) studied in the Gulf of Cadiz two specimens (186 and 189 cm LT) that belonged to the 41 and 42 year old classes.

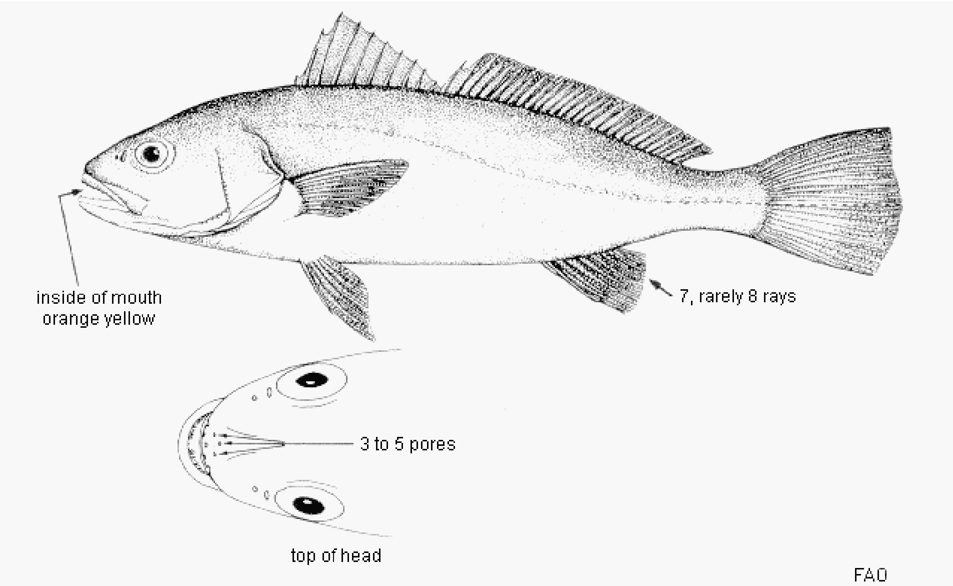


Fig 3. Morphological characteristics of meagre (from Schneider, 1990)

1.1.2. Natural distribution and associated fisheries

Meagre is an euryhaline fish found in subtropical climates (65ºN-6ºS, 23ºW-36ºE) in the eastern Atlantic (from Norway to Senegal) and also in the Mediterranean Sea and the Black Sea (Froase et al. 2019). The specie is fished in the East Atlantic Ocean, from Mauritania in the south to Norway in the north and in the Mediterranean Sea. Global fisheries production ranges from 5 000 to 10 000 tonnes per annum. Over of 80% of annual world catch take place in Mauritania, Morocco and Egypt. In Europe, the production of meagre from capture fisheries is low, ranging from a few hundreds tonnes to 1 500 t. The relevant fishing areas across Europe are on the Atlantic coasts of Spain, Portugal and France with annual catches of 800 t in France, 400 t in Portugal and 150 t in Spain. [Tab.1] In these areas, landed fish may have a large size (commonly above 5 kg) and local consumer appreciate meagre. In France meagre capture fisheries is highly concentrated in the west regions, near the Gironde mouth.

Tab 1. Captures of *A.regius* in Mediterrenean Sea from FishStatJ,2019

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Croatia	-	-	-	-	-	-	-	-	-	-	-	1	1	0 0	0 0	0 0
Egypt	987	1305	1252	2325	1153	1877	1437	977	1031	896	687	2387	599	602	533	690
France	-	-	-	-	-	-	-	-	5	16	1	1	0 0	3	0 0	0 0
Greece	...	...	...	...	...	...	...	...	...	-	-	-	-	-	-	-
Israel	223	273	249	144	6	2	22	18 F	13	8	20	44	5	5 F	5 F	5 F
Lebanon	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	26
Malta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palestine	3 F	3	21	3	5	3	9	5	6	4	7	3	1	1	1	9
Spain	-	-	-	-	-	...	...	...	...	...	...	...	32	9	10	13
Tunisia	...	...	...	...	...	...	6	...	...	...	...	...	...	...	...	...
Turkey	50	63	75	62	96	-	60	56	23	101	31	57	17	18	20	24
Totals - T	**1263**	**1644**	**1597**	**2534**	**1260**	**1882**	**1534**	**1056**	**1078**	**1025**	**746**	**2493**	**655**	**638**	**569**	**767**

1.1.3. Aquaculture of meagre

Meagre aquaculture started in the mid-1990s in Southern France and Italy, followed by Spain in 2004 and later by Greece, Turkey and Egypt (Monfort, 2010). Although it is presently farmed in several countries in the Mediterranean basin, its production has not yet reached its full potential and rearing trials are still very limited (Martínez-Llorens et al., 2011). However, as a result of achievement of reproduction in captivity, the production has significantly increased over recent years. The main markets for farmed meagre are Italy, Spain, Portugal and Israel where it is sold mostly as fresh product at a size around 2.5 kg (Monfort, 2010)

According to APROMAR (2018), in 2017 the countries in which the meagre is most bred were Turkey, Greece and Spain with 3 500 t, 2 300 and 2 200 t respectively, France, Italy and other European countries have a marginal production. It is the fourth most important species of marine aquaculture in Spain after sea bream, turbot and sea bass. For instance, despite being the most important suppliers of meagre fingerlings, France and Italy produced around 700 tonnes in 2016 (estimation of FishStatJ, 2019). In Croatia, 125 tonnes were produced in 2016 (FishStatJ, 2019). Meagre is cultivated on small scale also in Malta (12 tonnes in 2008, Vassallo Agius, pers. comm.). Considering the non-European Mediterranean countries, in 2018 Turkey produced 2 500 t, and Egypt showed a hight production of meagre of around 16 000 tonnes per year, but the information is unclear, there is no evidence if it is the same species and also the data are imprecise. [fig.4]

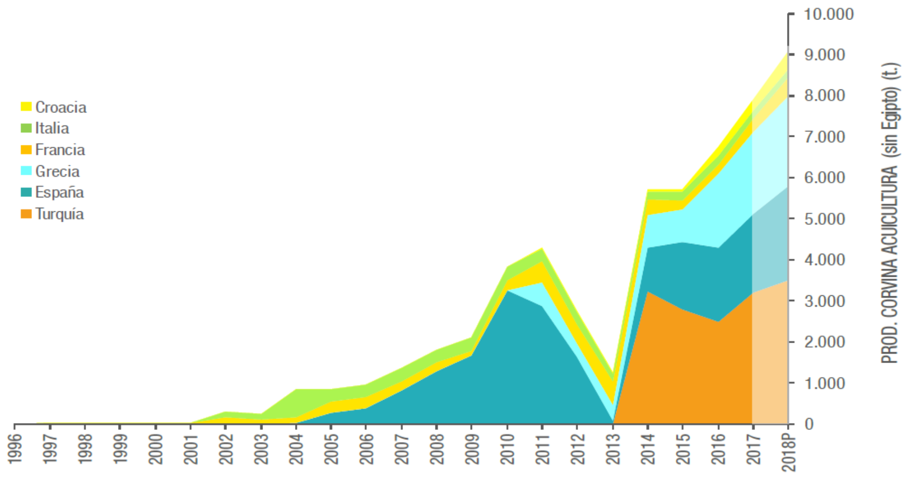
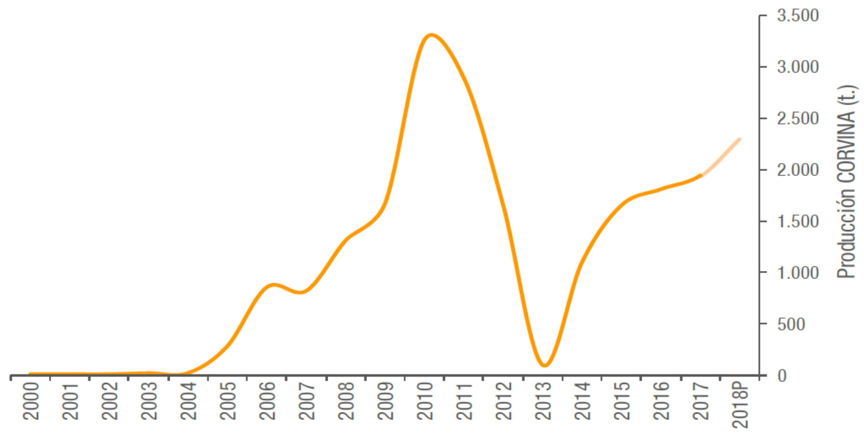


Fig. 4 Evolution of aquaculture production of meagre in tonnes in the world (without Egypt) in the period 1996-2018 (APROMAR, 2018).

Therefore, in an European context, Spain is the most relevant county in terms on meagre production, starting the activity around the year 2003 [fig.5], both in the Mediterranean coast as well the Canary Islands. The production has been suffering important oscillation related to fingerling availability and market. In 2017 the production was of 1 932 t being the Comunidad Valenciana the region with a higher production (APROMAR, 2018).



[fig.5]Evolution of aquaculture production of meagre in Spain in the period 2000-2018 (APROMAR, 2018).

1.1.4. Aquaculture production system of meagre

Meagre is a promising species for aquaculture because of its high growth rate (about 1 kg per year) and high feed conversion rate (Jiménez et al., 2005). The cultivation techniques are similar to those used for sea bass and sea bream , mainly in large (25 m in diameter) floating circular cages in the open sea. Production using cages is advisable because the jumping behaviour of meagre tending to jump out of tanks resulting in impact damage, such as contusions, loss of scales, wounds and often eye damage, i.e. exophthalmia. Therefore, aquaculture in land could be a challenge since the tanks must be covered with a strong upper net. Duncan et al. (2013) found mortality due to jumping animals out of tanks and excessive swelling of the swim bladder (not caused by bacterial and parasitic infections but probably by excessive stress). Meagre is possible to reproduce easily in farming conditions, if the breeding stock is well selected and around 6-8 kg. Once the origin of the broodstock has been selected, maintenance conditions and nutrition are two critical factors that must be optimal to ensure that the broodstock reaches the late stages of maturity from which spawning can be obtained. In this situation, the only parasites that caused problems and mortality during acclimatisation were monogenic worms and skin copepods (sea lice) that infect the skin and gills (Duncan et al., 2013).

In general, the technologies and practices used for meagre fattening are the same as those used for sea bream and sea bass, but meagre has higher growth rates and may achieve higher feed conversion rates (FCR). Pre-fattening is practiced mainly in land-based facilities and consists of cultivating meagre up to 3-15 g. The pre-fattening period is approximately two to four months, depending on the temperature and the desired juvenile size for the transfer. At breeding temperatures of 20 °C, the weight of the juveniles will double approximately every two weeks in the size range of 3-15 g. Once acclimatised, the juveniles are transferred to a vessel equipped with transport cisterns and taken to the cages. The most commonly used cages are 25 m in diameter (depth 15 m) and each cage has 100 000 juveniles (more or less 14 juveniles per m3) (Duncan et al. 2013).

Meagre, like sea bream and sea bass, are carnivorous and initially diets with 45-48% protein and 20-24% lipid are recommended (FAO, 2005). Chatzifotis et al. (2012) confirm that the highest growth rates were obtained with 40-50 % protein. However, meagre appears to require fewer lipids than those used in the initial diets and higher growth rates were obtained with a dietary lipid level of 17% (Chatzifotis et al., 2012).

1.2. Potential problems of escapes.

Several ecological impacts has been described to fish aquaculture, including negative effects on the benthos community and the pelagic system (Fernandes, 2001). As it was previously described for meagre, intensive marine fish aquaculture is carried out with cages, composed by floating rings and nets. Because of the inclusion of the net-pen systems in the marine environment, it exists always a high possibility of fish escapes into natural environment, which are regarded as one of the principal problem for the farmers (Jensen, 2010). Fish escapes are an inevitable occurrence caused by several management and environmental factors, which result in the casual loss of a big number of individuals (massive escape) or the frequent release of a small number of fish (leakage escapes). The main management cause of fish escapes are technical and operational failures of farming equipment, primarily through structural failure of containment equipment (e.g. nets). Net failure can occur in many ways, including biting by predators or caged fish, abrasion, holes caused by wear and tear of the netting, and operational accidents. External causes of escapes, normally link to massive escapes, are commonly due to oceanic conditions e.g. storms, sabotage or maritime accidents. Substantial fish escapes have been recorded for many species and localities (Arechavala-Lopez et al., 2018).

Escapes not only represent a considerable economic loss for the farmers, but can have drastic ecological, genetic, pathogenic and socio-economic impacts. The potential negative effects vary in relation to the intensity and frequency of occurrence, the location in relation to wild populations, whether the species are native or non-native, and the vulnerability of the recipient environment (Jackson et al., 2015).

Escapes are particularly problematic in areas outside the species' native ranges or where local wild populations are unusual, representing an important vector of introduction and subsequent spread of non-native or locally absent species (Crawford, 2008) . More frequent and extensive escape events translate in higher propagule pressure, which is an important determinant of the success of biological invasions (Simberloff, 2009). Ecological impacts of non-native species include direct competition for resources with wild fish, predation, alterations to habitat complexity and declines in native fishes populations . In addition, to the ecological and genetic risks, net-pen aquaculture can increase the risk of transmission of diseases and parasites into wild fish (Arechavala-Lopez et al., 2013).

1.3. Objectives

For aquaculture management and farming, meagre is generally considered an autochthonous Mediterranean species. However, there is evidences to support the thesis that meagre is a locally absent species across many areas of the Mediterranean Sea, because its presence is not homogeneous in all areas of the Mediterranean and over time (Sanchez-Jerez et al. Congreso de Rodhes procedding).

In the Mediterranean, 9 million farmed fish were estimated to have escaped over a three-year period (Jackson et al., 2015). There is mounting evidence, as it has been previously indicate, that the interactions of escapes with wild populations could be a major concern for the sustainability of wild fisheries and aquaculture (Valero-Rodriguez et al., 2015). This will be particularly relevant if the escaped species have a high trophic level and a big size, such as meagre. If the species is locally absent, escapes could increase competition with species with similar ecological niche, such as other locally present sciaenid species.

If meagre aquaculture is expected to increase during the next years, escapes will probably follow the same trend. For example, in Spain, the Comunidad Valenciana is increasing the production of meagre during the last year, trying to reach the level of seabass and seabream production. By 2018 it is estimated to have grown by 19% to 2,298 tonnes (APROMAR, 2018). Therefore, before a full development of meagre aquaculture, it is necessary to know the natural distribution of meagre across this region and evaluate the potential interaction of escapes with the fishing activities.

Consequently, the general aim of the present thesis was to evaluate the potential interaction of aquaculture and fisheries in relation to natural distribution of meagre. For that, the next objectives were targeted:

1) To explore the natural distribution of meagre and other relevant sciaenids (*Sciaena umbra* and *Umbrina cirrosa*) across the Mediterranean Sea for determining the geographical ranges at small scale and the potencial niche overlapping.

2) To evaluate the potential correlation between the development of meagre aquaculture and the fisheries at two scales: the overall Mediterranean sea and the province of Alicante, where meagre aquaculture has been solidly implemented.

3) To correlate the potential escapes of meagre due to high hydrodynamics condition of the sea with catches in the Comunidad Valenciana.

2. Materials and methods

In order to explore the natural distribution of the meagre and other relevant scianids, 44 scientific paper about the assemblages of fish in specific areas of the Mediterranean were considered. These have been researched in the online scientific archive (SCOPUS) by entering the key words "Mediterranean fish assemblages". These articles identify the three species of interest of scianids (*Umbrina cirrosa, Sciaena umbra, Argyrosomus regius*). From each paper, the position of the three species of sciaenids was extrapolated and where specified the type of habitat studied. A database was created to localize where these species are present and where not and mapped with Excel 3DMaps.

With regard to the correlation between the production of meagre aquaculture and the total catches in the Mediterranean, FAO data extrapolated from the FishStatJ (2019) database were used. The countries concerned were Algeria, Croatia, Cyprus, France, Greece, Italy, Spain, Tunisia and Turkey. The time series used was from 1950 to 2016 (latest data available on FishStatJ, 2019). Egypt is not considered in the Mediterranean data because most of the production takes place extensively in lagoons.

Local and complementary information was obtained from the catches data of the Fisherman Association (cofradías) in Spain. Data from four fishing ports have been taken into consideration: Santa Pola, Altea, Villajoyosa and Isla de Tabarca. The selection was made taking into account the three largest farms of the Andromeda aquaculture farm located in Villajoyosa, Calpe and Burriana, with the largest production of meagre in Villajoyosa. The analysed data were 2015, 2016, 2017 and 2018, for the ports of Santa Pola and Tabarca were also considered the data from 2011 (data from cofradías). These data were related with the aquaculture production of *A. regius* in the Comunidad Valenciana with a linear regression using the Excel software.

In addition, catch data were correlated with meteorological data from the historical archive of SIMAR, in particular the data of the buoy located near the coast of Altea identified by the code SIMAR-2084102 (website http://www.puertos.es/en-us/oceanografia/Pages/portus.aspx) to show whether the greatest capture of the species is related to extreme weather events, particularly at maximum wave height.

3. Results

3.1. Natural distribution of meagre and other relevant sciaenids (*Sciaena umbra* and *Umbrina cirrosa*) across the Mediterranean.

The data collected from the scientific papers have been reported in the table [ANNEX I-The table can be found in the last pages of the work].

Then the coordinates have been shown on a map to display the areas where the three species are present [fig.6].

Fig 6. points where scientific papers have reported the presence of *A.regius*, *S. umbra*, *U.cirrosa*

Comparing the three sciaenids species, *S. umbra* was the specie with a widespread distribution, present along the Mediterranean Sea and Black Sea. The main habitat was rocky bottom and sand but it was also reported in Posidonia meadows and in the all the MPA was present frequently.

It was detected with visual transepts and capture data up to a depth of 30 meters. However the other two species, *U. cirrosa* and *A. regius*, showed a narrow distribution. *U.cirrosa* was found in Turkey in the Mediterranean and in the Black Sea in Ukraine in sandy and shallow habitats; in Turkey was catched with artisanal fishing methods in Aksu River Estuary, confirming the fact that it is an euryhaline species (Innal, 2016); in the Black Sea was sampled at depths between 1.5 and 5 m using fixed 100 m long gillnets having a mesh size of 20 mm, and 3 m long having a mesh size of 8 mm. *A.regius* has been found in the waters of Israel and Egypt, both in the south-eastern Mediterranean: in Israel the detection refers to the capture of a few specimens with the trawling technique, therefore presumably in muddy or sandy bottoms (Edelist et al., 2011).

3.2. Potential interaction between meagre aquaculture and fisheries

For the Mediterranean, data from 1995 to 2016 have been taken into account, in Tab 2 are indicated tonnes of *A.regius* produced by the Mediterranean countries from 2000 to 2016.

Tab 2. Total production of *A.regius* across the Mediterranean countries from 2000 to 2016

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Aquaculture	33	35	296	103	859	800	943	725	1781.1	1840.8	2034.3	2261.1	1651.7	1434.9	5899.2	4800.1	7168.5
Captures	937	1263	1644	1597	2534	1260	1882	1534	1056	1078	1025	746	2493	655	638	569	767

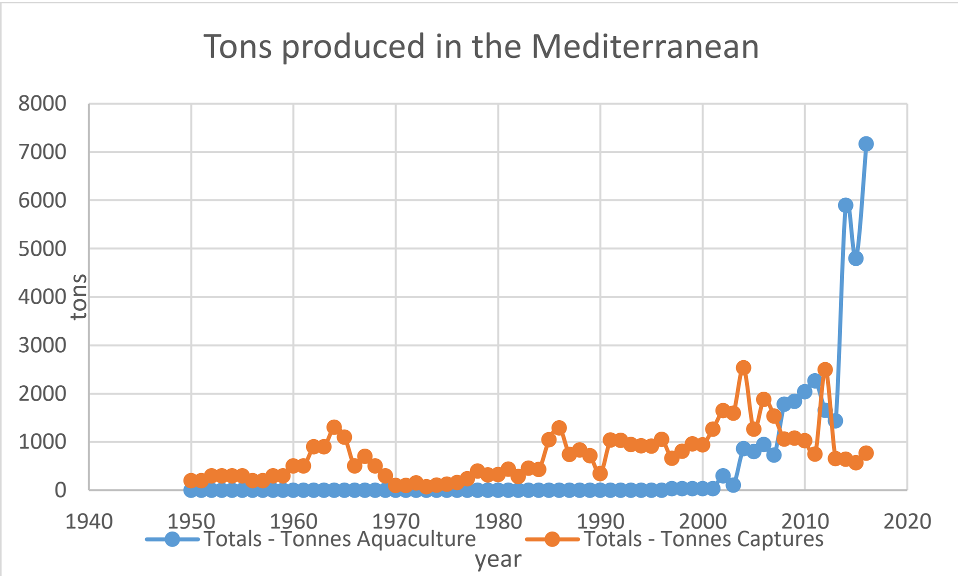


Fig 7. Tons of *A.regius* captured and produced in the Mediterranean Sea (FishStatJ, 2019)

Data show that there have always been catches of meagre in the Mediterranean, particularly from 1950 to 1959 catches ranged from 200 to 300 tonnes per year, particularly in Egypt and Spain. From 1960 to 1969 catches increased significantly in Spain reaching a peak of 1300 tonnes in 1964. From 1970 to '76 the catches in the Mediterranean were less than 200 tons per year with Egypt as the first country and Spain with a few dozen tons per year. Since 1976, catches have fluctuated widely, with peaks of 2 534 tonnes in 2004 and 2 493 tonnes in 2012 [fig.7] while the countries that most captured meagre were in descending order: Egypt with 38714 tonnes, Turkey with 5 078 tonnes, Israel with 2 204 tonnes and Spain with 1 974 tonnes.

Aquaculture, on the other hand, began in 1997 in France with a production of 30 tonnes per year. In a few years it spread to other countries such as Italy, Spain, Greece, Algeria, Croatia and Turkey. Spain is the country that has produced the most with 2213 tons starting in 2013.

Subsequently, the data of aquaculture and fishing (without considering the tons caught in Egypt) have been related both starting from 1997, the year in which the production of meagre in aquaculture started.

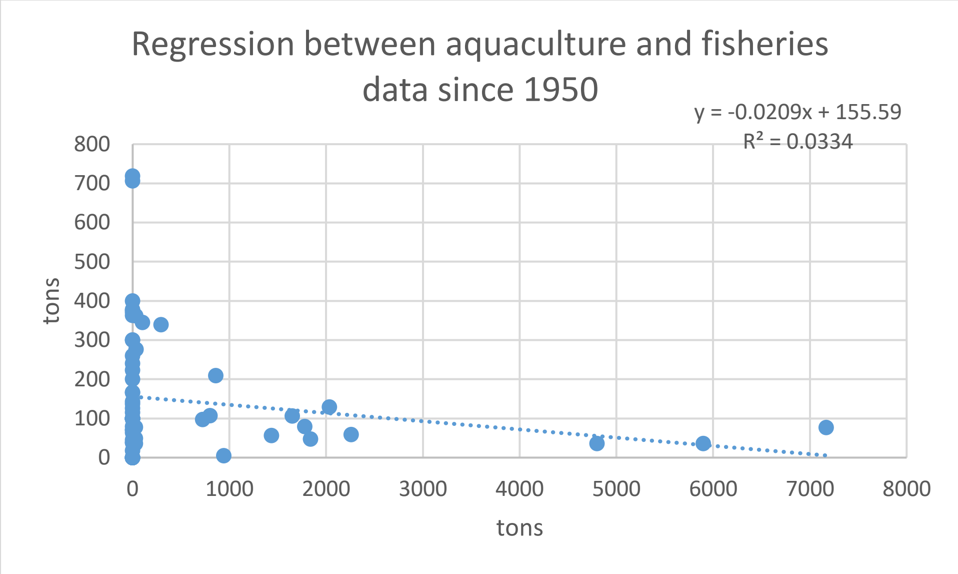


Fig 8. Linear regression between aquaculture and fisheries data since 1950

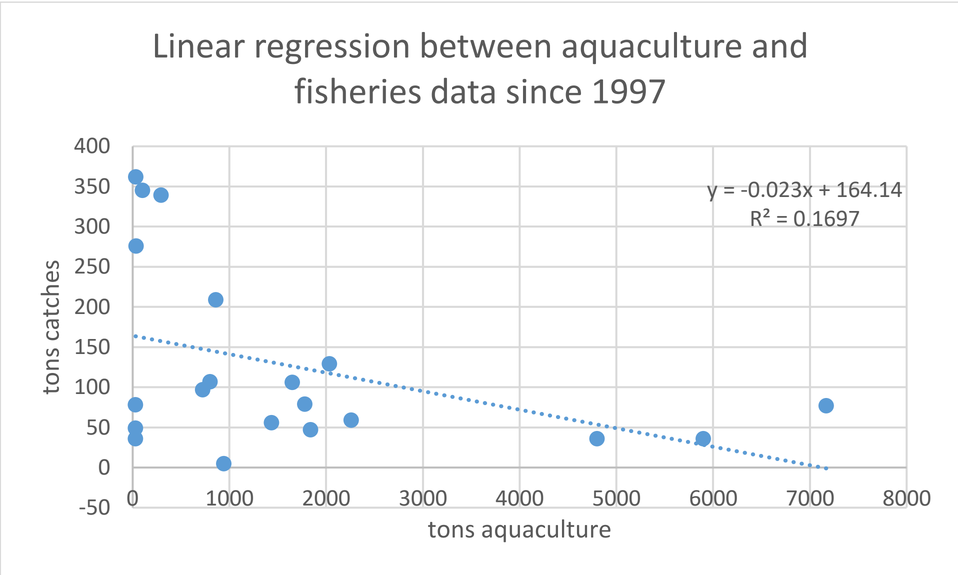


Fig 9. Linear regression between aquaculture and fisheries data since 1997

From the graphs of the linear regression you can see a negative correlation with very low R2, respectively 0.034 and 0.1697 and a p-value of 0.139 and 0.0711 [fig.8-9].

The catches in Spain were 100 tonnes per year from 1950 to 1955, then there were no catches until 1962 with a new production of 100 tonnes per year until 1969. Catches started again from 1975 until 1985 with a few dozen tonnes per year. After that there were no catches until 2005, while

FishStatJ (2019) data were missing from 2005 to 2012. A total of 64 tonnes were caught from 2013 to 2016, however it is not possible to calculate correlations because the lack of data.

The aquaculture production in Spain was [Tab.3]:

Tab 3. Aquaculture production in Spain from 2003 to 2016 (FishStatJ, 2019).

Spain	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Aq.	3	14	346	484	249	1117	1321	1815.6	989.8	606.6	482	1091	1281	1661

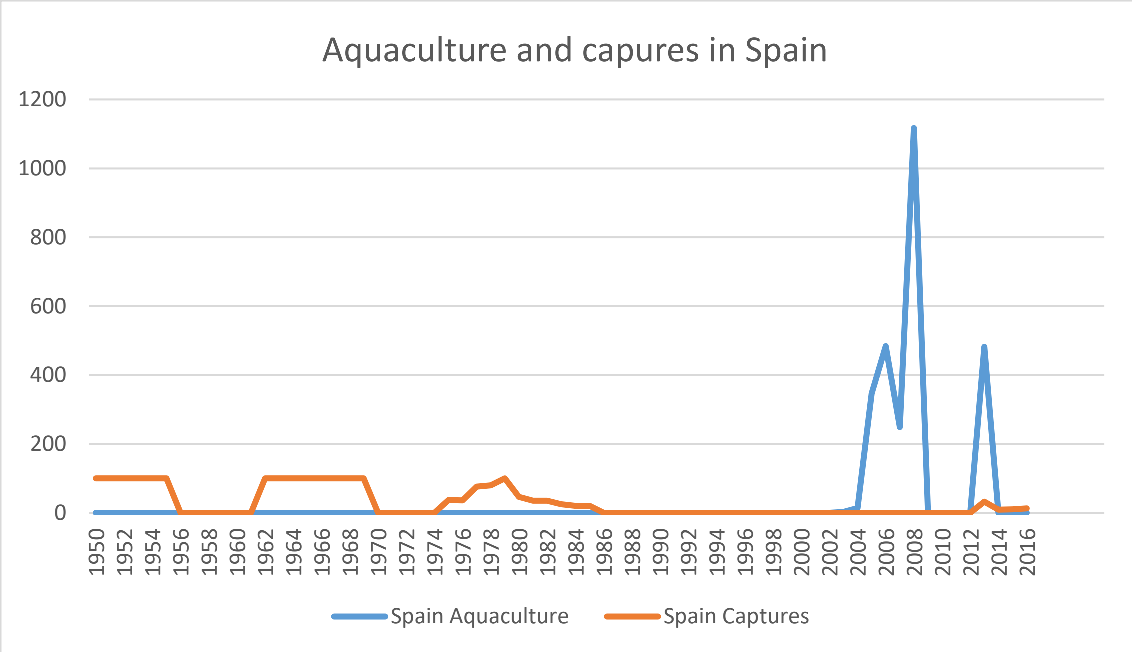


Fig 10. Aquaculture and captures of *A.regius* in Spain-data from FishStatJ (2019).

Regarding catch data of the ports of the Comunidad Valenciana in particular of Santa Pola, Altea, Villajoyosa and Isla de Tabarca. The tables with the data for each port are given below [Tab.6-7-8-9][fig.11-12-13-14].

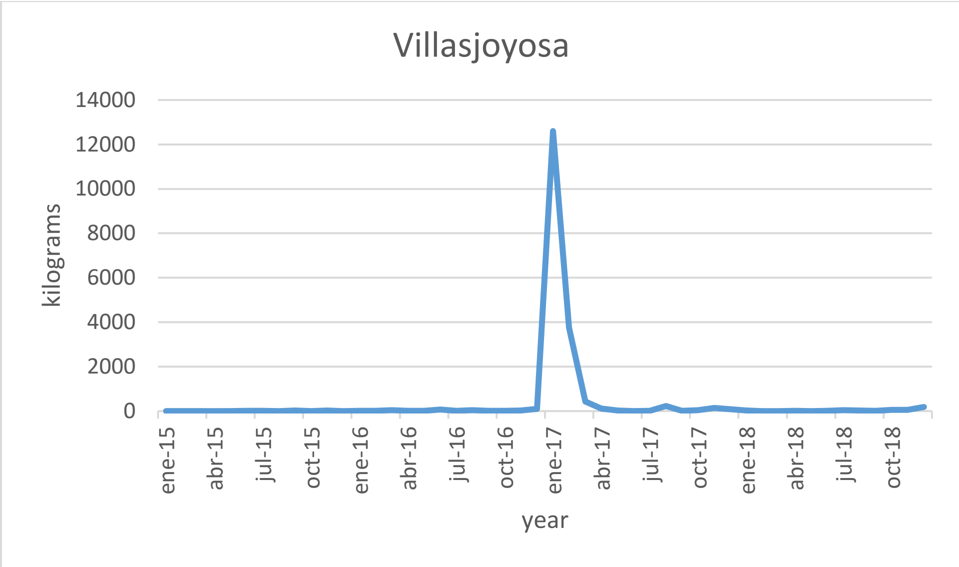


Fig 11. kilograms of *A.regius* caught inVillajoyosa, Spain

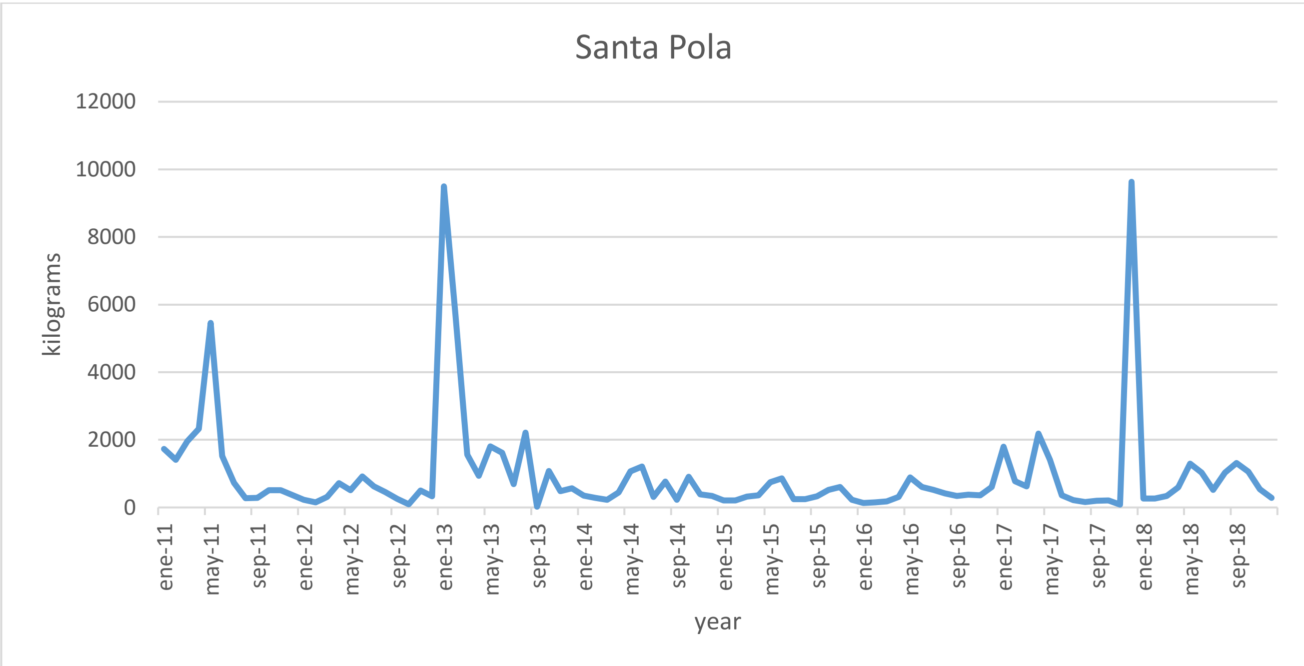


Fig 12. Kilograms of *A.regius* caught Santa Pola, Spain.

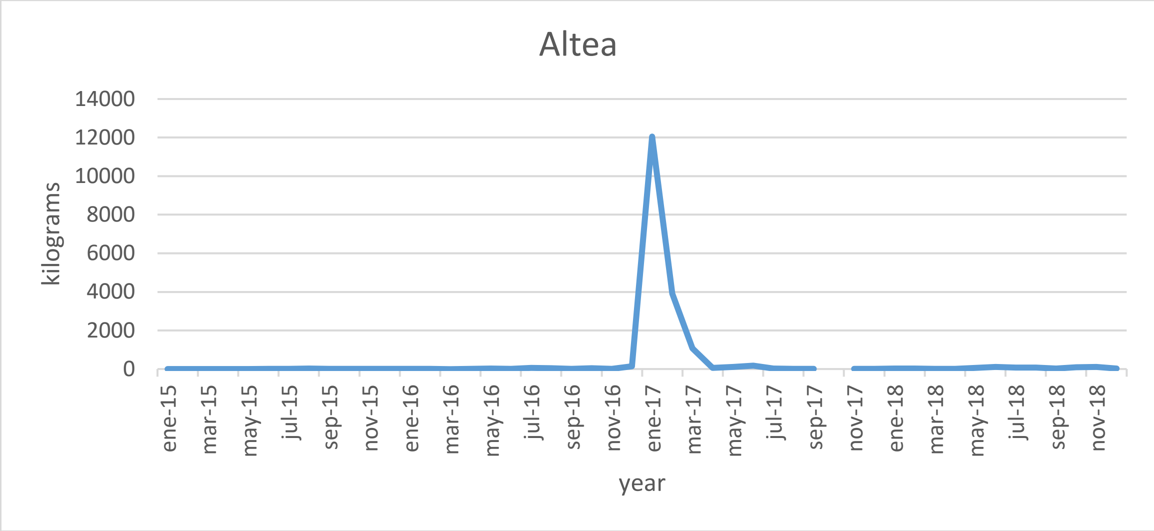


Fig 13. Kilograms of *A.regius* caught Altea, Spain

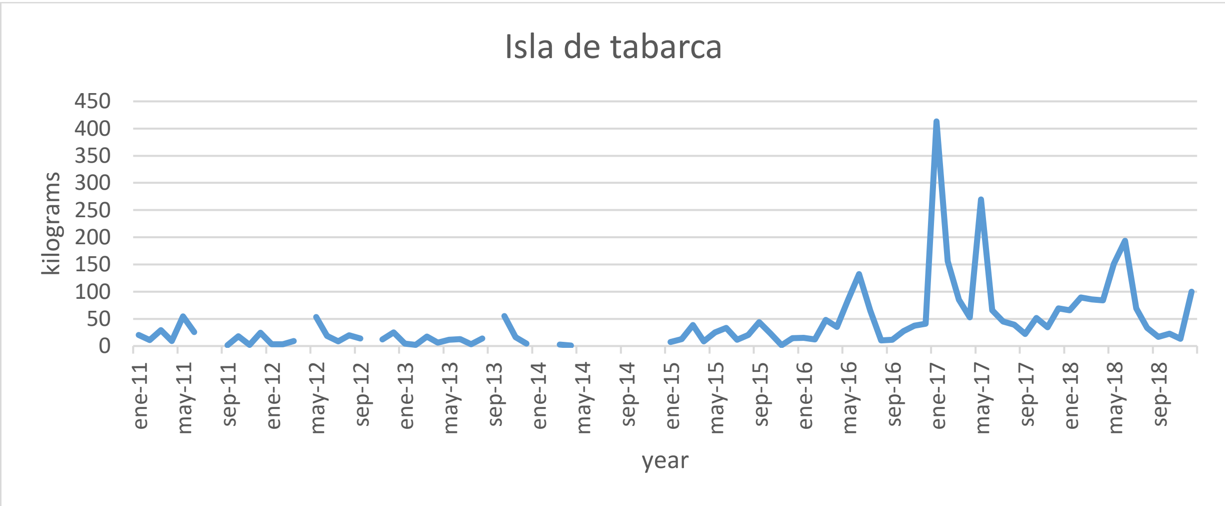


Fig 14. Kilograms of *A.regius* caught Isla de Tabarca, Spain

The aquaculture data of the whole Cominidad Valenciana (APROMAR, 2018) were then taken and related to the catch data of the different ports. [Tab.4]

Tab 4. Aquaculture production data Comunidad Valenciana- APROMAR 2018

Year	**Tons prod. C.V.**
2011	1510
2012	600
2013	89
2014	1067
2015	1600
2016	1752
2017	1886
2018	2258

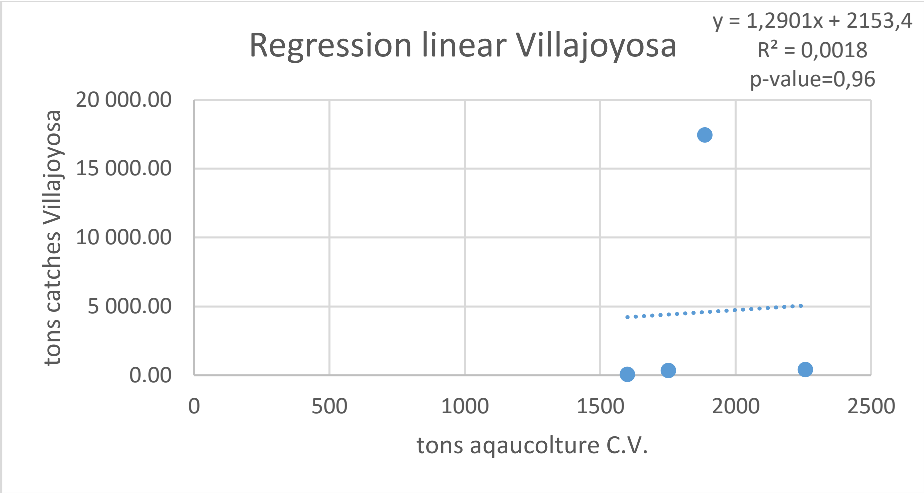


Fig 15.Linear regression between fisheries data and aquaculture data in the port of Villajoyosa

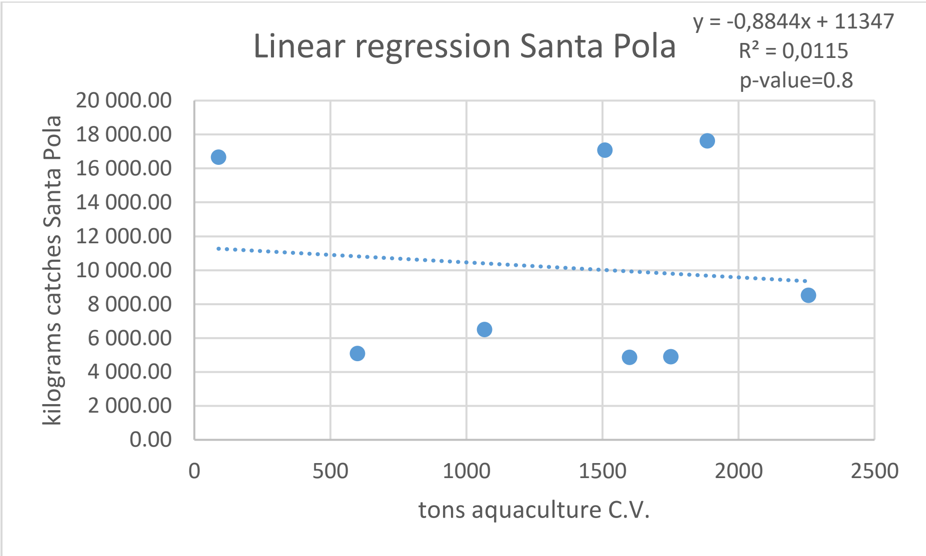


Fig 16. Linear regression between fisheries data and aquaculture data in the port of Santa Pola

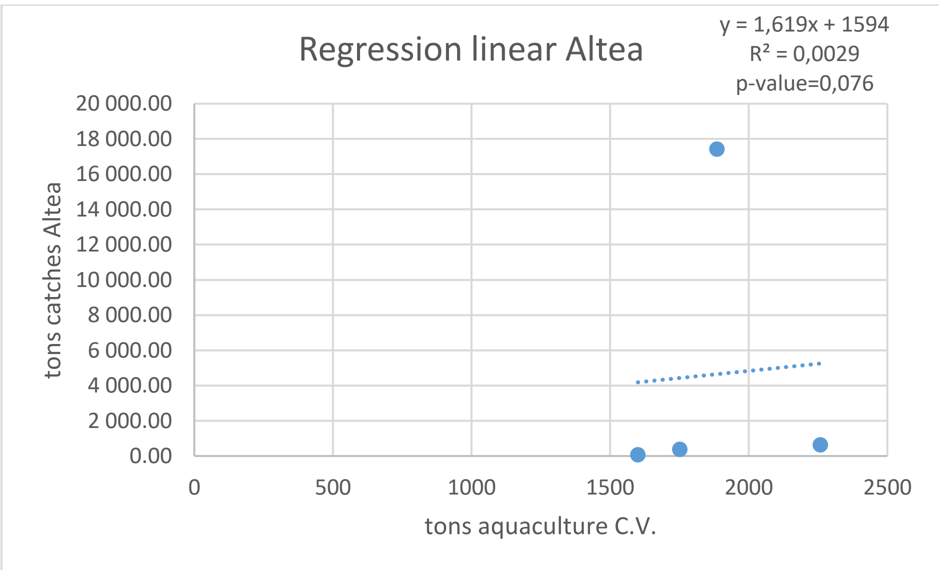


Fig 17. Linear regression between fisheries data and aquaculture data in the port of Altea

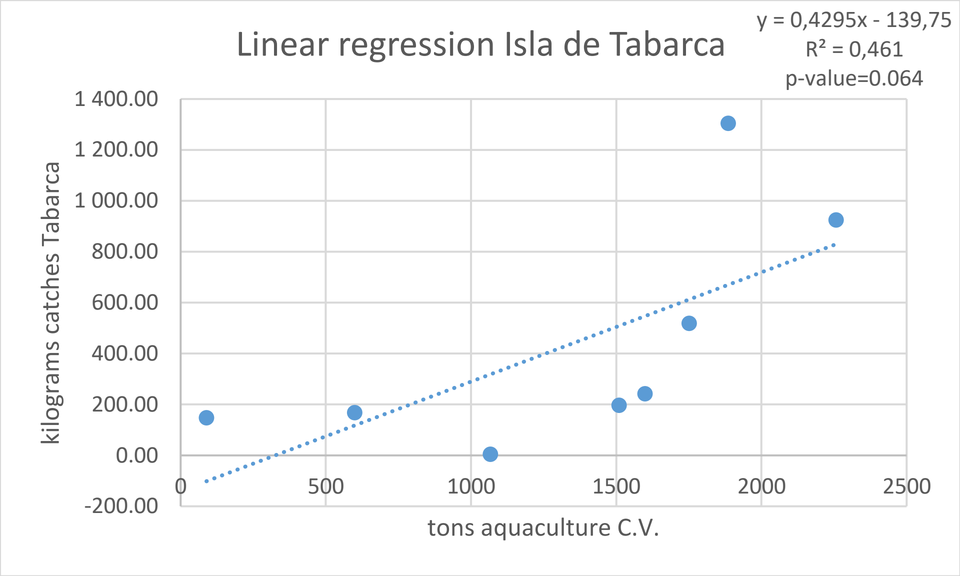


Fig 18. Linear regression between fisheries data and aquaculture data in the port of Tabarca

An R^2=0.0018 and p-value=0,96 was found with data from Villajoyosa, R^2=0.0115 and p-value=0.8 for Santa Pola, R^2=0.0029 and p-value=0,076 for Altea and R^2=0.461 and p-value=0.064 for Tabarca [fig. 15-16-17-18].

The graphs of captures in the differents ports shows that since 2011 this species has been found on the coast of the Comunidad Valenciana, but in limited quantities except in some cases, where the graphs and tables show peaks in catches.

3.3. Correlation of hydrodynamics with catches in the Comunidad Valenciana

The data that stand out most from the previous results are the peaks of catches in the various ports in the year 2017, in the chart 2017 [fig.19]are reported the catches for each port in the year 2017, it is interesting to note that in January and February in all three ports there is a dramatic increase in catches that exceed 26000 kg in January, while the average catch from March to November just exceeds 1600 kg. This peak is certainly a sign of an anomalous presence of meagre at sea.

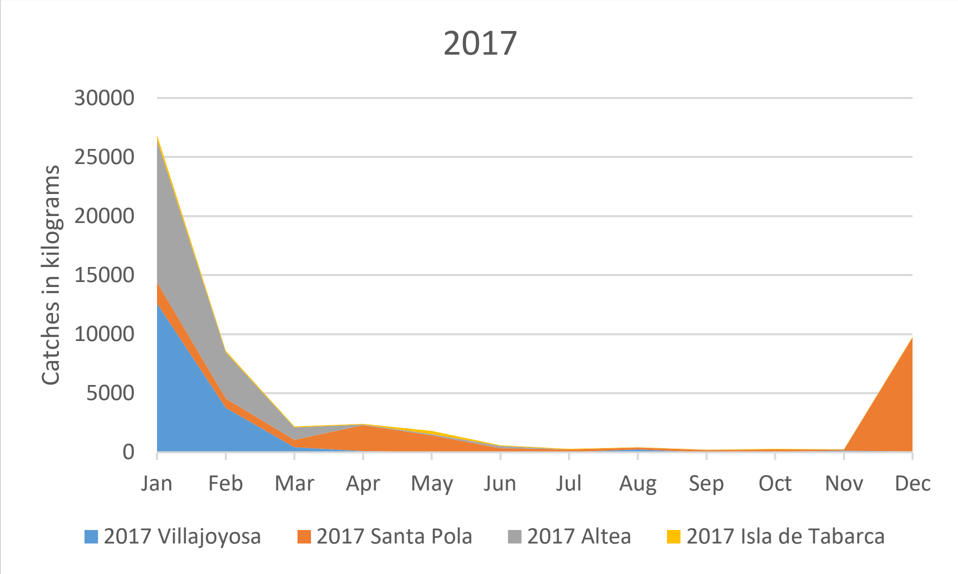


Fig 19. Kilograms of *A.regius* caught Villajoyosa, Santa Pola, Altea and Isla de Tabarca in 2017

To explain this anomalous peak, the data of the maximum wave height of the year 2017, recorded by a meteorological buoy near Altea, were extrapolated [fig.20].

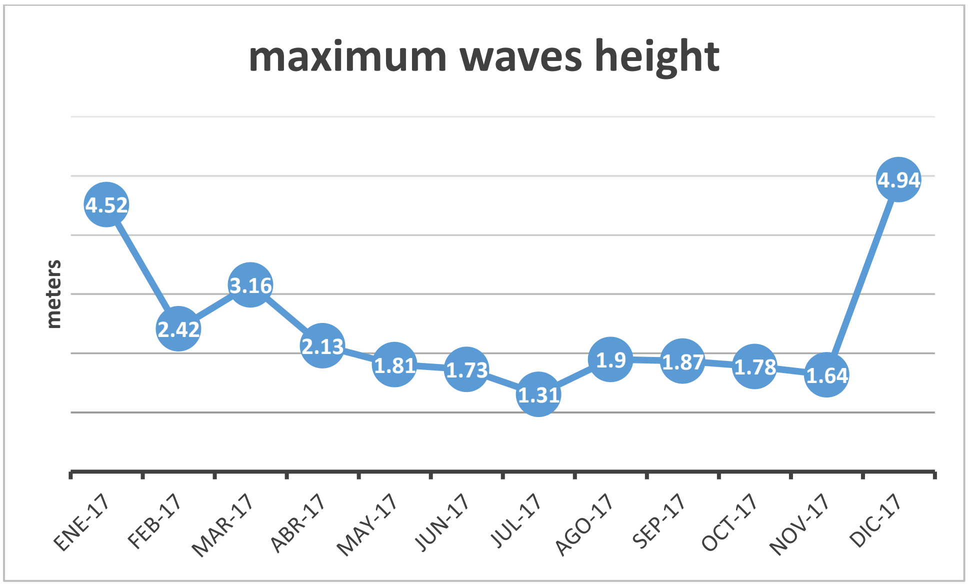


Fig 20. the maximum wave height of the year 2017, recorded by a meteorological buoy near Altea

These data have been analysed using linear regression: [Fig.21]

Tab 5. the maximum wave height of the year 2017, recorded by a meteorological buoy near Altea and kg of catches in C.V.

Months	***h waves m.***	***catches en C.V.***
Jen-17	4,52	12052,85
Feb-17	2,42	3908,4
Mar-17	3,16	1070,22
Apr-17	2,13	52,48
May-17	1,81	105,44
Jun-17	1,73	168,58
Jul-17	1,31	21,21
Aug-17	1,9	10,98
Sep-17	1,87	16,13
Oct-17	1,78	
Nov-17	1,64	9,3
Dec-17	4,94	4,75

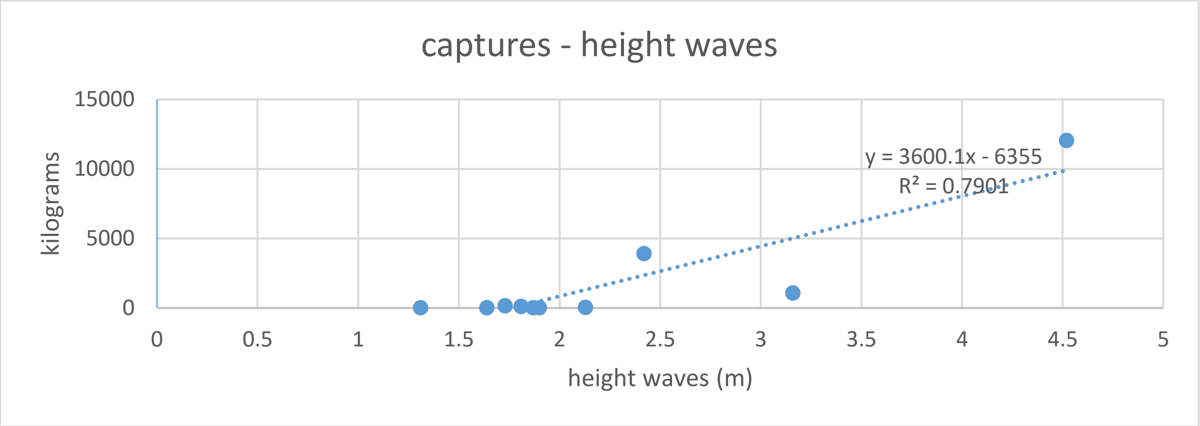


Fig 21. Linear regression between captures in Conunidad Valenciana and height waves in 2017

An $R^2 = 0.7901$ and a p-value=0.055 indicates an important correlation between catches and wave heights [fig.21]. The point that most gives weight to the regression is (4.52; 12052.85) which corresponds to the month of January.

4. Discussion

The results obtained from the analysis of the scientific papers showed that *A. regius* is present in the Mediterranean Sea, but with a very restricted distribution, similar to *U. cirrosa*. The most commonly and widely distributed sciaenid was *S. umbra*.

The most widespread was *S. umbra*, within the Mediterranean Sea, the species is widely distributed and has been recorded from the Spanish coasts (Sala, 1997, Garcia Charton et al.,1999, Macpherson et al., 2002, Cruz et al., 2004), the Balearic Islands (Deudero et al., 2004), the Gulf of Lion (Ruitton et al., 2000), the Ligurian Sea (Tunesi et al., 2005, Tunesi et al. 2006), the southern Tyrrhenian Sea (La Mesa et al., 1999), the northern Adriatic Sea (Lipej et al. 2003, Dulcic et al., 2006), the southern Adriatic Sea (Bussotti et al., 2002), the Aegean Sea (Koutrakis et al, 2003, Ayaz et al. 2006, Karakulak et al., 2006) and Lebanese coasts (Harmelin-Vivien et al., 2005), and some main islands (Sicily and Sardinia).

U. Cirrosa was found only in Turkey and this could be due to two possible reasons for, misidentification of *Umbrina* as *Sciaena* or a lower abundance which leads to “false zeros” in punctual studies. In addition, research using specific keywords limits the number of scientific aricles considered and could lead to a limited view of the actual reality.

It is interesting that the data on *A. regius* are in agreement with Haffray et al. (2012). According to this study this coastal semi pelagic species is distributed in the eastern Atlantic Ocean, from the Bay of Biscay to the coast of Senegal, and across the Mediterranean Sea, Black Sea and Gulf of Suez and is known to reproduce in the eastern Atlantic and Mediterranean Sea in just five distinct and restricted geographic areas: along the Mauritanian coast and at estuary openings (Gironde, Tagus, Guadalquivir and Nile). This is explained by the fact that it is an anadromous species, so to reproduce has to be near estuaries in the spring period (FAO, 2014). All this makes us understand that meagre is a species present in the Mediterranean but is not uniformly present in all areas.

The comparison between aquaculture production and fishing data in the Mediterranean has not shown any strong relation. However, the level of production are relatively low at the moment and it is not possible to detect a linear regression. It should be noted that the data are not complete, in fact for some years and countries there are missing values. The same weak regressions were found for Spanish aquaculture and fisheries trends national dataset. The hypothesis was that if the meagre aquaculture increase, the fishery of the specie that is locally absent could be artificially increase due to escapes from fish farm. Studies with other specie with a high production, such as the Atlantic salmon suggested that the increased salmon farming activity in Norway produced the subsequent increase in number of salmon escaping from fish farms. Lund et al. (1991) estimated that a high proportion of reared salmon both in the fisheries and in salmon spawning populations. During the fishing season in summer, the proportion of reared salmon was higher in the outer coastal areas than in fjords and rivers. Near spawning, the proportion of reared salmon in many rivers increased considerably, indicating that these fish ascend the rivers late in the season.

The fact that no strong relations have been found between fisheries and aquaculture is probably due to the low production of this species. In fact, other studies carried out on sea bream and sea bassand Atlantic salmon have shown that increased production in aquaculture has led to an increase in catches of these species.

When we analyzed this correlation at a local scale of Comunidad Valenciana, we found some evidences that could indicate the interaction of fisheries and aquaculture of meagre. In fact in the ports of Villajoyosa, Santa Pola and Altea weak relations have been verified, probably due to a limited number of data and a limited production, while for the port of Isla de Tabarca has been highlighted a stronger correlation. This could suggest that this locally absent specie is now a most common caught species due to the escapes from fish farm. The catchability of the specie by local fisheries has been study experimentally by Arechavala-López et al. (2018) indicating that in 48 h after the escape, near of 9% of the individual were recapture by local fisheries. It is interesting to note the peak catch in 2017 in all Spanish ports, which suggests a phenomenon of escapes. The confirmation that the impressive catches of 2017 are due to escapes from aquaculture facilities is given by the correlation with the wave height data In fact just in January 2017 the waves reached a maximum peak of 4.52 meters and can most likely be considered the reason why some breeding cages broke and allowed the escape of fish. Failure of the system due to big storms has been demonstrated that is one of the main reasons of massive escape from fish farms. For example, Toledo et al. (2014) studied the influence of a massive escape of 1.5 million fish into the wild off La Palma (Canary Islands) on artisanal fisheries, as a consequence of repeated sea storms, which generated waves up to 6 m high. Furthermore, in the study by Arechavala-Lopez et al. (2015), the authors found a linear correlation between aquaculture production and fishing catches in the same area covered by this study but they have worked on a previous database, i.e. from 2005 to 2012.

Considering that meagre is not a species locally present in the whole Mediterranean, it is legitimate to wonder what are the effects of aquaculture escapes in areas where the meagre is absent in nature.

Escape incidents lead to economic losses for farmers, but they can also cause environmental problems on coastal ecosystems through the spread of diseases and pathogens, competition for natural resources, predation on other species and interbreeding with wild con specifics (Dempster et al., 2007). Consequently, the interactions of escaped fish with wild populations can have also indirect socio-economic effects on local fisher ies and consumers (Dempster et al., 2007). Landings of small-scale fisheries might be affected through alterations of wild fish stocks due to escapees, modifying the pro portions and prices of targeted species (Dimitriou et al., 2007), and in consequence, might affect fish consumers. In addition, the escape of fish recently treated with antibiotics could be sold as fish caught and thus have health implications for consumers.

The environmental effects of escaped fish on wild populations may be divided into six general categories:

- Exploitation competition: the possibility that escaped meagre affect wild conspecific or other marine species indirectly through consumption (predation) of shared trophic resource's.
- Interference competition and habitat competition: escaped fish may compete directly with conspecifics or other species and interfere with foraging, survival and reproduction by preventing their physical establishment in natural habitats
- Predation impact: escaped meagre affect wild conspecifics or other marine species directly through predation on them
- Competition over mating opportunities may exist when wild fish are outcompeted by escaped fish disrupts the natural spawning pattern of wild fish
- Escaped fish could spread diseases to conspecifics or other species
- Genetic Impacts

Some of these aspects will be discussed below.

4.1. Trophic level of farmed fish

The trophic level of an organism is the position it occupies in a food chain. A food chain is a succession of organisms that eat other organisms and may, in turn, be eaten themselves. The trophic level of an organism is the number of steps it is from the start of the chain.

On the first trophic level are all photosynthetic organisms (plants, algae, photosynthetic bacteria). At the second trophic level you will find the primary consumers (all herbivores or grazers). At the third trophic level are the secondary consumers, i.e. the carnivores who feed on herbivores. At upper trophic levels n+1 there are carnivores feeding on carnivores at level n. In practice there are never more than 5 trophic levels.

When considering a new species for aquaculture, the trophic level must be taken into account.

In fact, a fish with a high trophic level will require very protein feed, with a significant impact on natural stocks. In addition, escapes from facilities could change the balance of local populations, creating competition between predators and depletion of benthic fish.Meagres are mainly piscivorous and feed mainly on clupeiform fish such as sardines and anchovies and demersal fish. According to the FishBase database the trophic level of the meagre is 4.3 (±0.75).

In the study (Hubans, 2017) the stomach content of 261 meagres with a length ranging between 25 and 136 centimeters caught during the IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) campaign in the Bay of Biscay was analysed.The diet was mainly made up of fish (more than 50% in juvenile meagre and more than 84% in older fish), a large part of crustaceans (more than 40% in juvenile meagre and 5% in older one) and even a small part of cephalopods and polychaetes. The fish found most frequently was anchovy (*Engraulis encrasicolus*), the second sardine (*Sardina pilchardus*). Two gadoids species, pout (*Trisopterus luscus*) and whiting (*Merlangius merlangus*) have a significant importance in the diet.

Furthermore, as regards the Mediterranean, in the study of Valero-Rodriguez et al. (2014) Stomach contents of 159 individuals were analysed and the identifiable prey items classified into major groups. The stomach content analysis showed that small meagre individuals (<30 cm in length) consumed mainly small crustaceans such as Pleocyemata and Dendrobranchiata (as the the commercially important decapod *Melicertus kerathurus*). However, a change observed in feeding habits of meagre occurred in sizes ranging from 40 to 45 cm in length, where individuals tended to shift their preference to Teleostea (particularly to *Platichthys flesu*) and reduce their capture of previously main prey crustaceans to being accidental prey. In addition, food pellets were occasionally consumed.

Therefore, due to the hight trophic level of meagre and the massive escapes from fish farms in determinate locations, the impact of this high density of individuals could produce negative impact on trophic resources, increase the predation on commercial species and affecting to the local communities by trophic competition.

4.2. Genetic impact

A major problem in aquaculture is the change in the genetic structure of natural stocks.

Many cultured fish species used in aquaculture are usually genetically different from local wild populations. In the case of escape from the aquaculture sites, the breeding of escaped fish with native ones have result in genetic changes in wild populations. (Kayaci et al., 2015).

Most studies on the genetic impact of escapes have focused on Atlantic salmon and sea bream and sea bass in the Mediterranean Sea. There is an overall lack of knowledge regarding genetic effects of meagre escapees on wild population. Surely, there is a lot of difference between the level of selection of salmon and meagre brood stock. While a high level of domestication has been reached for salmon, the tests for meagre are still at the beginning. However, this should not lower the attention, in fact several genetic improvement projects are underway (including the European project Diversify).

Often, fish used in aquaculture genetically differ from those in the wild and this, of course, can lead to problems of genetic pollution in natural stocks, which means different behaviors, particular ecological interactions, predisposition to diseases, different growth performances. All this can lead to an advantage for populations of aquaculture origin and a decrease in the genetic differentiation of the wild population (Kayaci et al., 2015).

Farmed fish differ in the selection of the most domesticated animals, the selection of the most economically significant traits and the genetic drift (Ferguson et al., 2007), so hybridization of aquaculture fish with wild fish can change the level of genetic variability and the presence and frequency of the types of alleles, furthermore, for genetic pollution, attention must be paid not only to the escape of fish, but also to the loss of fertilised eggs in the wild (Jensen et al., 2010).

For the time being, the species *Argyrosomus regius* has not received any significant genetic selection, but this may change in the future. A precautionary principle should be adopted. This aspect may be important because *A. regius* exhibited a very high level of genetic differentiation rarely reported in marine fishes (Haffray et al. 2012). The high geographic distances between the few reproductive areas leads one ask whether there is genetic differentiation in this species. These atuhors found at least two very distinct groups could be identified, separated by the Gibraltar Strait.

If the Spanish companies are buying meagre fingerlings from a French company, Les Poissons du Soleil (LPDS), which could be using reproducer from the Atlantic population, genetic changes on meagre population of Mediterranean Sea could be affected by escapes.

4.3. Spread of diseases

A risk related to fish escapes could be to introduce pathologies or parasites or unwanted environmental impacts on the local flora and fauna.

As regards the transmission of diseases, bidirectional pathogen transfer is highly possible (e.g. from the new species to the environment and vice versa), since new stocks represent a susceptible focal point of pathogen proliferation. In addition, increasing the production in the breeding unit increases the concentration of pathogens, which, also thanks to the immunodepression due to the stress of the animals in the cage, spread more easily. In consequence, pathogen concentration in the surrounding environment can increase with the increased numbers of infected fish on a farm (Murray, 2009).

Disease problems may arise because the current farming techniques and the open design of Mediterranean aquaculture systems permit transmission of pathogens among pens. The primary route for introduction of pathogens to a farm is through transport of infected seedlings from hatcheries (Piper et al. 1982), food, infected equipment, staff and vessels (e.g. Kennedy and Fitch, 1990, Ruiz et al., 2000, Murray, 2005), as well as through water currents (Fouz et al., 2000, Amundrud, 2009, Frazer, 2009, Salama, 2011).

Monitoring of animal health, biosecurity programmes and other disease control measures, including disease management areas or surveillance zones around farms must be designed to minimize the risk of spreading disease. (DAFF, 2000, Scottish Executive, 2000, Rae, 2002, Subasinghe et al., 2004, Bondad-Reantasoand Subasinghe, 2008, Lyngstad et al., 2008, Mardones et al., 2009, Marine Scotland, 2010).

The European Community basic legal provision ‘Council Directive 2006/88/EC’ lays down the minimum prevention, control and eradication measures for aquatic animal diseases to be implemented in aquaculture activity by the Member States. However, the efficiency depends on farmers following the rules. Although disease control regulations for the Mediterranean finfish aquaculture industry are well established (Le Breton, 1999, Rodgers, 2009), the current legislation is not consistent throughout the Mediterranean (Cardia, 2007). For instance, seedling import/ export regulations and quarantine measures still vary from country to country.

In addition to the ‘traditional’ pathways for disease transmission, movements of both wild fish and farm escapees also need to be considered as vectors for disease propagation. This has been studied in more temperate regions of the world (e.g. Diamant et al., 2004, Naylor et al., 2005, Raynard et al., 2007, Johansen et al., 2011), but not in the Mediterranean.

The main bacterial and parasitic diseases found in meagre breeding will be listed below

- **Systemic Granulomatosis**: The most important disease of cultured meagre is a newly described condition under this provisional name (Katharios et al., 2011). It is characterized by multiple systemic visceral granulomas and is manifested progressively by calcified and necrotic liver and kidney. Granulomas in fish are a common immune response to a wide range of stimuli, including bacterial infections such as by *Nocardia* spp. and *Mycobacterium* spp., as well as to infections by the Mesomycetozoan Ichthyophonus hoferi (Roberts, 2012). But Tsertou et al. has demonstrated that the granulomatosis in meagre is not caused by *Nocardia s*pp.. The causes are still unknown, so it is not known whether this disease can be transmitted to other organisms in the vicinity of the cages.

- ***Nocardia bacterium:*** Although not the cause of granulomatosis, the bacterium of *Nocardia* spp. has been found in several farms. Nocardia infection has been reported recently in large cultured meagre and may pose a significant threat and bottleneck for its production, since Nocardiosis is a chronic disease which is hard to eradicate and apart from the direct mortalities may also adversely affect the final product quality. As it is a disease of bacterial origin that is difficult to control, it must be taken into account for possible diffusion in the natural environment; also considering the fact that this bacterium has been isolated in several freshwater and salt water farms. (Labrie et al.).

- ***Sciaenacotyle panceri*****:** Gill monogenean (Polyopsithocotylea) is highly host-specific. It has a direct life-cycle, a large size (up to 10 mm) and it is a blood-feeding. Can propagate in extremely high numbers. Cause gill hyperplasia, anemia and eventually death, Mortalities can be severe especially in large fish (reaching commercial size). Being a species-specific parasite, it is difficult to propagate to fish of other species.

- ***Diplecatanum sciaenae***: It is a gill monogenean (Monoopsithocotylea), host specific, direct life-cycle, mucous-feeding, Can propagate in extremely high numbers, Cause gill hyperplasia, secondary infections and eventually death, Mortalities have been recorded in broodstock). It is however a parasite that is also found in other shanudes including *S. umbra* (Akmirza, 2013), so it is plausible the transfer of this parasite in the natural environment.

- ***Benedenia sciaenae***: A report (Toksen E., 2007) documents the occurrence of B. *scianeae* in cultured meagre in Izmir, Turkey and suggest that the parasites are responsible for pathological changes of the host skin. It is however a species-specific parasite so there is little chance that it will spread to wild populations.

- ***Amyloodinium ocellatum***: is a parasite that causes serious problems on cultured fish either in intensive production tanks or in ornamental fish aquaria (Noga and Levy, 1995). This disease is a major bottleneck in semi-intensive aquaculture production in Southern Europe where amyloodiniosis cause high mortalities in large number of fish farms. This parasite has been reported in aquaculture in the Mediterranean area (Alvarez-Pellitero et al., 1993; Fioravanti et al., 2006) and in the neighboring region of Eilat in the Red Sea (Paperna, 1980). In Portugal the disease was first diagnosed in 1994 in gilthead seabream reared in aquaculture (Menezes, 1994) and latterly in natural populations of seabass from the Óbidos coastal lagoon and the Sado estuary (Menezes, 2000). Since early 2000 it has been detected every year in Portuguese fish farms causing high mortalities in seabream, seabass and more recently in turbot (*Pseta maxima*)(Saraiva et al., 2011). The risk of spreading the parasite to wild populations and other fish that are often reared in cages near meagre should therefore be considered.

In a review, Arechavala-Lopez et al. (2013) analysed the triangle of pathogen transmission of concern to Mediterranean aquaculture management due to Reared fish, farmed escapees and wild fish stocks. The authors indicated that fish health and biosecurity programmes at farms have focused on the most obvious pathways for transmission of pathogens, however, little attention has been devoted to the potential risk of pathogen and disease transmission in Mediterranean open-sea aquaculture through movements of fish. This study did not consider the negative effect of meagre aquaculture due to the previously figured bacterial and parasitic diseases. If the production of this species increase exponentially, could increase the risk of potential effect on local population of sciaenids.

5. Conclusion and recommendations

The presence of locally absent fish species might alter the mean trophic level of coastal fish assemblages (Toledo-Guedes et al., 2014), thus affecting the natural balance of the coastal ecosystems (Casini et al., 2012). Nevertheless, the establishment of escaped fish populations in natural habitats will depend on their recruitment potential and adaptability to a new environment (Gil et al. 2013, 2014) and so, a risk assessment should be carried out for each aquaculture facility for the potential risks of a locally absent species escaping (Copp et al., 2014).

The European Commission enacted 'Council Regulation No. 708/2007 concerning use of alien and locally absent species in aquaculture', this Regulation aims to contribute to aquaculture sustainability, reduce economic distortion among European countries and support countries having limited regulation on both conservation and aquaculture issues. In particular, was intended to provide a scheme consisting of risk asessment protocols and decision support tools to help assess the safe use of alien species in aquaculture throughout the European Union (Copp et al., 2014).
The European Non-native Species in Aquaculture Risk Analysis Scheme consists of seven modules: Entry, Pre-screening (for invasiveness), Organism, Infectious Agent, Facility, Pathway and Socio-economic Impact (Copp et al., 2014).
In the ESCA-FEP Good Practice Guide on Escape Management in Marine Aquaculture (Izquierdo-Gómez et al., 2015) a plan to contain escapements is proposed. The following are the six suggested steps:

A. Alert the competent authority of the escape during the following 24 h, informing on the characteristics of the escape as the place, the species, size, approximate number of escaped fish, medical history of the escaped fish, causes of the escape and the description of damages in the installation.

B. Initiate recapture actions approved by the competent administration at the time of applying for the license to start the activity.

C. Repair the damage suffered in the installation so as not to aggravate the magnitude of the leak.

D. After 30 days, the administration should be informed of the success of the recapture, indicating the number of individuals escaped, location, sizes and methods used, in order to evaluate the contingency plan used and its improvement for future escapes. In addition, the actions taken to repair the damage that caused the leak will be detailed and the administration will reserve the right to inspect the leak in situ.

E. In terms of preventing possible damage, the administration should contact other agencies that may be affected by the escape of fish, such as the points of first sale of fish, fishermen's guilds, administration responsible for monitoring and maintenance of beaches and coasts, managers of marine reserves or sport fishing associations.

F. After the escape, the administration should carry out follow-up actions as part of an environmental surveillance plan, with the aim of detecting escaped fish in the environment. On the basis of this plan, eradication measures may be activated if deemed appropriate.

In addition, it is recommended to follow the escaped fish not only in the environment but also in the catches of sport and professional fishermen, as there is a risk that these individuals are marketed as fish derived from extractive fishing; this is not only a fraud but can also be a risk for public health as the caught fish could be under antibiotic treatment.

An example of an implementation protocol for the prevention and mitigation of escapes was launched with the resolution of 7 May 2018 from the Canary Islands. In the Mediterranean, the other countries should take such measures, Only through this kind of management measures, the sustainable development of the aquaculture industry along the Mediterranean coast will be achieved.

Meagre is an increasingly important species in aquaculture, and has been introduced massively in farms throughout the Mediterranean (especially Spain, Greece, Turkey and Egypt). Most of the studies funded by national and EU governments are aimed at implementing breeding techniques but few studies have been designed to assess whether this species is actually present uniformly throughout the Mediterranean, and what impact it can have on the environment and fish stocks. The present study showed an uneven presence of meagre in many Mediterranean regions. This should suggest that it should be considered as a not locally present species and therefore measures should be introduced to avoid negative effects on marine ecosystem. Focus on interaction with other sciaenids such as *S. umbra* must be considered. There are some evidences that escapes are affecting to local fisheries in areas where the meagre production is increasing and the monitoring of escapees on local market must be considered. The magnitude of the escapes could be related with storms and an optimal spatial planning considering sea conditions should be taken into account. Preventive and mitigative programs for meagre escapes must be compulsory for fish farmers.

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ANNEX I. review of articles, with latitude and longitude of the places where the species was found

Autor	Year	Title	Paper	Country	Habitat	Latitud	Longitud	*A. regius*	*U .cirrosa*	*S. umbra*
R. Embarek, et al.	2017	Fish assemblage structure in shallow waters of the Mellah Lagoon (Algeria):Seasonal and spatial distribution patterns and relation to environmental parameters	Acta Ichthyologica Et Piscatoria	Algeria	sands	36,89841	8,31809	0	0	0
P. Koulouri,et al.	2015	Fish and cephalopod assemblage structure of green alga Caulerpa prolifera (Chlorophyta) meadow in the eastern Mediterranean Sea (Elounda Bay, Crete Island)	ELSEVIER	Crete Island	Caulerpa prolifera meadow	35,24914	25,73982	0	0	0
I. Glavičić, et, al	2016	A quantitative assessment of the cryptobenthic fish assemblage at deep littoral cliffs in the Mediterranean	Scientia Marina	Croatia	reef	43,21397	16,378004	0	0	0
M. Nevine , et al.	2013	Reproductive biology of Argyrosomus regius (Asso, 1801) inhabiting the south eastern Mediterranean Sea, Egypt	Egyptian Journal of Aquatic Research	Egypt		31,12177	32,677385	1		
B. Pascaline, et al.	2011	MONITORING OF THE ARTIFICIAL REEF FISH ASSEMBLAGES OF GOLFE JUAN MARINE PROTECTED AREA (FRANCE, NORTH-WESTERN MEDITERRANEAN)	BRAZILIAN JOURNAL OF OCEANOGRAPHY	France	Several types of reefs of various sizes	43,55846	7,082092	0	0	1
C. Seytre et al.	2008	Is the Cape Roux marine protected area (Saint-Raphaël, Mediterranean Sea) an efficient tool to sustain artisanal fisheries? First indications from visual censuses and trammel net sampling		France		43,44447	6,91247			1
A. Tessier, et al.	2014	A case study of artificial reefs as a potential tool for maintaining artisanal fisheries in the French Mediterranean Sea	Aquatic Biology	French	basaltic rock/ artificial reefs	42,86759	3,053073	0	0	0
				French	basaltic rock/ artificial reefs	43,27441	3,469411	0	0	0
				French	basaltic rock/ artificial reefs	43,24148	3,288285	0	0	0
A. Tessier,et al.	2013	Video transects as a complement to underwater visual census to study reserve effect on fish assemblages	Aquatic Biology	French	rocky	42,44597	3,170708	0	0	1
				Greece	rocky reefs	39,20958	23,871366	0	0	1
				Greece	rocky reefs	39,20001	23,620602	0	0	1
D. Edelist, et al.	2011 (data 1990-94)	Spatiotemporal patterns of catch and discards of the Israeli Mediterranean trawl fishery in the early 1990s: ecological and conservation perspectives	Scientia Marina	Israel		31,81641	34,572723	1	0	0
D. Golani, et al.	2007	Ichthyofauna of the rocky coastal littoral of the Israeli Mediterranean, with reference to the paucity of Red Sea (Lessepsian) migrants in this habitat	Marine Biology Research	Israel		31,91996	34,529863	0	0	1
P. Guidetti, et al.	2018	Assessing the potential of marine Natura 2000 sites to produce ecosystem-wide effects in Sardinia Island (Italy)rocky reefs: A case study from		Italy	MPA	40,20197	9,683207			1
S. Marra, ,et al.	2015	Recovery Trends of Commercial Fish: The Case of an Underperforming Mediterranean Marine Protected Area	PLOSE ONE	Italy	basaltic/granitic substrate	39,8606	8,428975	0	0	1
S. Bussotti, et al.	2015	Fish Assemblages of Mediterranean Marine Caves	PLOSE ONE	Italy	caves	40,55731	8,173011	0	0	1

				Italy	caves	35,52222	12,637845	0	0	1
				Italy	caves	40,2481	17,888837	0	0	1
				Italy	caves	36,96264	15,328087	0	0	1
V. Esposito, et al.	2015	Fish community in a surf zone of the northern Sicilian coast (Mediterranean Sea): diversity and functional guild composition	Mediterranean Marine Science	Italy	sands	38,17917	14,833435	0	0	0
G. La Mesa, et al.	2017	Assessment of coastal fish assemblages before the establishment of a new marine protected area in the central Mediterranean: its role in formulating a zoning proposal	Mediterranean Marine Science	Italy	roky bottom	38,26732	15,254559	0	0	0
P. Consoli, et al.	2016	Fish Distribution and Habitat Complexity on Banks of the Strait of Sicily (Central Mediterranean Sea) from Remotely Operated Vehicle (ROV) Explorations	PLOSE ONE	Italy	different	37,62938	12,587186	0	0	0
A. Terlizzi, et al.	2013	SAMPEI project		Italy	sand and rock	40,2481	17,888837	0	0	1
				Italy	rocky reefs	44,30438	9,213755	0	0	1
				Italy	rocky reefs	40,93369	9,754073	0	0	1
				Italy	rocky reefs	40,88355	9,756876	0	0	1
				Italy	rocky reefs	40,2481	17,888837	0	0	1
				Italy	rocky reefs	42,13062	15,501135	0	0	1
				Italy	rocky reefs	40,5633	8,165521	0	0	1
P.Consoli, et al.	2012	The effects of protection measures onfish assemblage in the Plemmiriomarine reserve (Central Mediterranean Sea, Italy): Afirst assessment 5 yearsafter its establishment	ELSEVIER	italy	rocky	37,00348	15,316213	0	0	1
G. La Mesa , et al.	2012	Rocky reef fish assemblages at six Mediterranean marine protected areas: broad-scale patterns in assemblage structure, species richness and composition	Italian Journal of Zoology	italy	roky reef	44,30399	9,214155	0	0	0
				italy	roky reef	40,78998	13,439385	0	0	0
				italy	roky reef	37,55462	15,153092	0	0	0
				italy	roky reef	40,2481	17,888837	0	0	0
				italy	roky reef	40,72071	17,77751	0	0	0
				italy	Breakwaters	37,49992	15,104612	0	0	1
P. Consoli, et al.	2013	Factors affectingfish assemblages associated with gas platforms in theMediterranean Sea	Journal of Sea Research	italy	Sand muddy	39,0874	17,127095	0	0	0
				italy	sand mud flats	42,48313	14,206788	0	0	0
E. Cenci, et al.	2011	The influence of a new artificial structure on fish assemblages of adjacent hard substrata	Estuarine Coastal and Shelf Science	Italy	Artificial structure	45,24285	12,285749	0	0	1

P. Maiorano,et al.	2010	The demersal faunal assemblage of the north-western Ionian Sea (central Mediterranean): current knowledge and perspectives	Chemistry and Ecology	Italy		39,50307	17,756499	0	0	1
A. Di Franco, et al.	2009	Evaluating effects of total and partial restrictions to fishing on Mediterranean rocky-reef fish assemblages	MARINE ECOLOGY PROGRESS SERIES	Italy		40,90242	9,720164	0	0	1
S. Maci, et al.	2009	Composition, structural characteristics and temporal patterns of fish assemblages in non-tidal Mediterranean lagoons: A case study	estuarine Coastal and Shelf Science	Italy	Lagoons	40,44576	18,237245	0	0	1
S. Bussotti, P. Guidetti	2009	Do Mediterranean fish assemblages associated with marine caves and rocky cliffs differ?	Estuarine Coastal and Shelf Science	Italy	marine caves and rocky cliffs	39,89242	18,401726	0	0	1
M. Iannibelli, et al.	2008	Effects of anti-trawling artificial reefs on fish assemblages: The case of Salerno Bay (Mediterranean Sea)	Italian Journal of Zoology	Italy		40,657	14,787832	0	0	0
A. Pais , et al.	2007	Spatial variability of fish fauna in sheltered and exposed shallow rocky reefs from a recently established Mediterranean Marine Protected Area	Italian Journal of Zoology	Italy		41,06966	8,350346	0	0	1
				Marueco	rocky reefs	35,20313	-4,145442	0	0	1
P. Pengal, et al.	2013	A new design of multi-mesh survey gillnets to sample fish community in the Adriatic Sea	Acta Adriatica	Slovenia	sand and rock	45,53574	13,59023	0	0	1
Just T. Bayle-Sempere; et al.	2003	Effectiveness assessment of an artificial reef off Tabarca Island (Alicante southeastern Iberian Peninsula)	Boletin	Spain	arrecife	38,1677	-0,474933	0	0	1
J. M. González Correa; et al.	2019	Recreational boat traffic effects on fish assemblages: First evidence of detrimental consequences at regulated mooring zones in sensitive marine areas detected by passive acoustics	Ocean and Coastal Management 168 (2019) 22–34	Spain		38,82944	1,392603			1
				Spain		38,7278	1,402363			1
				Spain		38,1677	-0,474933			1
D. Lloris , et al.	2014	Spatial distribution of ichthyofauna in the northern Alboran Sea (western Mediterranean)	Journal of Natural History	Spain	different (MEDITS data)	36,52481	-3,978775	0	0	0
P. Guidetti et al.	2013	Large-Scale Assessment of Mediterranean Marine Protected Areas Effects on Fish Assemblages	PLOSE ONE	spain	rocky reefs	42,04565	3,225649	0	0	1
				spain	rocky reefs	42,31806	3,322155	0	0	1
				spain	rocky reefs	39,50517	2,67317	0	0	1
				spain	rocky reefs	39,14598	2,962754	0	0	1
R. Montserrat , et al.	2013	Deep epibenthic communities in two contrasting areas of the Balearic Islands (western Mediterranean)	ELSEVIER	Spain		39,80705	3,207461	0	0	0
D. Verdiell-Cubedo , et al.	2012	Fish assemblages in different littoral habitat types of a hypersaline coastal lagoon (Mar Menor, Mediterranean Sea)	Italian Journal of Zoology	Spain	sand	37,77769	-0,795662	0	0	0
J. Lloret, et al.	2008	Evolution of a Mediterranean Coastal Zone: Human Impacts on the Marine Environment of Cape Creus	Environmental Management	Spain		42,31576	3,32003	0	0	1
B.L. Emna, et al.	2018	Fish assemblages along the coasts of Tunisia: a baseline study to assess the effectiveness of future Marine Protected Areas	Mediterranean Marine Science	Tunez	rocky reefs	36,96407	8,762144	0	0	1
				Tunez	rocky reefs	37,10258	8,980888	0	0	1
				Tunez	rocky reefs	35,80849	11,035463	0	0	1

R. Ghanem, et al.	2017	Fish Assemblages Survey Technique (Fast) in Tunisian marine waters (Central Mediterranean)	Journal of Ichthyology	Tunisy	Rock, sand and P. oceanica meadows	37,24177	9,225424	0	0	1
				Tunisy	sand and rock	36,39167	10,623892	0	0	1
				Tunisy	sand and rock	37,29864	9,881065	0	0	1
D. Innal	2016	Fish Diversity and Distribution in the Aksu River Estuary (Antalya-Turkey), in Relation to Environmental Variables	Ecologia montenegrina	Turkey	sands	36,82248	30,794434	0	1	0
				Turkey	rocky reefs	36,82301	30,672267	0	0	1
C. Keskin, et al.	2010	Comparison of fish assemblages between the Sea of Marmara and the Aegean Sea (north-eastern Mediterranean)	Journal of the Marine Biological Association of the United Kingdom	Turkey		40,92045	28,515217	0	0	0
				Turkey		39,89395	25,962635	0	0	0
Çetin, et al.	2011	Distribution of the Demersal Fishes on the Continental Shelves of the Levantine and North Aegean Seas (Eastern Mediterranean)	Turkish Journal of Fisheries and Aquatic Sciences	Turkey		35,85592	31,787299	0	1	0
I. de Meo, et al.	2017	Ecological distribution of demersal fish species in space and time on the shelf of Antalya Gulf, Turkey	marine biodiv	Turkey		36,74458	30,897826	0	0	1
S. Snigirov, et al.	2011	The fish community in Zmiinyi Island waters: structure and determinants	Marine Biodiversity	Ukraina		45,25448	30,206935	0	1	1
					rocky reefs	40,72071	17,77751	0	0	0

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CIHEAM

El Máster Internacional en GESTIÓN PESQUERA SOSTENIBLE está organizado conjuntamente por la Universidad de Alicante (UA), el Centro Internacional de Altos Estudios Agronómicos Mediterráneos (CIHEAM) a través del Instituto Agronómico Mediterráneo de Zaragoza (IAMZ), el Ministerio de Agricultura, Pesca y Alimentación (MAPA) a través de la Secretaría General de Pesca (SGP).

El Máster se desarrolla a tiempo completo en dos años académicos. Tras completar el primer año (programa basado en clases lectivas, prácticas, trabajos tutorados, seminarios abiertos y visitas técnicas), durante la segunda parte los participantes dedican 10 meses a la iniciación a la investigación o a la actividad profesional realizando un trabajo de investigación original a través de la elaboración de la Tesis Master of Science. El presente manuscrito es el resultado de uno de estos trabajos y ha sido aprobado en lectura pública ante un jurado de calificación.

The International Master in SUSTAINABLE FISHERIES MANAGEMENT is jointly organized by the University of Alicante (UA), the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) through the Mediterranean Agronomic Institute of Zaragoza (IAMZ), and by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA) through the General Secretariat of Fisheries (SGP).

The Master is developed over two academic years. Upon completion of the first year (a programme based on lectures, practicals, supervised work, seminars and technical visits), during the second part the participants devote a period of 10 months to initiation to research or to professional activities conducting an original research work through the elaboration of the Master Thesis. The present manuscript is the result of one of these works and has been defended before an examination board.