UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI BIOLOGIA

Corso di Laurea magistrale in Biologia Marina

TESI DI LAUREA

Assessing the distribution of the European lobster (*Homarus gammarus*) in the Gulf of Trieste in areas with different protection levels by combining visual census and LEK.

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ANNO ACCADEMICO 2021/2022

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ABSTRACT

H. gammarus is a species of global commercial interest, and in some areas its existence and its habitat are impacted by fishing and other human behaviors.
Marine protected areas could be a solution to these problems.
In the Adriatic Sea, and in particular in the Gulf of Trieste, this species is mainly fished as by-catch, this suggests that it is not such an abundant species that it can be considered important for local fishermen.
This study focused on the European lobster populations present in the Gulf of Trieste. In particular, tried to study the distribution of this species within the gulf, and whether there is a possible reserve effect given by the Miramare MPA; and also, an attempt has been made to reconstruct a trend of the last 50 years (by the use of some questionnaires and LEK) aimed at reconstructing the change in the abundance of European lobsters within the gulf.
The study relies on the data collected in the 2 sampling campaigns carried out during 2022 by Visual Census technique in 7 locations inside the Gulf of Trieste, and some questionnaires addressed to the "most experts" in Trieste (fishermen, researchers, and divers) in this field.
A relevant result from the Visual Census campaign was seen as regards the favorite habitat of the European lobster: a significant difference was seen between those sampled on the bottom and those sampled not on the bottom, suggesting that this species prefers to stay between the rock and the sand and make the burrow in that area.
The questionnaires provided quite relevant results, making it clear that the general perception is that of a growing trend regarding the abundance of individuals belonging to this species within the Gulf of Trieste in recent years, and in general an almost linear growth trend has been observed for the last 50 years, for all the locations considered in the questionnaires.

1. INTRODUCTION

1.1. Fishing impact

Fishing is the most widespread cause of marine biodiversity erosion worldwide (Jennings and Kaiser 1998). Fishing is considered one of the most important disturbances for populations of marine species i.e. "a discrete event able to alter the structure of ecosystems, communities, populations, resources, the physical substrate or the physical environment" (White et al. 1985).
The first historical finds that note the use of fishing date back to 90,000 years ago (Yellen et al. 2016). From here on, fishing techniques showed important progresses becoming more efficient in captures, with little concern about the consequences and the impacts on the stocks exploited or their ecosystems (Pitcher 2001).
Thanks to archaeological evidences, we are now aware that these technological advances led to the result of a significant reduction in biodiversity and an evident decrease in many marine species populations (Pitcher 2001).
In order to increase catches, efforts have always been made to implement new more effective fishing options, which have increasingly proved to have a negative impact on the marine environment and ecosystems (Kennelly and Broadhurst 2002).
The turning point in the creation of the intensive and destructive fishing methods used today is the 19th century. Before, less impactful methods than those used today were used, such as longlines or other types of nets that were the main gears used (Kennelly and Broadhurst 2002).
We can distinguish two types of effects related to fishing:

1. Direct effects: those effects directly determined by the fishing practice/action, e.g., direct mortality, direct damage to commercial/non-commercial organisms, sediment/nutrient resuspension.
2. Indirect effects: those effects that are mediated by trophic processes (e.g., benthic communities recolonization, effects at population/community levels mediated by changes in demographics, habitat disruption, sublethal damage).

Also, other impacts of fishing have been recorded in various studies, such as:

- the selectively removing of large-sized individuals (Lester and Halpern 2008);
- the dramatic changes in the structures and functioning of food webs (Sandin et al. 2008);
- the changes in the physical properties of seafloor (Puig et al. 2012);
- the decrease in the resilience of populations and ecosystems in the face of climatic impacts and other disturbances (Sandin et al. 2008).

One of the worst impacts fishing can have, is known as *by-catch*. Throwing dead fish back into the sea is something that happens too often. In recent years, attempts have been made to find various solutions to this issue. The solutions that have been tried so far focus on the possibility of preventing the capture of unwanted animals by modifying the fishing nets in appropriate ways to ensure this, as for example the widening of the meshes (Broadhurst 2000).
Although it has been possible to take big steps forward to reduce bycatch, there are still some problems related to undetected bycatch mortality for fish that escape gear or are discarded after capture (Broadhurst 2000).
The capture process may determine some direct effects on discarded species like:

- Physiological stress;
- Physical damage.

These factors may determine a high direct/indirect mortality rate whose extent is modulate by species' features (physiology, fragility) and gear type.

The stress caused by fishing can be due to the combination of many stresses all together (Barton and Iwama 1991). The conditions of stress and mortality caused by fishing are very often a concentration of many stress factors that can be both physical and not, such as the passage through the meshes of the nets that could cause physical damage to the fish, or the time that the catch passes inside the net before being pulled up. Obviously all these stressors can have different impacts depending on the species in question (Chopin and Arimoto 1995; Murphy et al. 1995; Taylor et al. n.d.).

Below we have a conceptual diagram of interacting factors in discard mortality for fish caught with deep-water gears (trawl, trap, hook and line) (Davis 2002; Fig.1. "Key principles for understanding fish bycatch discard mortality". Diagram representing all the possible stresses that can occur during fishing, divided by depth of the fishing method. General view of the accumulation of stress. (Davis 2002)..

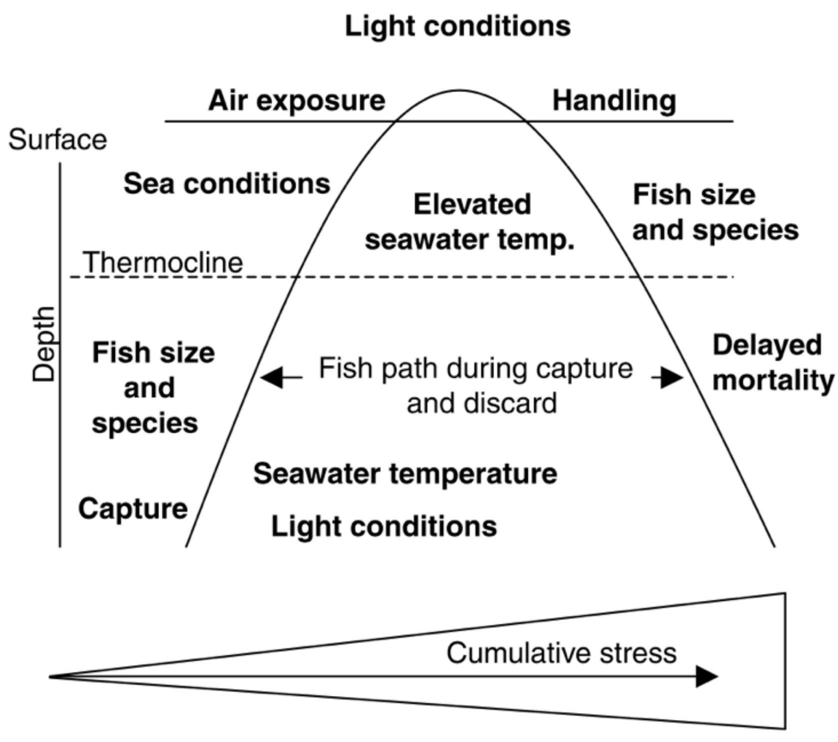

Fig.1. "Key principles for understanding fish bycatch discard mortality". Diagram representing all the possible stresses that can occur during fishing, divided by depth of the fishing method. General view of the accumulation of stress. (Davis 2002).

Sub-lethal damages are also considered to be among the most important impacts of fishing. They can cause many population-wide problems, such as mating success problems, or others such as higher likelihood of infections or other diseases (Pranovi et al. 2001).

Some crustaceans, for example, when caught in nets could suffer the loss of some limbs. This can cause damage to the animals that are forced to invest in the regeneration of these limbs and lose many chances to mate, or sometimes they can even die, if the loss has been too conspicuous. However, the ability to regenerate

limbs is a strategy that these animals have been able to implement during evolution due to predators, so they also have an advantage over other animals that are unable to do so, and could be damaged by fishing (Pranovi et al. 2001).
In marine habitats, subject to large variations of natural disturbances, fishing plays an important role (Jennings and Kaiser 1998). Fishing therefore represents one of the most impacting disturbances on marine ecosystems and biodiversity, and it has been seen that the smaller the natural disturbance (therefore the one due to natural effects, so normal for the environment), the more impacting is that due to fishing (Jennings and Kaiser 1998; (Fig.2. Relationship between natural disturbance and fishing disturbance (Jennings and Kaiser 1998)..

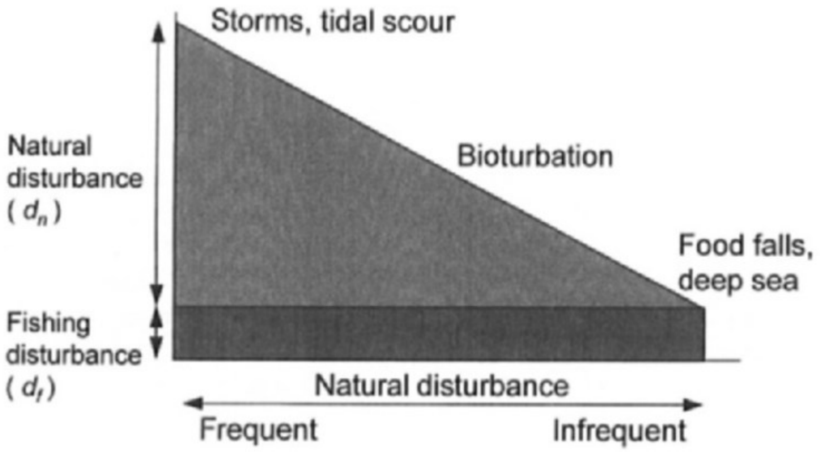

Fig.2. Relationship between natural disturbance and fishing disturbance (Jennings and Kaiser 1998).

While professional fishing has a much more important impact on marine environments, the impacts of recreational fishing should not be underestimated. For this type of fishing, it would be advisable to have some precautions. Leaving the hook attached to some fish, for example, can cause enormous damages both to the animal itself (high mortality rate) and to other animals (Lester and Halpern 2008).
Recreational fishing creates major problems especially at regional levels. The problem with this type of fishing is above all that it is often focused on the capture of species that are important both at ecosystem level, such as large fish, often predators (or species that in any case belong to high levels of the trophic chain) which can create an important imbalance if removed from the ecosystem; and species of great commercial interest, which are less and less abundant over the last decades (Lester and Halpern 2008).

On a global scale, the commercial fishing sector has grown significantly in the last 70 years, but catches, which had steadily increased until the end of the 1980s, have stabilized (FAO 2022; Fig.3), a symptom of the collapse of many commercial fish stocks.

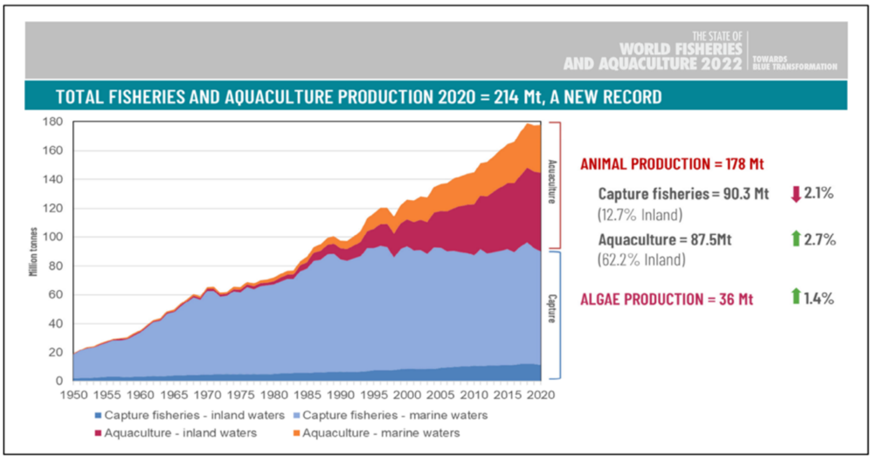

Fig.3. World fisheries and aquaculture 2022 (FAO 2022).

Of the total world production more than 80% is represented by aquatic animals, while the remaining 20% by algae or plant foods. Of that 80%, 55% comes from catches, while 45% comes from aquaculture (FAO 2022).
The Covid-19 pandemic has had a great impact on these values, because the demand and consequently the fish caught underwent a big decrease in that period, by recording much lower increases than in previous years in farmed fish (2.7% vs 4.5% in previous years) and even a decrease in that caught (2% less than the previous year) (FAO 2022).
Of the total production, more than 88% was used for human consumption, and this represents the highest rate ever recorded (FAO 2022).
As can be seen from Fig.4, the per capita consumption of aquatic food has a much higher trend than the World population, this means that the demand is already too much compared to the quantity of people. Consumption per capita/year fell in 2020 due to the pandemic, and then went up again in 2021. The forecasts for 2022 were of a possible drop in demand, due to the dizzying increase in prices which had already registered a + 25% in the first quarter of the year (FAO 2022; Fig.4).

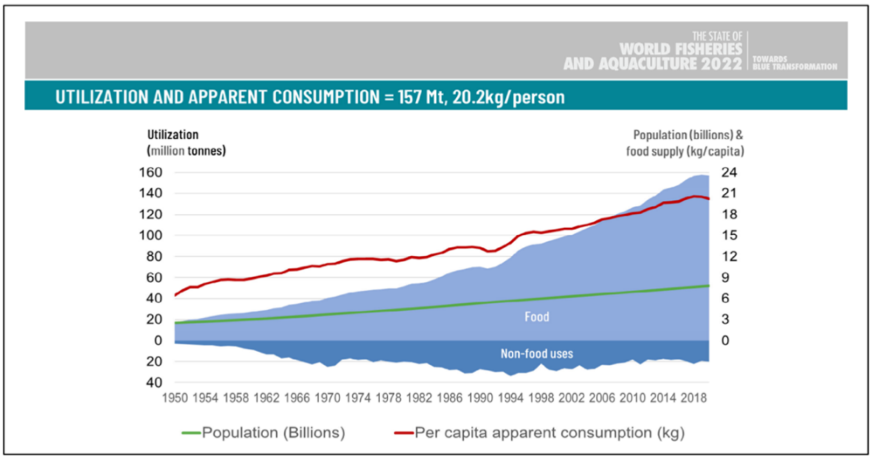

Fig.4. Utilization and apparent consumption of aquatic foods (FAO 2022).

1.1.1. The IUCN Red List

The IUCN Red List is a critical indicator of the health of the world's biodiversity. The list provides information on the conservation status of species, habitats, marine, coastal and terrestrial environments.
This list is used by governmental and non-governmental organizations around the World, as well as by scientists, researchers and students who rely on this list for all types of research, or for educational or dissemination purposes on various species.
To compile the Red List experts are involved, and species status is evaluated based on strict quantitative criteria. The IUCN red list is very reliable and is constantly updated (IUCN).
To date, more than 147,500 species have been assessed for the IUCN Red List (IUCN). According to these evaluations, "biodiversity is declining. Currently, more than 41,000 species are threatened with extinction, that is still 28% of all assessed species., including 41% of amphibians, 34% of conifers, 33% of reef building corals, 28% of crustaceans and 27% of mammals" (IUCN).

1.2. Impacts of climate change

In recent decades there has been a significant increase in the impacts related to climate change. The climate change has caused, is causing, and will cause even more, major changes at the ecosystem level in many natural environments and is also having important impacts on human society and life (Ferrario et al. 2014).
Very often climate change is underestimated, relating it only to rising temperatures. However, it should be noted that climate change also includes a series of events, atmospheric and otherwise, which most of the time are not even mentioned, such as the acidification of the oceans, the increase in hypoxia and anoxia events and other phenomena shown in the image below (Mckee 2012; Ward et al. 2016; Fig.5).

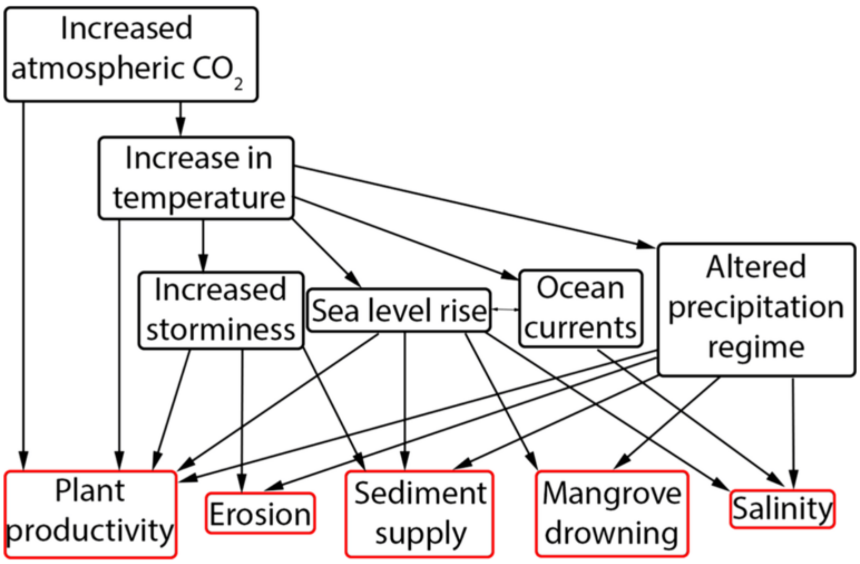

Fig.5. Principal impacting factors of climate change and how they are likely to negatively influence mangrove communities (Ward et al. 2016).

Climate interacts with other global changes like urbanization, overexploitation of natural resources, fragmentation, habitat loss, degradation of environmental quality/pollution and invasive species.

Climate change affects all levels of biological organisation, from genes to ecosystems (Scheffers et al. 2016) and at a wide range of spatial and temporal scales (Philippart et al. 2011).
There can be different impacts, which are analysed taking into consideration various factors at the ecosystem, biological, and population levels. In Scheffers et al. 2016 some ecological processes such as genetic diversity, body size and shape, species interactions, recruitment, and others, were investigated. As a result, a huge percentage of processes affected by climate change has been obtained. The impacted processes were mostly related to species distribution or genetics, but processes such as biomass and primary productivity or recruitment were also included in this group. The image below represents all the processes analyzed with the various results obtained (Scheffers et al. 2016; Fig.6).

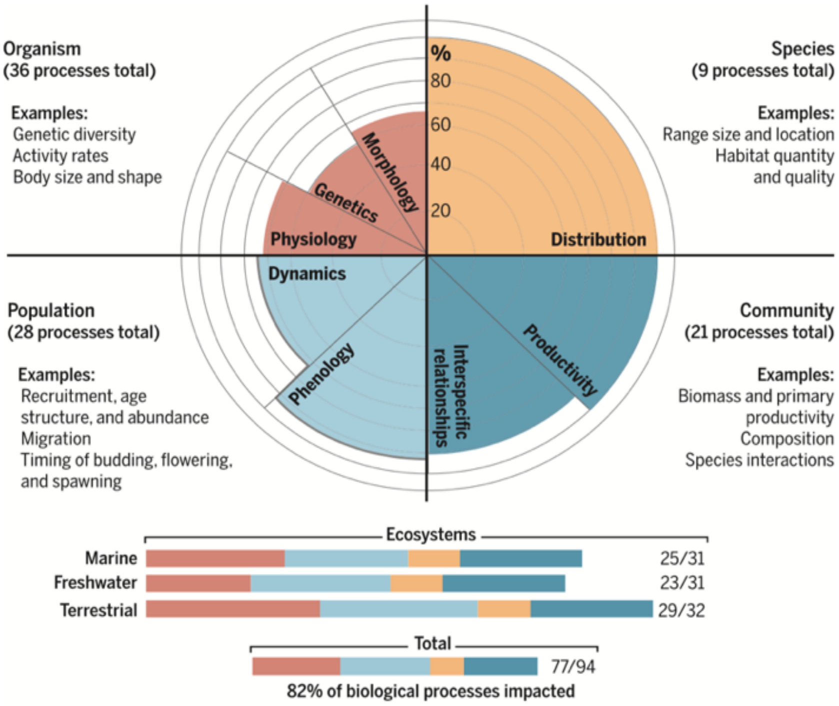

Fig.6. Climate change impacts on ecological processes in marine, freshwater, and terrestrial ecosystems (Scheffers et al. 2016).

Climate change can also have effects on human society.
Natural disasters are more frequent than 30 years ago and are costing us more. Inundation risks are very high, guaranteeing an ever increasing vulnerability of coastal populations (Neumann et al. 2015).

1.3. Marine Protected Areas

MPAs have effects that can curb climate change. They are in fact able to increase marine biodiversity and guarantee a long-lasting life of the species they protect. They can decrease the progress of ocean acidification due to the increase in density of mesopelagic ocean fish, as well as the increase in marine populations that can be very resistant to climate change (Roberts et al. 2017).
One of the best ways to protect biodiversity consists in the conservation and protection of habitats.

Protecting habitats allows us to protect single species, communities, ecosystems, and their functions and services. It's a successful strategy, in the long-term, and with good benefit-cost ratios (DeFries et al. 2007).
MPAs are key tool to achieve such goal and support marine conservation.
The definition of what an MPA is, was given by the *International Union for Conservation of Nature* IUCN in 1988: "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (McNeill.S.E 1994).
Originally, MPAs were often not established following an organized, well-thought planning, and a clear socio-ecological understanding of their impacts (Halpern and Warner 2002).
An MPA could be established for wildlife refugium, for species biodiversity (Gell and Roberts 2003; Roberts et al. 2001) for supporting ecosystem services like increased abundance of species targeted by fisheries outside MPA boundary (Gell and Roberts 2003). Within the MPAs there are also some "management tools" e.g., conservation NGOs, ecotourism and diving related stakeholders (Gell and Roberts 2003).
The world's first marine protected area (MPA) was probably the *Fort Jefferson National Monument* in Florida (1935), divided both in marine and terrestrial part: 18,850 *ha* of sea and 35 *ha* of coastal land (Gubbay 1989).
According to the *Marine Conservation Institute*, to date 8.1% of the world's ocean is covered by some form of marine protection. However, only 2.4% is covered by what the institute describes as 'full or highly protected' areas.
Raising the level of protection around the world could have a dramatic effect on biodiversity, fish populations and carbon dioxide levels. It has been estimated that 80% of the habitats that could be used by endangered marine species belong to a global network of areas. These areas should therefore be protected for the possible safeguarding of these habitats, which are of fundamental importance for the protection and conservation of biodiversity. To try to achieve this, the "30 x 30" was established, that is a campaign with the goal to reach the protection of 30% of the world's oceans by 2030. (Royal Museums Greenwich, 2022).
Not all MPAs are considered marine reserves. A marine reserve (like that of *Miramare* in Trieste, Italy, for example) is an MPA with a very high level of protection, the highest, namely the *no-take zone* (Costello and Ballantine 2015).
It has recently been estimated that globally there are 25% of MPAs that are recognized as marine reserves. However, this data could be conditioned by the fact that in recent years very large new marine reserves have been established which have caused the percentage to grow considerably. Looking at the past data, however, it can be seen how between 1950 and 2010 this data dropped from 27% to 5% (Costello and Ballantine 2015).
Speaking of the effects MPAs can have, it is very important to understand how well the MPA is able to guarantee protection of the species within it from fishing. Hence, some studies have stated the question of how much sea should be protected in the world. It was found that, depending on the method and intensity of fishing, between 10 and 80% of marine environments must be protected from fishing (Gell and Roberts 2003). In addition, fishing could also benefit from the positive implications given by the establishment of MPAs, it has been seen in fact as in areas that are

able to reach high levels of protection, fishing benefits a lot (Gell and Roberts 2003).
Another important thing to evaluate about the effects of an MPA is the size: you must understand if it is better to have a large one or several smaller ones. Obviously, there are some issues like: big areas cost too much, are "difficult" to manage, can disturb traditional jobs, may not be necessary to protect some species. Halpern 2003 reviewed 112 independent empirical measurements of 80 different no-take reserves. It was seen how the difference in size is relative, as even the smallest reserves have produced very satisfactory positive results in terms of quantity of biomass and biological responses, making it clear that even the largest reserves can make the difference in some cases.
It was also seen how the creation of new marine reserves can lead to a very rapid increase in biodiversity and biomass (it has been estimated that it takes 1-3 years) which then lasts over time, beyond the reserve is large or small. Clearly the larger ones will have more favourable results on highly mobile species (Halpern and Warner 2002; Micheli, Halpern, and Botsford 2004).
The size of the MPA is also very important for conservation and related to dispersal. There are some very small MPAs like the one of *Miramare - Trieste* (0.3 km^2), and some others that are very big, like *Marae Moana - Cook Islands* (1,976,000 km^2). It has been noted that if the MPA is too small, all larvae are exported, import takes place from unprotected areas; if it's too big there's no positive spillover of individuals and egg export to surrounding unprotected areas (Sale et al. 2005).
Highly mobile species are not expected to benefit from protection. However, some tagging studies revealed some intra-species differences in movement behaviour. A study focusing on some commercially important African coastal fish, for example, found that 67-93% of individuals who had been tagged were recaptured at distances that did not exceed 1km from the tagging point. However, other fish have been recorded at much greater distances (Gell and Roberts 2003).
For what concern the Mediterranean Sea, the MPAs established in this sea are not enough to protect all the species, habitats and marine environments that would need this protection, but there are evidences that certifies that these MPAs have very positive effects on some individuals and especially on the effects that fishing could have on them (Guidetti and Sala 2007).
Marine protected areas are one of the best ways to conserve marine biodiversity. However, the current number of legally protected areas does not appear to be high enough to contrast the increasingly important decrease in biodiversity (Costello and Ballantine 2015).
It was also seen that protected areas could be seen as investments by States: as seen for the MPA of Llevant (Mallorca), where it was estimated that for every *Euro* invested there is a benefit of €10 (Marilles Foundation, 2021).
Therefore, world governments should invest more in the creation of new MPAs to have in return both a positive result from a conservation of biodiversity point of view, and from an economic point of view.
In addition, MPAs can also lessen the disastrous effects of fisheries related to climate change such as the release of carbon from sediments disturbed by fishing gear, which can have very significant impacts on marine ecosystems and habitats (Costello and Ballantine 2015; Gell and Roberts 2003; Roberts et al. 2017).
It is also of fundamental importance to understand how MPAs are classified.

A standard classification of Marine Protected Areas that is recognized by the most important world organizations and governments is that given by the IUCN.
The classification proposed by the IUCN consists in a list of categories ranging from the most restrictive area (Ia) to the less restrictive (V or VI). In general, these are the categories:

- Ia: nature reserves, where the human impact is rather reduced due to the checks that are carried out (Day et al. 2019);
- Ib: highly controlled areas that have no significant human impacts, thanks to the impossibility of constructing buildings or houses of any kind (Day et al. 2019);
- II: this category is made up of national parks, which often have the intention of providing visitors with a spirit of safeguarding nature and ecosystems. They are also sometimes used for tourism or educational activities (Day et al. 2019);
- III: category established for the protection of natural monuments (Day et al. 2019);
- IV: category of areas with the purpose of protecting some particular habitats or species (Day et al. 2019);
- V: this category is for areas that could have been created with the interaction between nature and man over the years. This interaction has worked, managing to create some particular environment of social, ecological or scientific importance, that have to be safeguard (Day et al. 2019);
- VI: this category includes all areas that are mostly natural but associated with some small human impact. In any case, these are areas in which the impact of man does not exceed a certain threshold (Day et al. 2019).

However, the categorization of the IUCN also has some flaws because it classifies protected areas in categories with too large variability (within the same category) and in many cases it does not follow the various regulations that are applied to some areas (Horta et al. 2016).
In Horta et al. 2016 there is an insight into how zones (Fig.7) and MPAs (Fig.8) might be classified.

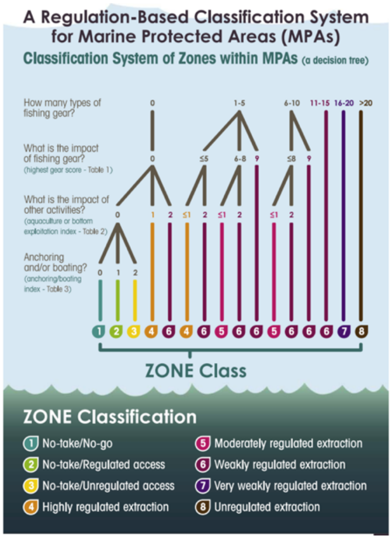

Fig.7. Decision tree of the regulation-based classification system. Step-by-step sequence of decision tree for classifying zones (Horta et al. 2016).

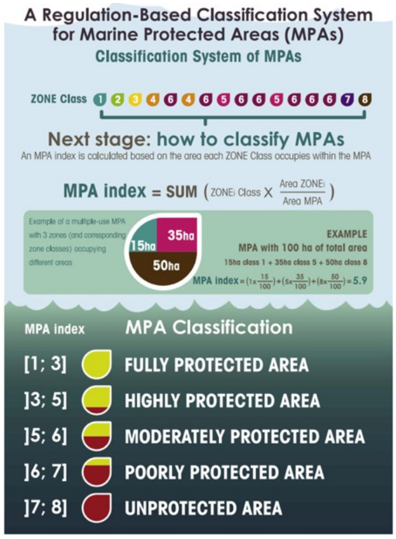

Fig.8. Decision tree of the regulation-based classification system. Step-by-step sequence of decision tree for classifying MPAs (Horta et al. 2016).

Other important types of protected areas (in Europe) are represented by the Natura 2000 (N2k) network. There can be 2 kinds of area: Special protection areas (SPA), Directive “Birds”, 79/409/EEC (whose codified version is 2009/47/EC); Sites of Community Importance (SCI) or proposed SCI (by Member States) (pSCI), are sites going to be designated as a SAC (special area of conservation) (art. 4).
This network has been created by the Habitat Directive - 92/43/CEE, on the conservation of natural habitats and of wild fauna and flora. This directive has some goals like to promote the maintenance of biodiversity through the conservation of natural and seminatural habitats, even aquatic, and of wild fauna and flora; or to ensure the restoration or maintenance of natural habitats and species of community interest at a favourable conservation status.
In Italy, 19% of the landscape and 13% of the seascape belong to the Natura 2000 network (Natura 2000). A curious fact to underline is that all MPAs located in Italy are part of the N2k Network (Natura 2000).
As regards the Mediterranean Sea, and the different levels of protection that exist in Italy, the categorization of Marine Protected Areas in Italy is divided into zones: “Zone A” that is the equivalent of a "no-take zone", which is generally surrounded by some areas with decreasing protection levels which are “Zone B” and “Zone C”.

1.3.1.Miramare MPA

Established in 1973 as a Marine Park under state concession by the Trieste Harbor Master's Office to WWF Italy, the Miramare Marine Reserve was officially born in 1986 (the first marine protected area to be established in Italy together with that of Ustica) with a decree of the Ministry of the Environment which guaranteed the continuity of its management by entrusting it to the WWF Italy onlus Association (Ministerial Decree 12 November 1986).
Today the Miramare MPA protects 30 hectares of marine-coastal biodiversity subjected to integral protection (Zone A) and 90 hectares of buffer zone (Zone B), established in 1995 by an order of the Port Authority to preserve the core area from fishing activities with lamps (“lampare”), in those years widely practiced in the Gulf of Trieste.
The tasks of the Miramare MPA are well defined and outlined by its founding decree and by the “Regolamento di esecuzione e organizzazione”: protect and preserve the integrity of the protected area, its geomorphological characteristics and its biodiversity; support scientific research applied to the management of marine resources, through the study of ecosystems and local species as well as through periodic scientific monitoring campaigns; promote knowledge of the protected environment, with the implementation of educational programs on marine-coastal biodiversity, ecology and education for sustainability.
Although it’s the smallest among the Italian MPAs, it has more than thirty years of experience in conservation and scientific research activities, management effectiveness and the high standard of environmental dissemination achieved over the years (with proposals ranging from schools to families, from immersive teaching to environmental interpretation paths in nature and guided excursions at sea). Today the Miramare MPA is a focal point and an important hub within the articulated network of institutions established at local, national and Mediterranean level to protect biodiversity marine and coastal areas and ensure its sustainable use.

Miramare is also one of the SPAMI - Specially Protected Areas of Mediterranean Importance, a prestigious status that requires constant monitoring of the state of health of the seabed and the maintenance of a high degree of biodiversity to be achieved and preserved.
From 1979 Miramare is part of the worldwide network of Biosphere Reserves established by UNESCO as part of the MaB - Man and Biosphere program: these are marine and/or terrestrial areas that promote and demonstrate a balanced relationship between the human community and ecosystems and represent privileged sites for research, training, and environmental education, as well as experimentation poles of good sustainable development practices. Thanks to the expansion requested by UNESCO and carried out in 2014, today the Miramare Biosphere Reserve consists of a coastal territory with a large marine transition area and the karst ridge above.
Since 2011, thanks to the recognition of the Marine Protected Area as a Site of Community Importance (DIRETTIVE 79/409/CEE and 92/43/CEE) - SIC IT3340007 (Friuli-Venezia-Giulia, La rete europea Natura 2000 per la tutela della biodiversità), due to the presence of different habitats and species protected by the two Community directives, Miramare is also part of the "Natura 2000" European ecological network. In 2020 the site was designated SAC: special area of conservation, and by DGR 2004 of December 23, 2021, the site was identified as a new Special Protection Area (SPA).
Miramare MPA has also promoted the ISEA project, a WWF project carried out in collaboration with the Ministry of the Environment, Land and Sea Protection, which carries out interventions to support the management of Italian MPAs to strengthen their efficiency, promoting standardized management and facilitating the exchange of good practices within the network (*all these data were courtesy of the Miramare Marine Protected Area*).

1.4. *Homarus gammarus*

1.4.1. Distribution, basic biology, and taxonomy of the species

The European lobster, *Homarus gammarus* is a crustacean belonging to the order of the decapods. The taxonomic classification of the species is shown in Tab.1.

Tab.1. Taxonomy of the species *Homarus gammarus.*

Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Suborder	Pleocyemata
Infraorder	Astacidea
Superfamily	Nephropoidea
Family	Nephropidae
Subfamily	Nephropinae
Genus	Homarus

H. gammarus (Linnaeus 1758), has a broad geographical distribution. In its northern range, it occurs from the Lofoten Islands in Northern Norway to southeastern Sweden and Denmark. Its distribution southwards extend along the mainland European coasts around Britain and Ireland, to a southern limit of about 30° north latitude on the Atlantic coast of Morocco. The species also extends around the Greek coasts and in the Black Sea areas. Less abundant are the captures documented throughout the coastal and island areas of the Mediterranean Sea, even if in the North Adriatic Sea there is a large concentration of catches (Schmalenbach and Franke 2010) (FAO, 2022)(Fig.9).

Fig.9. European geographical distribution of the *H.gammarus (FAO, 2022)*.

The European lobster has a smooth and very resistant exoskeleton as it must protect the soft tissues of the animal. The typical coloration of the adults is intense blue on the back and lighter on the belly, with some orange or yellow shades. This color is due to astaxanthins, pigments that turn red when heated significantly, hence the color of the lobster after cooking. The coloring is determined by the presence of different types of astaxanthins. Sometimes, one or more of these pigments may be missing and this can cause an unusual coloration. Although extremely rare, lobsters have been observed with bright blue, red, orange or entirely albino liveries.

The general morphology of the species is composed by two asymmetrical claws, the largest used for splitting and the smallest denticulated used for slicing prey; four pairs of legs for locomotion; the head (from the end of the rostrum to the beginning of the abdomen); two pairs of antennae, the first pair is short, the second very long; a mouth apparatus; an abdomen (from the end of the head to the beginning of the tail); the swimmerets used for swimming and for oxygenating eggs; the telson (tail) (Rozemeijer and Van De Wolfshaar 2019).

The presence of a rigid exoskeleton forces the lobster to carry out a process known as molting, a phenomenon under hormonal control during which water is absorbed by the body and stored in the tissues. The European lobster swells until the exoskeleton breaks. The process of forming the new exoskeleton begins after the carapace has been removed by the animal (Beaumont and Gjedrem 2004). Immediately after the moult, the lobsters are vulnerable to predation and tend to remain hidden until the new exoskeleton has definitively hardened; this process can be completed within a period of a few hours but can also last several weeks, depending on the size of the animal, the availability of calcium and the speed with which it is deposited (Beaumont and Gjedrem 2004).

In the period between the beginning and the end of the moulting process, new tissues are generated which will compensate and absorb the excess water that had been accumulated to favour the rupture of the carapace (Coleman et al. 2021).
During each moult, the length of the carapace usually increases by 10-15% and the total weight by up to 50% (Tully, Roantree, and Robinson 2001).
After moulting, the lobster consumes the old exoskeleton which will provide much of the calcium needed to solidify the new shell. Young lobsters moult up to 25 times in the first five years, while adults moult less frequently; for older animals this could continue to happen at least every two years allowing them to grow for life (Diego and Factor 1995).
The largest specimen known was captured in 1931 in Fowey, England. It measured 1.26 m and weighed 9.3 kg; the exoskeleton of its crushing claw alone weighed 1.2 kg (Rozemeijer and Van De Wolfshaar 2019).
The diet of adult European lobsters, which hunt mainly at night, consists mainly of benthic invertebrates such as crabs, molluscs, sea urchins, starfish, and polychaete worms, but can also include some fish, algae, and zooplankton. The amount of food ingested is reduced in winter due to the slowing of the metabolic rate because of the lowering of the sea temperature. Although these animals are generally sedentary, they can travel to find food usually within a 2 km radius from their burrow, while some specimens have moved to distances of 10 km from their burrows (Bannister, Addisom, and Lovewell 1994; G I Van Der Meeren 2003).
Female reach sexual maturity between 5 and 7 years, age depending on the water temperature, at a carapace length of about 85 mm, while males at slightly smaller sizes (Aiken and Waddy 1982).
Usually mating occurs between a male with a hard exoskeleton and a female who, having just made the moult, does not have a solidified exoskeleton. The spermatophores are transferred from the male to the female's sperm vessel. The female can retain the spermatophores while egg formation is still in progress. Deposition usually takes place in summer (Atema 1986). The eggs are fertilized as soon as they come out from the female and under natural conditions they are carried under the abdomen for 9-11 months (Coleman et al. 2021).
To distinguish the sex, it is necessary to examine the first pair of swimmerets placed immediately after the legs (Fig.10). If they are hard and rigid with a thorn shape, the individual is male, if they are soft and feather-shaped, the individual is a female (Fig.10)(Maine department of Marine Resources 2017).

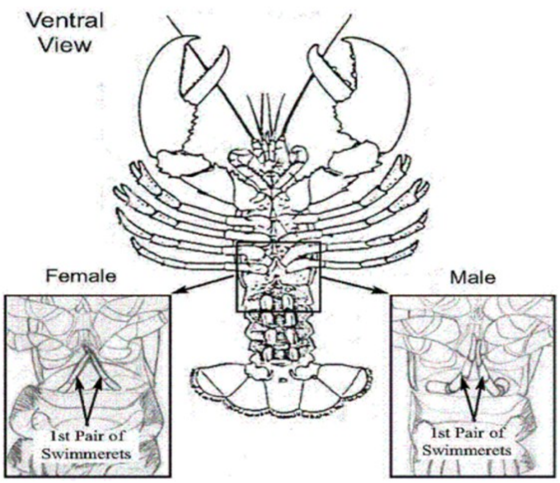

Fig.10. Difference between female and male’s swimmerets (Maine department of Marine Resources 2017).

1.4.2. Impacts of fishing on the species

On the Italian market, the prize of fished lobsters is around 70€/kg, while for those reared mostly from Canada (*H. americanus*) it is around 45€/kg.
The low number of specimens captured in the Mediterranean contributes to maintaining these high costs. However, European lobsters caught in the Atlantic is often sold on our markets, and in this case they have lower prices due to the greater abundance of these animals in ocean waters. In some European countries facing the Atlantic, the European lobster represents an important resource for many fishing communities.
The landing of European lobsters in England and Wales (Bannister and Addison 1986), France and Ireland (Browne, Mercer, and Duncan 2001), Norway and Scotland (Gro I van der Meeren and Soldal 1998), Switzerland, Denmark and Spain (Gro I van der Meeren and Soldal 1998) recorded before the 1970s was between 1,700 and 3,500 tons per year. In Europe since 1960, catches have drastically decreased and dropped to a minimum until 1980 (Bannister and Addison 1998). Since then, until the mid-90s, stocks have not recovered. During these years the decline in Denmark was 90% (Gro I van der Meeren and Soldal 1998), in Norway the catch fell by up to 90% of the previously caught quota and landings dropped dramatically from 1,000t in 1930 to 50t within 20 years (Gro I van der Meeren and Soldal 1998).
In Fig.11 we can see how the trend of catches has changed from 1980s to today, at a global level.
The general situation of European lobster fisheries underwent a considerable slowdown between 1960 and 1990 (FAO, 2022).. This trend led to the funding of studies aimed at the breeding and active restocking the species. The countries that have chosen to operate in this sector have found a reversal of the trend thanks to the numerous repopulations carried out along the coasts. At a global level, 2006 represents the turning point: it went from 2,327t in 2005 to 4,100t in 2006. From 2006 onwards the tonnes/year have remained more or less the same, with years a little more productive and others less, but never going below 4,100t (FAO, 2022).. These data confirm the fact that a good job has been done to safeguard this species (Fig.11) (FAO, 2022)..

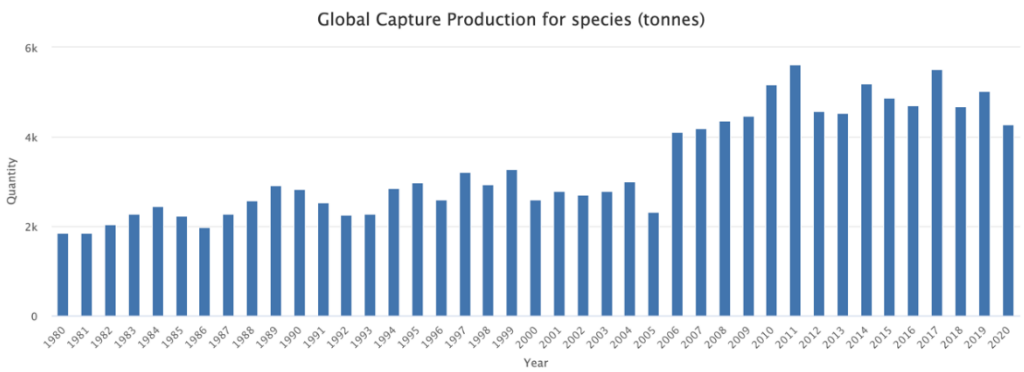

Fig.11. Global capture production for species *H. gammarus* (tonnes) *(FAO, 2022)..*

In Italy, fishing for this crustacean is a localized activity.
The fishery is based on traps of various designs, shapes, and sizes (Cobb and Castro 2006). Along the Mediterranean coast, *H. gammarus* is not a target species and is more often a by-catch occurring in trammel nets targeting other species like the

common spiny lobster *Palinurus elephas* (Quetglas et al. 2004) or in gillnets targeting fish during the fishing season (Kampouris et al. 2020; Goñi and Latrouite 2005).

1.4.3. Impacts of climate change on the species

Climate change effects have already been reported in several lobster stocks around the World, mainly due to the rise in water temperatures (Caputi et al. 2010; Cockcroft, Van Zyl, and Hutchlngs 2008; Wahle et al. 2015).
Two of the biggest impacts that climate change can have on the species *H. gammarus*, are certainly the rise of sea surface temperatures and the increase in pCO_2 levels. It has been demonstrated that climate warming have some impacts in the annual peak abundance of pelagic larvae of some benthic animal species, including some decapods, in the North Sea (Edwards and Richardson 2004). More specifically, for the species we will focus on, an ongoing warming trend in the North Sea (increase in mean monthly temperatures throughout the annual cycle, but particularly in winter) strongly affected the recruitment success of the European lobster (*Homarus gammarus*) (Schmalenbach and Franke 2010). The embryonic development duration and the larval development duration are mainly influenced by the temperature and so changes in temperature can have a big impact on this species (Branford 1978).
As for the increase in pCO_2, it has been noted that a change in its levels could have serious repercussions on the larval stages of some crustaceans, leading them to a great risk for their survival (Walther, Anger, and Pörtner 2010; Walther, Anger, and Pörtner 2010). Some studies have also revealed important effects of pCO_2 on larval organic content and mineralization, metabolism, and energetic trade-offs between physiological processes (Carter et al. 2013).
As the prospects regarding rising sea surface temperatures and CO2 (Sokolov et al. 2009; Caldeira and Wickett 2003) are not good, this species could face serious problems related to climate change, which could also lead it to populate areas that generally would never have been considered as possible habitat for the European lobsters populations.

1.5. Study techniques

1.5.1. Visual census

The method adopted for this research to survey European lobster is the underwater *Visual Census*. This technique has been used for many years to assess marine animals' populations and is regarded as relatively accurate and cost effective (Sale and Douglas 1981; Thresher et al. 1986).
The visual census is a technique that is used to census populations of fish, crustaceans, or others, without the use of too complex equipment that could cause a huge disturbance to the biodiversity of the area. It therefore constitutes a type of sampling that guarantees the minimum impact on ecosystems and habitats. Visual census encompasses many techniques used to quantify reef fish populations (Thresher et al. 1986) but also lobsters' populations (Lenihan et al. 2021).
The most used method is represented by the classic Visual Census described by Brock 1954 was used, which provides the drafting of a transect, as a reference method for divers, to be followed in its entirety to conduct the surveys. This method

has been widely used in many studies and has always provided excellent results, if conducted in the correct manner (Samoilys and Carlos 2000).
For this type of survey, it is advisable to consider all the types of errors that could occur, from the number of divers who conducted the experiment, to the differences in the possible sightings that each person could make. For this reason, generally before implementing this type of sampling, briefings are made in which the people who will participate are informed and trained.

1.5.2. LEK and questionnaires

An increasingly pressing globalization and an education that wants to be as equitable as possible among the various countries, is leading more and more towards a World in which populations are unable to recognize their local nature. This leads to a conspicuous increase in "ignorance" of natural environments and habitats, as well as of the species that inhabit them (Nazarea 2006; Godoy 1994; Gómez-Baggethun and Reyes-García 2013). The loss of naturalistic knowledge that the world population is having is also due to an increasingly important loss of indigenous populations (Dewalt 1994). Naturalistic knowledge should also be adapted to the changes the world is undergoing, and people should try to pass it on with the appropriate variations dictated by these changes. This is a very difficult thing to do, but the populations have to look for a solution to not making this knowledge completely lost (Gómez-Baggethun and Reyes-García 2013).
The use of the *Local ecological knowledge* (LEK) dates back to the 90s, when some researchers recognized that it is a very valid tool to be included in conservation and development projects, using it with some local people (Titilola, 1990).
Modern LEK-based research tries to focus on some fundamental aspects such as conservation, management, policy and some "knowledge systems". It has been seen that many times local populations are the least responsible for human impacts on the environment. In fact, most of the time the local populations are very careful to the conservation of the nature that surrounds them, especially if we are talking about populations that live thanks to that nature (Godoy 1994).
Even if the general impression on local knowledge is of a clear decrease, which will lead to their disappearance (Cox 2000), scientific evidence points out that in reality the LEK has only transformed and evolved, aggregating to many external factors and new methods of disseminating information (Gómez-Baggethun, Corbera, and Reyes-García 2013).
There are not many studies on this field. These studies mostly try to analyze the changes through the information collected by a community composed of several generations, studying the possible changes in biodiversity (also analyzing the possible errors in the recognition of some species), but also in other fields (Case, Pauli, and Soejarto 2005; Pilgrim et al. 2008; Grünberg and Bidegain 1965; Godoy 1994; Kai et al. 2014; Reyes-García et al. 2013). The loss of knowledge about one's own territory can lead some populations to a very high risk of environmental degradation. It has been noted how some populations, following the loss of knowledge of the functioning of the surrounding natural ecosystems, have been subject to many implications such as the ever wider degradation of the environment and the biodiversity of the territories (Padilla and Kofinas 2014). However, on the other hand, there are evidences that certify that some populations have resisted to the "invasions" of their lands by non-indigenous peoples, and this has guaranteed

them to protect their territories and maintain an adequate culture regarding the cycle and functioning of their natural ecosystems and a fair exploitation of natural resources (Maffi 2005).

2. OBJECTIVES

The research is aimed at providing data for one of the management objectives of the *Miramare MPA*, namely the discipline of fishing for species not allowed within the Z.T.B. ("Biological Protection Area") of Miramare (Fig.12). Both monitoring methods used aim to quantify the population of *H. gammarus* species in the *Gulf of Trieste*, in the current year and historically in the last 50 years. The so called "Z.T.B. Miramare" (Fig.12) was established with a decree dated 03/16/04 and made permanent with the subsequent *Decree of 22 January 2009*. As stated in article 4. of the "*Gazzetta Ufficiale della Repubblica Italiana*": within the area, it is allowed, as regards professional fishing, the use of gillnets, purse seines, and pots only for the capture of cuttlefish and mantis shrimp (*Squilla mantis*), while for sport fishing the use of a maximum of 5 hooks per fisherman is allowed.
On the other hand, fishing for juveniles of all species of fish is prohibited (Gazzetta Ufficiale della Repubblica Italiana, 2004).

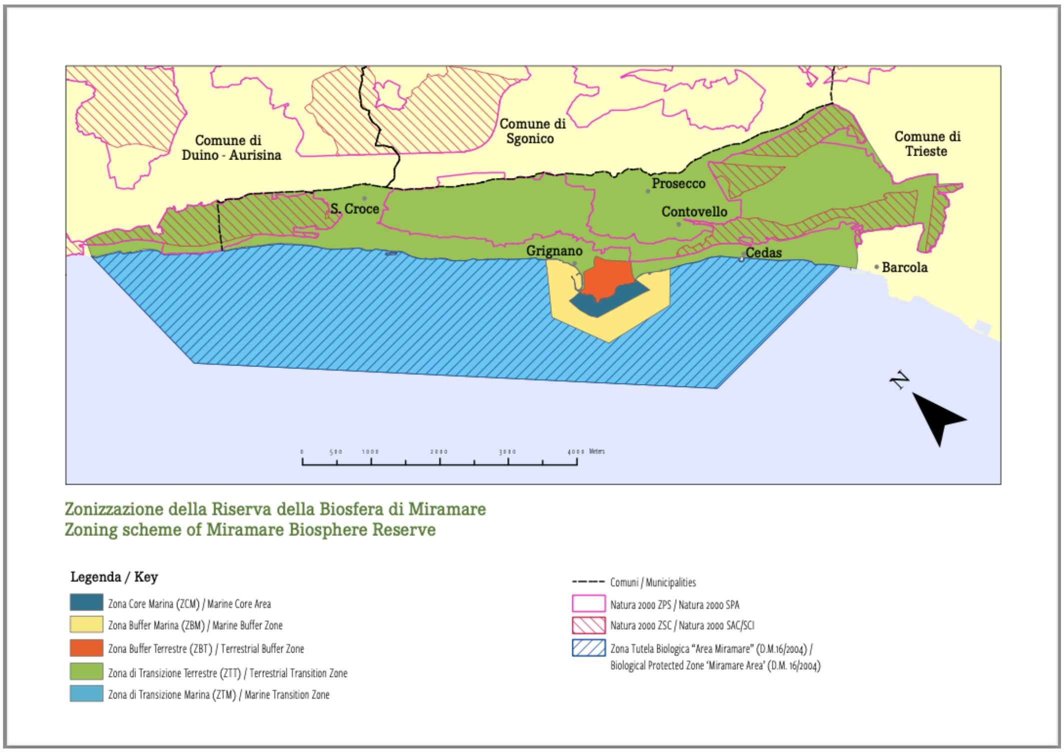

Fig.12. Graphic representation of the Z.T.B. of Miramare *(Ciriaco S.)*.

2.1. Assessment of the distribution of *H. gammarus* in the Gulf of Trieste

For this purpose, surveys were conducted in *Visual Census*, aimed at sampling the various individuals belonging to the species *H. gammarus*. The present study will be based on the samplings conducted during 2022 in the *Gulf of Trieste*.

The samplings concerned locations throughout the gulf, belonging to different levels of protection, including the *MPA of Miramare*.
Studies on the distribution of European lobster populations comparing the inside and outside of the *Miramare MPA* had never been conducted before.
The expectations are to find a difference between the inside and the outside of the *Marine Protected Area of Miramare*, and an increasing level of individuals as the level of protection of the various locations increases.
An analysis of the data will then be carried out to verify if it is present or not the so called "reserve effect" on the *H. gammarus* species in the *Gulf of Trieste*.

2.2. History of the change in the quantity of *H. gammarus* in the Gulf of Trieste

For this objective, the LEK (Titilola, 1990) and some questionnaires (Garrabou, Bensoussan, and Azzurro 2018) have been used, for the possible construction of a trend of the last 50 years (which were then reduced to 30) in the density of European lobsters within the *Gulf of Trieste*.
Also in this case it is a research that has never been conducted before, so no hypotheses have been made about what the possible trend could be. Although, being the majority of the people participating in the work assiduous divers of the gulf, a possible increase in individuals (especially in recent years) would be expected, due to the increasingly frequent sightings of European lobster individuals.

3. MATERIALS AND METHODS

3.1. Study area

The *Gulf of Trieste* (Fig.13) is the northernmost section of the Adriatic Sea, with a surface area of about 600 km^2 (Malej et al. 1995), and a volume of 9.5 km^3 (Olivotti, Faganeli, and Malej 1986). The deepest part reaches 23m in its southernmost part and in general it is considered a Gulf with low depths (Russo and Artegiani 1996).
The *Gulf of Trieste* is also characterized by many freshwater inflows, the most important being that supplied by the *Isonzo river*, coming from the north-west (Russo and Artegiani 1996).
The strong wind and the local currents are factors that should not be underestimated when talking about hydrodynamic conditions, because guarantee a recirculation of the gulf and a mixing of the deposits on the seabed (Solidoro et al. 2007).
The Slovenian Sea is entirely included in the *Gulf of Trieste*, which extends up to the Istrian peninsula. The *Gulf* is shared by 3 states: Italy, Slovenia, and Croatia (Fig.13). The *Gulf of Trieste* is also considered part of the *Gulf of Venice* (Malej et al. 1995).
The current in the gulf moves counterclockwise and its average speed is 0.8 knots.
The tides are considered the largest of the whole Adriatic Sea, even if compared to other places are rather light as they generally do not exceed 60 cm (Malej et al. 1995).
The average salinity hovers around levels ranging from 37‰ to 38‰, but sometimes in the summer it was also recorded below 35‰ (Malej et al. 1995).
In general, all chemical and physical parameters undergo to some seasonal variabilities that may be due to various factors such as strong wind events or

atmospheric events that increase the flow rate of the water flows mentioned above, or also anthropogenic pressures of different types (Malej et al. 1995).

Fig.13. Gulf of Trieste

3.2. Sampling and experimental design for the distribution of *H. gammarus* in the Gulf of Trieste

Samplings were conducted inside the *Gulf of Trieste*, including 7 different locations (Fig.14).
Samplings were performed in each location 2 times in a period from the end of April to the beginning of October 2022 including 7 daytime and one night (in L.5) sampling.
The first sampling time (T1) took place between the end of April and the end of August, while the second (T2) between the beginning of September and the beginning of October.
The locations considered had different levels of "protection" Tab.2:

Tab.2. Levels of "protection" of the different locations.

	L.1	L.2	L.3	L.4	L.5	L.6	L.7
MPA (PR.1)					✅		
Bathing prohibition (PR.2)						✅	✅
No prohibition (PR.3)	✅	✅	✅	✅			

For the *Miramare MPA* (L.5), the samplings were carried out only inside the 30 hectares of marine-coastal biodiversity subjected to integral protection (Zone A).

Fig.14. Map of the sampling areas.

In each location, 4 random transects of 100 m length and 5 m width each, were performed, spaced at least 50 m from each other. Tab.3 shows the distances between the transects expressed in meters (m).
The medium of the distances is 287.2 m, with a maximum of 2,232 m and a minimum of 50.7 m.

Tab.3. Distances between the transects in each site.

Meter (m)	**L.1**	**L.2**	**L.3**	**L.4**	**L.5**	**L.6**	**L.7**
Dist. from 1 to 2	67.6	51.8	1372	53.1	52.2	59.2	52.4
Dist. From 2 to 3	111	51.7	2232	181	55.6	58.6	50.7
Dist. from 3 to 4	404	1241	51.2	330	52.7	153	50.8

Each transect could have different depths, but in any case, the visual census was conducted by placing the transect in such a way as to cover the area of the bottom (in the outermost part) and a part of the cliff (in the innermost part). The assessments were carried out on rocky, sandy, and muddy substrates. This was made to include a similar environment in all sites and because it is known that the favorite habitat of the European lobster for the creation of its burrow is located between rocks and sand (Galparsoro et al. 2009).

In summary, for each of the 16 samplings, 4 transects were performed (1, 2, 3 and 4 starting from the one on the left looking at the coast from the sea). In total, 64 surveys of 100 m transect were carried out. Half of these were conducted in T1 and the other half in T2.
We can see an example of how the transects were carried out in (Fig.15), in which the Miramare MPA (L.5) is represented.

Fig.15. Transects carried out in Miramare MPA, with relative distances. Transects (100 m each) are represented in purple, and the distances (52.2 m; 55.6 m; 52.7 m) in green.

The sampling design considered the location (L) in which the individuals were sampled, the level of protection of the location (PR.1, PR.2 or PR.3), the time (T1 or T2). In addition, another factor was taken into consideration, namely "period of the day": a location (L.5) was repeated in both diurnal (LI.D) and nocturnal (LI.N) dives for both times (T1 and T2). The data obtained from these dives were treated separately from the others.
Some environmental factors were also taken into consideration, such as:

- Depth (DE): detected between 2.6m and 17.8m;
- Temperature (TE)*: detected between 13.22°C and 24.68°C;
- Oxygenation (O_2)*: from 6.025 mg/L to 8.41 mg/L;
- Salinity (SA)*: between 37.94 and 38.28.

The Depth was recorded directly by the dive computers, while chemical and physical parameters (*) were collected by probe IDRONAUT OCEAN SEVEN 316Plus.
Then, other 3 important variables have been considered:

- Lobster position (POS): divided in 2 levels, so Bottom (B) and Non-bottom (NB). It makes clear if the detected individual was found in a point of the transect that was on the bottom or not;
- Slope (SL): divided in 3 levels, so SL.1 (between 0% and 30%); SL.2 (between 30% and 60%); SL.3 (between 60% and 90%). It represents the slope at which the detected individual was found.

- Size (SI): divided in 3 levels, so size S; size M; size L. It represents the size of the sampled individual.

The Lobster position was documented by photos or videos of the animals sampled; the Slope was calculated in this way: the three divers who conducted multiple samplings assigned a Slope level (SL.1, SL.2, or SL.3) to each location, the various assigned levels were then compared with each other and, if equal they were taken directly; if different were discussed among these people and then assigned.
The size was assigned to each individual sampled taking into consideration these parameters:

- Size S: individuals belonging to the 0 – 18 cm of total length range;
- Size M: individuals belonging to the 18 – 40 cm of total length range;
- Size L: individuals of more than 40 cm of total length.

Only size S and size M individuals have been detected.

3.2.1.Data collection

The distribution of the European lobster inside the *Gulf of Trieste* has been studied using the *Visual Census* technique (Fig.16).
The field work was conducted by a research team composed of a variable number (from 2 to 8) of underwater scientific operators with Scuba Diving equipment.
During the underwater dive, each transect was carried out by 2 operators: one operator lay out a reel of 100 meters, and the other pulled it up when the transect was finished, covering its entire length at a variable speed. Each operator sampled 2.5 m on one side of the transect covering a total area of 250 m^2 (in 2, therefore 500 m^2 in total) (Fig.16).
The data collected were: number of sampled individuals, locations, transects, level of protection, position of the sampled individuals (Bottom or Non-Bottom), period of the day (diurnal dive (LI.D) or nocturnal dive (LI.N)), depth, temperature, oxygen, salinity, slope and size. Along each transect, a video (or photo) of the individual and its burrow were collected.
Some variables did not show variability or the variability was very little, therefore they were not further analyzed (Depth, Temperature, Oxygenation, Salinity and Slope).
The transects were conducted in a medium time of 22 minutes, with a minimum of 10 min. and a maximum of 46 min. (Tab.4).

Tab.4. Time (in minutes) taken to carry out the transects.

	Transect	L.1	L.2	L.3	L.4	L.5 Day	L.6	L.7	L.5 Night
T1	1	31	10	25	17	13	23	34	17
	2	28	28	22	20	18	27	12	20
	3	22	12	27	16	24	13	17	30
	4	15	27	23	13	15	20	17	35
T2	1	15	28	21	17	22	28	17	44
	2	15	36	34	16	23	18	16	46
	3	13	17	20	20	13	30	15	44
	4	16	19	15	21	16	17	20	45

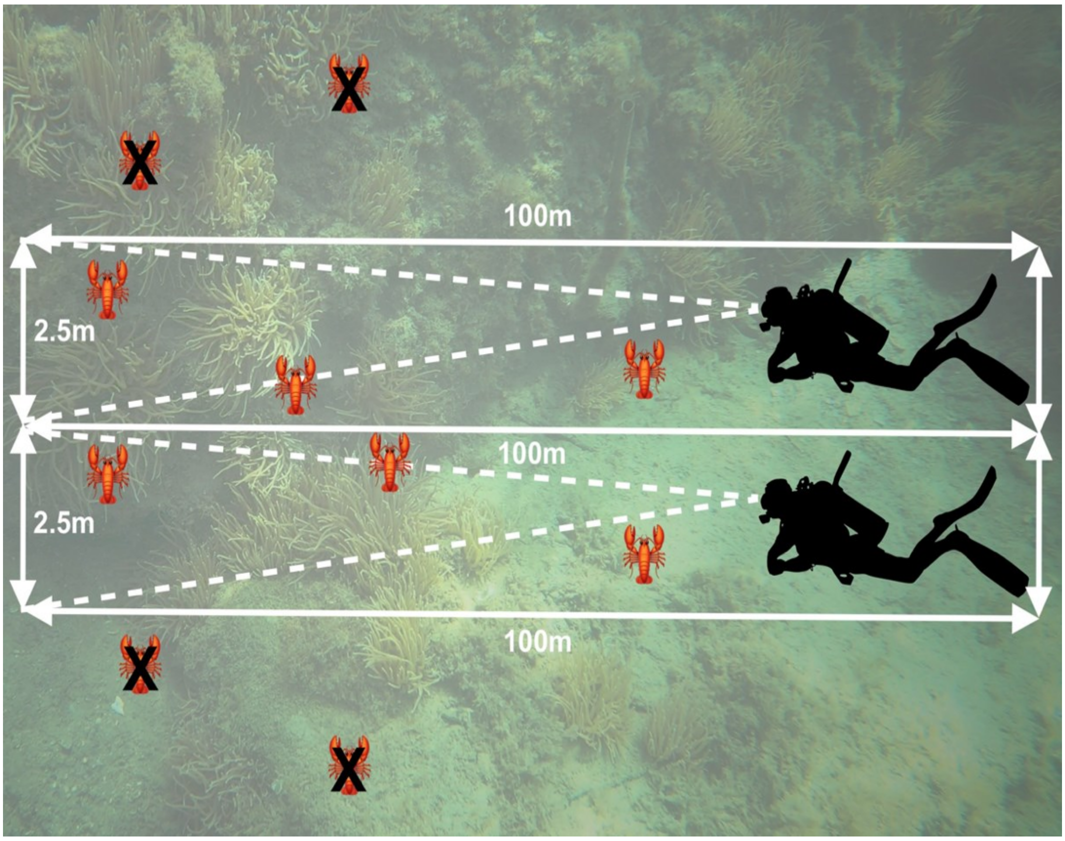

Fig.16. Sampling technique.

3.3. LEK and questionnaires

To understand what is the perception of different stakeholders (fishermen, divers, researchers) on changes in distribution and abundance of the European lobster over the years in the *Gulf of Trieste*, questionnaires have been created taking as a model those already tested by Garrabou, Bensoussan, and Azzurro in 2018.
In these questionnaires fishermen, divers, and researchers (among the most experts in the field of European lobsters that can be found in Trieste) were involved.
Three different questionnaires (Fig.17) were developed for fishermen, divers, or researchers.
To the fishermen the following questions were asked: name, age, how long have they been fishing, type of fishing (sport or professional), method of fishing, if they would say that there has been a change in the number of European lobsters in the Gulf of Trieste since they started fishing to nowadays (and how it has changed according to them), greater European lobster catch (when, how many, method, weight in kg).
To the researchers the following questions were asked: name, age, what they do in life, if they fish or not (if they fish, sport or professional and method of fishing), if they have ever embarked on a fishing boat in the Gulf of Trieste (if they did it, method of fishing), if they would say that there has been a change in the number of European lobsters in the Gulf of Trieste since they have memory until today (and how it has changed according to them), greater European lobster catch that they have done or seen (when, how many, method, weight in kg).
To the divers the following questions were asked: name, age, if they fish or not (if they fish, sport or professional and method of fishing), how many dives they do in a year in the Gulf of Trieste and where (Miramare, Barcola, Sistiana, Muggia), if they would say that there has been a change in the number of European lobsters in the in the areas where they dive the most in Gulf of Trieste since they have started diving until today (and how it has changed according to them), greater European lobster catch that they have done or seen (when, how many, method, weight in kg).
For what regards divers, the responses of people who make at least 20 dives/year in the Gulf of Trieste have been taken into consideration. For the researchers, on the other hand, we contacted people who knew about European lobsters or who had embarked on some fishing boat, the "most experts" in the field, precisely. For the fishermen the matter was a little more complicated, because in *Trieste* European lobster fishing is not very common, so we interviewed fishermen using gillnets or trawls.

OUR QUESTION: **'Have you noticed a change in the distribution of *H.gammarus* in the Gulf of Trieste in the recent years?'**

INTERVIEW NUMBER.................... DATE.................... COMPILER.................... Location.................... Country.................... NAME INTERVIEWED.................... Age....................

☐ Resercher [☐ OGS ☐ ISPRA ☐ ARPA ☐ Others....................] ☐ Scuba Diver ☐ OTS ☐ Fisherman [SINCE (Year).................... ☐ PROFESSIONAL ☐ SPORTIVE]

Fishing method: ☐ SPEAR FISHING ☐ NET ☐ PURSE SEINE ☐ TRAPS ☐ LONGLINES ☐ HOOKS ☐ TRAWLS ☐ Others....................

TRUSTWORTHINESS OF INTERVIEW
☐ HIGH (very trustworthiness)
☐ MEDIUM (acceptable)
☐ LOW (doubtful)

0 = Absent; **1** = RARE (Once in a Year); **2** = OCCASIONAL (sometimes in a Year); **3** = COMMON (regularly in a Year); **4** = ABUNDANT (regularly in captures and abundant); **5** = DOMINANT (always in captures and with great abundances)

I=increase; F=Fluctuant; S=Stable; D=Decreasing

FISHING AREA	RANK	1970	1980	1990	2000	2010	2020
	5						
	4						
	3						
	2						
	1						
	0						

MAX DAY CAPTURE (Absolute): Tot Kg .... N.Individuals .... Year .... Month .... Fishing Gear ....

OUR QUESTION: **'If you often dive in Miramare, have you noticed a change in the distribution of *H.gammarus* inside the Miramare MPA in the recent years?'**

INTERVIEW NUMBER.................... DATE.................... COMPILER.................... Location.................... Country.................... NAME INTERVIEWED.................... Age....................

☐ Resercher [☐ OGS ☐ ISPRA ☐ ARPA ☐ Others....................] ☐ Scuba Diver ☐ Diving guide

TRUSTWORTHINESS OF INTERVIEW
☐ HIGH (very trustworthiness)
☐ MEDIUM (acceptable)
☐ LOW (doubtful)

0 = Absent; **1** = RARE (Once in a Year); **2** = OCCASIONAL (sometimes in a Year); **3** = COMMON (regularly in a Year); **4** = ABUNDANT (regularly in captures and abundant); **5** = DOMINANT (always in captures and with great abundances)

I=increase; F=Fluctuant; S=Stable; D=Decreasing

ZONE	RANK	1970	1980	1990	2000	2010	2020
MIRAMARE	5						
	4						
	3						
	2						
	1						
	0						

OUR QUESTION: **'Have you noticed a change in the distribution of *H.gammarus* outside the Miramare MPA in the recent years?'**

INTERVIEW NUMBER.................... DATE.................... COMPILER.................... Location.................... Country.................... NAME INTERVIEWED.................... Age....................

☐ Resercher [☐ OGS ☐ ISPRA ☐ ARPA ☐ Others....................] ☐ Scuba Diver ☐ Diving guide

TRUSTWORTHINESS OF INTERVIEW
☐ HIGH (very trustworthiness)
☐ MEDIUM (acceptable)
☐ LOW (doubtful)

0 = Absent; **1** = RARE (Once in a Year); **2** = OCCASIONAL (sometimes in a Year); **3** = COMMON (regularly in a Year); **4** = ABUNDANT (regularly in captures and abundant); **5** = DOMINANT (always in captures and with great abundances)

I=increase; F=Fluctuant; S=Stable; D=Decreasing

ZONE	RANK	1970	1980	1990	2000	2010	2020
BARCOLA	5						
	4						
	3						
	2						
	1						
	0						

OUR QUESTION: **'Have you noticed a change in the distribution of *H.gammarus* outside the Miramare MPA in the recent years?'**

INTERVIEW NUMBER.................... DATE.................... COMPILER.................... Location.................... Country.................... NAME INTERVIEWED.................... Age....................

☐ Resercher [☐ OGS ☐ ISPRA ☐ ARPA ☐ Others....................] ☐ Scuba Diver ☐ Diving guide

TRUSTWORTHINESS OF INTERVIEW
☐ HIGH (very trustworthiness)
☐ MEDIUM (acceptable)
☐ LOW (doubtful)

0 = Absent; **1** = RARE (Once in a Year); **2** = OCCASIONAL (sometimes in a Year); **3** = COMMON (regularly in a Year); **4** = ABUNDANT (regularly in captures and abundant); **5** = DOMINANT (always in captures and with great abundances)

I=increase; F=Fluctuant; S=Stable; D=Decreasing

ZONE	RANK	1970	1980	1990	2000	2010	2020
SISTIANA	5						
	4						
	3						
	2						
	1						
	0						

OUR QUESTION: **'Have you noticed a change in the distribution of *H.gammarus* outside the Miramare MPA in the recent years?'**

INTERVIEW NUMBER.................... DATE.................... COMPILER.................... Location.................... Country.................... NAME INTERVIEWED.................... Age....................

☐ Resercher [☐ OGS ☐ ISPRA ☐ ARPA ☐ Others....................] ☐ Scuba Diver ☐ Diving guide

TRUSTWORTHINESS OF INTERVIEW
☐ HIGH (very trustworthiness)
☐ MEDIUM (acceptable)
☐ LOW (doubtful)

0 = Absent; **1** = RARE (Once in a Year); **2** = OCCASIONAL (sometimes in a Year); **3** = COMMON (regularly in a Year); **4** = ABUNDANT (regularly in captures and abundant); **5** = DOMINANT (always in captures and with great abundances)

I=increase; F=Fluctuant; S=Stable; D=Decreasing

ZONE	RANK	1970	1980	1990	2000	2010	2020
MUGGIA	5						
	4						
	3						
	2						
	1						
	0						

Fig.17. Types of questionnaires conducted.

The quantitative answers consisted in giving a value from 0 to 5 (in which 0 meant absent and 5 dominant, therefore always present in their catch, in their dives or in their perceptions).
The qualitative answers, on the other hand, consisted in making a judgment among the following on how the density of lobsters in the Gulf of Trieste has changed over the years:

- "Increased"
- "First decreased and then increased"
- "Unchanged"
- "First increased and then decreased"
- "Decreased"

All questionnaires have been compiled by the same person during the first half of October 2022.

3.4. Data analysis

The data analysis was mainly of a descriptive type, making use of the data collected from the dives and from the questionnaires carried out for this study.
All data was taken from the datasets created based on the collected data.
Another dataset was created to store all the information obtained from the questionnaires.

Visual census samplings

For the analysis of the data collected with transects, the following data have been analyzed:

- The density of individuals sampled / 500m^2 were analyzed, considering them by level of protection of the location in which they were identified and dividing them also by time (T1 or T2), both for the total of individuals sampled in day dives and for the comparison between day dives and those at night.
- The average number of individuals of size S and M sampled inside and outside the Miramare AMP.
- The number of animals sampled on the bottom (B) and not on the bottom (NB).

For the number of individuals sampled / 500m^2 during day dives a *two-sample T-test* (Cressie and Whitford 1986) was used to analyze possible differences between the data. In this case, the analysis have been made for: the values between T1 and T2 within the same protection level, for T1 at different protection levels, for T2 at different protection levels, and finally between the different times (T1 and T2) at different protection levels.
For the number of individuals sampled / 500m^2 in day dives and at night the same statistic method (*two-sample T-test*) was used to compare the two different "periods of the day".
For the average number of individuals of size S and M sampled inside and outside the *Miramare MPA* the *Fisher's exact test* (Upton 1992) was used to compare the two data.
For the number of animals sampled on the bottom (B) and not on the bottom (NB) the *binomial distribution* (EDWARDS 1960) was used to compare the two data.

Questionnaires

As regards the analysis of the data concerning the questionnaires, an attempt was made to reconstruct a trend for the last 30 years regarding the density of European lobsters in the *Gulf of Trieste*. This was possible thanks to the comparison between all the data obtained, in particular between the quantitative and qualitative answers. The data concerning the divers interviewed (who represented the largest sample) were first analyzed, starting with the analysis of the quantitative answers for each location taken into consideration in the questionnaires, then analyzing them all together and ending with the analysis of the qualitative answers.
The same process was used for the analysis of the data collected by the questionnaires of researchers and divers, except for not being able to analyze the qualitative data of the researchers because they were too few. Finally, the data taken from the questionnaires were represented all together to compare trends.
As for the statistics:

- For the quantitative answers for the locations, calculations were made of the probabilities of finding a European lobster in the various locations taken into consideration in the questionnaires to divers (consider a "0" like 0% and a "5" like 100%).
- For the quantitative data of all divers together, a linear regression line was used to better explain the trend and a *two-sample t-test* (Cressie and Whitford 1986) to verify if the quantitative values have been assigned correctly by the interviewees (trying to understand if some diver's responses could be influenced from the fact that they do a lot of diving inside the *Miramare MPA*).

For the quantitative data of fishermen and researchers, histograms were used to represent the results.
The same approach was used for all qualitative data (except those of the researchers, due to the few questionnaires it was not possible to carry out data analysis) but using pie charts to analyze the percentages of the qualitative answers.

4. RESULTS

4.1. Assessment of the distribution of *H. gammarus* in the Gulf of Trieste

During the two sampling campaigns conducted for the evaluation of the European lobster distribution in the *Gulf of Trieste*, a total of 24 lobsters were surveyed (19 during day dives and 5 during night dives) (Tab.5; Tab.6).

Tab.5. Sampled European lobsters during Time 1 (T1).

T1											
Lobster	**L**	**Transect**	**POS**	**PR**	**LI**	**DE (m)**	**TE (°C)**	**O_2 (mg/L)**	**SA**	**SL**	**Size**
Lob1	L1	L1-2	B	PR3	//////	2.6	13.22	8.41	38.28	SL1	M
Lob2	L2	L.2-2	B	PR3	//////	2.6	16.65	7.95	38.23	SL2	S
Lob3	L2	L.2-4	B	PR3	//////	3	16.65	7.95	38.23	SL3	M
Lob4	L3	L.3-1	B	PR3	//////	3.7	15.44	8.25	38.18	SL1	M
Lob5	L3	L.3-2	NB	PR3	//////	3.2	15.44	8.25	38.18	SL1	M
Lob6	L3	L.3-4	B	PR3	//////	3.6	15.44	8.25	38.18	SL2	S
Lob7	L4	L.4-2	B	PR3	//////	5.8	19.65	8.19	38.17	SL1	S
Lob8	L4	L.4-2	NB	PR3	//////	5.8	19.65	8.19	38.17	SL1	M
Lob9	L4	L.4-2	B	PR3	//////	5.8	19.65	8.19	38.17	SL1	S
Lob10	L5	L.5-2	B	PR1	D	6.9	24.2	6.76	37.96	SL2	S
Lob11	L6	L.6-4	B	PR2	//////	17.8	21.64	7.98	38.22	SL2	M
Lob12	L7	L.7-1	B	PR2	//////	7.6	24.24	7.25	38.13	SL2	S
Lob13	L8	L.5-4	B	PR1	N	5.4	24.68	6.025	38.22	SL1	M

Tab.6. Sampled European lobsters during Time 2 (T2).

T2											
Lobster	**Lob24**	**Lob23**	**Lob22**	**Lob21**	**Lob20**	**Lob19**	**Lob18**	**Lob17**	**Lob16**	**Lob15**	**Lob14**
L	L8	L8	L8	L8	L7	L5	L4	L4	L3	L3	L2
Transect	L.5-2	L.5-1	L.5-1	L.5-1	L.7-1	L.5-3	L.4-2	L.4-2	L.3-4	L.3-1	L.2-4
POS	NB	B	B	B	B	B	B	B	B	B	B
PR	PR1	PR1	PR1	PR1	PR2	PR1	PR3	PR3	PR3	PR3	PR3
LI	N	N	N	N	//////	D	//////	//////	//////	//////	//////
DE (m)	6.9	4.4	4.2	4	8.7	5	6.6	6.8	4.1	3.8	5.4
TE (ºC)	20.77	20.77	20.77	20.77	22.64	21.2	24.17	24.17	24.17	24.17	21.05
O_2 (mg/L)	6.38	6.38	6.38	6.38	6.72	6.52	7.72	7.72	7.52	7.52	7.48
SA	37.94	37.94	37.94	37.94	38.17	38.1	37.62	37.62	37.61	37.61	37.95
SL	SL2	SL1	SL1	SL1	SL2	SL1	SL1	SL1	SL2	SL1	SL3
Size	M	M	M	M	S	M	M	S	S	M	S

In total, more individuals were sampled in areas with no protection (PR3) but areas with "PR.3" protection level were also the most abundant (Fig.18).

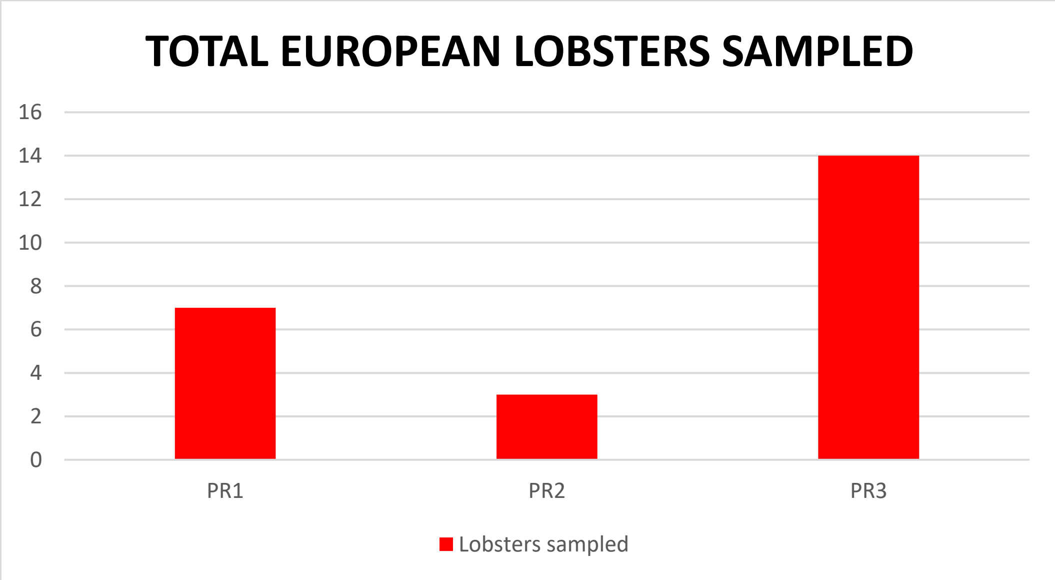

Fig.18. Sampled European lobsters, divided according to the level of protection (number of European lobsters).

However, these results must also consider the number of locations with the different protection respect to the total number of locations, in this case we have: 4/7 with "PR3"; 2/7 with "PR2"; 1/7 with "PR1".
Going to analyze the data in another way, so by don't take the total number of individuals sampled, but only the number of individuals sampled by day (LI.D) = 19, for those sampled at night there will be a separate analysis; and dividing the sampled European lobsters by level of protection (PR1, PR2, PR3) and analyzing the densities of individuals/500m^2 for Time 1 (T1) and Time 2 (T2), we obtain the graph in (Fig.19).

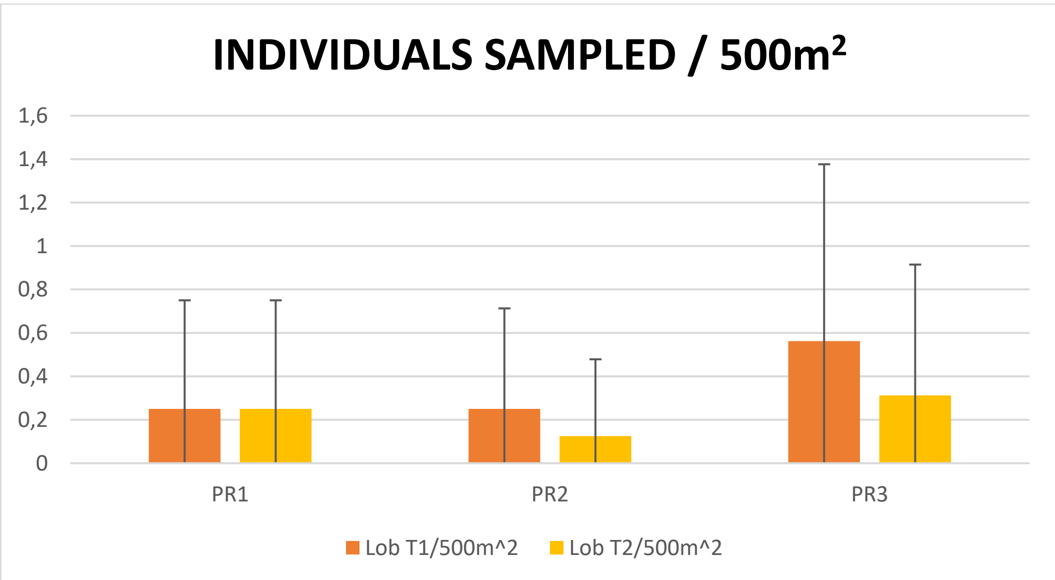

Fig.19. Sampled individuals divided by level of protection (PR1, PR2, PR3), densities of individuals/500m^2 for Time 1 (T1), Time 2 (T2) and the total ((T1 + lobsters T2)/500m^2) expressed in (number/500m^2) ± Standard Deviation (SD).

Comparing the density of the individuals (n/500m^2) (Fig.19), the results in Tab.7 were obtained.

Tab.7. *Two sample T-test* for individuals sampled / 500m^2 divided by level of protection (PR.1, PR.2, PR.3). The data were compared with each other with all possible combinations. If the *t* was greater than the *critical value,* then there was a statistical difference between the two values. In some values you there is $t = 0.00$, this is because those values were the same or statistically not different.

	t	*df*	Critical Value	*t* > Critic. Value?
T1 VS T2 (PR1)	0.00	6	2.45	NO
T1 VS T2 (PR2)	0.59	14	2.15	NO
T1 VS T2 (PR3)	0.99	30	2.04	NO
T1 (PR1) VS T1 (PR2)	0.00	10	2.23	NO
T2 (PR1) VS T2 (PR2)	0.49	10	2.23	NO
T1 (PR1) VS T2 (PR2)	0.49	10	2.23	NO
T2 (PR1) VS T1 (PR2)	0.00	10	2.23	NO
T1 (PR1) VS T1 (PR3)	0.72	18	2.1	NO
T1 (PR1) VS T2 (PR3)	0.18	18	2.1	NO
T2 (PR1) VS T1 (PR3)	0.72	18	2.1	NO
T2 (PR1) VS T2 (PR3)	0.18	18	2.1	NO
T1 (PR2) VS T1 (PR3)	1.00	22	2.07	NO
T1 (PR2) VS T2 (PR3)	0.25	22	2.07	NO
T2 (PR2) VS T1 (PR3)	1.42	22	2.07	NO
T2 (PR2) VS T2 (PR3)	0.78	22	2.07	NO

No significant differences emerged among protection levels.

Day VS night

During the night a total higher number of lobsters were samples, in particular in T2 (Fig.20..

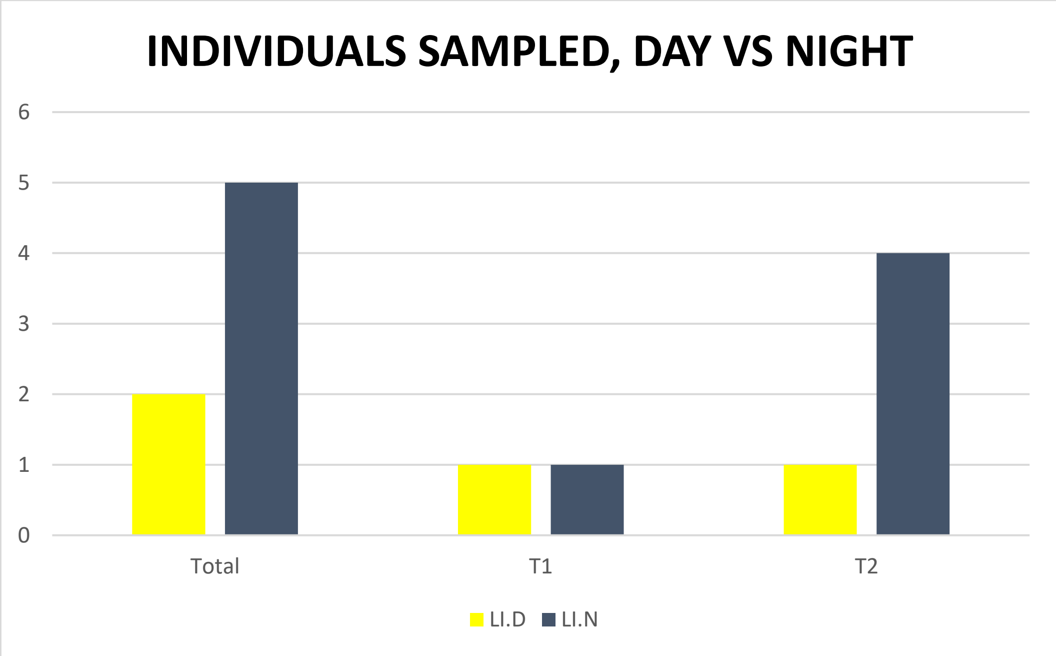

Fig.20. Sampled European lobsters divided by "period of the day" (LI.D or LI.N). Numbers expressed in total, Time 1 (T1) and Time 2 (T2).

Using the same procedure adopted before, then calculating the abundances / 500 m^2 the graph in (Fig.21) was obtained.

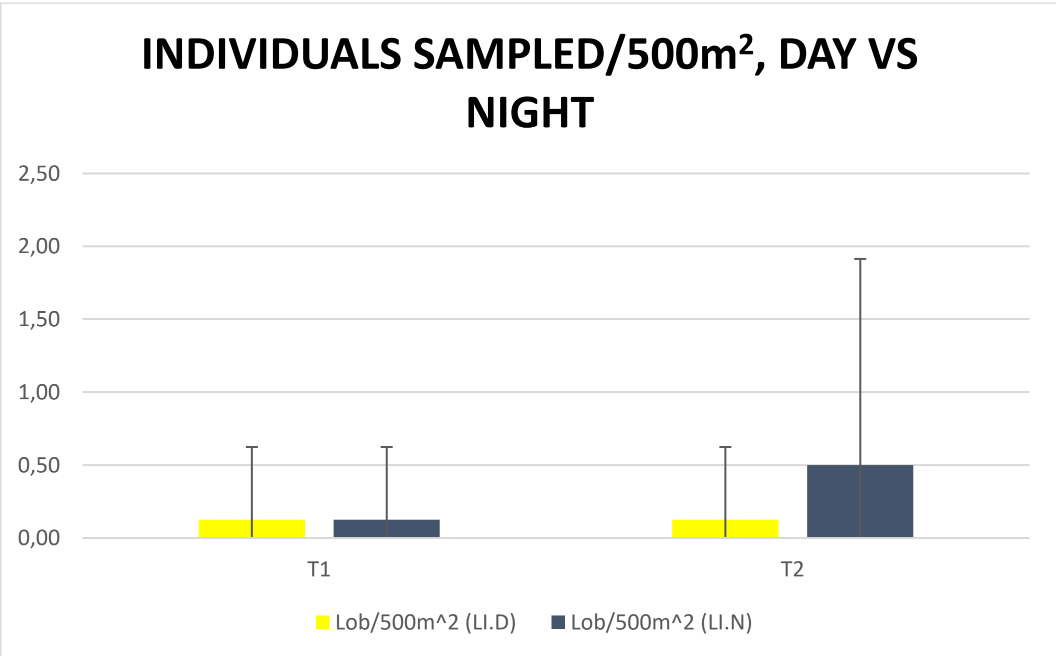

Fig.21. Sampled European lobsters/500m^2 divided by "period of the day" (LI.D or LI.N). Numbers expressed in total, Time 1 (T1) and Time 2 (T2).

Comparing, also in this case, the density of the individuals (n/500m^2) (Fig.21), the results in Tab.8 were obtained.

Tab.8. *Two sample T-test* for individuals sampled / 500m^2 divided by diurnal (LI.D) and nocturnal (LI.N) dives, and by T1 and T2. The data were compared with each other with all possible combinations. If the *t* was greater than the *critical value* then there was a statistical difference between the two values. In some values you there is $t = 0.00$, this is because those values were the same or statistically not different.

	t	*df*	Critical Value	*t* > Critic. Value?
T1 (LI.D) VS T1 (LI.N)	0.00	14	2.15	NO
T1 (LI.D) VS T2 (LI.D)	0.00	14	2.15	NO
T1 (LI.D) VS T2 (LI.N)	0.70	14	2.15	NO
T1 (LI.N) VS T2 (LI.D)	0.00	14	2.15	NO
T1 (LI.N) VS T2 (LI.N)	0.70	14	2.15	NO
T2 (LI.D) VS T2 (LI.N)	0.70	14	2.15	NO

No significant differences emerged among diurnal and nocturnal data.

Difference in size: inside MPA VS outside MPA

The size of the European lobsters sampled were analyzed considering the total sample (Fig.22).

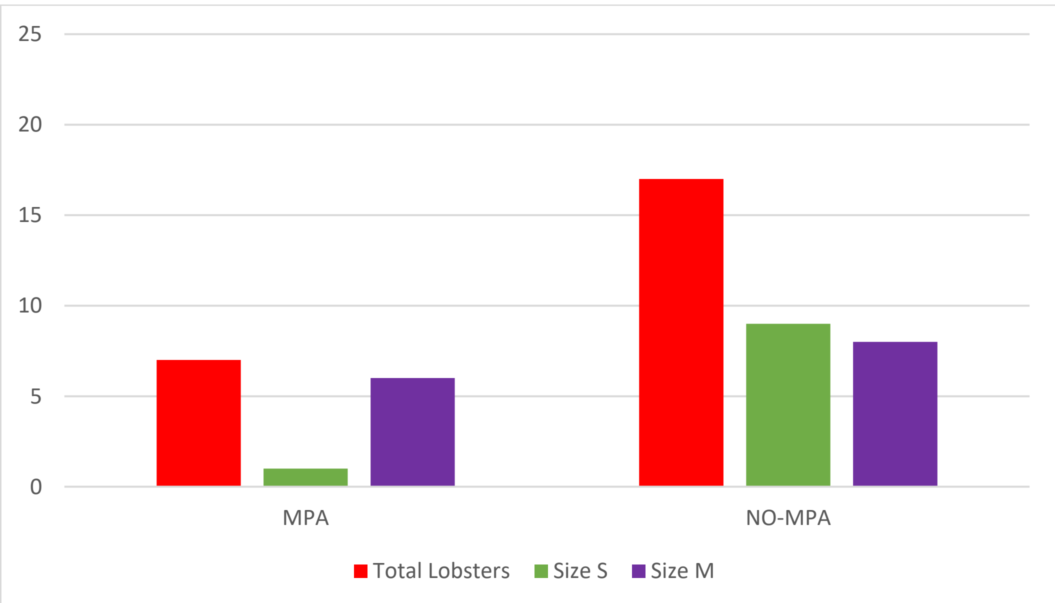

Fig.22. S and M size European lobsters compared between inside and outside the MPA (total number).

Proportionally, more medium-sized European lobsters were sampled within the MPA (6 out of 7) than outside the MPA (8 out of 17) (Fig.23).

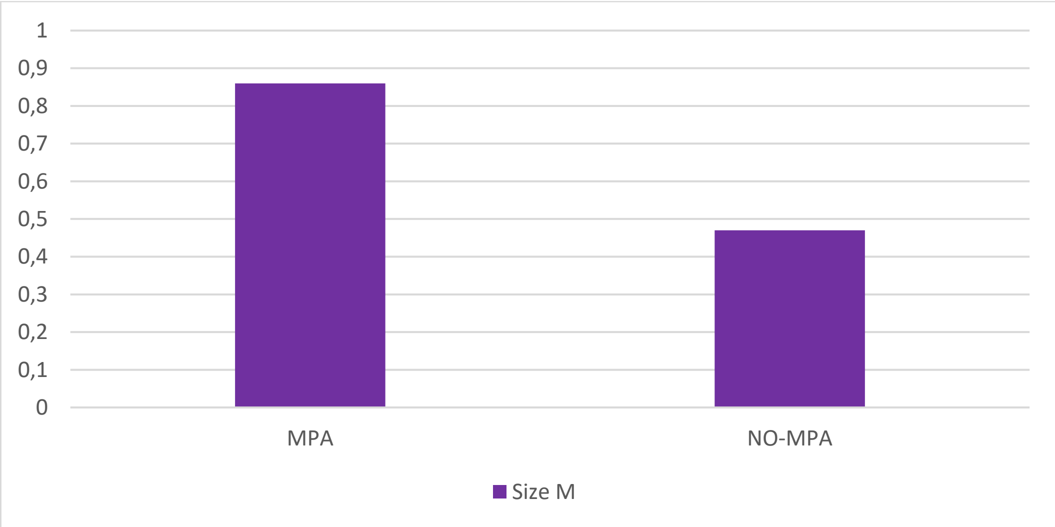

Fig.23. Proportion of sampled European lobsters of size M respect to the total number.

Differences in size were tested using *Fisher's exact test* (Tab.9).

Tab.9. Calculation of the probabilities of obtaining the same size differences using *Fisher's exact test*.

P_0	0.087
P_1	0.019
$P (P_1+P_2)$	$0.11 > 0.05$

No significance emerged from this test.

Habitat

The majority of the European lobsters were found close to the bottom (B) (Fig.24).

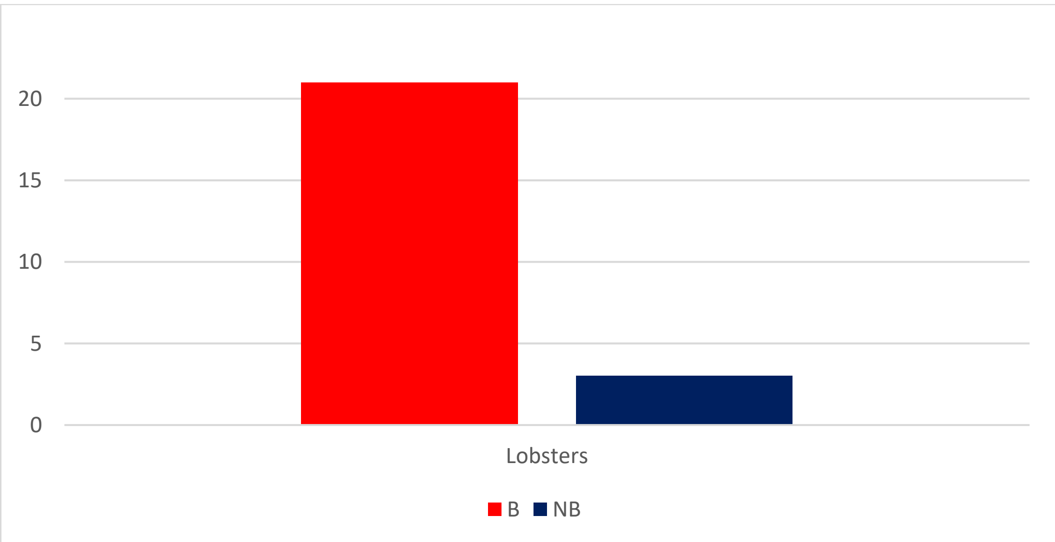

Fig.24. Difference between European lobsters found on the bottom (B) and not on the bottom (NB). Values expressed as total number of individuals.

Using the *binomial distribution*, European lobsters resulted to be significantly more abundant on the side of the transect more towards the bottom, rather than the side towards the reef (Tab.10).

Tab.10. Probability of finding the same number of individuals on the bottom and not on the bottom as those found during samplings.

$\binom{n}{k}$	2024
P ($S_n = k$)	$1.21 \cdot 10^{-4} <<< 0.05$
P ($S_{24} = 21$)	0.012%

4.2. History of the change in the quantity of *H. gammarus* in the Gulf of Trieste

To investigate the change in the abundance of European lobsters in the Gulf of Trieste, the questionnaires described in the *Materials and methods* part were used.
All the questionnaires carried out were aimed at understanding what has been the change in the density of European lobsters in the Gulf of Trieste in the last 50 years, but we focused more on the last 30 years as we had more data.
In total, the perceptions of 40 "experts" on the subject were taken into consideration: 29 divers, 5 researchers and 6 fishermen.
The data are not equally distributed over the years: for the 1970s we received the opinions of 5 people (3 divers and 2 fishermen); for the 80's 9 people (6 divers and 3 fishermen); for the 90's 16 people (11 divers, 4 fishermen and 1 researcher); since the 2000s almost everyone has been able to answer.
An example of a correctly completed questionnaire, taken from an interview with a professional fisherman, is shown in (Fig.25).

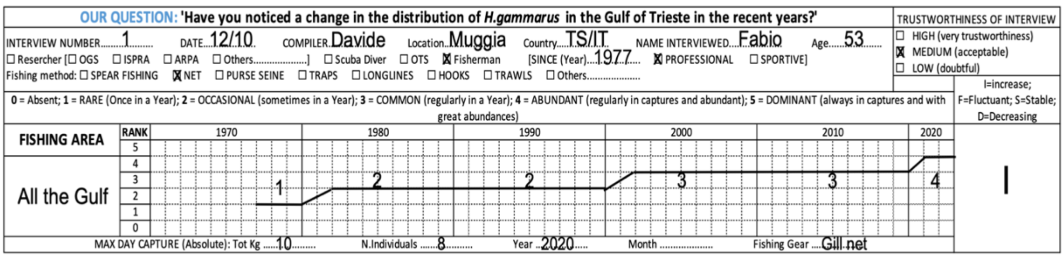

Fig.25. Questionnaire completed correctly.

Questionnaires for divers

Quantitative data

Being the largest sample, the questionnaires made to divers were analyzed in more detail.
Analyzing the data in order, the quantitative data obtained from the locations most visited by divers in the Gulf of Trieste (*Barcola, Sistiana, Muggia, Miramare MPA*) were first analyzed.

In *Barcola*, the abundance of the European lobster is perceived as increases in the last 50 years, albeit with a decrease around the 2000s (Fig.26).

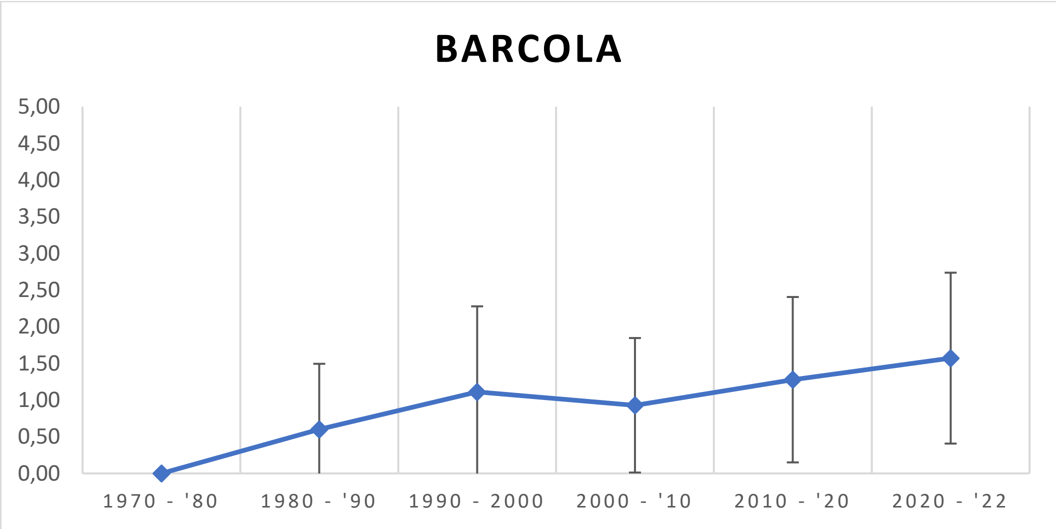

Fig.26. Quantitative data collected from interviews with divers, regarding the location of *Barcola*. Data expressed in average ± SD. On the y axis there are the quantitative values expressed (0 minor value, 5 maximum value).

Data go from an average of 0.00 (in the 70's) to an average of 1.57 (nowadays), so the increase was 1.57. From 90's onwards (we take these values into account because we have more data) has increased by 0.46, passing from 1.11 to 1.57. This means that, transforming these data into percentages (where 0 is 0% and 5 is 100%), on average if you go diving in *Barcola* (in recent years) there is a probability that is between 30 and 35% of finding a European lobster, respect to a probability from 20 to 25% in the 90's.

Also in *Sistiana*, the abundance of European lobsters is perceived as increases in the last 50 years (Fig.27).

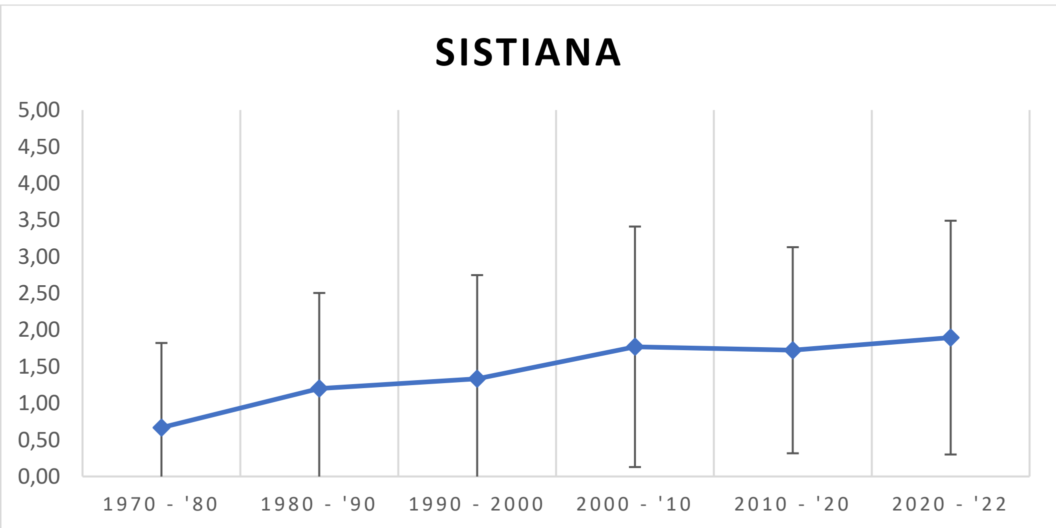

Fig.27. Quantitative data collected from interviews with divers, regarding the location of *Sistiana*. Data expressed in average ± SD. On the y axis there are the quantitative values expressed (0 minor value, 5 maximum value).

In this case values go from an average of 0.67 (in the 70's) to an average of 1.89 (nowadays), so the increase was 1.22. From 90's onwards has increased by 0.56, passing from 1.33 to 1.89. This means that on average if you go diving in *Sistiana,* in these years, there is a probability that is between 35 and 40% of finding a European lobster, respect to a probability from 25 to 30% in the 90's.

For what regards *Muggia*, the abundance of European lobsters has followed an ever-growing trend in the last 50 years (Fig.28).

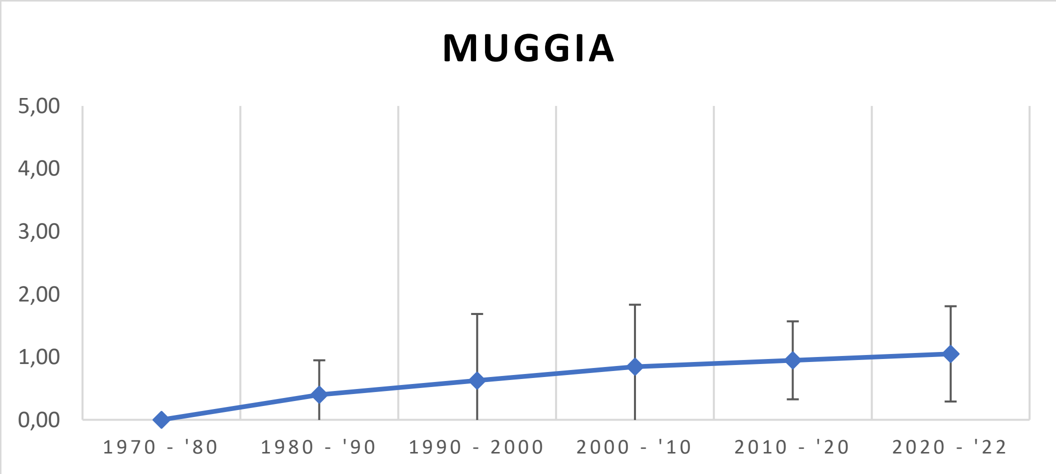

Fig.28. Quantitative data collected from interviews with divers, regarding the location of *Muggia*. Data expressed in average ± SD. On the y axis there are the quantitative values expressed (0 minor value, 5 maximum value).

Values go from an average of 0.00 (in the 70's) to an average of 1.05 (nowadays), so the increase was 1.05. From 90's onwards has increased by 0.42, passing from 0.63 to 1.05. This means that on average if you go diving in *Muggia* (in recent years) there is a probability that is between 20 and 25% of finding a European lobster, respect to a probability from 10 to 15% in the 90's.

In *Miramare*, the abundance of the European lobster is perceived as increases in the last 50 years, albeit with a decrease between 2010 and 2020 (Fig.29).

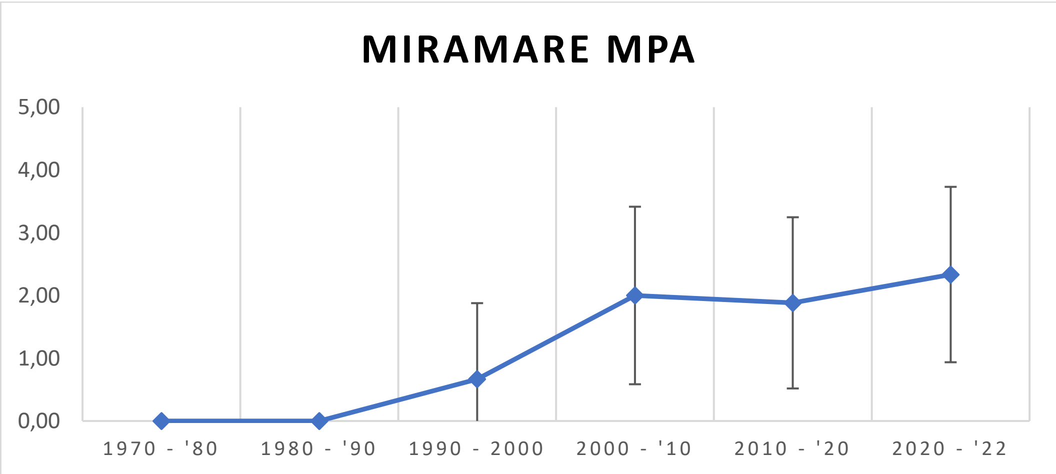

Fig.29. Quantitative data collected from interviews with divers, regarding the location of *Miramare MPA*. Data expressed in average ± SD. On the y axis there are the quantitative values expressed (0 minor value, 5 maximum value).

These data need to be examined more carefully. The *Miramare MPA* was established in 1973, in fact up to 2000 we have no certainty of the data as there was no control and there was also a lot of illegal fishing compared to today.
From these data, it can be said that also in this location there has been an increase in the density of European lobsters in the last 50 years.
Data in this case go from an average of 0.00 (in the 70's) to an average of 2.33 (nowadays), so the increase was 2.33 (the highest of all the locations examined). From 90's onwards has increased by 1.66 (with a little decrease in 2010s), passing from 0.67 to 2.33. This means that on average if you go diving in the *MPA of Miramare*, nowadays, there is a probability that is between 45 and 50% (the highest of the locations examined) of finding a European lobster, respect to a probability from 30 to 35% in the 90's.

Results of the divers' quantitative data

Collecting all the quantitative data of the divers and putting them all together, the graph in (Fig.30) was obtained.

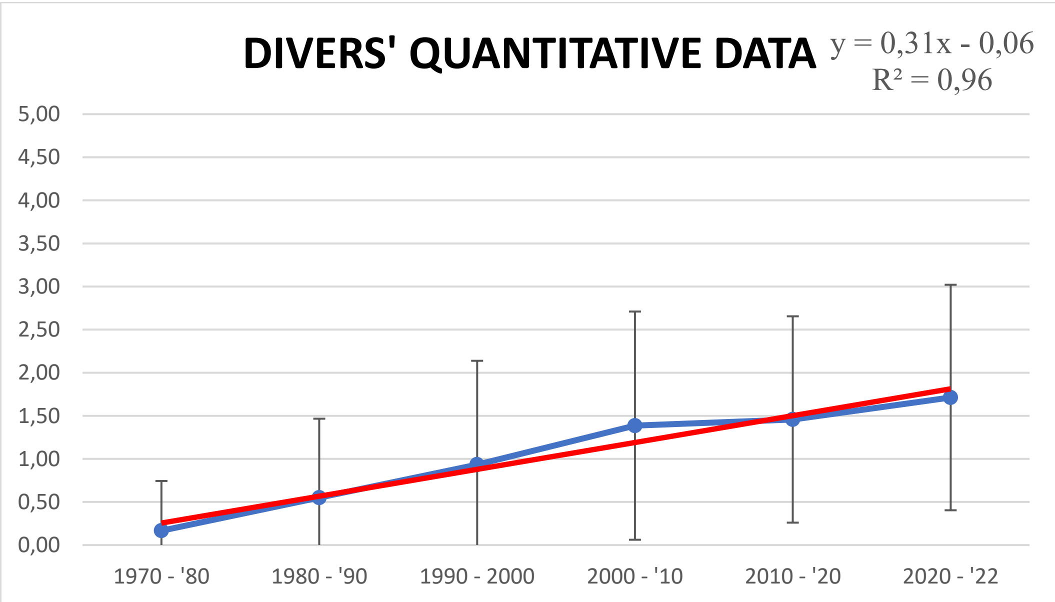

Fig.30. Graph representing all the quantitative data obtained from the questions to the divers. Data expressed as average ± SD. On the y axis there are the quantitative values expressed (0 minor value, 5 maximum value).

The increasing trend resulted very significant (Tab.11).

Tab.11. Statistical values of the linear regression line obtained as result of the analysis of the quantitative data obtained from divers.

R^2	F	df	p
0.96	110.01	4	$0.47 \cdot 10^{-3} <<< 0.05$

The average values increased from 0.17 in the 70's to an average of 1.71 nowadays, highlighting an increase of 1.54.
From 90's onwards this value has increased by 0.78, passing from 0.93 to 1.71. This means that on average if you go diving in one of the locations considered of the

Gulf of Trieste, nowadays, there is a probability that is between 30 and 35% of finding a European lobster, while in the 90's the odds were between 15 and 20%. To verify if these results could be biased by people who dive more frequently within the MPA, the data were analyzed taking into account the answers given for locations outside the MPA, to further reduce the possibility that the data were biased from that taken within the MPA. People were divided into 2 groups:

- Group 1: people performing at least 5 dives per year within the Miramare MPA.
- Group 2: people performing from 0 to 4 dives per year within the Miramare MPA.

This division is visible in Tab.12 (Group 1) and Tab.13 (Group 2).

Tab.12. Perceptions, regarding the locations outside the MPA (Barcola, Sistiana, Muggia) of people performing at least 5 dives per year within the Miramare MPA.

People	N^0 of dives in MPA	N^0 of 0	N^0 of 1	N^0 of 2	N^0 of 3	N^0 of 4	N^0 of 5
A	5	0	3	1	4	1	0
B	10	13	5	0	0	0	0
C	30	7	3	5	0	3	0
D	50	0	2	1	2	1	0
Total		20	13	7	6	5	0
Average of all values					1.30		

Tab.13. Perceptions, regarding the locations outside the MPA (Barcola, Sistiana, Muggia) of people performing from 0 to 4 dives per year within the Miramare MPA.

People	N^0 of dives in MPA	N^0 of 0	N^0 of 1	N^0 of 2	N^0 of 3	N^0 of 4	N^0 of 5
D	1	4	5	2	1	0	0
E	0	0	5	2	2	0	0
F	0	0	4	0	2	0	0
G	1	4	6	2	1	0	0
H	0	0	2	1	2	0	0
I	2	0	5	0	2	1	0
J	0	14	0	2	2	0	0
K	3	2	0	0	0	2	0
L	4	2	4	3	2	1	0
M	0	4	5	3	0	0	0
N	0	1	2	0	0	0	0
O	0	3	2	1	0	0	0
P	0	2	0	0	0	0	0
Q	1	0	2	2	3	0	0
R	1	3	3	0	0	0	0
S	2	0	3	3	3	0	0
T	0	6	2	0	0	0	0
U	1	3	2	0	0	0	0
V	0	3	2	1	2	1	0
Total		51	54	22	22	5	0
Average of all values					1.19		

To understand if the values provided by divers who dive more often within the MPA are conditioned by this factor, the two averages were compared using a *two-sample T-test* (Tab.14).

Tab.14. Data obtained from the calculation of the *two-sample T-test*.

	N^0 of dives in MPA	Average of all values	$Sx_{1}x_{2}$	t	df	Critical value
Group 1	> 4	1.30	1.17	0.17	21	2.08
Group 2	< 5	1.19				

No significant differences between the two groups have been observed.

Qualitative data

The analysis on the qualitative answers given by the divers was done by reducing the data sample. This is because there were many people who have declared to dive from a few years, and since the intention was to build a trend for at least the last 30 years, the answers of people who have been diving in Trieste for at least 30 years were taken (Tab.15).

Tab.15. Qualitative answers of the divers.

Name	Years of diving	Qualitative answer
P1	30	First decreased and then increased
P2	33	First decreased and then increased
P3	37	First decreased and then increased
P4	35	First decreased and then increased
P5	34	Unchanged
P6	30	First increased and then decreased
P7	38	Increased
P8	35	First decreased and then increased
P9	30	First decreased and then increased
P10	30	Decreased
P11	45	Decreased
P12	30	First decreased and then increased
P13	30	Increased

The pie chart obtained from the previous data is represented in (Fig.31).

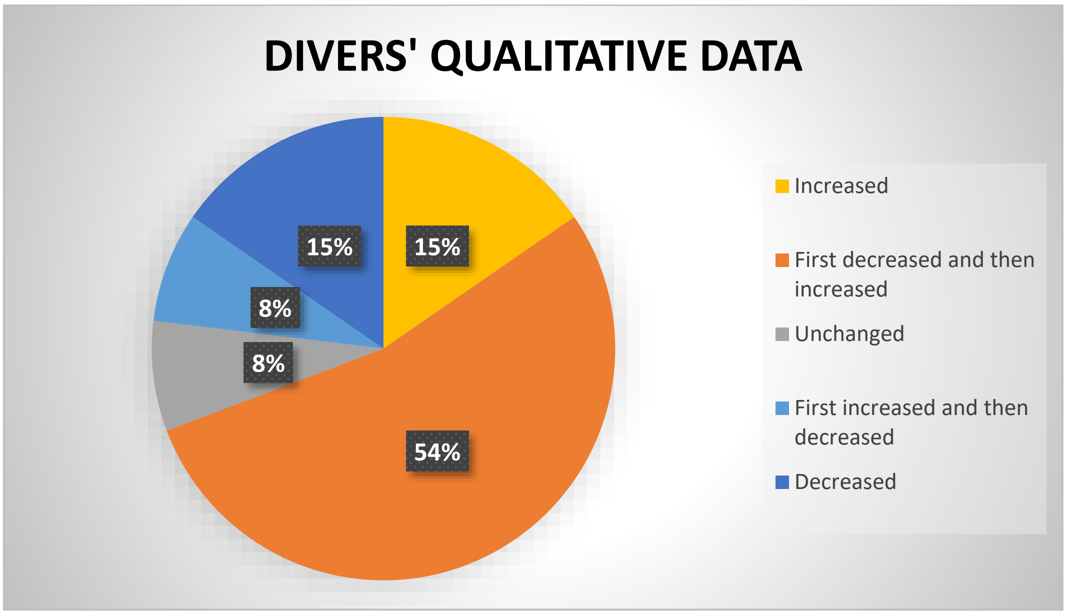

Fig.31. Graph representing the qualitative answers of the divers. Values expressed in percentages.

From this graph it can be seen that the majority of people interviewed (54%), who have been diving for at least 30 years, stated that the trend in the density of European lobsters in the *Gulf of Trieste* did not follow a linear trend, but first went down and then up.
Grouping these answers into only 3 categories, *"Increased"*; *"Unchanged"*; *"Decreased"*, which means combining the *"First decreased and then increased"* option with *"Increased"* and the *"First increased and then decreased"* option with *"Decreased"* the majority of the answers is in the "Increased" category (Fig.32).

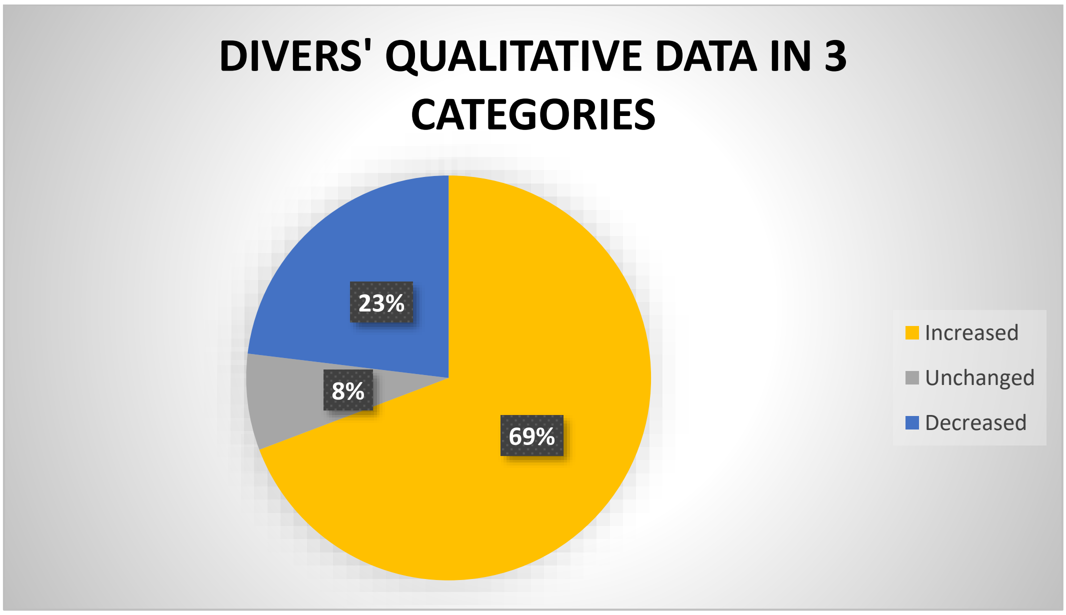

Fig.32. Graph representing the qualitative answers of the divers grouped all in 3 categories. Values expressed in percentages.

Questionnaires for researchers

Quantitative data

The quantitative data obtained from the questionnaires to the researchers were few because, as already mentioned, the purpose was to interview the most experts on the subject (Fig.33).

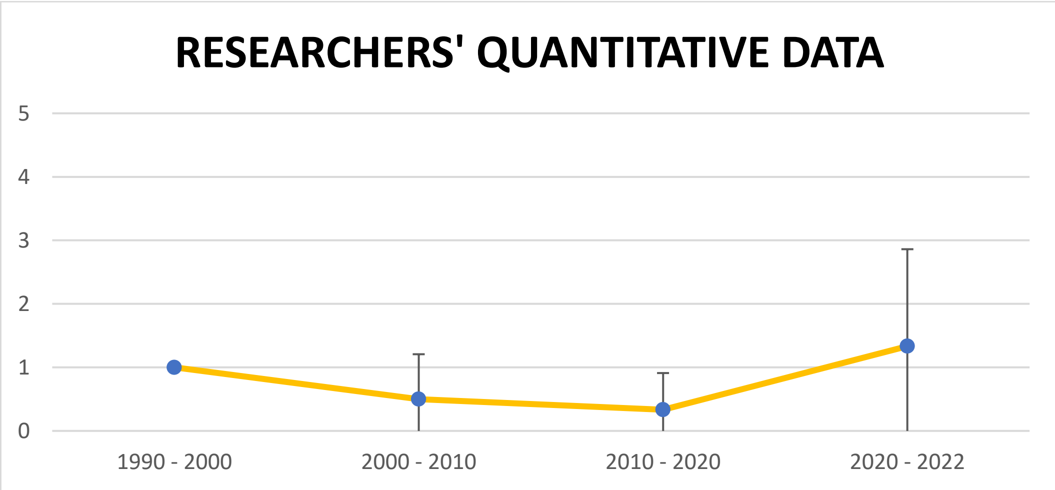

Fig.33. Graph representing all the quantitative data obtained from the questions to the researchers. Data expressed in average ± SD.

Even if the data are few, it can be seen that a very big increase in the density of European lobsters in the *Gulf of Trieste* in the last few years is confirmed. In fact, looking at the change over the last 10 - 12 years, it can be seen that data go from an average of 0.33 to an average of 1.33.
This means an increase of 1 point on the average which graphically shows the growing trend in the density of European lobsters in the *Gulf of Trieste*.

Qualitative data

The qualitative data provided by the researchers were not analyzed due to the scarcity of data and their high variability.
Furthermore, 3 over 5 researchers have stated that they cannot give a qualitative answer with absolute certainty, so they preferred not to answer.

Questionnaires for fishermen

Quantitative data

Also in this case, the quantitative data obtained from the questionnaires to fishermen (Fig.34) were few because, as for the researchers, the purpose was to interview the most experts on the subject, therefore only people who can fish European lobsters, so fishermen with gillnet or trawl.

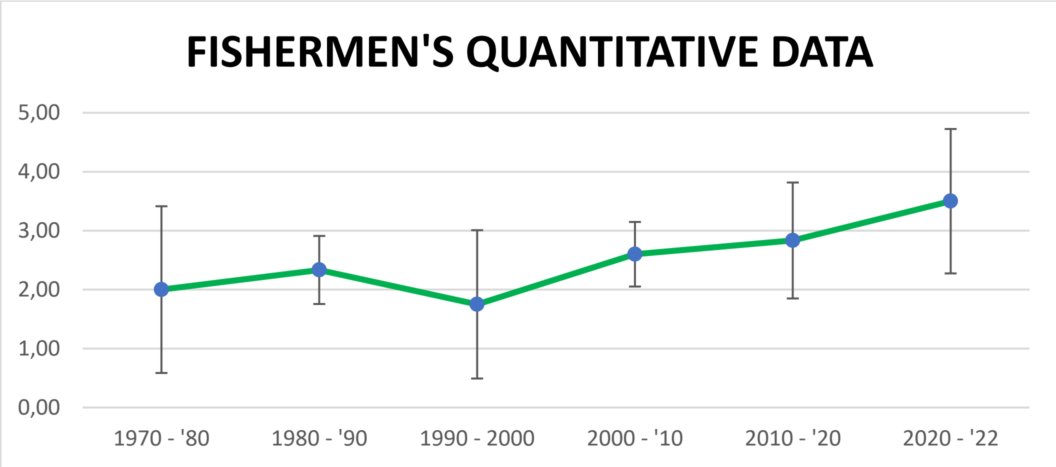

Fig.34. Graph representing all the quantitative data obtained from the questions to the fishermen. Data expressed as average ± SD.

From the data analysis a decrease around "1990 – 2000" decade emerges, then an increase. From 90's onwards has increased by 1.75, passing from 1.75 to 3.50
In total, it has gone from an average of 2.00 in the 70's to an average of 3.50 nowadays, highlighting an increase of 1.50.
Therefore, according to the fishermen, the density of *H. gammarus* species in the *Gulf of Trieste* has doubled in the last 30 years, registering a steady increase from the 90's until today.
It is also important to underline how fishermen gave higher values than researchers and divers: in this case the minimum average value is 1.75 while in the case of researchers it is 0.58, and in that of divers (the total one) it is 0.17; the maximum average value, on the other hand, is 3.50 in this case, while in the case of researchers is 1.53, and in that of divers (the total one) it is 1.71.

Qualitative data

Also in this case, the answers of fishermen who have been practicing professional fishing for at least 30 years have been extrapolated from the total.
Here it was not necessary to group the answers into 3 categories, because only the "Increased" and "Decreased" options were chosen (Fig.35).

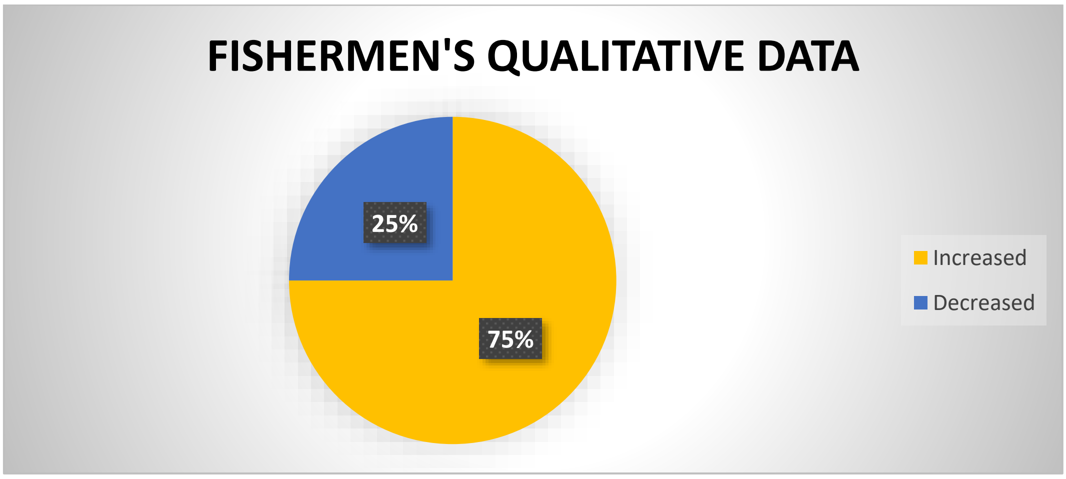

Fig.35. Graph representing the qualitative answers of the fishermen. Values expressed in percentages.

From this graph it can be seen that the majority of people interviewed (75%) stated that the trend in the density of European lobsters in the *Gulf of Trieste* increased.

Questionnaires grouped together

Quantitative data

For the analysis of the general quantitative data of all the questionnaires, the trends constructed by the answers of fishermen (in green), researchers (in yellow), and divers (in blue) were plotted in the same graph.
Data from the 1990s onwards were taken into consideration to take into account the last 30 years (Fig.36).

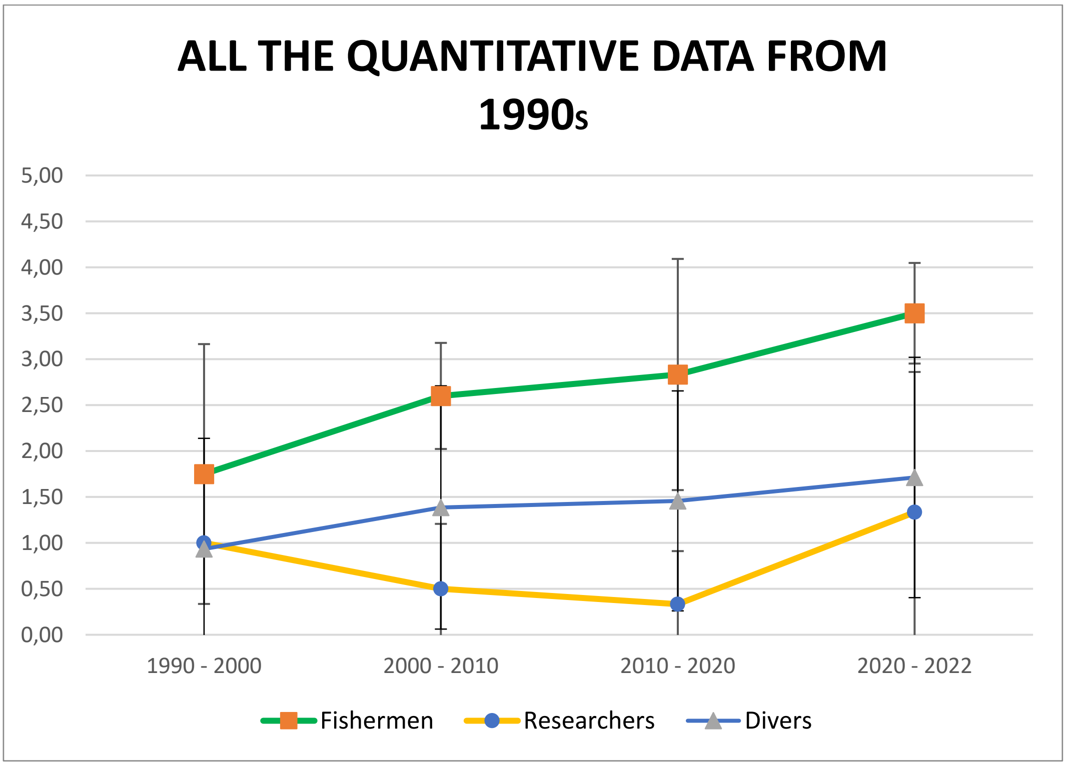

Fig.36. Graph representing all the quantitative data obtained from the questionnaires, from 1990s until today. Data expressed in average ± SD.

These trends have already been commented in the previous paragraphs, and it can be seen graphically how all three show an increase in the density of *H. gammarus* species in the *Gulf of Trieste* over the last 30 years, albeit with different average values.
These results are also supported by the graph below, representing the values of the quantitative answers of all questionnaires placed all in the same column (for every decade considered) and divided into percentages (Fig.37).

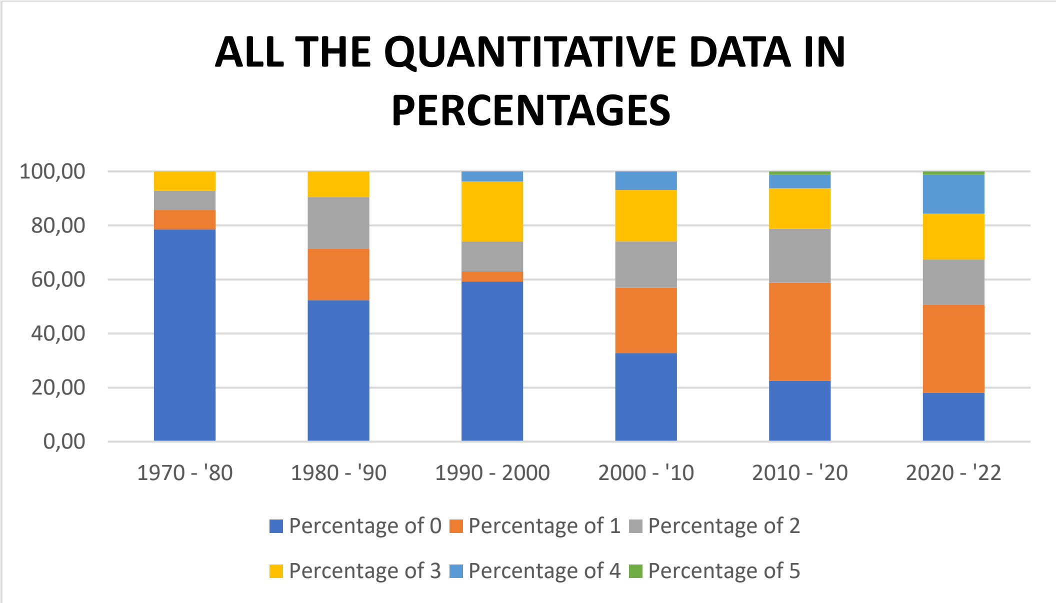

Fig.37. Graph representing the quantitative answers of all questionnaires. Values placed all in the same column (for every decade considered) and divided into percentages.

As can be seen very well from this graph, leaving aside the decade from 1990s to 2000s, there is a big decrease in the percentage of "0" from 1970s to present, while the percentages of "1", "2", but most of all of "3", "4" and "5"; increase.

Qualitative data

Grouping all answers together, the largest percentage (40%) of the total number of people interviewed said that the trend in recent years is an increase in the density of European lobsters in the *Gulf of Trieste* (Fig.38).

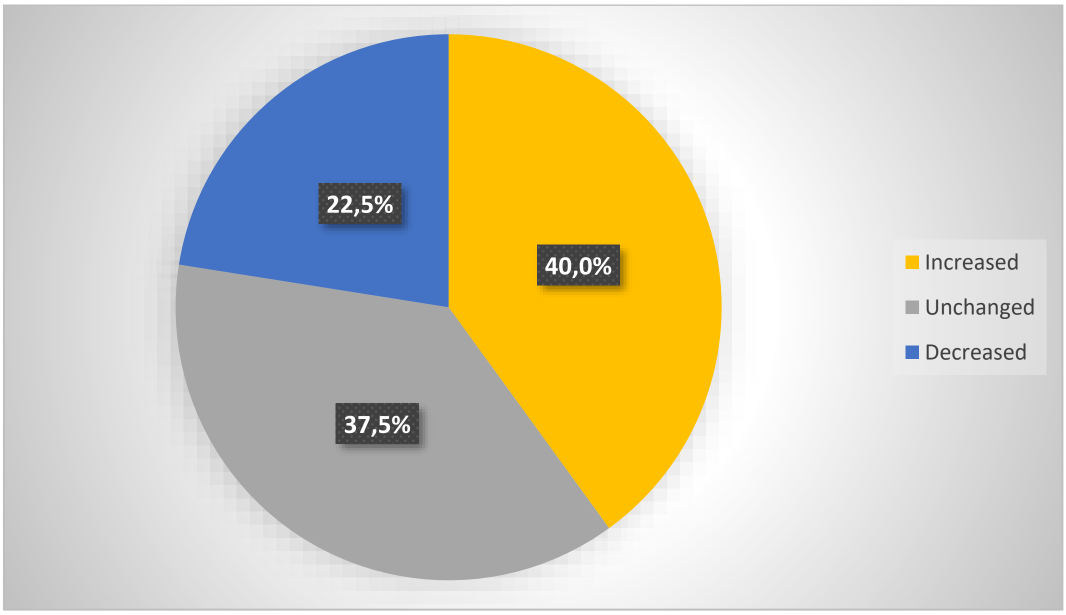

Fig.38. Graph representing the qualitative answers of all questionnaires. Values grouped in 3 categories (increased, unchanged, decreased) and expressed in percentages.

However, the previous graph considers all people, not just those who have been able to give values for the last 30 years. Considering only the people able to answer for 30 years, the percentage of people highlighting an increase was higher (Fig.39).

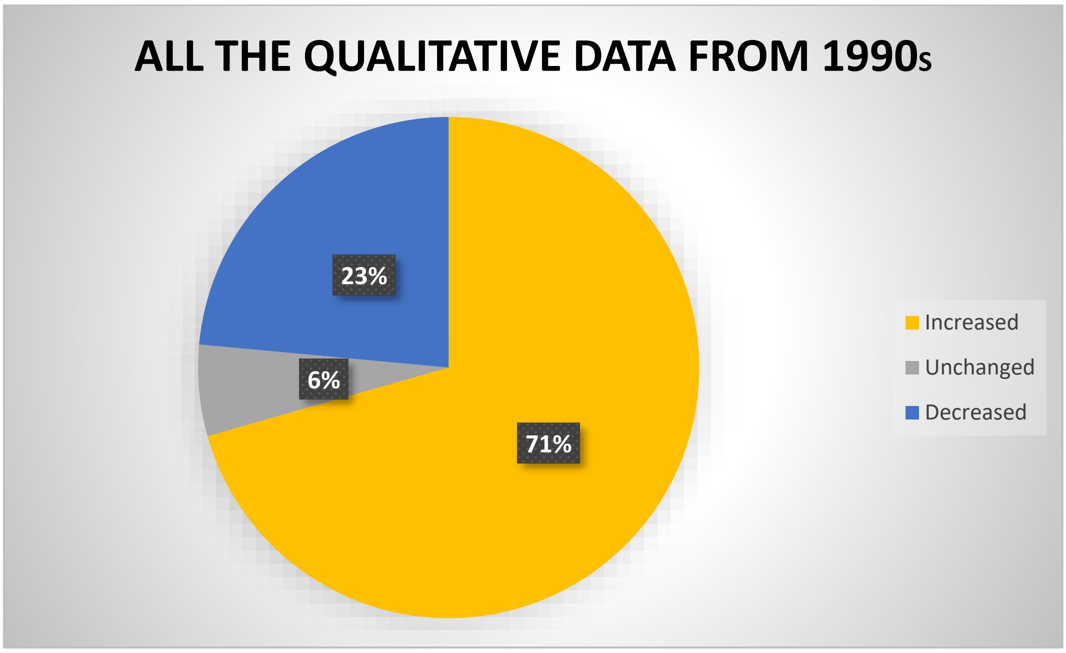

Fig.39. Graph representing the qualitative answers drawn from the questionnaires of people with at least 30 years' experience in the field. Values grouped in 3 categories (increased, unchanged, decreased) and expressed in percentages.

5. DISCUSSION

The results obtained from the analysis of the data concerning the questionnaires turned out to be very satisfactory and strong, while from the visual census ones it was found that more in-depth investigations would be needed.
This study provided a first assessment of the occurrence and density of the European lobster in the Gulf of Trieste. The first aim was to see if there was a difference in the number of individuals between inside and outside the Marine Protected Area, or among areas with different levels of protection. This study did not highlight any difference in density. The lack of a clear reserve effect in terms of abundance could be related to the fact that the *Miramare MPA* is very small, as already described above. This could negatively affect what could be the "reserve effect" on animals particularly prone to move a lot, such as the *H. gammarus* species, which can move a lot during the night for feeding (Mehrtens et al. 2005). In fact, in studies conducted on larger MPAs, it was observed that the European lobster preferred to remain within the MPA (Fernández-Chacón et al. 2021; Pettersen et al. 2009). A difference, even if not significant, in the average of medium-sized European lobsters was evidenced by the number of individuals found between those detected inside the *MPA of Miramare* and those found outside the MPA. A difference has already been noted in other works (Fernández-Chacón et al. 2021; Øresland, Oxby, and Oxby 2018).
Knowing that the European lobster is a nocturnal predator it was expected to find more individuals during night dives (Mehrtens et al. 2005). Indeed, the highest number of individuals found in a location (4 individuals) was recorded in the T2 night dive. However, no significant effect of night vs day dives was observed.
A substantial difference was seen by comparing the individuals found towards the bottom (Fig.41) with those found not on the bottom (Fig.40).

Fig.40. Example of individual spotted on the cliff (NB).

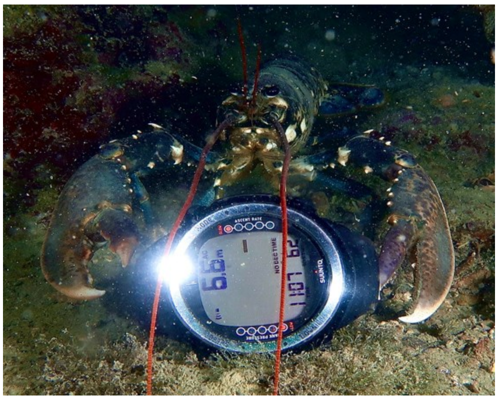

Fig.41. Example of individual sighted on the bottom (B).

This data could be influenced by the fact that mainly diurnal dives were conducted and therefore European lobsters were found mostly inside or near the burrows, which are created by the same animals usually between the rock and the mud or the sand on the bottom (Mehrtens et al. 2005).
These data allow us to advise as a starting point for future investigations, carried out with the *Visual Census* method on the *H. gammarus* species, to deploy the

transects in such a way as to sample only the seabed, leaving aside the part of the reef.

The surveys conducted through questionnaires provided interesting results on historical trend in the abundance of *H. gammarus* species in the *Gulf of Trieste.*

All the interviews (divers, researchers, and fishermen) go in the same direction, confirming a positive trend with both quantitative and qualitative data for the abundance of the *H. gammarus* species in the *Gulf of Trieste* in the last 50 years. The data are consistent even across different areas of the *Gulf* (*Barcola, Sistiana, Muggia, Miramare*), confirming a growing trend in all areas, even if both the quantitative and qualitative data showed that the trend is not exactly linear but has undergone some fluctuations in some locations such as *Barcola* (decreased in "2000 – '10" decade and then increased) (Fig.26), *Sistiana* (decreased in "2010 – '20" decade and then increased) (Fig.27), and *Miramare MPA* (decreased in "2010 – '20" decade and then increased) (Fig.29).

This increase in the abundance of European lobsters in the *Gulf of Trieste* was unable to find explanations in the experts interviewed.

However, it could be linked to the lack of fishing that this species undergoes in this area, or to the fact that fishing is well regulated and well executed, favoring the release into the sea of females caught with eggs. This could have favored the proliferation of the species over the years, to the point of making it grow in abundance.

Another plausible hypothesis is that linked to the ever higher frequency of absence of predators both for the larval stages of the species and for the adult stages (Conversi, Peluso, and Fonda-Umani 2009).

A third hypothesis could be linked to climatic change which could also have favored the decrease of predators, but above all could be linked to the big increase that almost all the experts interviewed have been able to observe for the last 2 years (2020 -2022). This big increase could be related to the abnormally warm marine conditions of spring 2020 and winter 2021 which could have favored a longer reproductive period and greater survival of larval and adult stages of *H. gammarus*, as found in other species such as *R. pulmo* (Reyes Suárez et al. 2022).

6. CONCLUSIONS

From this study emerges the need to go deeper and therefore to conduct future research on the *H. gammarus* species in the *Gulf of Trieste*.

Although from this study it was not possible to notice a “reserve effect” deriving from the presence of the *Miramare MPA*, a proposal for future studies on this possible positive effect of this MPA on the European lobster could be to tag the animals to analyze their movements, as already done in other works (Fernández-Chacón et al. 2021; Jézéquel, Bonnel, and Chauvaud 2021; Lees et al. 2018). This would allow to understand if the reserve effect is actually absent due to the reduced area that the *Miramare MPA* is able to cover, or if instead a possible positive effect could exist.

Some very interesting results emerged from the interviews made with the most experts at the local level and this should be taken as an excellent starting point for a more detailed analysis in the future. Since in literature it is very difficult to find historical data on the trend of the density of European lobsters in the *Gulf of Trieste*, this study could represent a good starting point for a more detailed reconstruction.

The use of the LEK proved to be of fundamental importance for the study, confirming the fact that local naturalistic knowledge (of the most expert in the field) should be considered much more often as a possible source of data to be taken into consideration.

In any case, more in-depth studies with a greater number of opinions would be necessary to confirm the positive trends that resulted.

In conclusion, this work offers some very interesting ideas and cues, from which, it could be possible to obtain a lot of results of scientific interest, but also economic.

ACKNOWLEDGEMENTS

The author would like to thank before anyone else Prof.ssa Carlotta Mazzoldi, Dott. Marco Segarich, Dott. Saul Ciriaco and Dott. Paolo Guidetti without whom it would not have been possible to develop all this.
Then, a special thanks also goes to the divers who were able to help by collaborating for the various dives for the samplings, and all the other people who have helped in some way for the realization of this paper: Carlo Franzosini, Lorenzo Fant, Lisa Faresi, Vera Cirinnà, Ilaria Gnesda, Pierfrancesco Pece, Barbara Belaz, Andrea Moretti, Alessio Coslovi, Giulia Mazzero, Riccardo Senigalia, Fabrizio Gianni, Luciano Cirinnà.

7. REFERENCES

Aiken, D. E., and S. L. Waddy. 1982. "Cement Gland Development, Ovary Maturation, and Reproductive Cycles in the American Lobster Homarus Americanus." *Journal of Crustacean Biology* 2(3): 315–27.

AMP Miramare Specie e Habitat [Online] // Area Marina Protetta Miramare. - Miramare, Area Marina Protetta.

Atema, Jelle. 1986. " Review of Sexual Selection and Chemical Communication in the Lobster, Homarus Americanus ." *Canadian Journal of Fisheries and Aquatic Sciences* 43(11): 2283–90.

Bannister, R. C.A., and J. T. Addison. 1986. "Effect of Assumptions about the Stock-Recruitment Relationship on a Lobster (Homarus Gammarus) Stock Assessment." *Canadian Journal of Fisheries and Aquatic Sciences* 43(11): 2353–59.

Bannister, R. C.A., and J. T. Addison. 1998. "Enhancing Lobster Stocks: A Review of Recent European Methods, Results, and Future Prospects." *Bulletin of Marine Science* 62(2): 369–87.

Bannister, R.C.A., J.T. Addisom, and S.R.L. Lovewell. 1994. "Growth , Movement , Recapture Rate and Survival of Hatchery-Reared Lobsters (Homarus Gammarus (Linnaeus , 1758)) Released into the Wild on the English East Coast Author (s): R . C . A . Bannister , J . T . Addison and S . R . J . Lovewell Source : Cr." 67(2): 156–72.

Barton, Bruce A., and George K. Iwama. 1991. "Physiological Changes in Fish from Stress in Aquaculture with Emphasis on the Response and Effects of Corticosteroids." *Annual Review of Fish Diseases* 1(C): 3–26.

Beaumont, A, and T Gjedrem. 2004. *Evaluation of Genetic Impact of Aquaculture Activities on Native Populations. A European Network: Scallops - Pecten Maximus and P. Jacobaeus*.

Branford, J. R. 1978. "Incubation Period for the Lobster Homarus Gammarus at Various Temperatures." *Marine Biology* 47(4): 363–68.

Broadhurst, M. K. 2000. "Modifications to Reduce Bycatch in Prawn Trawls: A Review and Framework for Development." *Reviews in Fish Biology and Fisheries* 10(1): 27–60.

Brock, V.E. 1954. "A Preliminary Report on a Method of Estimating Reef Fish Populations Author (s): Vernon E . Brock Source : The Journal of Wildlife Management , Vol . 18 , No . 3 (Jul ., 1954), Pp . 297-308 Published by : Wiley on Behalf of the Wildlife Society Stable." *Journal of Wildlands Management* 18(3): 297–308.

Browne, R.M., J.P. Mercer, and M.J. Duncan. 2001. Coastal Shellfish — A Sustainable Resource *An Historical Overview of the Republic of Ireland's Lobster (Homarus Gammarus Linnaeus) Fishery, with Reference to European and North American (Homarus Americanus Milne Edwards) Lobster Landings*.

Caldeira, Ken, and Michael E. Wickett. 2003. "Anthropogenic Carbon and Ocean PH." *Nature* 425(6956): 365.

Caputi, Nick et al. 2010. "The Effect of Climate Change on the Western Rock Lobster (Panulirus Cygnus) Fishery of Western Australia." *Canadian Journal of Fisheries and Aquatic Sciences* 67(1): 85–96.

Carter, Hayley A., Lina Ceballos-Osuna, Nathan A. Miller, and Jonathon H.

Stillman. 2013. “Impact of Ocean Acidification on Metabolism and Energetics during Early Life Stages of the Intertidal Porcelain Crab Petrolisthes Cinctipes.” *Journal of Experimental Biology* 216(8): 1412–22.
Case, Ryan J., Guido F. Pauli, and D. Doel Soejarto. 2005. “Factors in Maintaining Indigenous Knowledge among Ethnic Communities of Manus Island.” *Economic Botany* 59(4): 356–65.
Chopin, F. S., and T. Arimoto. 1995. “The Condition of Fish Escaping from Fishing Gears-a Review.” *Fisheries Research* 21(3–4): 315–27.
Ciriaco, Saul, Riserva di Biosfera di Miramare.
Cobb, J Stanley, and Kathleen M Castro. 2006. “Shell Disease in Lobsters: A Synthesis.” (May): 1–18.
Cockcroft, A. C., D. Van Zyl, and L. Hutchlngs. 2008. “Large-Scale Changes in the Spatial Distribution of South African West Coast Rock Lobsters: An Overview.” *African Journal of Marine Science* 30(1): 149–59.
Coleman, Matthew T. et al. 2021. “From the Adriatic to Northern Norway - Geographic Differences in Moult Increment and Moult Probability of the European Lobster (Homarus Gammarus), across the Natural Range.” *ICES Journal of Marine Science* 78(2): 611–20.
Conversi, A., T. Peluso, and S. Fonda-Umani. 2009. “Gulf of Trieste: A Changing Ecosystem.” *Journal of Geophysical Research: Oceans* 114(7): 1–10.
Costello, Mark J., and Bill Ballantine. 2015. “Biodiversity Conservation Should Focus on No-Take Marine Reserves: 94% of Marine Protected Areas Allow Fishing.” *Trends in Ecology and Evolution* 30(9): 507–9. http://dx.doi.org/10.1016/j.tree.2015.06.011.
Cox, P. A. 2000. “Will Tribal Knowledge Survive the Millennium?” *Science* 287(5450): 44–45.
Cressie, N. A.C., and H. J. Whitford. 1986. “How to Use the Two Sample T-Test.” *Biometrical Journal* 28(2): 131–48.
Davis, Michael W. 2002. “Key Principles for Understanding Fish Bycatch Discard Mortality.” *Canadian Journal of Fisheries and Aquatic Sciences* 59(11): 1834–43.
Day, Jon et al. 2019. Best Practice Protected Area Guidelines Series *Guidelines for Applying the IUCN Protected Area Management Categories to Marine Protected Areas Second Edition*. www.iucn.org/pa_guidelines.
DeFries, Ruth et al. 2007. “Land Use Change around Protected Areas: Management to Balance Human Needs and Ecological Function.” *Ecological Applications* 17(4): 1031–38.
Dewalt, B. R. 1994. “Using Indigenous Knowledge to Improve Agriculture and Natural Resource Management.” *Human Organization* 53(2): 123–31.
Diego, San, and Jan Robert Factor. 1995. “Book Reviews.” 147: 172–73.
EDWARDS, A. W. F. 1960. “The Meaning of Binomial Distribution.” *Nature*.
Edwards, Martin, and Anthony J. Richardson. 2004. “Impact of Climate Change on Marine Pelagicfile:///Users/Amougi/Desktop/ Ecosystem 1.Txt Phenology and Trophic Mismatch.” *Nature* 430(7002): 881–84.
FAO. 2022. “29 June, 2022.”
FAO Homarus gammarus Linnaeus,1758. [Journal]. - [s.l.] : © FAO 2022. Homarus gammarus Linnaeus,1758., 2022. - Vol. Fisheries and Aquaculture Division [online]..
Fernández-Chacón, Albert et al. 2021. “Demographic Responses to Protection

from Harvesting in a Long-Lived Marine Species." *Biological Conservation* 257(March).
Ferrario, Filippo et al. 2014. "The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation." *Nature Communications* 5(May): 1–9.
Friuli-Venezia-Giulia Regione Autonoma La rete europea Natura 2000 per la tutela della biodiversità [Online] // Tutela dell'ambiente, sostenibilità e gestione delle risorse naturali. - January 2022, La rete europea Natura 2000 per la tutela della biodiversità. - https://www.regione.fvg.it/rafvg/cms/RAFVG/ambiente-territorio/tutela-ambiente-gestione-risorse-naturali/FOGLIA203/FOGLIA119/.
Galparsoro, Ibon et al. 2009. "Predicting Suitable Habitat for the European Lobster (Homarus Gammarus), on the Basque Continental Shelf (Bay of Biscay), Using Ecological-Niche Factor Analysis." *Ecological Modelling* 220(4): 556–67.
Garrabou, J., N. Bensoussan, and E. Azzurro. 2018. "Monitoring Climate-Related Responses in Mediterranean Marine Protected Areas and beyond: FIVE STANDARD PROTOCOLS." : *Institute of Marine Sciences, Spainsh Research Council ICM-CSIC, Passeig Marítim de la Barceloneta*. http://dx.doi.org/10.20350/digitalCSIC/8612.
Gazzetta Ufficiale della Repubblica Italiana Art.4 [Online] // Gazzeta Ufficiale. - 2004. - https://www.gazzettaufficiale.it/atto/serie_generale/caricaArticolo?art.versione=1&art.idGruppo=0&art.flagTipoArticolo=0&art.codiceRedazionale=09A01349&art.idArticolo=4&art.idSottoArticolo=1&art.idSottoArticolo1=10&art.dataPubblicazioneGazzetta=2009-02-14.
Gell, Fiona R., and Callum M. Roberts. 2003. "Benefits beyond Boundaries: The Fishery Effects of Marine Reserves." *Trends in Ecology and Evolution* 18(9): 448–55.
Godoy, R. 1994. "The Effects of Rural Education on the Use of the Tropical Rain Forest by the Sumu Indians of Nicaragua: Possible Pathways, Qualitative Findings, and Policy Options." *Human Organization* 53(3): 233–44.
Gómez-Baggethun, Erik, Esteve Corbera, and Victoria Reyes-García. 2013. "Traditional Ecological Knowledge and Global Environmental Change: Research Findings and Policy Implications." *Ecology and Society* 18(4).
Gómez-Baggethun, Erik, and Victoria Reyes-García. 2013. "Reinterpreting Change in Traditional Ecological Knowledge." *Human Ecology* 41(4): 643–47.
Goñi, Raquel, and Daniel Latrouite. 2005. "Review of the Biology, Ecology and Fisheries of Palinurus Spp. Species of European Waters: Palinurus Elephas (Fabricius, 1787) and Palinurus Mauritanicus (Gruvel, 1911)." *Cahiers de Biologie Marine* 46(2): 127–42.
Grünberg, J., and S. Bidegain. 1965. "Estudio Práctico de La Funcionalidad Renal." *Archivos de pediatria del Uruguay* 36(7): 469–80.
Gubbay, Susan. 1989. . . . ". . . And Future." *Nature* 342(6248): 374–374.
Guidetti, Paolo, and Enric Sala. 2007. "Community-Wide Effects of Marine Reserves in the Mediterranean Sea." *Marine Ecology Progress Series* 335: 43–56.
Halpern, Benjamin S. 2003. "The Impact of Marine Reserves: Do Reserves Work

and Does Reserve Size Matter?” *Ecological Applications* 13(1 SUPPL.).
Halpern, Benjamin S., and Robert R. Warner. 2002. “HalpernWarnerEL.Pdf.” : 361–66.
Horta, Bárbara et al. 2016. “A Regulation-Based Classi Fi Cation System for Marine Protected Areas (MPAs).” 72: 192–98.
IUCN Red List [Online]. - https://www.iucnredlist.org/.
Jennings, Simon, and Michel J. Kaiser. 1998. 34 Advances in Marine Biology *The Effects of Fishing on Marine Ecosystems*. Elsevier Masson SAS. http://dx.doi.org/10.1016/S0065-2881(08)60212-6.
Jézéquel, Youenn, Julien Bonnel, and Laurent Chauvaud. 2021. “Potential for Acoustic Masking Due to Shipping Noise in the European Lobster (Homarus Gammarus).” *Marine Pollution Bulletin* 173(September).
Kai, Zhang et al. 2014. “Shifting Baselines on a Tropical Forest Frontier: Extirpations Drive Declines in Local Ecological Knowledge.” *PLoS ONE* 9(1).
Kampouris, Thodoros E. et al. 2020. “New Data on the Biology and Fisheries of the Threatened Palinurus Elephas (Fabricius, 1787) (Decapoda, Achelata, Palinuridae) from the North-West Aegean Sea, Greece.” *Water (Switzerland)* 12(9).
Kennelly, Steven J., and Matt K. Broadhurst. 2002. “By-Catch Begone: Changes in the Philosophy of Fishing Technology.” *Fish and Fisheries* 3(4): 340–55.
Lees, Kirsty J. et al. 2018. “Movement Patterns of a Commercially Important, Free-Ranging Marine Invertebrate in the Vicinity of a Bait Source.” *Animal Biotelemetry* 6(1): 1–12. https://doi.org/10.1186/s40317-018-0152-4.
Lenihan, Hunter S. et al. 2021. “Evidence That Spillover from Marine Protected Areas Benefits the Spiny Lobster (Panulirus Interruptus) Fishery in Southern California.” *Scientific Reports* 11(1): 1–9. https://doi.org/10.1038/s41598-021-82371-5.
Lester, Sarah E., and Benjamin S. Halpern. 2008. “Biological Responses in Marine No-Take Reserves versus Partially Protected Areas.” *Marine Ecology Progress Series* 367: 49–56.
Maffi, Luisa. 2005. “Linguistic, Cultural and Biological Diversity.” *Annual Review of Anthropology* 34: 599–617.
Maine department of Marine Resources. 2017. “LOBSTERING.” (July): 1–24.
Malej, A. et al. 1995. “Phytoplankton Responses to Freshwater Inputs in a Small Semi-Enclosed Gulf (Gulf of Trieste, Adriatic Sea).” *Marine Ecology Progress Series* 120(1–3): 111–22.
Marilles Foundation 10 EUR of benefit for every euro invested in the MPA of Llevant (Mallorca) [Online] // Marilles Foundation. - July 23, 2021. - https://marilles.org/en/post/10--de-beneficio-por-cada-euro-invertido-en-la-reserva-.
Mckee, Karen. 2012. Global Change and the Function and Distribution of Wetlands *Global Change and the Function and Distribution of Wetlands*.
McNeill.S.E. 1994. “The Selection and Design of Marine Protected Areas: Australia as a Case Study.” *Biodiversity and Conservation* 3(7): 586–605.
Van Der Meeren, G I. 2003. *The Potential of Ecological Studies to Improve on the Survival of Cultivated and Released Aquatic Organisms: Insights from Functional Morphology and Behaviour Studies of the European Lobster _Homarus Gammarus_ .*

van der Meeren, Gro I, and Oddvar Soldal. 1998. "The European Lobster Homa R Us Gammar Us (L.) Proceedings From the Seminar At Kvitsøy 1995." : 100.
Mehrtens, Folke et al. 2005. "Locomotory Activity and Exploration Behaviour of Juvenile European Lobsters (Homarus Gammarus) in the Laboratory." *Marine and Freshwater Behaviour and Physiology* 38(2): 105–16.
Micheli, Fiorenza, Benjamin S Halpern, and Louis W Botsford. 2004. "NO-TAKE MARINE RESERVES." 14(6): 1709–23.
Murphy, Michael D. et al. 1995. "Mortality of Spotted Seatrout Released from Gill-Net or Hook-and-Line Gear in Florida." *North American Journal of Fisheries Management* 15(4): 748–53.
Natura 2000 Network [Online]. - https://natura2000.eea.europa.eu/.
Nazarea, Virginia D. 2006. "Local Knowledge and Memory in Biodiversity Conservation." *Annual Review of Anthropology* 35: 317–35.
Neumann, Barbara, Athanasios T. Vafeidis, Juliane Zimmermann, and Robert J. Nicholls. 2015. "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment." *PLoS ONE* 10(3).
Olivotti, R., J. Faganeli, and A. Malej. 1986. "Impact of 'organic' Pollutants on Coastal Waters, Gulf of Trieste." *Water Science and Technology* 18(9): 57–68.
Øresland, Vidar, Gert Oxby, and Fredrik Oxby. 2018. "A Comparison of Catches of the European Lobster (Homarus Gammarus) in a Lobster Reserve Using Traditional Pots and Scuba Diving Technique." *Crustaceana* 91(12): 1425–32.
Padilla, Elisabeth, and Gary P. Kofinas. 2014. "'Letting the Leaders Pass': Barriers to Using Traditional Ecological Knowledge in Comanagement as the Basis of Formal Hunting Regulations." *Ecology and Society* 19(2).
Pettersen, Alf Ring, Even Moland, Esben Moland Olsen, and Jan Atle Knutsen. 2009. "Lobster Reserves in Coastal Skagerrak - An Integrated Analysis of the Implementation Process." *Integrated Coastal Zone Management*: 178–88.
Philippart, C. J.M. et al. 2011. "Impacts of Climate Change on European Marine Ecosystems: Observations, Expectations and Indicators." *Journal of Experimental Marine Biology and Ecology* 400(1–2): 52–69. http://dx.doi.org/10.1016/j.jembe.2011.02.023.
Pilgrim, Sarah E., Leanne C. Cullen, David J. Smith, and Jules Pretty. 2008. "Ecological Knowledge Is Lost in Wealthier Communities and Countries." *Environmental Science and Technology* 42(4): 1004–9.
Pitcher, T. J. 2001. "Fisheries Managed to Rebuild Ecosystems? Reconstructing the Past to Salvage the Future." *Ecological Applications* 11(2): 601–17.
Pranovi, F. et al. 2001. "Discard Analysis and Damage to Non-Target Species in the 'Rapido' Trawl Fishery." *Marine Biology* 139(5): 863–75.
Puig, Pere et al. 2012. "Ploughing the Deep Sea Floor." *Nature* 489(7415): 286–89.
Quetglas, Antoni et al. 2004. "Common Spiny Lobster (Palinurus Elephas Fabricius 1787) Fisheries in the Western Mediterranean: A Comparison of Spanish and Tunisian Fisheries." *Bolleti de la Societat d'Historia Natural de les Balears* 47: 63–80.
Reyes-García, Victoria et al. 2013. "Evidence of Traditional Knowledge Loss among a Contemporary Indigenous Society." *Evolution and Human*

Behavior 34(4): 249–57. http://dx.doi.org/10.1016/j.evolhumbehav.2013.03.002.
Reyes Suárez, Nydia Catalina et al. 2022. " Multi-Platform Study of the Extreme Bloom of the Barrel Jellyfish Rhizostoma Pulmo (Cnidaria: Scyphozoa) in the Northernmost Gulf of the Mediterranean Sea (Gulf of Trieste) in April 2021 ." *Ocean Science* 18(5): 1321–37.
Roberts et al. 2001. "Effects of Marine Reserves on Adjacent Fisheries." *Science* 294(5548): 1920–23.
———. 2017. "Marine Reserves Canmitigate and Promote Adaptation to Climate Change." *Proceedings of the National Academy of Sciences of the United States of America* 114(24): 6167–75.
Royal Museums Greenwich What exactly is 30x30? [Online] // Royal Museums Greenwich,. - 2022. - https://www.rmg.co.uk/stories/our-ocean-our-planet/what-is-30x30-marine-protected-areas-ocean-2030.
Rozemeijer, M J C, and K E Van De Wolfshaar. 2019. "Desktop Study on Autecology and Productivity of European Lobster (Homarus Gammarus, L) in Offshore Wind Farms." : 65. https://edepot.wur.nl/466861.
Russo, Aniello, and Antonio Artegiani. 1996. "A d Ria Tic S Ea h y d r o g Ra p h y *." 60: 33–43.
Sale, Peter F. et al. 2005. "Critical Science Gaps Impede Use of No-Take Fishery Reserves." *Trends in Ecology and Evolution* 20(2): 74–80.
Sale, Peter F., and William A. Douglas. 1981. "Precision and Accuracy of Visual Census Technique for Fish Assemblages on Coral Patch Reefs." *Environmental Biology of Fishes* 6(3–4): 333–39.
Samoilys, Melita A., and Gary Carlos. 2000. "Determining Methods of Underwater Visual Census for Estimating the Abundance of Coral Reef Fishes." *Environmental Biology of Fishes* 57(3): 289–304.
Sandin, Stuart A. et al. 2008. "Baselines and Degradation of Coral Reefs in the Northern Line Islands." *PLoS ONE* 3(2).
Scheffers, Brett R. et al. 2016. "The Broad Footprint of Climate Change from Genes to Biomes to People." *Science* 354(6313).
Schmalenbach, Isabel, and Heinz Dieter Franke. 2010. "Potential Impact of Climate Warming on the Recruitment of an Economically and Ecologically Important Species, the European Lobster (Homarus Gammarus) at Helgoland, North Sea." *Marine Biology* 157(5): 1127–35.
Sokolov, A. P. et al. 2009. "Probabilistic Forecast for Twenty-First-Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters." *Journal of Climate* 22(19): 5175–5204.
Solidoro, Cosimo et al. 2007. "Understanding Dynamic of Biogeochemical Properties in the Northern Adriatic Sea by Using Self-Organizing Maps and k-Means Clustering." *Journal of Geophysical Research: Oceans* 112(7): 1–13.
Taylor, Publisher et al. "North American Journal of Fisheries Factors Influencing Bycatch Mortality of Trawl-Caught Pacific Halibut Factors Influencing Bycatch Mortality Of." (January 2013): 37–41.
Thresher, Ronald E, John S Gunn, Csiro Marine Laboratories, and G P Box. 1986. "<Thresher&Gunn1986.Pdf>."
Titilola S. The economics of incorporating indigenous knowledge systems into agricultural development: a model and analytical framework. [Book

Section]. - 1990. - Vol. Stud Technol Soc Chang..
Tully, O., V. Roantree, and M. Robinson. 2001. “Maturity, Fecundity and Reproductive Potential of the European Lobster (Homarus Gammarus) in Ireland.” *Journal of the Marine Biological Association of the United Kingdom* 81(1): 61–68.
Upton, Graham J. G. 1992. “Fisher’s Exact Test.” *Wiley*.
Wahle, Richard A., Lanny Dellinger, Scott Olszewski, and Phoebe Jekielek. 2015. “Receding in the Face of Climate Change.” 72.
Walther, Kathleen, Klaus Anger, and Hans O. Pörtner. 2010. “Effects of Ocean Acidification and Warming on the Larval Development of the Spider Crab Hyas Araneus from Different Latitudes (54° vs. 79° N).” *Marine Ecology Progress Series* 417: 159–70.
Ward, Raymond D., Daniel A. Friess, Richard H. Day, and Richard A. Mackenzie. 2016. “Impacts of Climate Change on Mangrove Ecosystems: A Region by Region Overview.” *Ecosystem Health and Sustainability* 2(4).
Warren D. Indigenous knowledge, biodiversity conservation and development. [Book Section]. - 1996. - Vol. Sustain Dev third world Ctries..
White, D. P. et al. 1985. “Influence of Testosterone on Ventilation and Chemosensitivity in Male Subjects.” *Journal of Applied Physiology* 59(5): 1452–57.
Yellen, John E et al. 2016. “A Middle Stone Age Worked Bone Industry from Katanda , Upper Semliki Valley , Zaire Kathlyn Stewart Published by : American Association for the Advancement of Science Stable URL : Http://Www.Jstor.Org/Stable/2886646 A Middle Stone Age Worked Bone Industry.” 268(5210): 553–56.