ngo pomalo

For us, living here for a whole year long, Komiža, with our fishermen, stone homes and Adriatic Sea, is the place to be (Fig. 1). In order to preserve it so that future generations can live here in balance with nature, we feel obliged to initiate a discussion on climatic changes that our environment is facing today, and seek climate justice for our fishermen.

MANUAL ON THE IMPACT OF CLIMATE CHANGE ON SUSTAINABLE DEVELOPMENT OF FISHERY OF THE VIS ARCHIPELAGO

Fisherman stories

The content of this brochure is the responsibility of:

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Supported by a grant from Open Society Institute –Sofia Foundation (OSIS) with the support of Open Society Foundations (OSFs) and in cooperation with the Open Society European Network (OSEN). Responsibility for the contents and views expressed in the manual therein lies entirely with the Association Pomalo and in no way can be construed as reflecting the official position of OSIS, OSFs or any affiliated entities.

Year: 2021

Content

Introduction

Figure 1.
Komiža main city port.

Prompted by the unfavorable situation of the local fishing community of the island of Vis, which arises from the fact of the non-existence of a strategy for the sustainable development of fishery, we have prepared a document aiming to inform local community, as well as Vis visitors, on the impacts of climate change on the Adriatic Sea fishery. Along with education on the effects of climate change and affirmation of fishing activities, the purpose of this publication is to conduct a survey on presence of foreign thermofilic fish species in the Adriatic sea and their effects on the sea ecology and sustainability of fishery. The survey is based on the knowledge and experience of local fishermen, as well as on published scientific records on the impacts of climate change on the ichthyofauna of the Adriatic Sea. The survey revealed the increase in the abundance of some key thermofilic fish species within target area of a Vis archipelago. In addition, cooperation with local fishermen in monitoring of the impact of climate change revealed some key problems that local fishery is facing today, crucial for decision-making processes on ways of sustainable management of the Adriatic Sea.

Geomorphology of the Adriatic Sea

Situated in the northmost part of the Mediterranean, Adriatic Sea is a rather small semi-enclosed marine environment very susceptible to climate change [55, 21, 41]. It is characterized with an elongated shape *(Fig. 2)*, with a shallow northern and a deeper southern part [51]. North Adriatic never exceeds 100 meters [21]. Greatest depth in the area of Middle Adriatic is 273 m in the Jabuka Pit, while the South Adriatic hosts the South Adriatic Pit with the depth of 1233 m [21].

Eastern coast of the Adriatic Sea is high, rocky and articulated with many islands *(Fig. 2)*, and thus characterized by the abundance of coastal habitats [21]. Level of fish biodiversity of these coastal habitats however, are defined by thermohaline properties (temperature and salinity) of the marine environment [51], determined by the interactions between sea and air, river discharge, mixing, currents, water exchange and topography of the basin [21].

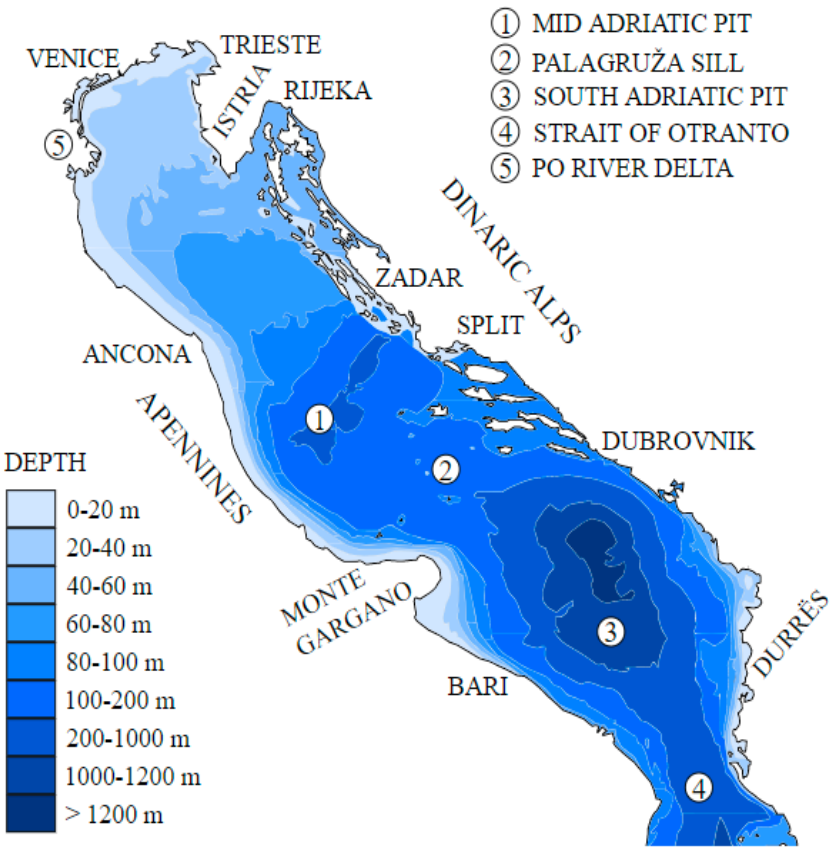

Figure 2.
Depth of the Adriatic Sea [40].

Thermohaline properties of the Adriatic Sea

The Adriatic Sea is a peculiar area with a strong latitudinal gradient *(Fig. 3)*, characterized by very low winter temperatures in the northern part and very hot summers in the southern part [77, 22, 49]. Mean temperatures of the deepest layers of the Adriatic Sea are above 10 °C during the whole year [51, 21]. In winter, temperatures of the surface water are between 6 and 15 °C, with lower temperature in the northern part and higher ones in the southern part of the basin [51, 21]. In summer, the upper water layers can reach temperatures of 22–25 °C [51]. The open sea is generally warmer than the coastal waters [78, 21].

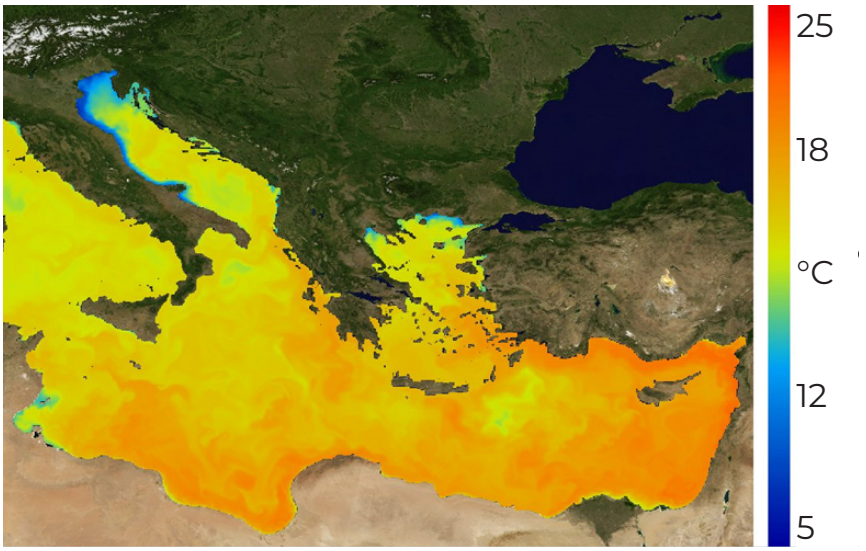

Figure 3.
Temperature of the Adriatic Sea [33].

The average salinity of the Adriatic Sea is 38.3 ‰, with the lower values observed during the winter months [51]. The highest salinity occurs in the South Adriatic (38.4 to 38.9 ‰). Overall, salinity decreases from south to north, and from open sea to the coast [21].

Currents in the Adriatic Sea consist of surface, intermediate and bottom layer and are influenced by general Mediterranean circulation regimes [21]. The surface circulation of the Adriatic Sea (Fig. 4) is characterized with northerly flow along the eastern coast (EAC), and southerly flow along the western coast (WAC) [46, 21]. Furthermore, as shown in *Fig. 4* we differentiate subcurrents: North Adriatic Gyre (NAdG), Middle Adriatic Gyre (MAdG), and South Adriatic Gyre (SAdG) [38].

Currents in the Adriatic Sea consist of surface, intermediate and bottom layer and are influenced by general Mediterranean circulation regimes [13]. The surface circulation of the Adriatic Sea *(Fig. 4)*, is characterized with northerly flow along the eastern coast (EAC), and southerly flow along the western coast (WAC) [29, 13]. Furthermore, as shown in *Fig. 4* we differentiate subcurrents: North Adriatic Gyre (NAdG), Middle Adriatic Gyre (MadG), and South Adriatic Gyre (SadG) [24].

Influx of water from the Ionian Sea and/or central Mediterranean into the Adriatic Sea depends upon the cyclonic or anticyclonic regime, and occurrence of extreme weather conditions [21, 41]. Influx of warmer, nutrient rich and more saline Ionian waters contributes to the presence of some rare (and foreign) species in the Adriatic waters and has a profound influence on the Adriatic biodiversity [21].

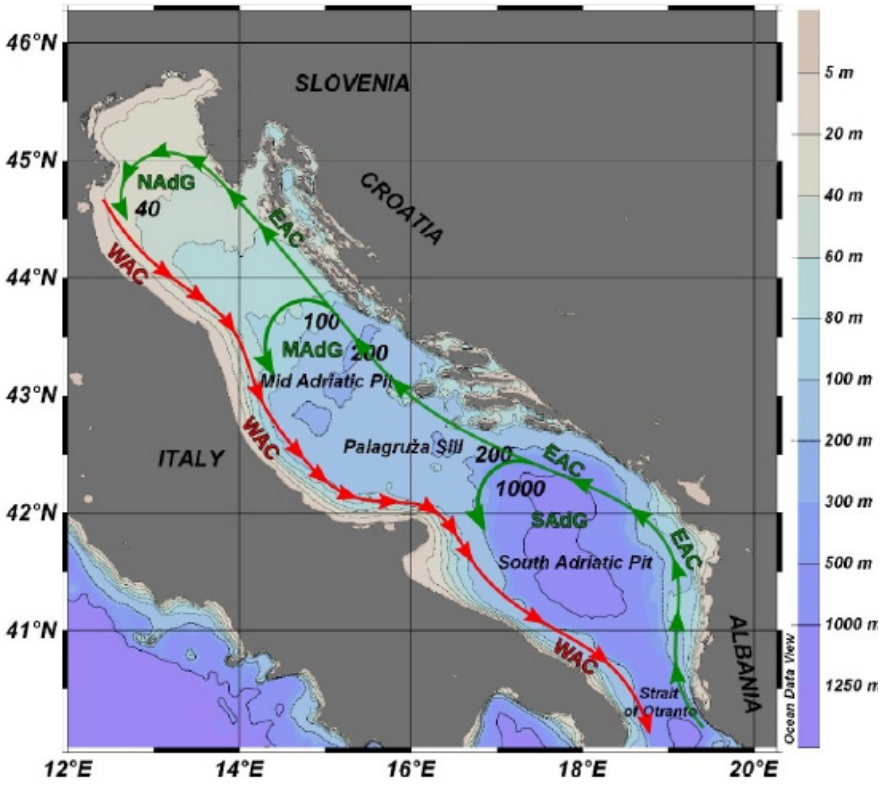

Figure 4.
Sea currents of the Adriatic Sea [24].

Influence of the climate change on the Adriatic Sea

The climate change is usually perceived as the buildup of carbon dioxide and other greenhouse gases in the atmosphere, causing a rise in mean atmospheric temperature [21]. Changes in mean atmospheric temperature and rainfall are reflected in changes in temperature, salinity, oxygen level, circulation and seasonal patterns of seas and oceans [41]. Namely, increase in water temperature leads to reduction of oxygen and increase in salinity level of the marine environment, while indirect effects are modification in water circulation [41, 13]. In addition, excess carbon dioxide in atmosphere leads to increase in acidity or pH level of the Adriatic Sea [41].

The consequences of the climate change are reflected in significant changes in biodiversity of the Adriatic Sea [21]. Namely, the flora and fauna of the Adriatic Sea is a result of the numerous geological, geographical, climatic and biological processes [21]. During the last few decades however, in addition to factors such as significant anthropogenic activity, it is the climate change that has played a crucial role in shaping of the Adriatic ecosystem [21]. As a result, the Adriatic ecosystem is subjected to a continuous process of alteration, including ichthyofauna [13, 37, 51, 21]. For that reason, fishes are excellent indicators of the effects of environmental changes and climate variability [21]. In that perspective, data collected by fishermen in their professional activity are crucial for monitoring of the current status of climate change effects and its repercussions on the Adriatic Sea ichthyofauna.

Time series of the mean annual sea surface temperature measured at Split, Hvar, and Komiža stations *(Fig. 5)*, in last three decades clearly show increasing trend, with values for Komiža being annually the highest [9]. Recent reports estimate an increase in the temperature of the Adriatic Sea by 1.6 to 2.4 °C, and an increase in the mean annual salinity in the Adriatic between 0.4 and 0.8 ‰ by 2070 [41]. The expected consequences are migration of fish into deeper waters and to the north, increased number of foreign species, and significant impact on biodiversity and abundance of domestic fish species [41]. In order to adapt to the climate change, it is crucial to encourage local fishermen to use their own knowledge and experience to participate in monitoring of the climate change impacts on the state of ichthyofauna of the Adriatic Sea, to cooperate with information on issues related to their needs, as well as to participate in the decision making processes on ways of sustainable management of the Adriatic Sea.

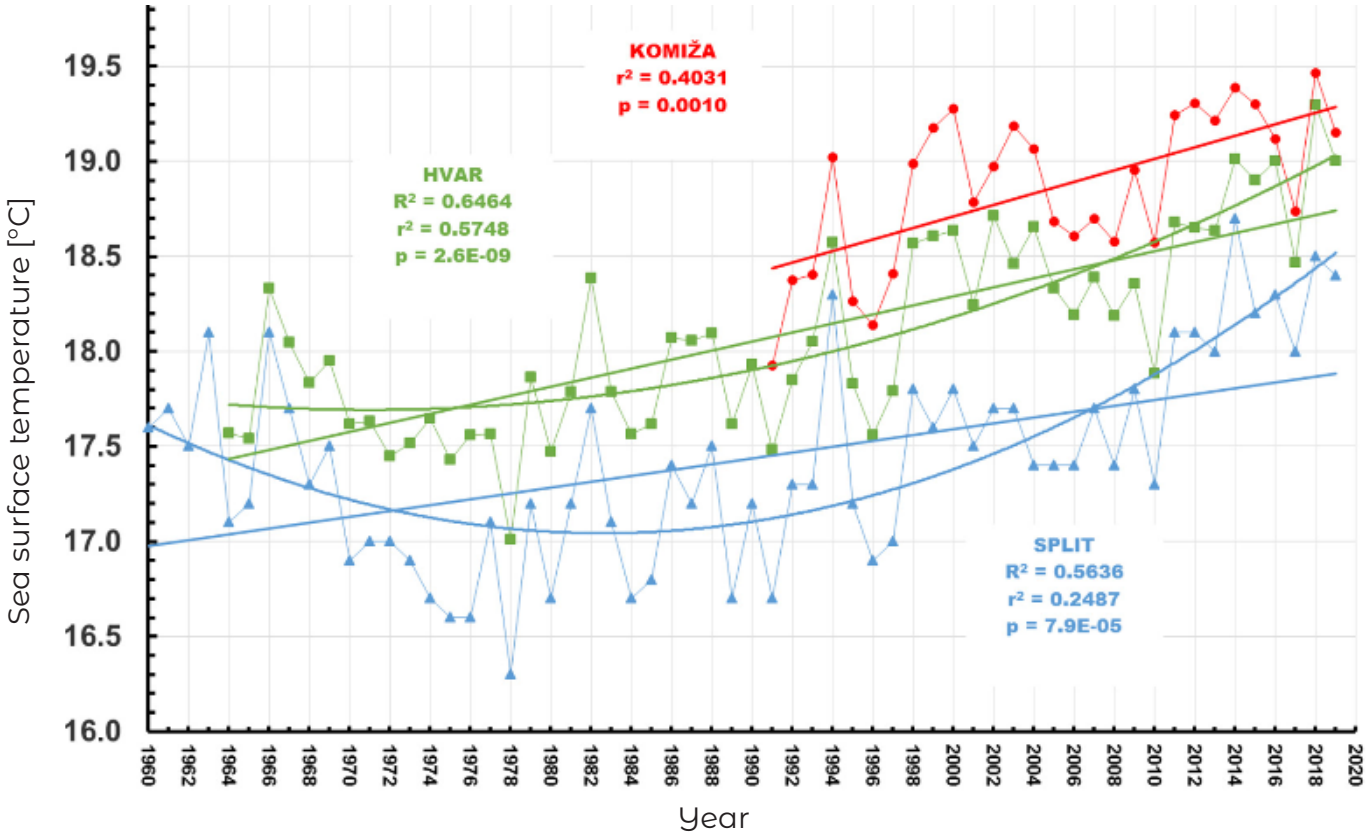

Figure 5.
Time series of the mean annual sea surface temperature measured at Split, Hvar, and Komiža stations [9].

Changes in the Adriatic Sea ichtyofauna

Monitoring the effects of climate change

Climate change affects the entire marine ecosystem, and these changes can be reflected in the abundance of specific fish species, so that some become more abundant, and for some the number decreases [21]. Often these changes are the result of expansion or narrowing of the distribution range of specific species depending on their temperature preferences, but also on the number of other ecological changes such as reduced prey presence or increased predation rate [21].
For that reason, the consequences of the climate change are monitored by the influx of foreign fishes, distributional shifts of native fishes and community-level changes of native population of fishes [21]. In the Adriatic Sea, local information on tracking the dynamic of ichthyofauna changes is scarce [49]. Indeed, there is a gap of knowledge on such dynamics mainly due to the lack of high resolution data both in space and time [49]. Most scientific knowledge is limited to published records of the first occurrence of species in new areas and long-term data series are usually lacking [49].

Marine fishers accumulate a vast amount of Local Ecological Knowledge (LEK) during their fishing activity that is of paramount importance for monitoring how climate change affects the structure of biological communities [49]. Investigating local ecological knowledge of specific target groups such as professional and recreational fishers, information on changes in ichthyofauna can be easily accessed on large geographical scale and can be used to identify and monitor occurrence and abundance of those fish species that are regarded as indicators of climate change [49]. Monitoring such phenomena is of paramount importance for adaptive management of the Adriatic Sea [49]. In continuation of this chapter, we show examples of the impact of climate change on the abundance of small pelagic fish species in the Adriatic. It is important to emphasize that the impact of climate change on the marine fisheries sector is complex, due to the fact that the effects can be both positive and negative in economic terms [21]. The consequences of climate change on fishing communities will depend on their exposure to change, the sensitivity of important species and ecosystem in general to climate change, but also on fishermen ability to adapt to new situations [23, 21].

Distributional shifts of native fishes

Fishery of the Eastern Mediterranean is traditionally based on fishing of small pelagic fish of cold water affinity such as Sardine *(Sardina pilchardus, Fig. 6)*, Anchovy *(Engraulis encrasicolus, Fig. 7)*, Sprat *(Sprattus sprattus, Fig. 8)*, and to a lesser extent Picarel *(Spicara smaris, Fig. 9)* [41, 29]. Three first mentioned small pelagic fish species are traditionally and economically the most important species of the Eastern Adriatic fishery [41]. Furthermore, small blue fish is the basic raw material of the traditional processing industry which was once based primarily on salting and canning [24, 41]. Nowadays, Sardine and Anchovy still amount up to 80 % of total commercial catch [41].

Figure 6.
Sardine (Sardina pilchardus).

Figure 7.
Anchovy (Engraulis encrasicolus) [62].

Figure 8.
Sprat (Sprattus sprattus) [65].

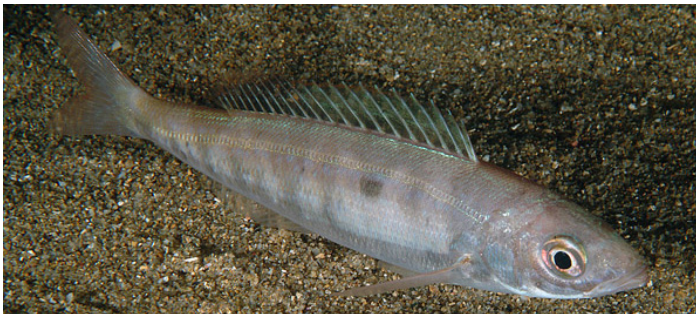

Figure 9.
Picarel (Spicara smaris) [76].

Pelagic fish species such as Chub mackerel *(Scomber japonicus, Fig. 10)*, Horse mackerel *(Trachurus trachurus, Fig. 11)*, and Atlantic mackerel *(Scomber scombrus, Fig. 12)*, are of considerable importance for Adriatic Sea fishery as well. They amount up to about 10 % of commercial catch [41]. Furthermore, these species feed upon small pelagic fish such as Anchovy and Sardine and small sea crabs. It is worth of noting that several decades ago Atlantic mackerel almost entirely disappeared from the Adriatic [72].

Figure 10.
Chub mackerel (Scomber Japonicus).

Figure 11.
Horse mackerel (Trachurus trachurus).

Figure 12.
Atlantic mackerel (Scomber scombrus) [72].

Fluctuations in sea temperature in the last decades are directly related to the catch of small pelagic fish in the Adriatic [41]. Because of their sensitivity to climate change, distribution and abundance of small pelagic fish are excellent ecological indicators [21]. Due to an increase in sea temperature, the fish species of cold water affinity are subjected to reduction of distribution due to northward shift of population or meridionalization [21]. The North Adriatic, being the coldest part *(Fig. 3)*, serves as a refuge for cold temperate species, but continuation of warming might cause the trapping effect and may cause the extinction of the endemic species [21, 4].

Community-level changes of native population of fishes

Native cold water fish species such as European sprat and Sardine, are in decline in the last few decades [30, 21]. In the Mediterranean Sea, a replacement of Sardine and European sprat with Round sardinella *(Sardinella aurita, Fig. 13)*, already occurs in the catches [57], due to Round sardinella expansions [47, 21]. Round sardinella is well known to our fishermen. In the mid of 19th century, due to low amount of Sardine in the Adriatic Sea, fishermen from Hvar in an organized manner caught large quantities of this fish species in the vicinity of Lampedusa and Northern African coast [24]. Nowadays however, due to its northern expansions, this species is also becoming increasingly abundant in the Adriatic Sea, although it is still being caught in lower quantities than Anchovy and Sardine [21]. This species also enters the Northern Adriatic in economically interesting quantities, but has not yet found its place in the fishing industry, despite the fact that in some other countries it plays a very significant role in catches and the economy [12].

Figure 13.
Round sardinella (Sardinella aurita) (left) and Sardine (Sardina pilchardus) (right) [24].

Influx of foreign fishes

Another example of the impact of climate change on small pelagic fish species relates to the gradual spread of lessepsian fish species towards the north. Namely, since its opening in 1869, over 87 fish species have invaded the Mediterranean Sea through Suez Canal [43, 21]. Of those, over 14 lessepsian fish species were encountered in the Adriatic Sea [21]. These foreign species alter the faunal composition but may also cause severe alterations to ecosystem structure and function [48, 6]. One example is that of Brushtooth lizardfish *(Saurida lessepsianus, Fig. 14).* Unlike Round sardinella, this species is in prey- predator relationship with native Sardine and Anchovy, and thus have possible negative influence on local communities of those pelagic species [21]. Other example is that of top predator Bluespotted cornetfish *(Fistularia commersonii, Fig. 15),* which can potentially affect populations of native fish species like: Sardine, Anchovy, and Picarel [21]. Impacts do not have to be of ecological or economical nature [21]. Records including occurrences of juveniles indicate that Bluespotted cornetfish established its populations in the South Adriatic [18, 21].

Figure 14.
Brushtooth lizardfish (Saurida lessepsianus) [7].

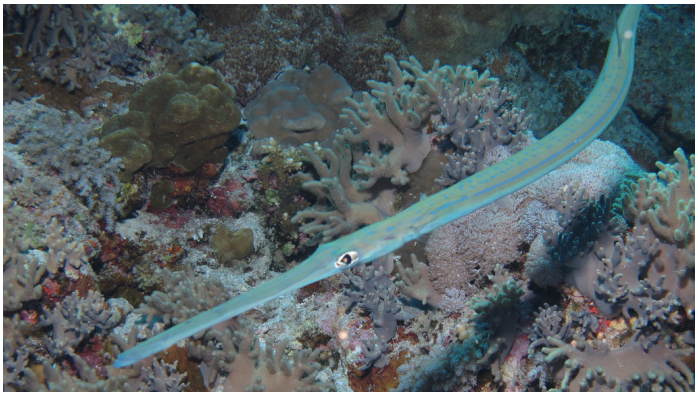

Figure 15.
Bluespotted cornetfish (Fistularia commersonii) [68].

Arrival of foreign species of tropical origin affecting thermophilic species well adapted to worm waters is termed tropicalization [21]. Consequences may be an increase of abundance of certain species due to extension of the northern limit of species distributions [21]. Presence or increase in abundance of certain thermophilic species in the Adriatic Sea is usually attributed to water warming [21]. These can be a result of seasonal sea temperature change, yet in the case of first encountered species this effect is related to climate change or facilitated by it [21]. For that reason, thermophilic fishes in the Adriatic are categorized into: A) native species, and B) exotic species recently entered in [2, 21]. These both are a migratory species, moving northwards in the summer months and returning southwards when the sea temperature starts to fall. Native thermophilic species in Adriatic however, are those that require temperatures high enough for the reproductive processes and development of eggs, and minimum winter temperatures above their lethal limits [44, 49].

Questionnaire

Comprehensive information about the northward expansion of the foreign thermophilic species is difficult to obtain and available data is usually fragmented in space and time [49]. To address this issue, we have accessed the Local ecological knowledge of professional fishers, recreational fishers and spearfishes in this part of the Adriatic Sea, i.e., Vis archipelago. Local fishers represent a huge and widespread network of observers with a great potential source of information to investigate local changes on fish communities and monitor sea ecology [49]. Firstly, we have investigated the information on increase in the abundance of northward expanding thermophilic fish species. Also, investigated were information on abundance of domestic, and especially, on presence of rare and endangered domestic fish species. Finally, we have investigated fishermen views on current state and future development of fishery.

To access the Local ecological knowledge, we used direct survey approach, i.e., personal communication with local fishermen. Local fishermen were asked to answer eleven questions shown in *Table 1.* Questions 1-3 aimed to identify level of the fishing experience of the respondents, as well as to identify fishing methods and techniques used. Questions 1-7 aimed collecting information on foreign thermophilic and rare fish species caught in this part of Adriatic Sea, as well as obtaining information on where the fish species were caught. The respondents were invited to indicate which fish they have caught among those reported on a list of 36 foreign thermophilic species reported so far in the Adriatic. To clearly identify species, each option was associated to a species picture, together with its common and scientific name [49]. Then the respondents were asked to identify the geographical location where the fish species were caught. Questions 8-10 aimed to identify the fishermen view on the development of fishery, as well as to identify the most important problems they face today. Final question aimed to measure fishermen perception about recent changes in the fish species abundance and distribution in the Adriatic Sea. Data collection was confidential, as we did not record any sensitive personal information about respondents, who were informed about the purpose of the study [49].

1.	When did you start fishing and how long have you been fishing?
2.	What type of fishing do you do, commercial or recreational?
3.	What fishing tools and techniques do you use?
4.	What is your favorite type of fish or catch?
5.	What is the most unusual fish species you have caught?
6.	Have you encountered foreign fish species in the Adriatic?
7.	Which foreign fish species is your most common catch and where do you catch it?
8.	How do you see the future of fishery?
9.	What do you consider to be the biggest problem of fishery today?
10.	What do you enjoy the most about fishing?
11.	Do you notice changes compared to the period about twenty years ago?

Table 1.
Questionnaire on development of fishery and presence of foreign and rare fish species.

Results

Fishermen's experience, methods and techniques used in fishery

A total of 42 respondents completed the questionnaire. Among the fishermen participating in this survey, 50 % of respondents is commercially engaged in fishery. Age and fishing experience of the local fishermen participating in the survey is shown in *Figure 16*. The average age of respondents was 43, and the average period of fishing activities was 27.9 years. In average our respondents are engaged in fishery for 62.5 % of their lifetime. Thus, our survey considered local fishermen with considerable fishing experience.

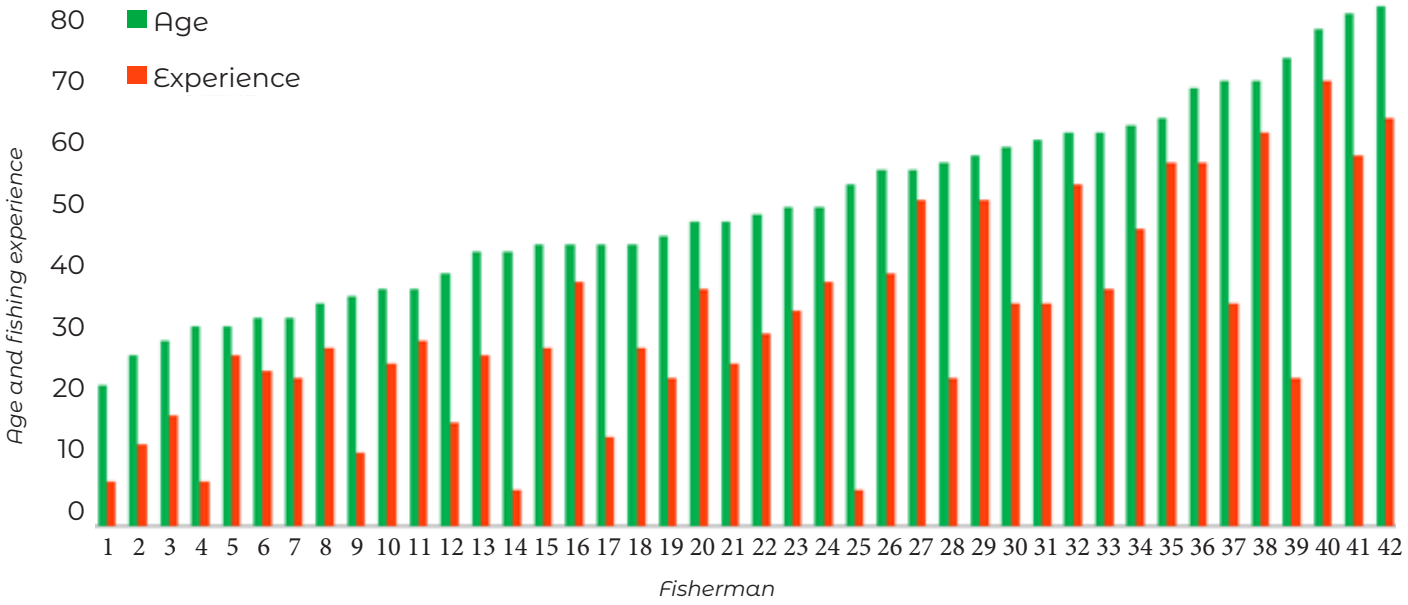

Figure 16.
Age and fishing experience of the local fishermen participating in the survey.

Among fishing techniques used *(see Fig. 17)*, local fishermen predominantly used: longline (23.5 % of replies), followed by angling (21.7 %), and trap fishing (14.8 %). Remaining techniques such as spearfishing, purse-seine and drift-net fishing were marked with 13.0, 8.7 and 7.8 % of use, respectively. The least used technique was trawl line fishing with 0.9 % of respondent replies. Fishing technique used influenced the possible catch, as many of the selective fishing techniques omit ability of catching certain fish species.

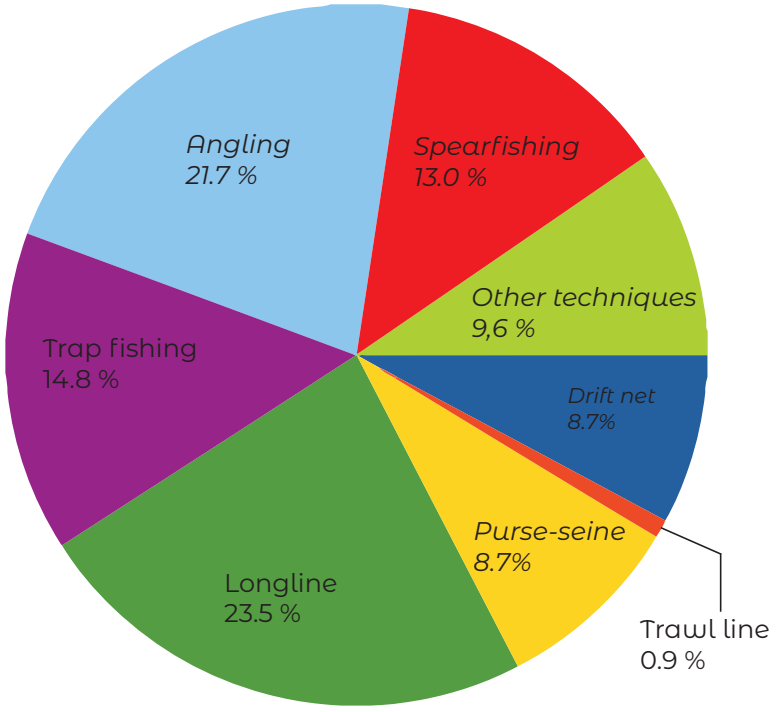

Figure 17.
Fishing techniques used by the local fishermen participating in survey.

Foreign thermophilic fish species

Overall, 78.6 % of respondents had encountered foreign fish species in the Adriatic Sea. This rather high percentage shows that encounters with foreign fish species in this part of the Adriatic are not uncommon. Indeed, in the last 20 years numerous thermophilic fish species have been recorded for the first time in the Adriatic Sea [21]. Observed changes are primarily governed by the climate change [79]. Awareness of the role of these new species within an Adriatic ecosystem is crucial, and their adaptation and influence on the abundance of local population of fishes should be monitored and analyzed [79].

As shown in Figure 18, foreign thermophilic species overall perceived as the most increasing in abundance in Vis archipelago were: Mediterranean parrotfish (Sparisoma cretense, 50.0 % of respondent replies), followed by Grey triggerfish (Balistes carolinensis, 38.1 %), African sailfin flying fish (Parexocoetus mento, 19.0 %), Yellowmouth barracuda (Sphyraena viridensis, 19.0 %), and finally Atlantic lizardfish (Synodus saurus, 19.0 %). Other foreign thermophilic species whose population are experiencing significant increase, marked with range between 10 % and 17 % of respondent replies *(see Fig. 18)*, were: Bluefish (Pomatomus saltatrix, 16.7 %), Yelowstripe barracuda (Sphyraena chrysotaenia, 11.9 %), Silver cheeked toadfish (Lagocephalus sceleratus, 9.5 %), and Keel-jawed needlefish (Tylosurus acus imperialis, 9.5 %). In addition to the above listed fish species, less than 5 % of fishermen also encountered the remaining foreign thermophilic species listed in Figure 18. Among those species, because of their significant impact on Adriatic Sea ecology or importance in socioeconomic terms, we would like to emphasize: Common lionfish (Pterois miles, 4.8 %), Flying burnard (Dactylopterus volitans, 4.8 %), White grouper (Epinephelus aeneus, 4.8 %), Bluespotted cornetfish (Fistularia commersonii, 2.4 %), Mottled grouper (Mycteroperca rubra, 2.4 %), and Blunthead puffer (Sphoeroides pachygaster, 2.4 % of replies).

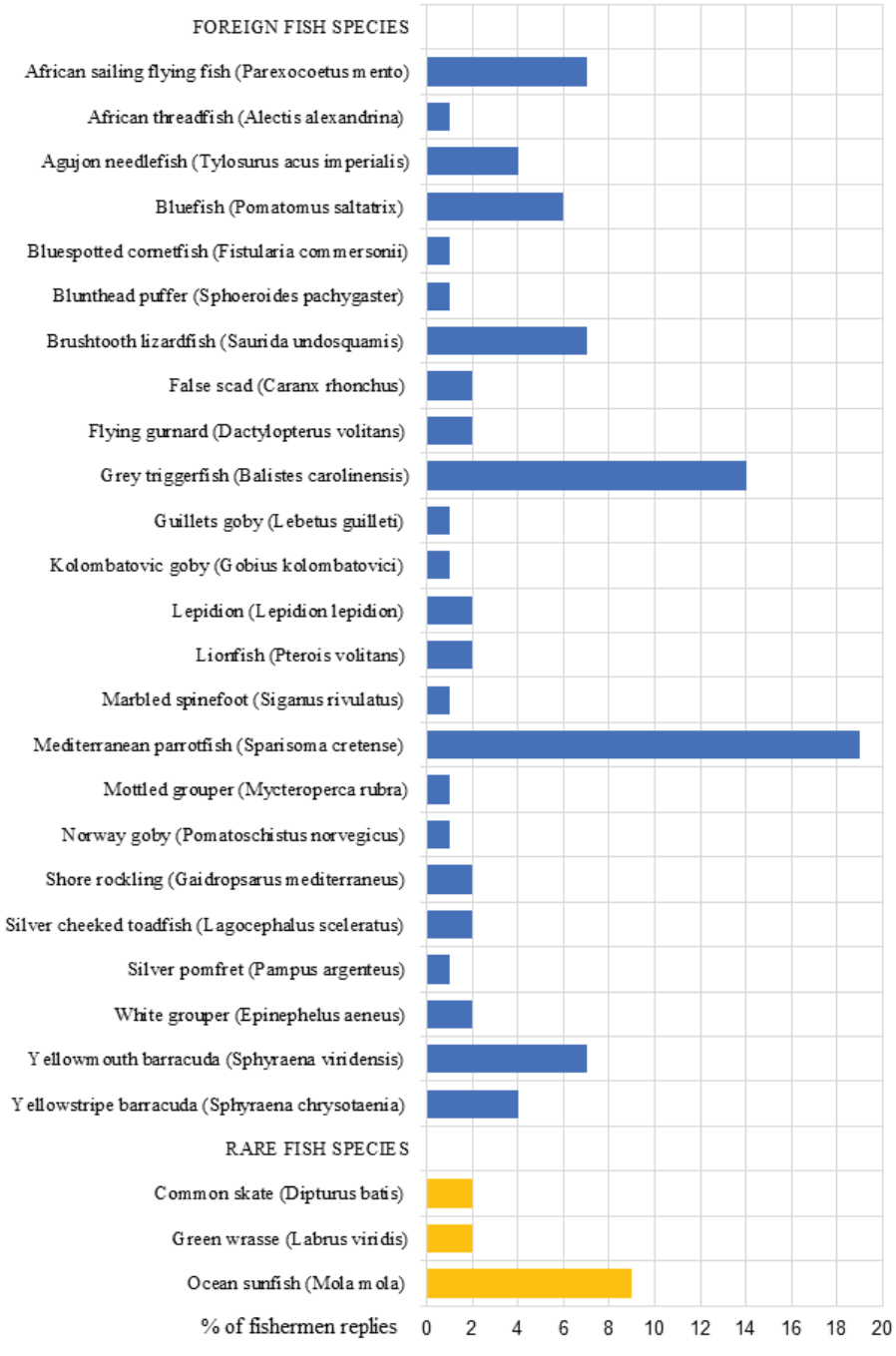

Figure 18.
Results on presence of foreign thermophilic fish species in the Adriatic Sea.

These results are in line with scientific reports on increase in abundance of thermophilic species in Adriatic Sea which are increasingly observed at higher latitudes than those in their native geographical distribution [11, 14, 6, 20, 21, 49]. Indeed, in recent year those thermophilic fish species occur in the catches more often [21]. In the continuation of this chapter, the most important thermophilic fish species reported in our survey are briefly described.

Mediterranean parrotfish (Sparisoma cretense)

The species identified as the most abundant in our survey was Mediterranean parrotfish *(Sparisoma cretense, Fig. 19)*. This fish can change sex as many times as it wants during its lifetime [1]. Males of this species are grayish, while females are colorful. Parrotfish feeds mainly on algae and coral seaweed, thus cleaning coral reefs [1]. This species is native to Mediterranean Sea. First encounter of this species in Adriatic was in 2011 near Cavtat [25]. The available scientific information about Mediterranean parrotfish indicated that the abundance fluctuated in the recent decades with a peak of increase for central Adriatic in 1999 [49]. This species is now becoming more abundant and has become a common species on the southern Adriatic islands [25, 21]. This is confirmed by the results of our survey with 50.0 % of respondent replies confirming encounters with this species, mostly in shallow waters of Komiža and Vis Bay, up to 50 m of depth. It is most commonly caught using drift net fishing technique. Although in our region it is rarely used for food, this fish is edible and has tasty meat.

Figure 19.
Mediterranean parrotfish (Sparisoma cretense).

Grey triggerfish

Second the most abundant thermophilic fish species in our survey was Grey triggerfish *(Balistes carolinensis, Fig. 20)*, with 38.1 % of respondent replies. It is mostly found in the shallow warmer waters of the Atlantic Ocean, yet it is also common in the Mediterranean Sea. Grey triggerfish body is short and broad, flattened at the sides, while its color may be yellowish, brown, blackish, or gray-purple. It feeds on hard shelled animals [21]. In the 1960s, Grey triggerfish was not present in the Southern Adriatic, while today it is a common species in that area [26]. In recent years, population of this species is experiencing significant increase in abundance in Southern and Middle Adriatic due to distributional shift [21]. We have obtained data on presence of juvenile specimens of this species in the main port of the city of Vis. Thus, our results confirm that this thermophilic fish species is domesticated in the Adriatic waters [12]. Although in the older literature Grey triggerfish is not recommended for consumption, recent data indicate that Grey triggerfish from the Adriatic Sea is of excellent quality and can be consumed fresh, smoked, dried and salted [53].

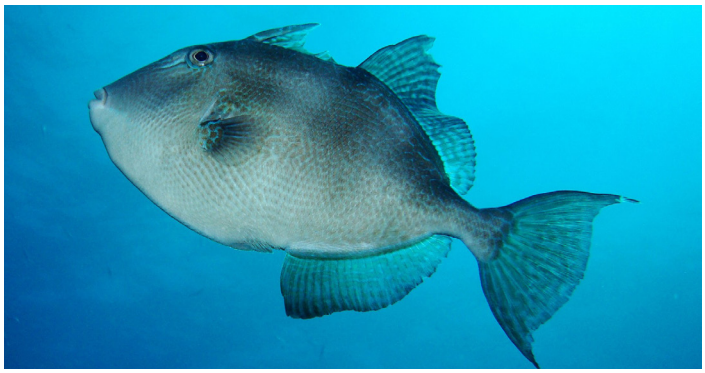

Figure 20.
Grey triggerfish (Balistes carolinensis) [67].

African sailfin flying fish

African sailfin flying fish *(Parexocoetus mento, Fig. 21)* is a Lesepssian fish species. Peculiar characteristic of this species is that they glide over the sea surface up to 200 m in distance [32].
They developed the gliding technique as a means of escape from predators [32]. It resembles sardine and has a very light body structure that includes a large air bubble [32]. For flight, they rely mostly on large pectoral fins that serve as air sailing wings, while tail fins are used as rudder for achieving higher velocity when flying out of the sea [32]. They live in flocks, in warm seas close to the surface [32]. Although in some parts of the Mediterranean these species can be seen all year round, in the Adriatic Sea they are present only in warmer years, when the sea temperature is above 20 °C, and are for that reason more numerous in the Southern Adriatic [32]. This fish species is suitable for human consumption [32]. All species of flying fish are similar in appearance and difficult to distinguish, especially as they are rare in Adriatic [32]. According to the results of our

survey, the African flying fish was encountered by most fishermen catching pelagic fish using purse-seine technique (19.0% of respondent replies), but due to the similarity with other species of flying fish, we can not be sure that it was the said species.

Figure 21.
African sailfin flying fish (Parexocoetus mento) [35].

Yellowmouth, Yelowstripe barracuda and European barracuda

Beside European barracuda *(Sphyraena sphyraena, Fig. 22)*, native to Mediterranean, two new lessepsian species have been recorded in the Adriatic Sea in the last decades: Yelowstripe barracuda *(Sphyraena chrysotaenia, Fig. 23)*, and Yellowmouth barracuda *(Sphyraena viridensis, Fig. 24)* [21]. Yellowmouth barracuda was decade ago either rare or totally absent in the Adriatic Sea [21]. Indeed, the first record of Yellowmouth barracuda in Adriatic was in 2003 near Dubrovnik [14, 49, 25]. In recent years, it has become quite abundant especially in the coastal areas, possibly due to distributional shift [49]. In our survey, Yellowmouth barracuda was reported by 19.0 % of fishermen, indicating considerable increase in abundance, especially nearby the island of Biševo. The presence of Yelowstripe barracuda in the area of Vis archipelago was marked somewhat less (11.9 % of respondent replies). It is expected that the lessepsian barracuda will outnumber the native European barracuda in catches, although Yelowstripe barracuda is still very rare in Adriatic Sea [21]. It is worth noting difficulties in distinguishing these species [21]. One of the main differences in appearance is that compared to European barracuda, Yelowmouth barracuda has more pronounced darker patterns on their sides, while compared to both, Yelowstripe barracuda is characterized with yellowish tail and lighter body colors. These species feed upon small fish and are very interesting in socio-economic sense for purse-seine and jigging fishery due to tasty meat with low fat content [21, 25].

Figure 22.
European barracuda (Sphyraena sphyraena).

Figure 23.
Yelowstripe barracuda (Sphyraena chrysotaenia) [74].

Figure 24.
Yellowmouth barracuda (Sphyraena viridensis) [75].

Atlantic lizardfish

Atlantic lizardfish *(Synodus saurus, Fig. 25)* is a species native to the Mediterranean [25]. It is very common in the Southern Adriatic, while in the northern parts this species is completely unknown [25]. Its natural habitat is sandy and rocky bottom at depths less than 50 m [25]. In the last few years, an increase in the number of this species has been observed along the Eastern Adriatic coast [58, 21]. According to our survey, 19.0 % of fishermen had encounters with lizardfish. In the Adriatic Sea, along with the Atlantic lizardfish, a Brushtooth lizardfish *(Saurida lessepsianus, see Fig. 13)* very similar in appearance can be found. The latter species is a Lesepssian migrant and is

considered very rare [25, 17]. Due to the similarity of these two species, we cannot precisely identify species encountered by the fisherman. Sea lizards are extremely aggressive and voracious carnivores, most often feeding on other fish, crabs and cephalopods [7]. They camouflage perfectly on the seabed. They lurk for their prey while buried in the sand, and at an opportune moment they catch it instantly [7]. The most common prey of sea lizards in the Adriatic are Sardines and Picarel, namely Sardines in the spring-summer period, and Picarel in the autumn-winter period [52]. In some parts of the Eastern Mediterranean, sea lizards are used for human consumption [17].

Figure 25.
Atlantic lizardfish (Synodus saurus).

Bluefish

Perhaps the most striking change in the fish community is an increase in abundance of Bluefish *(Pomatomus saltatrix, Fig. 26)*, decade ago either rare or totally absent in Adriatic Sea [15, 21, 49]. This marine pelagic fish is widely distributed around the world in temperate and subtropical waters. For the area of Northwestern Mediterranean, this species reacts to the increased sea surface temperature by shifting areas of distribution and reproduction northward [15, 47]. An increase in the number of Bluefish, with its simultaneous movement towards the northern parts, was registered during 2002 and 2003 [12]. An unusual catch of Bluefish at the extreme North of the Adriatic was reported in 2005 [15, 49]. In our survey 16.7 % of fishermen encountered this species, and it was caught only using boat angling fishing technique. Furthermore, the respondents stated continuous increase in the abundance of this species in area of Vis archipelago. This fish is a predator of mugils, and it decimated their populations from native habitats in Neretva Estuary [28, 21]. Significant negative effects of this species on communities of native fishes could be compensated through targeted commercial fisheries of this species [21].

Figure 26.
Bluefish (Pomatomus saltatrix) [71].

Silver cheeked toadfish and Blunthead puffer

Not all foreign thermophilic species are suitable for consumption. One such example Silver cheeked toadfish *(Lagocephalus sceleratus, Fig. 27)*. Silver cheeked toadfish is considered a Lessepsian species, although it is also widespread in the warmer parts of the Atlantic Ocean [25]. This species represents a threat to human health and can be fatal if consumed [21]. This problem triggered awareness-raising campaigns in some Adriatic countries [21]. First occurrence of this species in Adriatic Sea was in 2004 nearby Dubrovnik [17]. Multiple occurrences of Silver cheeked toadfish raised doubt whether this species also has self-sustaining population, since its presence might be of periodical nature [21]. It feeds mostly on crabs and cephalopods, often directly from the fishing net [17]. As a defense against predators, it uses the possibility of inflating by swallowing large amounts of water. There is a lack of detail landing data on this species for the Adriatic Sea. In our survey, 9.5 % of fishermen had encountered this species. Furthermore, one more fish species of similar appearance, Blunthead puffer (Sphoeroides pachygaster, Fig. 28)

Figure 27.
Silver cheeked toadfish (Lagocephalus sceleratus) [66].

was reported in our survey (2.4 %). This fish species was registered by the respondent for the first time in the Adriatic Sea 15 years ago in the area of Vis archipelago. This species most likely originates from Atlantic Ocean, and it used to be unregistered in Mediterranean waters until early 80`s [45].

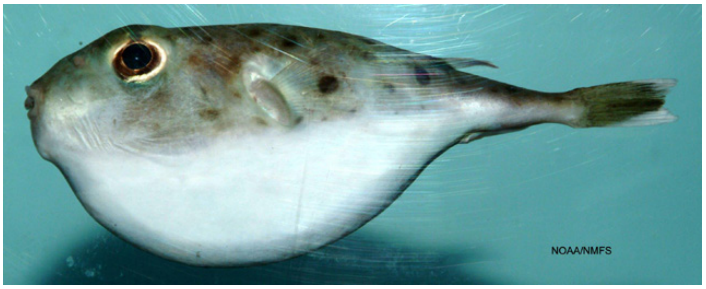

Figure 28.
Blunthead puffer (Sphoeroides pachygaster) [73].

Keel-jawed needlefish

Keel-jawed needlefish *(Tylosurus acus imperialis, Fig. 29)*, is an elongated and thin shaped fish species whose needle-shaped jaw contains lot of small sharp teeth [54]. It is a native fish species in the Atlantic Ocean and Mediterranean Sea [79] Unlike native Adriatic needlefish species, Keel-jawed needlefish is much larger in size, and can grow up to 5 kg in weight and 150 cm in length [54]. It feeds upon smaller fish [32]. In the Adriatic Sea, occurrence of this species was first recorded in its southern part in 1995 in the vicinity of Bari [17, 79]. In 2015, its presence was recorded as purse-seine catch in the vicinity of the island of Mljet. [79]. This was its first appearance within Croatian fishing grounds. Hence, this capture represented the northernmost record of this species in the Adriatic Sea. [79]. In our survey, 9.5 % of respondents reported encounters with Keel-jawed needlefish, indicating that this species shows its presence in the area of Vis archipelago as well. Due to its rarity in the Adriatic Sea, this species has no commercial importance [17].

Figure 29.
Keel-jawed needlefish (Tylosurus acus imperialis) [79].

Common lionfish

Common lionfish *(Pterois miles, Fig. 30)*, is one more foreign species recently reported as a newcomer to the Adriatic Sea [39]. It has been registered for the first time on the location of cape of Stupišće, nearby the city of Komiža. The same result has been confirmed in our survey (4.8 % of respondent replies). This colorful fish is lessepsian migrant that has reached the Eastern Mediterranean from the Red Sea via Suez channel [31, 39]. Often, it can be found near underwater reefs up to 80 meters of depth, yet also in much shallower waters [31, 39]. Lack of natural enemies, the possibility of year-round reproduction, fast and efficient colonization of new areas, and a high rate of predation over indigenous species, place this fish high on the scale of invasiveness and harmfulness to the ecosystem [31, 39]. Furthermore, it is a fish whose sting is poisonous. Its poison is found in its dorsal fins, and its stab should be treated in a similar way as with the Spider fish [31, 39]. In the area of the Eastern Mediterranean, numerous campaigns have been launched with the purpose of monitoring, but also controlling the population of this species in a way that it is targeted for fishing, but also popularized as food, as it is a very tasty fish [31, 39].

Figure 30.
Common lionfish (Pterois miles) [10].

Flying burnard

Flying gurnard *(Dactylopterus volitans, Fig. 31)*, is a native species in Mediterranean Sea and Atlantic Ocean [60]. It is very rare in the Adriatic Sea, and there is a lack of landing data on this species. It was reported encountered by fishermen in Bay of Kotor in 2021 [64]. In our survey, it was confirmed by 4.8 % of fishermen in Komiža and Vis Bay. It can reach size up to 50 cm in length and 1.8 kg in weight [63]. It is variable in coloration, being brownish or greenish with reddish or yellowish patches [8]. The enlarged and colorful pectoral fins are used for defensive displays, courtship displays, and feeding [40]. When excited, the fish spreads its pectoral fins, which are semi-transparent, with a phosphorescent bright blue coloration at their tips [60]. They are benthic species found on sandy bottoms in shallow to moderate depths amid 20 and 100 m [63]. These fishes are seldom observed off the bottom, as their bodies are too heavy and fins too delicate for gliding [40]. An interesting feature of this species is that it makes a snoring sound when stretched to the shore. The Flying gurnard is used for human consumption and has very tasty meat, but due to its rarity in the Adriatic it has no commercial value.

Figure 31.
Flying gurnard (Dactylopterus volitans).

White grouper and Mottled grouper

In the last 10 years on take is significant expansion of groupers, such as White grouper *(Epinephelus aeneus, Fig. 32)*, and Mottled grouper *(Mycteroperca rubra, Fig. 33)* [21]. These species, native in Mediterranean and Atlantic, were first time recorded in South Adriatic in 1999 and 2000, respectively [27, 16]. Since then, they have experienced a northward expansion and were occasionally reported from the areas of South and Middle Adriatic Sea [27, 16]. Recent records show signs of established population in the Eastern Adriatic coast [21]. In our survey, 4.8 % of fishermen reported encounters with White grouper, while Mottled grouper was reported by 2.4 % of fishermen. Our survey results thus confirm expansion of these species in the area of Vis archipelago. Similar to other species of its kind, groupers are not built for long-distance, fast swimming [56]. Typically, they have a stout body and a large mouth, as they swallow prey rather than biting pieces off it [56, 36]. They eat fish, octopuses, and crustaceans and their natural habitats are rocky sea caves [36]. Although the influence of climate change is easily seen through the emergence of new species in the areas where they were previously absent, it is necessary to simultaneously monitor populations of native species and track their adaptation to changing ecosystem [21]. For example, groupers occupied ecological niches of overfished sparides, which is ecologically unacceptable, but their catches might compensate for the economic loss and biomass of sparides [21]. This is especially so because groupers are considered as one of the most delicious sea food in Adriatic. On the other hand, groupers are one of the few animals that are the predator of lionfish and can be used for controling spreading of that species [42].

Figure 32.
White grouper (Epinephelus aeneus) [63].

Figure 33.
Mottled grouper (Mycteroperca rubra) [70].

Rare and endangered domestic fish species

Ocean sunfish

Ocean sunfish *(Mola mola, Fig. 34)*, is the largest bony fish in the world. It has a flat body with an unusual oval shape and can grow up to 2000 kg in weight [64, 32]. It is categorized as vulnerable fish species by the International union for nature conservation [64]. It inhabits depths of more than 500 m all over the world at places rich in vegetation, but often it also comes to the sea surface [32]. It is a real attraction for divers and fishermen to see this fish due to its slow swimming and large body mass [32]. When coming the surface, it usually turns sideways and floats [32]. Its beak is as sharp as a bird's, tucked into its body and toothless [32]. This fish species feeds upon mollusks, fish, crustaceans, even algae, but mostly on jellyfish [32, 64]. Ocean sunfish does not play a significant role in human consumption, mainly because as a rule its flesh is not edible [32, 64]. [32, 64]. The results of our survey showed that encounters with this species are common (23.8% of fishermen replies), as reports of catches in range from 150-220 kg in the Vis area were confirmed.

Figure 34.
Ocean sunfish (Mola mola) [64].

Green wrasse

Green wrasse *(Labrus viridis, Fig. 35)*, is rare domestic fish species considered vulnerable and protected in Croatia with measure of permanent fishing ban [34]. It is very specific due to its coloring. Usually, it is of green color with white dots, that gradually turns into a lighter greenish color, almost white towards the belly [69]. It feeds on mollusks, crabs and sea urchins, and is very timid [34]Its endangerment is caused by mortality due to accidental catches of drift-nets, small fishing gears and especially spear fishing, followed by degradation or disappearance of habitats due to fishery and spread of allochthonous algae in Posidonia meadows, and finally, urbanization and industrialization of the coast including coastal pollution and harassment. [34]. Nevertheless, this species was encountered in Komiža Bay by 2.4 % of fishermen participating in our survey.

Figure 35.
Green wrasse (Labrus viridis).

Common skate

Common skate *(Dipturus batis, Fig 36)*, is a native fish species in Mediterranean, including Adriatic Sea [33, 61]. It generally grows to a length of 2.8 m, and weight up to 97 kg, making it the largest skate in the world [33]. Overall shape features a pointed snout and rhombic shape, with a row of thorns along the tail [61]. The top surface is generally colored olive-grey to brown, and the underside is lighter blue-grey [61]. The species is considered critically endangered by the International union for conservation of nature [61]. It has been described as the first clear case of a fish species brought to the brink of extinction by commercial fishing [19].

Figure 36.
Common skate (Dipturus batis) [3].

The main cause of endangerment of this rye is accidental catch by demersal trawl and deep-line, and rarely by some other fishing gear [19]. It is also threatened by habitat degradation and habitat narrowing due to fishing [19]. Declining population density is further and significantly contributed by some biological characteristics of the species, such as poor reproductive power and slow population renewal, high juvenile mortality, slow growth and low settlement density [19]. However, in our survey, 4.8 % of fishermen stated that they have encountered this fish species, indicating that there is a chance for the recovery of the population of this species.

Fishermen's view on development of fishery

In our Survey, as the most important problems that the local fishery is facing nowadays, fishermen identified *(see Fig. 37)*: irresponsible practices of some fishermen (26.3 % of replies), followed by overfishing (23.8 %), inadequate implementation of fishery legislation (23.8 %), lack of infrastructure (7.5 %), and finally, inadequately organized fish catch market (3.8 %). It is important to note that lack of infrastructure is predominantly a problem of fishermen of the city of Komiža. Namely, 38 % of Komiža fishermen participating in this survey identified this issue as crucial. The main infrastructural shortcomings are: the lack of a pumping station, the unsecured mooring of fishing vessels, as well as the lack of a suitable place for unloading of fish.

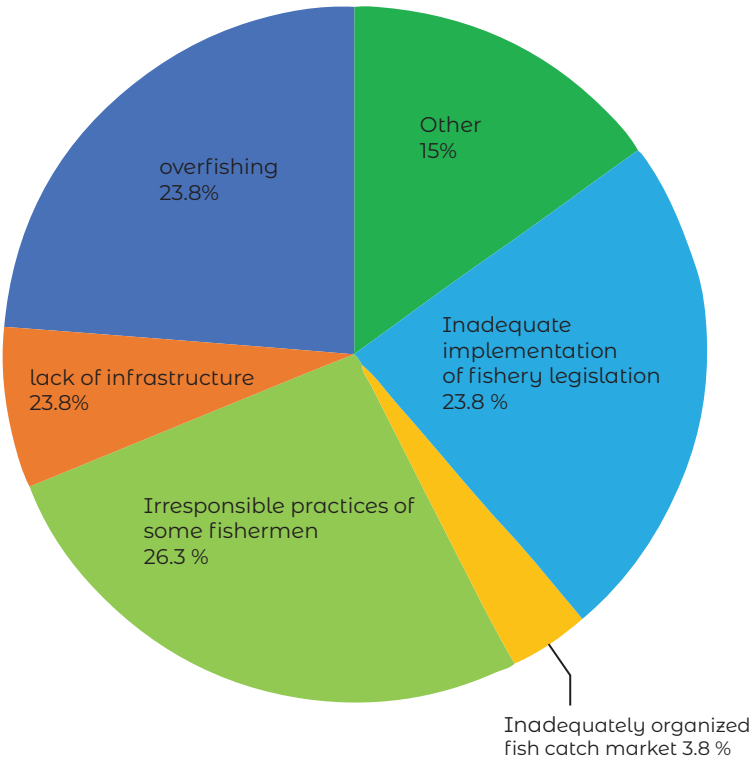

Figure 37.
The most important problems fishery of Vis archipelago is facing today.

Fishermen were asked to define their perception on future of fishery on the island of Vis *(see Fig. 38)*. Predominant answer, with 42.9 % of respondents, was that of pessimistic view on future of local fishery. Main argument of this respondent group is that overfishing very negatively reflects upon fish abundance. Furthermore, the respondents often stated that future generations of fishermen will have much more difficulties in commercial fishery as the abundance of fish is in continuous decline. Neutral stand on future of local fishery shared 29 % of respondents. These group mainly stated that there is future for local fishery, if fishing legislation is adequately implemented and controlled. Same percentage of replies characterized fishermen with positive views on future of local fishery and their optimism was mainly based on good perception of the new legislative decisions. As the most important positively receipted legislative decision, ban of fishing in Jabuka pit was identified. Overall, these results suggest that significant actions in the area of preventing overfishing and implementing fishery regulations are necessary for sustainability of fishery of Vis archipelago.

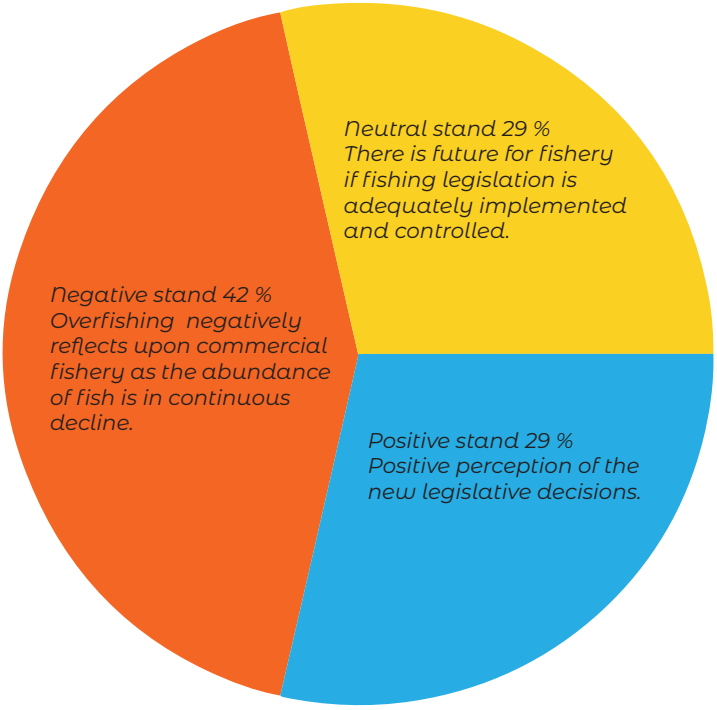

Figure 38.
Fishermen views on future of fishery on the island of Vis.

Conclusion

It is a big disadvantage that the City of Komiža (i.e. its residents and management structures) do not have a strategy for sustainable development of fishery. This is especially so because on the coast and islands, fishing is one of the very few activities that can provide a source of income throughout the year [41]. It is precisely the Local Ecological Knowledge of fishermen, who based on their own experience provide information from the field, that is essential prerequisite for the quality of the studies that are the basis for the development of sustainable fishery strategies. Indeed, Local Ecological Knowledge, defined as the cumulative body of knowledge of individuals during their lifetimes is a suitable tool for environmental monitoring and natural resources management [5, 49].

The advance of the thermophilic species in the last two decades is the evidence of the linkage between climate change and distribution patterns of biodiversity [21]. Effective monitoring of the phenomena is of paramount importance for adaptive management of the Adriatic Sea [49]. This is of particular importance for the Adriatic Sea since the impacts of the global warming are critical in semi-enclosed seas [55, 21, 49]. As a consequence of climate change, abundance of the species of cold water affinity, which are traditionally and economically the most important, have significantly decreased during the last decades [21]. These resources are already under significant stress from overfishing, pollution, coastal development, and habitat degradation [21]. Climate change is an additional stressor impacting coastal systems and communities [21].

The survey revealed the increase in the abundance of some key thermophilic fish species within target area of a Vis archipelago. Overall, 78.6 % of 42 respondents had encountered foreign fish species. Foreign thermophilic species overall perceived as the most increasing in abundance were: Mediterranean parrotfish (50.0 % of replies), followed by Grey triggerfish (38.1 %), African sailfin flying fish (19.0 %), Yellowmouth barracuda (19.0 %), and finally Atlantic lizardfish (Synodus saurus) (19.0 %). Cooperation with local fishermen in monitoring of the impact of climate change revealed some key problems that local fishery is facing today, crucial for decision-making processes on ways of sustainable management of the Adriatic Sea. Those are: irresponsible practices of some fishermen (26.3 % of replies), followed by overfishing (23.8 %), inadequate implementation of fishery legislation (23.8 %), lack of infrastructure (7.5 %), and finally, inadequately organized fish catch market (3.8 %).

Changes in distribution of fish species may lead to changes in income of fisheries sector with both positive and negative consequences [21]. Understanding how climate change influences the fishery revenues is a crucial step towards the development of effective socio-economic policy and food sustainability strategies in adaptation efforts [21]. In order to reduce fishing pressure on native, overexploited stocks, commercial fishery should include adaptive measures to target those species whose population are experiencing significant increase [21]. Thus, it is necessary to simultaneously monitor populations of native and foreign species and track their adaptation to changing ecosystem [21]. For foreign species frequently caught in commercial fisheries, it is necessary to boost their value through public awareness-raising campaigns, educating about their nutritional value, and promote their products in the market [21].

Statement

The results presented in this publication were collected by conducting a survey with local fishermen from the island of Vis, as well as by the analysis of already published scientific literature. Used sources of information are adequately referenced, and the list of references is shown at the end of the publication. In addition to Local ecological knowledge of fishermen, the presented information is mostly based on the research results of the Institute for Oceanography and Fisheries from Split.
Our intention is to present the results of studies on the impact of climate change on the biodiversity of the Adriatic Sea to the local community of the island of Vis. The aim is to encourage local fishermen to cooperate with scientific community in monitoring the impacts of climate change on Adriatic ichthyofauna, to cooperate with information on questions about their needs, and most importantly, to participate in climate change adaptation processes, as well as in decision making processes on ways of sustainable management of the Adriatic Sea.

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About Children of Neptune

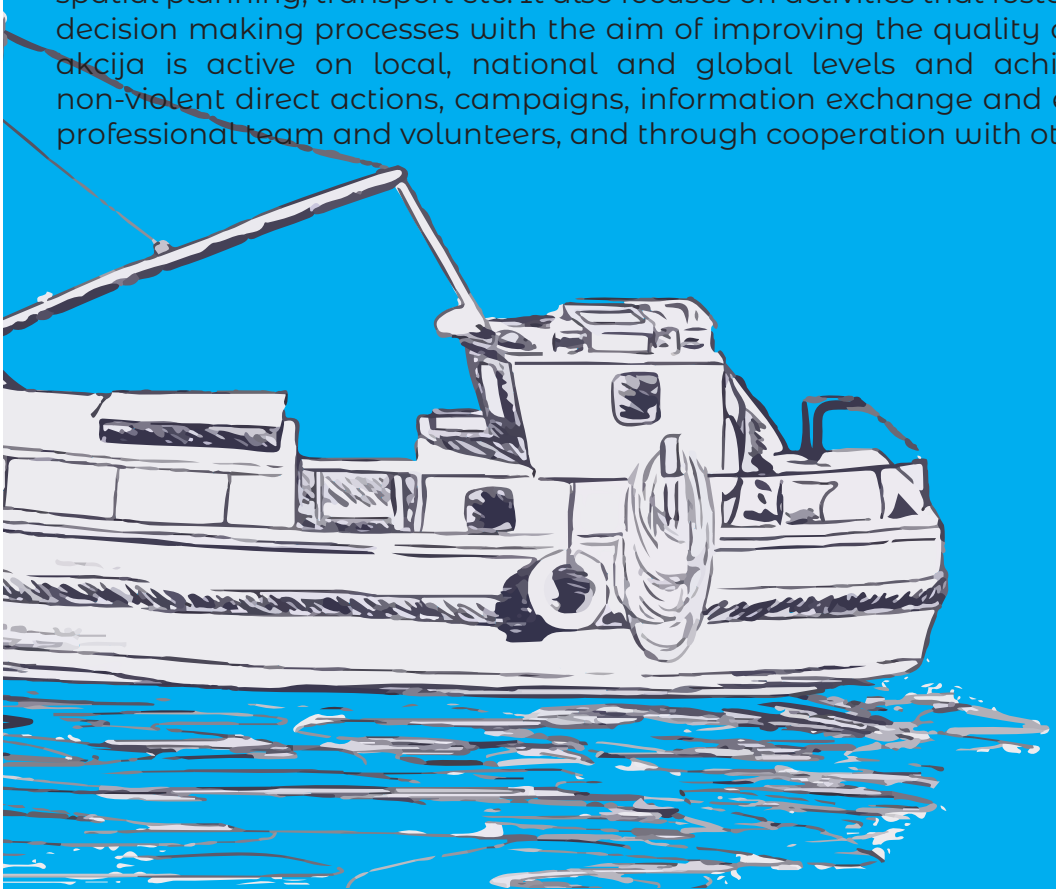
Manual was created as an integral part of the project: Children of Neptune - Climate Change and Sustainable Development of Fishery, funded by the Open Society Institute (OSIFE), Sofia. The project was implemented by partner organizations: Pomalo, Institute for Political Ecology and Zelena Akcija. Aim of the project is to empower citizens of the island of Vis, in particular fishermen as the most vulnerable group, in the face of climate emergency. Focus of the project is on collaborating with small-scale fishers in order to identify practices and systems that might support them; particularly solutions for a more just distribution of climate change-related risks in the local community.

About us

Pomalo is a non-profit organization based on the island of Vis, Croatia. Founded on an intercultural dialogue, the organization advocates for the island of Vis by promoting and protecting sustainable development, cultural values, the environment, nature, social tolerance, and a multicultural society. The goal of the association is to encourage and facilitate the local adoption of sustainable development technologies, as well as to construct a free, open, democratic, pluralistic, and tolerant society based on the values of peace, nonviolence, human rights, internationalism, dialogue, and social justice.

Institute for Political Ecology (IPE) is a research and educational organisation that designs alternative development models and innovative institutional frameworks for democratic political and economic transformation of society. The Institute addresses contemporary ecological changes as social phenomena that reduce or magnify social inequalities and influence power relations. Since its start in 2014, IPE has published a seria of studies and research papers and organised at least 20 voluminous events in the field of IPE program areas.

Zelena akcija is a leading environmental NGO in Croatia, established in 1990, covering broad range of issues such as climate, energy, waste management, nature protection, spatial planning, transport etc. It also focuses on activities that foster public participation in decision making processes with the aim of improving the quality of life in Croatia. Zelena akcija is active on local, national and global levels and achieves its aims through non-violent direct actions, campaigns, information exchange and education, joint work of professional team and volunteers, and through cooperation with other organizations.



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