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.

fishermen, fishery and climate change

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Year: 2021

Content

Introduction

Prompted by the unfavorable situation of the local fishing community of Komiža and the island of Vis, which arises from the fact of the non-existence of a strategy for the sustainable development of fishery, we have decided to prepare a brochure aiming to inform the local community of fishermen, as well as Komiža visitors on the impacts of climate change on Adriatic Sea fishery. Along with education on the effects of climate change and affirmation of fishing activities, the purpose of this publication is to encourage local fishermen to use their knowledge and experience to participate in monitoring of the impacts of climate change on the ichthyofauna of the Adriatic, and cooperate with information on their needs, as well as in decision-making processes on ways of sustainable management of the Adriatic Sea.

Figure 1.
Komiža main city port.

Situated in the northmost part of the Medditerranean, Adriatic Sea is a rather small semi-enclosed marine environment very susceptible to climate change [36, 13, 26]. It is characterised with an elongated shape *(Fig. 2)*, with a shallow northern and a deeper southern part [34]. North Adriatic never exceeds 100 meters [13]. Greatest depth in the area of Middle Adriatic is 273 m in the Jabuka/pomo Pit, while the South Adriatic hosts the South Adriatic Pit with the depth of 1233 m [13].

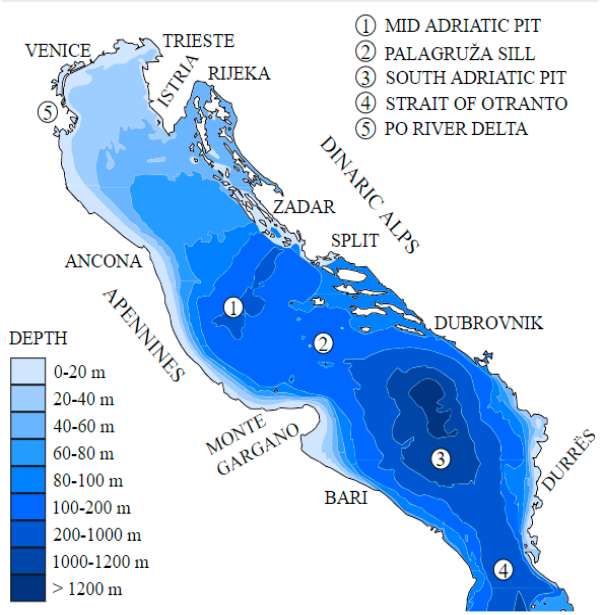

Figure 2.
Depth of the Adriatic Sea [40].

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 [13]. Level of fish biodiversity of these coastal habitats however, are defined by thermohaline properties (temperature and salinity) of the marine environment [34], determined by the interactions between sea and air, river discharge, mixing, currents, water exchange and topography of the basin [13].

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 [38, 14, 32]. Mean temperatures of the deepest layers of the Adriatic Sea are above 10°C during the whole year [34, 13]. In winter, temperatures of the surface water is between 6 and 15°C, with lower temperatures in the northern part and higher ones in the southern part of the basin [34, 13]. In summer, the upper water layers can reach temperatures of 22 – 25°C [34]. The open sea is generally warmer than the coastal waters [39, 13].

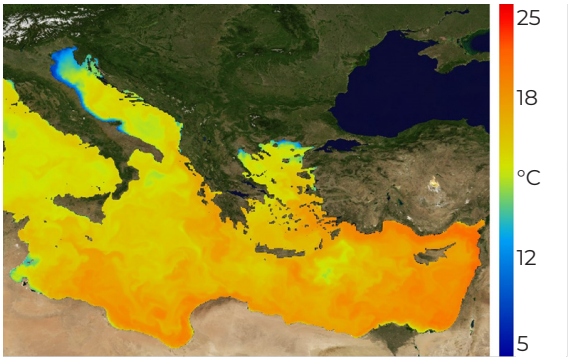

Figure 3.
Temperature of the Adriatic Sea [33].

The average salinity of the Adriatic Sea is 38.3 ‰, with the lower values observed during the winter months [34]. 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 [13].

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 [13, 26]. Influx of more warmer, nutrient rich and more saline Ionian waters contributes to the presence of some rare (and alien) species in the Adriatic waters, and has a profound influence on the Adriatic biodiversity [13].

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 [26]. The expected consequences are migration of fish into deeper waters and to the north, increased number of invasive species, and significant impact on biodiversity and abundance of domestic fish species [26].

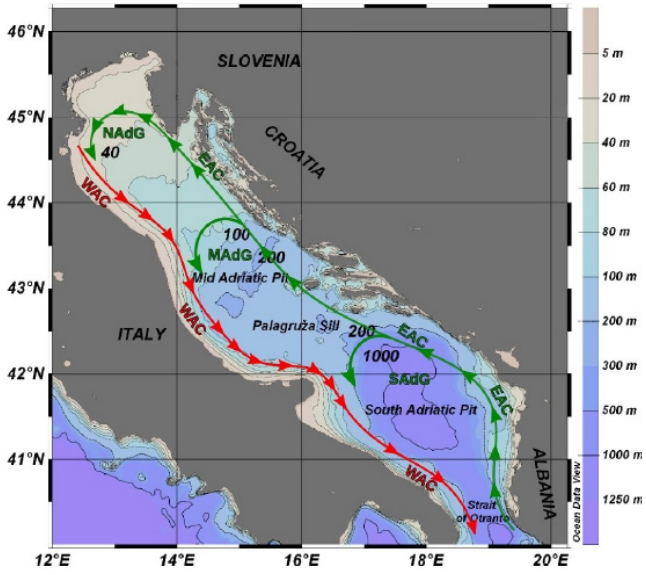

Figure 4.
Sea currents of the Adriatic Sea [24].

In order to adapt to the climate change, it is crucial to encourage local fishermen to use their own knowledge and experiences to participate in monitoring the impacts of climate change on the state of ichthyofauna of the Adriatic Sea, and 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.

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 [13]. Changes in mean atmospheric temperature and rainfall are reflected in changes in temperature, salinity, oxygen level, circulation and seasonal patterns of seas and oceans [26]. 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 [26, 6]. In addition, excess carbon dioxide in atmosphere leads to increase in acidity or pH level of the Adriatic Sea [26].

The consequences of the climate change are reflected in significant changes in biodiversity of the Adriatic Sea, which are dominated by the influx of alien fishes, distributional shifts of native fishes and community-level changes of native population of fishes [13]. Namely, the flora and fauna of the Adriatic Sea is a result of the numerous geological, geographical, climatic and biological processes [13]. During the last few decades however, in addition to factors such as significant anthropogenic activity and that of lessepsian migration, it is the climate change that has played a crucial role in shaping of the Adriatic ecosystem [13]. As a result, the Adriatic ecosystem is subjected to a continuous process of alteration, including ichthyofauna [6, 23, 34, 13]. For that reason fishes are excellent indicators of the effects of environmental changes and climate variability [13]. In that perspective, data collected by fishermens in their professional activity are crucial for monitoring of the current status of climate change effects and its repercussions on the Adriatic Sea ichtyofauna.

Changes in the Adriatic Sea ichtyofauna

Sea ecology is monitored for increased abundances, northward extension or decline in occurrence of some species [13]. In the Adriatic Sea, local information on tracking the dynamic of ichtyofauna changes is scarce [32]. Indeed, there is a gap of knowledge on such dynamics mainly due to the lack of high resolution data both in space and time [32]. 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 [32].

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 [32]. LEK of specific target groups such as professional and/or recreational fishers can be easily accessed on large geographical scale and it can be useful to identify and monitor amount of those fish species that are regarded as indicators of climate change [32]. Monitoring such phenomena is of paramount importance for adaptive management of the Adriatic Sea [32].

Examples of the results of studies on the impact of climate change on the presence of certain fish species in the Adriatic are shown in this publication, so to enable fishermen to assess the quality of those data using their own exceptional personal experience, and thus become better informed and involved in monitoring of the climate change processes and conditions of the Adriatic Sea ichthyofauna. 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 [13]. 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 fishermens ability to adapt to new situations [15, 13].

Small pelagic fish

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. 5)*, Anchovy *(Engraulis encrasicolus, Fig. 6)*, Sprat *(Sprattus sprattus, Fig. 7)*, and to a lesser extent Picarel *(Spicara smaris, Fig. 8)* [26, 19]. Three first mentioned small pelagic fish species are traditionally and economically the most important species of the Eastern Adriatic fishery [26]. Furthermore, small blue fish is the basic raw material of the traditional processing industry which was once based primarily on salting and canning [16, 26]. Nowdays, Sardine *(Sardina pilchardus)* and Anchovy *(Engraulis encrasicolus)* still amount up to 80 % of total commercial catch [26].

Figure 5.
Sardine (Sardina pilchardus).

Figure 6.
Anchovy (Engraulis encrasicolus) [43].

Figure 7.
Sprat (Sprattus sprattus) [48].

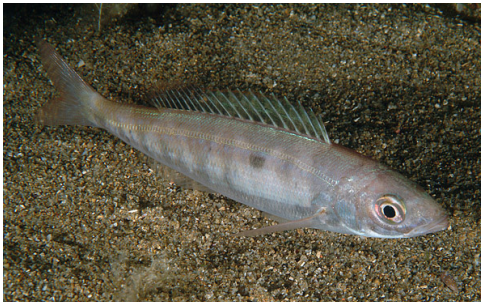

Figure 8.
Picarel (Spicara smaris) [57].

Pelagic fish species such as Chub mackerel *(Scomber Japonicus, Fig. 9)*, Horse mackerel *(Trachurus trachurus, Fig. 10)*, and Atlantic mackerel *(Scomber scombrus, Fig. 11)*, are of considerable importance for Adriatic Sea fishery as well. They amount up to

about 10 % of commercial catch [26]. Furthermore, these species feed upon small pelagic fish such as Anchovy *(Engraulis encrasicolus)* and Sardine *(Sardina pilchardus)*, and small sea crabs. It is worth of noting that several decades ago Atlantic mackerel *(Scomber scombrus)*, almost entirely disappeared from the Adriatic [54].

Figure 9.
Chub mackerel (Scomber Japonicus).

Figure 10.
Horse mackerel (Trachurus trachurus).

Figure 11.
Atlantic mackerel (Scomber scombrus) [54].

Fluctuations in sea temperature in the last decades are directly related to the catch of small pelagic fish in the Adriatic [26]. Due to their sensitivity to climate change, distribution and abundance of small pelagic fish are excellent ecological indicators [13]. 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 [13]. The North Adriatic, being the 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 [13, 2].

Community-level changes of native population of fishes

Native cold water fish species such as European sprat *(Sprattus sprattus)* and Sardine (*Sardina pilchardus)*, are in decline in the last few decades [20, 13]. In the Mediterranean Sea, a replacement of Sardine *(Sardina pilchardus)*, and European sprat *(Sprattus sprattus)* with Round sardinella *(Sardinella aurita, Fig. 12)*, already occurs in the catches [37], due to Round sardinella *(Sardinella aurita)* expansions [30, 13]. Round sardinella *(Sardinella aurita)* is well known to our fishermen. In the mid of 19th century, due to low amount of Sardine *(Sardina pilchardus)* 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 [16]. Nowdays 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 *(Engraulis encrasicolus)* and Sardine *(Sardina pilchardus)* [13].

Figure 12.
Round sardinella (Sardinella aurita) (left) and Sardine (Sardina pilchardus) (right) [16].

Influx of alien fishes

Other example of impact on small pelagic fish species is that of Lessepsian migrants. Namely, since its opening in 1869, over 87 fish species have invaded the Mediterranean Sea through Suez Canal [27, 13]. Of those, over 14 lessepsian fish species were encountered in the Adriatic Sea [13]. These invaders alter the faunal composition but may also cause severe alterations to ecosystem structure and function [31, 4]. One example is that of Brushtooth lizardfish *(Saurida undosquamis, Fig. 13)*. Unlike Round sardinella *(Sardinella aurita),* this species is in prey - predator relationship with native Sardine *(Sardina pilchardus)* and Anchovy *(Engraulis encrasicolus)*, and thus have possible negative influence on local communities of those pelagic species [13]. Other example is that of top predator Bluespotted cornetfish *(Fistularia commersonii, Fig. 14)*, which can potentially affect populations of native fish species like: Sardine *(Sardina pilchardus)*, Anchovy *(Engraulis encrasicolus)*, and Picarel *(Spicara smaris)* [13]. Impacts do not have to be of ecological or economical nature [13]. Records including occurrences of juveniles

indicate that Bluespotted cornetfish *(Fistularia commersonii)* established its populations in the South Adriatic [10, 13].

Figure 13.
Brushtooth lizardfish
(Saurida undosquamis) [35].

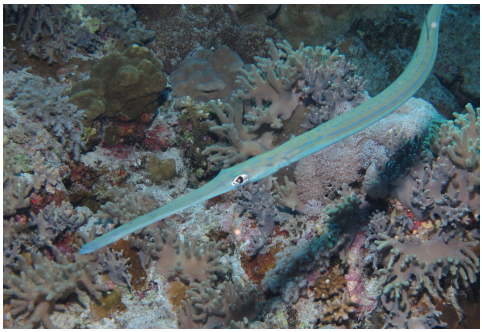

Figure 14.
Bluespotted cornetfish
(Fistularia commersonii) [50].

Thermophilic fish species

Native thermophilic species

Process of arrival of alien species of tropical origin affecting thermophillic species well adapted to worm waters is termed tropicalization [13]. Consequences may be an increase of abundance of certain species due to extension of the northern limit of species distributions [13]. Presence or increase in abundance of certain thermophilic species in the Adriatic Sea is usually attributed to water warming, i.e. the increased sea temperature [13]. 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 [13]. For that reason, thermophilic fishes in the Adriatic are categorized into: A) native species, and B) exotic species recently entered in [1, 13]. 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 [28, 32].

One example of native thermophilic species well known to our fishermen is Dolphinfish *(Coryphaena hippurus, Fig. 15)*. This species regularly enters Adriatic waters in the warmer period of the year,

but was considered rare in the older literature [22, 13]. In the last two decades, Dolphinfish sporadically occurred even in the Northern Adriatic [5, 11, 23, 32]. Abundance of this species in Adriatic Sea is on the increase in the recent years [13, 32]. This species already reproduces in the Adriatic waters, indicated by presence of larvae and early juveniles [5, 12]. It is a popular food fish in meny countries around the globe, usually caught and sold as a by product of tuna and swordfish commercial fishing operators [41]. Due to its economic potential Dolphinfish is now frequently available in local fishmarkets.

Figure 15.
Dolphinfish (Coryphaena hippurus) [41].

Exotic thermophilic species – negative examples

In the last 20 years numerous thermophilous fish species have been recorded for the first time in the Adriatic Sea [13]. Perhaps the most striking change in the fish community is an increase in abundance of Bluefish *(Pomatomus saltatrix, Fig. 16)*, decade ago either rare or totally absent in Adriatic Sea [8, 13, 32]. For the area of Northwestern Mediterranean, this species reacts to the increased sea surface temperature by shifting areas of distribution and reproduction northward [8, 30]. An unusual catch of Bluefish *(Pomatomus saltatrix)*, at the extreme North of the Adriatic was reported in 2005 [8, 32]. This fish is a predator of the Flathead grey mullet *(Mugil cephalus, Fig. 17)*, and it decimated their populations from native habitats in Neretva Estuary [18, 13]. Significant negative effects of this species on communities of native fishes could be compensated through targeted fisheries of this species [13]. However, local fishermen still don't have effective fishing gears for catching Bluefish *(Pomatomus saltatrix)* [13].

Figure 16.
Bluefish (Pomatomus saltatrix) [53].

Figure 17.
Flathead grey mullet (Mugil cephalus) [46].

Recently, one more exotic thermophilic species, Common lionfish *(Pterois miles, Fig. 18)*, has been reported as a newcomer to the Adriatic Sea [25]. This is an Indo-Pacific fish species that has reached the Eastern Mediterranean from the Red Sea via Suez channel [21, 25]. 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 [21, 25]. 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 [21, 25]. 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 [21, 25]. Often, it can be found near underwater reefs up to 80 meters of depth, yet also in much shallower waters [21, 25].

Figure 18.
Common lionfish (Pterois miles) [47].

Not all exotic thermophilic species are suitable for consumption. One such example is Silver cheeked toadfish (*Lagocephalus sceleratus, Fig. 19)*. This species represents a threat to human health and can be fatal if consumed [13]. This problem triggered awareness-raising campaigns in some Adriatic countries [13]. Multiple occurrences of Silver cheeked toadfish *(Lagocephalus sceleratus)* raised doubt whether this species also has self-sustaining population, since its presence might be of periodical nature [13]. There is a lack of detail landing data on this species for the Adriatic Sea, as in the case of Bluefish *(Pomatomus saltatrix)* and Common lionfish *(Pterois miles)*.

Figure 19.
Silver cheeked toadfish (Lagocephalus sceleratus) [49].

Exotic thermophilic species-positive examples

In the last 10 years on take is significant expansion of groupers [13]. Three new species of groupers recorded in the Adriatic Sea are: Orange-spotted grouper *(Epinephelus coioides, Fig. 20)*, White grouper *(Epinephelus aeneus, Fig. 21)*, and Mottled grouper *(Mycteroperca rubra, Fig. 22)* [13]. Later two species were first time recorded in South Adriatic in 1999 and 2000, respectively [17, 9]. Since then they have experienced a northward expansion and were occasionally reported from the areas of South and Middle Adriatic Sea [17, 9]. Recent records show signs of established population in the Eastern Adriatic coast [13]. This is not surprising since the native groupers also show positive response to sea warming [13]. Successful spawning of groupers in the South Adriatic resulted in better recruitment and new colonization of groupers in the Middle and Northern Adriatic, particularly of Dusky grouper *(Epinephelus marginatus, Fig. 23)* [13]. 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 populations of native species and track their adaptation to changing ecosystem [13]. For example, groupers occupied ecological niches of overfished sparides, such as of the White seabream (*Diplodus sargus sargus, Fig. 24)*, which is the economic loss and biomass of sparids [13].

Figure 20.
Orange-spotted grouper
(Epinephelus coioides) [45].

Figure 21.
White grouper
(Epinephelus aeneus) [44] .

Figure 22.
Mottled grouper
(Mycteroperca rubra) [52].

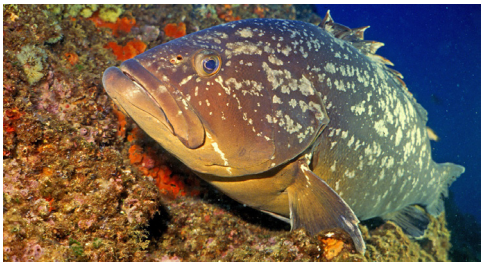

Figure 23.
Dusky grouper
(Epinephelus marginatus) [51].

Figure 24.
White seabream
(Diplodus sargus sargus) [42].

Figure 25.
European barracuda
(Sphyraena sphyraena)

Figure 26.
Yelowstripe barracuda (
Sphyraena chrysotaenia) [55].

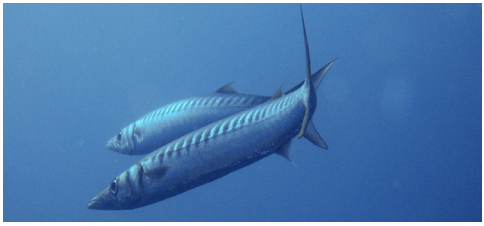

Figure 27.
Yellowmouth barracuda
(Sphyraena viridensis) [56].

Representatives of thermophilic species of Sphyraena family are very interesting in socio-economic sense for purse-seine fisheries in the Adriatic Sea [13]. Beside native European barracuda *(Sphyraena sphyraena, Fig. 25)*, two new lessepsian species have been recorded in the last decades: Yelowstripe barracuda (*Sphyraena chrysotaenia, Fig. 26)*, and Yellowmouth barracuda (*Sphyraena viridensis, Fig. 27)* [13]. Yellowmouth barracuda *(Sphyraena viridensis)* was decade ago either rare or totaly absent in Adriatic Sea [13]. Indeed, the first record of Yellowmouth barracuda *(Sphyraena viridensis)* in the Adriatic was reported in 2004 [7, 32]. Possibly due to distributional shift, in the recent years it has became quite abundant especially in the coastal areas [32]. However, fishermens still have difficulty in distinguishing thermophilic from native species [13]. It is expected that the lessepsian baracuda will outnumber the native European barracuda *(Sphyraena sphyraena)* in catches, although Yelowstripe barracuda *(Sphyraena chrysotaenia)* is still very rare in Adriatic Sea [13].

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 due to the fact that on the coast and islands, fishing is one of the very few activities that can provide a source of income throughout the year [26]. 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 development 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 [3, 32].

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 [13]. Effective monitoring of the phenomena is of paramount importance for adaptive management of the Adriatic Sea [32]. This is of particular importance for the Adriatic Sea since the impacts of the global warming are critical in semi-enclosed seas [36, 13, 32]. 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 [13]. These resources are already under significant stress from overfishing, pollution, coastal development, and habitat degradation [13]. Climate change is an additional stressor impacting coastal systems and communities [13].

Changes in distribution of fish species may lead to changes in income of fisheries sector with both positive and negative consequences [13]. Understanding how climate change influences the fisheries revenues is a crucial step towards the development of effective socio-economic policy and food sustainability strategies in adaptation efforts [13]. 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 [13]. Thus, it is necessary to simultaneously monitor populations of native and alien species and track their adaptation to changing ecosystem [13].

For alien 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 [13].

Statement

The research results presented in this brochure are not outcome of our individual research. The information presented herein was collected by 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 brochure. 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 fishermen. The aim is to encourage local fishermen to participate with scientific community in monitoring the impact of climate change on Adriatic ichthyofauna, cooperate with information on questions about their needs, and most importantly, to participate in climate change adaptation processes, and decision making processes on ways of sustainable management of the Adriatic Sea.

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About Children of Neptun

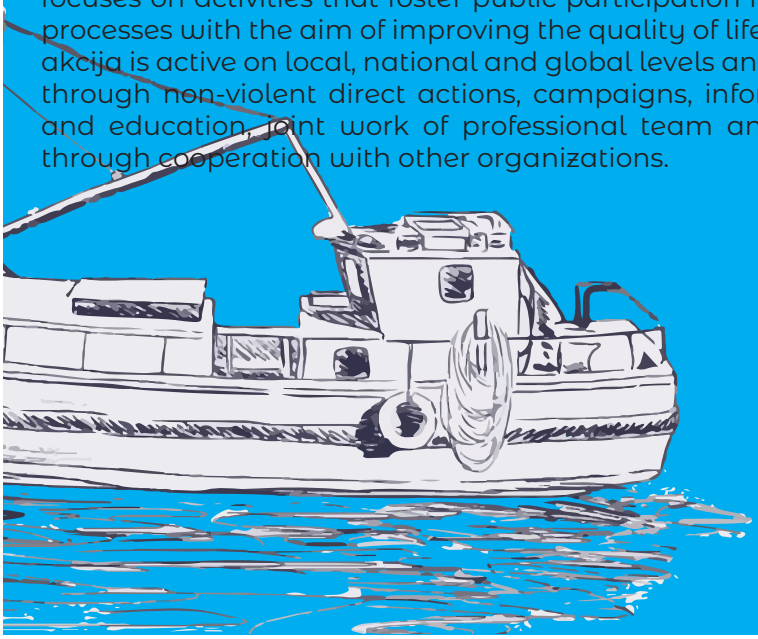
Brochure was created as an integral part of the project: Children of Neptune - Climate Change and Sustainable Development of Fishery, funded by the Open Society Institute (OSIFE), Sofia. The project was implemented by partner organizations: Pomalo, Institute for Political Ecology and Zelena Akcija. Aim 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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