

PRESENT CHANGES AND PREDICTIONS FOR FISHERY AND MARICULTURE
IN THE EASTERN ADRIATIC (CROATIA) IN THE LIGHT OF CLIMATE CHANGE*Branko GLAMUZINA & Marlena ČUKTERAŠ*University of Dubrovnik, Department of Aquaculture, HR-20000 Dubrovnik, Ćire Carića 4, Croatia
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ABSTRACT

Over the past decade, the waters of the Croatian Adriatic Sea have been marked by significant changes in the characteristics of the marine ecosystem. Although a link between these changes and the common explanation of climate change has not been scientifically proven, the effects of the changes are already clearly evident. This includes the effects on the fisheries and mariculture sectors through the invasion of new fish species, better performance of native warm-water species and significant pressure on cold-water species. As some of the recent effects have clear economic consequences for the fisheries, this paper provides an overview of the impact of climate change as well as predictions for future management strategies for the Croatian fisheries and mariculture sectors.

Key words: Climate change, Adriatic Sea, Croatia, fishery, maricultureCAMBIAMENTI ATTUALI E PREVISIONI PER LA PESCA E LA MARICOLTURA
NELL'ADRIATICO ORIENTALE (CROAZIA) ALLA LUCE DEL CAMBIAMENTO CLIMATICO

SINTESI

Durante il decennio scorso nelle acque adriatiche croate sono stati riscontrati cambiamenti significativi delle proprietà degli ecosistemi marini. Sebbene il legame tra questi mutamenti e la spiegazione comune del cambiamento climatico non sia stato scientificamente provato, gli effetti dei mutamenti sono già evidenti. Gli autori rilevano gli effetti sulle attività di pesca e maricoltura attraverso l'invasione di nuove specie ittiche, con adattamenti migliori di specie provenienti da acque più calde e una forte pressione sulle specie di acque più fredde. Poiché alcuni degli effetti più recenti hanno evidenti conseguenze economiche sulle attività di pesca, l'articolo fornisce un esame degli impatti dei cambiamenti climatici, nonché le previsioni per le future strategie di gestione per la pesca e la maricoltura croate.

Parole chiave: Cambiamenti climatici, mare Adriatico, Croazia, pesca, maricoltura

INTRODUCTION

As a country with a large coastline and thousands of islands, Croatia has developed fishing and mariculture industries that are important to its economy, especially in those coastal areas and on islands where other economic activities, except tourism, are limited (Katavić, 2004).

Climate change is becoming more evident. As it intensifies, it will alter the productivity of the fisheries and the distribution of fish stocks (Daw *et al.*, 2009). From an economic point of view, such changes will impact the fisheries and coastal communities differently. These expected changes require adaptable and flexible fisheries, aquaculture management policies and governance frameworks. However, the form of climate change and the extent of its impacts remain uncertain. Therefore, under such uncertainty, fisheries policy makers need to develop strategies and decision-making models in order to adapt to climate change while taking into account the social and economic consequences. The physical and biological effects of climate change are increasingly becoming better understood, particularly for well-studied temperate shelf ecosystems (Barange & Perry, 2009). However, relatively little is known of the likely climate change impacts on other ecosystems and their associated fisheries (Glamuzina, 1999). In general, climate change indeed appears to be having an impact on fish ecology and fisheries but the strength and direction (both positive or negative) of the effects vary from place to place. The social and economic effects of climate change are less clear; however, it is likely that the economies of countries with the lowest levels of adaptive capacity will be most vulnerable to the effects of climate change and less able to anticipate and capitalise on any climate change induced advantages that may arise (Dulvy *et al.*, 2011).

Changes in the sea temperature may make some fish and shellfish more susceptible to diseases or make the water inhabitable (De Silva & Soto, 2009). Other marine species may be affected by new invaders, either through food web changes or pressure on habitats. Finally, the ecological makeup of the sea may change, creating opportunities for new commercially viable fisheries and necessitating changes in the marketplace.

This paper will examine the potential threats and opportunities for fishery and mariculture in the Eastern Adriatic (Croatia) as brought about by climate change, and make recommendations for moving forward in addressing climate change.

THE IMPORTANCE OF THE FISHING AND MARICULTURE SECTORS TO CROATIA

Even though the fishery and mariculture sectors account for a relatively small share of Croatia's GDP, they play an important role in the socio-economic status of

a large number of people. More than 20,000 are directly employed in the commercial Croatian fishery sector, with the number of commercial fishermen tending to hold relatively steady throughout the years. Currently, 70 % of fishing, mariculture and processing activities take place on islands, where income sources are limited; thus, this activity is important for development in areas that are economically vulnerable. At the regional level, mariculture is an important industry in the Zadar and Dubrovnik counties. In some regions, fisheries, particularly fish farming, is strongly linked to the development of rural tourism. Fish also represents a source of high-protein food, which is an important element of human nutrition in vulnerable coastal-based communities.

The Croatian fishery is multispecies oriented. There are 444 fish species presently living in the Adriatic Sea (Lipej & Dulčić, 2010), more than 100 of which are commercially exploited (Cetinić & Soldo, 1999). In 2009, the total catch of marine fish and other marine organisms amounted to more than 53,596 tonnes. Small pelagic fish predominate (49,459 tonnes), which mainly comprise fish destined for fish-processing plants and for the feeding of farmed tuna (Croatian Chamber of Economy, 2010). Small pelagic fish are also the most common fish consumed in the domestic market. Between 2004 and 2007, the demand for pelagic fish increased at the same rate as overall production (7 %). However, the demand for demersal/bottom-feeding catches has also increased over the last few years. Continuous monitoring of marine resources (Cetinić & Soldo, 1999) has shown that as much as 80 % of demersal catches are composed of only ten species, with the most important being hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*) and striped mullet (*Mullus barbatus*). This can be attributed to the overfishing of other important demersal fish species.

The total mariculture species production in Croatia in 2009 was 11,300 tonnes, which included 5,000 tonnes of European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*), 4,200 tonnes of tuna (*Thunnus thynnus*), 2,100 tonnes of mussels (*Mytilus galloprovincialis*) and 100 tonnes of European flat oysters (*Ostrea edulis*) (Croatian Chamber of Economy, 2010).

The potential impact of climate change on the Croatian fishery and mariculture sectors is complex since both positive and negative effects can be brought about. These include changes in the marine environment, changes in the migration patterns of fish in the open sea (including migration pressures on cold-water species), potential changes in the growing season and rearing time for farmed fish and a potential increase in invasive species, which has increased catches of new species but threatened the production of others.

EXISTING IMPACTS FROM CLIMATE CHANGE

The abundance of marine fish populations in the Adriatic is already showing significant fluctuations (Dulčić & Grbec 2000; Grbec *et al.*, 2002; Dulčić *et al.*, 2004). Changes in fish behaviour and migration patterns are also seen in these Adriatic populations, having implications for fish catches (Dulčić *et al.*, 2004; Lipej & Dulčić, 2004). The relationship between these fluctuations and large-scale climate change is of great concern.

Previous researches in the Adriatic Sea have shown that the inflow of Mediterranean water into the Adriatic increases productivity in Adriatic waters that otherwise have relatively low nutrient levels (Zore-Armanda *et al.*, 1999). Different biological phenomena have been observed and linked to the stronger inflow of water from the Mediterranean into the Adriatic. In addition, the temperature and salinity properties of the water (*i.e.* its thermohaline properties) have been shown to have impacts on phytoplankton and fisheries (Zore-Armanda *et al.*, 1999). In general, the level of fish biodiversity in the Adriatic Sea generally increases from north to south. While there is a range of factors that may affect this pattern, the main factor appears to be temperature. Already, research has shown a large northward expansion of fish species that are more suited to warmer waters (Glamuzina & Skaramuca, 1999; Dragičević & Dulčić 2010) (Fig. 1). This indicates a change in marine biodiversity, as numerous fish species that previously lived in southern areas are moving northward. Numerous species new to the northern parts of the Adriatic Sea have been recorded over the last thirty years (Dulčić & Dragičević, 2011).

During 1973–2003, a strong correlation was found between the average annual air and sea surface temperatures and the number of species (Dulčić *et al.*, 2004). A strong correlation between annual sea surface temperature and the annual total number of fish has also been found. The variations in the Adriatic temperature conditions correlate with the North Atlantic Oscillation (NAO) index, indicating that local temperature changes at least partly result from hemispheric temperature changes. This implies that variations in Adriatic temperature changes are likely to be affected by climate change, since climate change influences the NAO (Grbec *et al.*, 2002).

In order to establish the relationship between the hydro-climatic variables and the pelagic species (sardine, anchovy and sprat), year-to-year fluctuations of small pelagic fish landings (*i.e.*, the number of fish that are taken ashore) on the eastern Adriatic coast were compared with climatic fluctuations over the northern hemisphere and salinity fluctuations in the Adriatic (Grbec *et al.*, 2002). Using this approach, basic climatic oscillations were determined over a period of approximately 80 years, with which researchers found a correlation between climatic fluctuations over the northern hemisphere and small pelagic fish landings (Dulčić & Grbec, 2000; Grbec *et al.*, 2002). Bombace (1992) suggested that the



Fig. 1: Rainbow wrasse (*Thalassoma pavo*) is a northward spreading warm-water species. (Photo: B. Mavrič)

Sl. 1: Pavji knez (*Thalassoma pavo*) je značilna vrsta, povezana s segrevanjem morja, ki se širi proti severu. (Foto: B. Mavrič)

fluctuations of small pelagic stocks in the Adriatic Sea may be due to the modifications of the production level in the ecosystem, determined by variations in the river nutrient input. The fluctuation period of 11–12.5 years in the fish landing data can be connected to a major solar activity cycle, which is observed in many biological processes worldwide. All the analysed series – fish species, salinity and pressure differences – have the same fluctuating periods, which indicate a connection to climatic oscillations (Grbec *et al.*, 2002). Although the NAO index has the same fluctuation period, there was no significant correlation with it except for the anchovy (*Engraulis encrasicolus*) and sprat (*Sprattus sprattus phalericus*). The sardine (*Sardina pilchardus*), mackerel (*Scomber scombrus*) and anchovy respond to salinity changes, which are modulated by the climate oscillations in the Adriatic, as described by the pressure differences between the mid-north Atlantic and southeast Mediterranean (Grbec *et al.*, 2002).

Such long-term variation has been observed worldwide and was considered a normal part of the life cycle of pelagic fish (Dulčić *et al.*, 2004). However, the most recent observed changes in sardine populations in the Adriatic Sea include prolonged spawning seasons and spawning in areas that were historically unknown. This change in behaviour can be attributed to global climate change. In other words, climate change is already changing the behaviour and migration patterns of pelagic fish in the Adriatic.

Other categories of biological response include the changed migration patterns of sprats and the drastic collapse of the European anchovy stock since 1995. Mass mortalities of round sardinella were recorded along the Apulian and central Croatian coasts in January 2002, when an abrupt fall in seawater temperatures occurred (Guidetti *et al.*, 2002). This fish is a warm-water species that was recorded for the first time along the Croatian coast 40 years ago. As this fish is not yet commercially utilised in Croatia, this event did not have any commercial influence on the fishing sector. Furthermore, this event did not have any impact on the native species.

FUTURE IMPACTS: TEMPERATURE CHANGES

Climate change-related warming may have the following impacts on the Croatian fishing sector:

- Due to accelerated biological processes at all levels of marine ecosystems, the growth rate of fish should be higher and reproduction seasons should be longer for most species. As a result, the recruitment of species that thrive in warm water should be significantly improved.
- The opposite will likely occur with species that thrive in cold-water, such as Norway lobster (*Nephrops norvegicus*). These species will migrate to colder areas, either horizontally (north, south, east, or west) or vertically (to deeper levels).
- Temperature increases will heighten the risk of depleted oxygen levels in the shallow areas of the Adriatic. This situation will create conditions that allow for an increase of species that tolerate warm water and lower oxygen levels (Fig. 2).
- The introduction of new disease organisms or exotic and undesired species will likely occur due to increased sea surface temperatures.
- Tuna (*Thunnus thynnus*), which is the most important economic product within the fishery and mariculture sectors, is a typical warm-water species. Tuna farming, as it is currently practiced in the Eastern Adriatic, will likely benefit from climate change due to higher growth rates resulting from more intensive feeding and a higher feed conversion index.

In general, it is likely that there will be an increased potential for aquaculture, which would yield a positive impact. The increase in the sea surface temperatures in the winter as a consequence of climate change might create favourable conditions for the growth of marine organisms during this season. Therefore, rearing times could be shorter and aquaculture production could become more efficient.

The influence of climate change on species presently under mariculture in the Eastern Adriatic should be generally positive, due to a prolonged growing season and a shortening of rearing cycles. This particularly applies to two species: the gilthead sea bream (*Sparus aurata*) and the Mediterranean mussel (*Mytilus gallopro-*

vincialis). These two species are better adapted to higher temperatures and thus will tend to benefit from a rise in Adriatic water temperatures. The only potential problem here involves the reproduction period of mussels, during which freshwater inflow is required; this inflow could be limited due to lower precipitation levels in the area. This will be especially important during the summer months, when precipitation levels on the coast are expected to drop by up to 39.3 % in the summer months in Dalmatia (UNDP, 2009).

The situation with two other species – sea bass (*Dicentrarchus labrax*) and the European flat oyster (*Ostrea edulis*) – is different due to the fact that they generally prefer colder water. Current situations in Greece and Turkey regarding these species are applicable to the future conditions of the Croatian coastline. In Greece and Turkey, sea bass farming is not dominant due to warmer water and the associated susceptibility to disease (Stephanis, 1995). Presently, sea bass farming operations in the Eastern Adriatic are among the best in the Mediterranean due to excellent water conditions, which include lower temperatures. Temperature increases will confront Adriatic growers with conditions similar to those that were previously faced by Greek growers; the result will likely be a necessary shift to gilthead sea bream, a species that is tolerant to higher temperatures. Alternatively, the sea bass cages will have to be moved to colder zones or deeper nets up to 10 m in depth will need to be used. This would substantially increase the costs of sea bass production.

The scenario for sea bass is similar to that for the flat oyster. The dangerous or lethal temperature for the flat oyster is 26 °C, which has already been measured along



Fig. 2: Would the populations of some edible crustaceans face a decline due to higher temperatures and oxygen depletion in the bottom layer? (Photo: B. Mavrič)

Sl. 2: Bodo zaradi višjih temperatur v pridnem sloju in slabših kisikovih razmer upadle populacij nekaterih užitnih rakov? (Foto: B. Mavrič)

the coastline and in the traditional culture grounds of Mali Ston Bay (Bratoš *et al.*, 2002). Events of summer mortality of the flat oyster in some areas of the Mali Ston Bay have already been reported. As the Integrated Developmental Strategy of Mali Ston Bay (Glamuzina, 2009) calls for a significant increase in the production of this lucrative species, water temperature increases will be one of the major future obstacles in long-term planning for this area. As with sea bass, production should be transferred to deeper water during the critical summer months as the sea temperatures rise; as before, new costs are associated with this. For most farms, this should only entail the simple addition of a few metres of rope; however, for farms situated in shallow water, this change will involve completely moving the production site. While this is not a complicated adaptation measure, it will certainly increase the costs of flat oyster production. However, the flat oyster should receive a benefit similar to the mussels – a prolonged growing season, an earlier and longer reproduction season and a reduction in the time of the rearing cycle.

In general, the effects of climate change on shellfish cultures appear to be positive but some changes in culture practice would be necessary.

FUTURE IMPACTS: INVASIONS OF NEW SPECIES

Since fish respond to warming by migrating, they may be a useful index of the effects of warming in the Adriatic. The incoming northwestward current along the eastern Adriatic coast carries food and plankton and makes the entrance of species from southern areas more likely. The northward spread and increase in abundance of the southern fish species occurs in several phases. At first, only a single adult appears. Subsequently, more adult individuals are observed. Reproduction then begins and larval and juvenile stages occur in the area. Finally, the southern species achieves the status of a new settler. It can be concluded with certainty that, within the Adriatic Sea, warm-water species are extending their range northward. Two factors may be causing this migration: 1) demographic expansions, which affect individual species, and 2) climatic fluctuations, which shift the bio-geographical boundaries (Fig. 3).

Historical temperature data and hydrological information favour the second hypothesis. Examples of invasive species in the Adriatic Sea include the following: the common dolphinfish (*Coryphaena hippurus*), the grey triggerfish (*Balistes capriscus*), the bluefish (*Pomatomus saltatrix*), the parrotfish (*Sparisoma cretense*), the round sardinella (*Sardinella aurita*), the Atlantic lizardfish (*Synodus saurus*), the Atlantic pomfret (*Brama brama*) and the European barracuda (*Sphyraena sphyraena*) (for a comprehensive review, see Dragičević & Dulčić, 2010; Dulčić & Dragičević, 2011). Some of these species, such as the bluefish, can affect local fisheries due to having a significant impact on the food chain. In the Adriatic,



Fig. 3: *Terapon* (*Terapon theraps*) is a Lessepsian migrant, recorded in the Adriatic Sea. (Photo: B. Mavrič).
Sl. 3: *Terapon* (*Terapon theraps*) je lesepska selivka, ujeta v Jadranskem morju. (Foto: B. Mavrič)

bluefish feed mainly on mullet and anchovies. At the same time, bluefish could be treated as an alternative species in local fisheries. Here, four categories of biological response to climate change can be distinguished: the appearance of indicator species, the appearance of new populations, the increase or decrease of fish stocks based on year-class strength and structural changes in the ecosystem, including demographics of fish populations and interactions within food chains (Lipej & Dulčić, 2004).

Species introductions into the Adriatic Sea have not yet been systematically studied although current data implies the existence of new species. The settling of new species in the environment has caused a generally progressive decline in biodiversity but at present there are no studies regarding the impact on the diversity of fish species. Over the past century, the northern hemisphere's average surface air temperature has increased by about 0.6 °C, while at over the same time period the northern Adriatic air temperature increased by 0.79 °C (Grbec *et al.*, 2008). Since the beginning of recording of temperatures, the 1990s was the warmest decade ever and 1998, 2000, 2002 and 2003 were the four warmest years (Grbec *et al.*, 2008). There is considerable year-to-year variability in the sea surface temperatures for the Adriatic stations of Dubrovnik, Split and Trieste. Based on the long-term mean for the period 1961–2004, the two most recent warm periods in the Adriatic were 1985–1987 and 1990–1995, for which there were positive temperature anomalies of 0.15 °C and 0.30 °C respectively (Grbec *et al.*, 2008). Most of the new occurrences of species were recorded during these two periods. This indicates that when the water is warmer, fish migrate and new species invade the Adriatic (Dulčić *et al.*, 2004; Dulčić & Dragičević, 2011).

Extensive research has been carried out concerning the phenomenon of species migration in and from neighbouring ecosystems. After the construction of the Suez Canal between the eastern Mediterranean and

the Gulf of Suez in 1869, hundreds of Red Sea and Indian Ocean species traversed the channel and settled in the Mediterranean (Streftaris & Zenetos, 2006). This process is known as the Lessepsian migration and is considered to have been an important factor in the increase of Mediterranean fish diversity. Thirteen migrant Lessepsian fish species were recently recorded in the Adriatic Sea (Dulčić & Dragičević, 2011). Again, temperature is the most important non-biological factor in determining the dispersal of Lessepsian fish. Although the detailed impact of the Lessepsian migrants on the Adriatic environment is still not fully known, some of the newcomers could potentially affect the environment, since a few of them have established populations in the Adriatic (such as *Fistularia commersonii* and *Saurida undosquamis*). Their rapid spread throughout the Adriatic, followed by rapid population increases in invaded areas, could have impacts on the local fish populations (Dulčić *et al.*, 2008).

CASES OF INVASIVE SPECIES IN THE EASTERN ADRIATIC

The impact of previously-introduced new species in the Adriatic Sea has been mixed from an economic standpoint and highly troubling from an environmental standpoint, with significant threats to both commercial and non-commercial indigenous species. Groupers and bluefish provide two examples where the effects on fish populations and the industry have been mixed or wholly negative.

Groupers were rare in the Southern Adriatic and not at all present in the Middle and Northern Adriatic before the 1990s. In the 1990s, they began to propagate and migrate, first migrating as bigger adults and then establishing populations. Several additional grouper species have been identified for the first time in the Middle and Northern Adriatic in the last ten years (Glamuzina *et al.*, 2000, 2002). The overall impact on commercial fishing has been positive: they are lucrative, marketable fish. However, from a biological and ecological standpoint, the effect has been negative; the abundance of some native species is now significantly lower due to competition with groupers for food and hiding places (Glamuzina & Skaramuca, 1999).

While the invasion of groupers had a positive economic impact, the invasion of bluefish did not. Bluefish were first recorded in 2004 in the Northern Adriatic, where it was unknown to fishermen (Dulčić *et al.*, 2005). The bluefish is a typical predator species, preying mainly on grey mullets. This species also appeared several years ago in the Neretva River estuary, where grey mullet fisheries are the most important segment of the fishing industry. In only a few years, the bluefish had decimated the grey mullets in the area. They also destroyed the nets adapted to the traditional grey mullet fishery. In the meantime, fishermen failed to develop techniques

to effectively catch the bluefish. As a result, the current condition of the traditional grey mullet fishery is close to collapse, while any economic benefits that may have been gained by catching bluefish have been ignored. In fact, most suggestions for addressing this crisis focus on eradicating the bluefish by any means possible (Glamuzina & Bartulović, 2010).

CASE OF BLUE CRAB (*CALLINECTES SAPIDUS*) IN THE NERETVA RIVER ESTUARY

This species originates from the western Atlantic and is considered an invasive species in the Mediterranean (Streftaris & Zenetos, 2006). Since it was first recorded in the Mediterranean (in the Northern Adriatic, Venice Lagoon), this species has been widely found in different Mediterranean regions, especially in the eastern areas (Galil *et al.*, 2002). Several records have been published in recent years with regard to this species' distribution in the Adriatic (Scaravelli & Mordenti, 2007; Onofri *et al.*, 2008), relating its expansion to the increase in maritime transportation. The first specimen at the Parila Lagoon (Neretva Estuary) was caught in 2004. In the following five-year period, this crab established a strong population in the lagoon and potentially presented new lucrative species for the local fishery (Dulčić *et al.*, 2011). Paradoxically, monitoring activities in the area during the summer of 2011 showed a complete disappearance of blue crab in the Parila Lagoon. Some specimens were caught in northern coastal areas, however; hence, we suppose that the whole population migrated to the northern coastal areas. Although this has not been scientifically verified, this confirms the complexity of the behaviour of new species and the uncertainty of any prediction.

POTENTIAL SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE ON FISHERIES AND MARICULTURE

Changes in the distribution of fish species in the Adriatic will result in revenue changes for the fisheries sector, with the benefits and losses not necessarily being distributed equally. The invasive species provide an instructive example. The destruction of the grey mullet population in the Neretva Estuary by bluefish represented an acute economic loss for the artisanal fishermen. On the other hand, reductions in the populations of some coastal fish due to the arrival of groupers were offset by the ability to catch and sell this newer invasive species, resulting in a net economic benefit. However, due to the illegal marketing of these lucrative species, it is hard to estimate the present revenue loss or benefit in both of these cases. These examples also indicate the importance of adaptive capacity. In the case of the groupers, the fishing sector was able to adapt to the arrival of the new species by catching and selling it. In the case of the bluefish, the inability to commercially capitalise

on its presence meant that the loss in the grey mullet population was not offset by any new revenue.

The observed changes in habitat also affect the revenues in the fishing sector. Species that thrive in cold-water will require more expensive fishing or farming methods or may vacate their current habitats. Species that thrive in warm water will have a longer growing season and may grow more quickly. Again, these are relationships that remain to be quantified both in terms of magnitude and in terms of revenue gained or lost. The location of the fishing sector along the coastline and on islands where there are very limited opportunities for employment means that the fishing sector may be particularly vulnerable to climate change.

Institutional problems could also affect individuals in the industry. For example, poor economic performance in the sector and a failure to modernise could threaten to close down enterprises and increase the unemployment rate. The decrease in employment will hinder the development of coastal and island rural areas, which depend significantly on these sectors.

ANALYSIS OF AVAILABLE TECHNOLOGICAL OPTIONS FOR ADAPTATION

The available technological options to deal with the impacts of climate change on the fisheries and mariculture sectors can be found in the neighbouring countries already affected by warmer climates, particularly Turkey and Greece. Their experiences in fishing techniques and catching invasive species should be transferred to local Adriatic conditions. Their experiences in growing sea bass and sea bream under warmer conditions should also be used to prevent similar problems in the Croatian mariculture economy.

Policies should be developed and measures applied in the future that take into account the potential impact

of global climate change. This should include the transfer of knowledge from adjacent marine areas where such changes have already occurred. It should also include the strengthening of knowledge about fundamental biological and ecological changes under new environmental conditions. For example, it is likely that a shift will be necessary from sea bass to gilthead sea bream, a species that is more tolerant to higher temperatures. Alternatively, the cages with sea bass could be moved to colder zones, or deeper nets up to 10 m in depth may need to be used. This will increase the costs of sea bass production, such as purchasing nets or moving cages, but the level of costs is difficult to estimate due to the specificities of each location. As a result of these activities, adaptive fishery management should be established, which will involve all fishery sectors including scientific institutions, governmental organisations and bodies and individuals within the fishing community.

Additionally, in areas where new species have negative impacts on the overall performance of the fishing industry, compensation mechanisms or intervention strategies should be proposed. These strategies could include the following measures: compensation for net damages made by invasive species such as bluefish, the purchasing of new fishery tools for the fishing of new species, the eradication or population control of the most dangerous invasive species and education of the fishing community regarding the potentials and threats of new fish species.

In conclusion, the fishery and mariculture sectors are likely to face challenges due to climate change but will also be provided with some opportunities to expand production and increase competitiveness. Knowledge concerning the impacts of climate change should be transferred to actors within the relevant sectors in order to ensure that opportunities are exploited and threats minimised.

TRENTNE SPREMEMBE IN PROGNOZE NA PODROČJU RIBIŠTVA IN MARIKULTURE V VZHODNEM JADRANU (HRVAŠKA) V LUČI PODNEBNIH SPREMEMB

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POVZETEK

V zadnjem desetletju so za hrvaški del Jadranskega morja značilne pomembne spremembe v značilnostih morskih ekosistemov. Čeprav je zvezo med njimi in običajnimi razlagami podnebnih sprememb še treba znanstveno dokazati, so posledice sprememb jasno opazne na področju ribištva in marikulture. Zaznavamo namreč vdor novih ribjih vrst, boljšo prilagodljivost sredozemskih toploljubnih vrst in povečan stres na hladnoljubne vrste. Glede na to, da imajo nekatere nedavne posledice opazne gospodarske učinke na ribje populacije, smo v članku pripravili pregled vplivov podnebnih sprememb in prognozo, kakšne upravljaljske strategije bi bilo v prihodnje treba uvesti na področju ribištva in marikulture na Hrvaškem.

Ključne besede: podnebne spremembe, Jadransko morje, Hrvaška, ribištvo, marikultura

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