

## Bulgarian marine aquaculture: Development and prospects – A review

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### Abstract

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The reduction of the fish and non-fish resources in the World Ocean (in particular in the Black Sea) over the last 20 - 30 years is an indisputable fact. This is due to many factors, but anthropogenic ones are dominant. Among them the most important are overfishing of hydrobionts, poor water quality and climate change. A real alternative to compensate these losses and to create healthy sources of quality seafood for humans is aquaculture - technology that can satisfy the “protein” hunger worldwide. In this regard, the purpose of the present article is to analyze the state of the Bulgarian Black Sea aquaculture and to outline the prospects for its development, based on native and introduced marine species. Modern aquaculture production in Bulgaria is dominated by the production of cyprinids and salmonids in freshwater aquaculture farms, and by black mussel (*Mytilus galloprovincialis*) only in marine aquaculture farms. This imbalance (81.7% vs 18.3%) shows that the resources of the Bulgarian Black Sea water areas are not used sufficiently for this purpose. The in-depth analysis of available literature sources (scientific articles, official reports, monographs, plans and programs, etc.), as well as the shared experience of colleagues from China, the world leader in the field of fish farming and aquaculture, give us grounds to consider the following species as promising for cultivation in the Bulgarian Black Sea water areas: Rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792), Mullet (*Mugil cephalus* Linnaeus, 1758), Turbot (*Psetta maxima* Linnaeus, 1758), White mussel (species of bivalve molluscs: *Chamelea galina* Linnaeus, 1758, *Donax trunculus* Linnaeus, 1758, *Mya arenaria* Linnaeus, 1758 and *Anadara kagoshimensis* Tokunaga, 1906), Rapana (*Rapana venosa* Valenciennes, 1846), shrimp, micro- and macro- algae, introduced marine species like *Sea cucumber* (Holothuroidea). Future studies will show which species are environmentally friendly and cost-effective for cultivation in Bulgarian Black Sea aquaculture.

**Keywords:** algae; aquaculture; black mussel; Black sea; commercial species; sea cucumber

### Introduction

Aquaculture is one of the fastest growing agricultural sectors in the world. The production of aquatic organisms (from fish catch and aquaculture) is making steady progress and according to a FAO report in 2020 half of the total production of hydrobionts obtained by catching and farming will be from aquaculture (FAO, 2012; 2020). Aquaculture is the prospect to relieve the pressure on “wild” fish and non-fish resources in the oceans, providing alternatives of organic and healthy food and raw materials for the food industry (Anderson et al., 2019; Southgate & Lucas, 2019). While catches of fish and hydrobionts increase annually (1970 – 2010) by about 1.2%, the yields of cultivated aquatic organisms increase significantly more

- up to 8.9% (Boyadzhiev et al., 2011; FAO, 2016). This growth was enabled by the expansion of the aquaculture production and the intensification of aquaculture systems by significant investments (Troell et al., 2014; Bjarnason & Magnúsdóttir, 2019) as well as by the innovations applied (Joffre et al., 2017). It is noteworthy that the fish catches have remained relatively constant over the last 3 decades, while aquaculture production continues to grow. Global fish production reached about 179 million t in 2018 (Fig. 1). Of the overall total, 156 million t were used for human consumption, equivalent to an estimated annual supply of 20.5 kg per capita. The remaining 22 million t were destined for non-food uses, mainly to produce fishmeal and fish oil. Aquaculture accounted for 46% of the total production and 52% of fish for human consumption. China

has remained a major fish producer, accounting for 35% of global fish production in 2018, followed by Asia (33%), without China, the Americas (14%), Europe (10%), Africa (7%) and Oceania (1%), (FAO, 2020). In this regard Dauda et al. (2018) point out that aquaculture is sustainable solution with a potential to meet the ever-increasing demands for fish and fish products. Based on an in-depth analysis of many literature sources, Bush et al. (2019) concluded that future research is needed to elucidate the different aspects of the aquaculture, contributing to the sustainable expansion of this sector as an increasingly important component of the global food system. Andrada (2014) noted that the concept for aquaculture changes and the desire of each country is to create suitable fish farming centres for the production of good quality products that are safe for human consumption.

Scientific developments of the last 50 years have led to a much improved understanding of the functioning of aquatic ecosystems, and to global awareness of the need to manage them in a sustainable manner. Twenty-five years after the adoption of the Code of Conduct for Responsible Fisheries (the Code; FAO, 1995), the importance of utilizing fisheries and aquaculture resources responsibly is now widely recognized and prioritized. The Code has informed the development of international instruments, policies and programs to support responsible management efforts globally, regionally and nationally (FAO, 2020; EU, 2020).

One promising area is the use of fast-growing transgenic fish including both cold-water (salmon, trout) and warm-water (tilapia, carp) species. The transgenic fish can serve as suitable experimental models for basic scientific investigations in the field of the environmental toxicology and biotechnologies. The fast growth transgenic fish, being efficient feed converter, have potential to support aquaculture production and economic efficiency. Thus they will be more economical for the producer as the feed

accounts for 60-70% of total costs in aquaculture (Wakchaure et al., 2015). Another alternative is the cultivation of 'mini-mussels' in more open and deeper marine areas. The system, which is in the stage of creation, will solve the problems with the mussel dredging, overfishing and aquaculture farming in eutrophicated shallow coastal waters (Riisgård, 2014). Deep sea/ocean water honored as "Blue Gold Industry" is an extraordinary natural resource with big potential for aquaculture development. Deep marine / ocean water possesses three main characteristics: low temperature, cleanliness and nutrient richness. All these advantages offer possibilities for recycling energy used, high productivity and high economic efficiency (Chen et al., 2018). In 1997 - 2002 in Trabzon, Turkey started a project for growing turbot (*Scophthalmus maxima*, *Psetta maxima* (Linnaeus, 1758), and development of technology the production of fingerlings, implemented jointly by the Central Institute for Fisheries Research at the MARA, Republic of Turkey and the Agency for International Cooperation of Japan (JICA), (Çiftci et al., 2002). Kelp farming is increasing along the temperate coastlines of the Americas and Europe. Increased food security, improved restoration efforts, greater fisheries productivity, and alternative livelihoods development are determined to be potential positive impacts of kelp aquaculture (Grebe et al., 2019).

From ancient times the aquatic organisms have been used as a source of valuable proteins, essential fatty acids and trace elements. The role of hydrobionts in feeding the population is becoming increasingly important, especially in areas rich in water resources (Ottolenghi et al., 2002; Zaykov, 2006; Zengin et al., 2016). The world aquaculture development has a thousand-year history. In China, fish farming as an economic sector dating back 2400 years. Fish farming is the best-developed in Hubei province, with more than 6 million acres of water areas (Jilin, 1997).

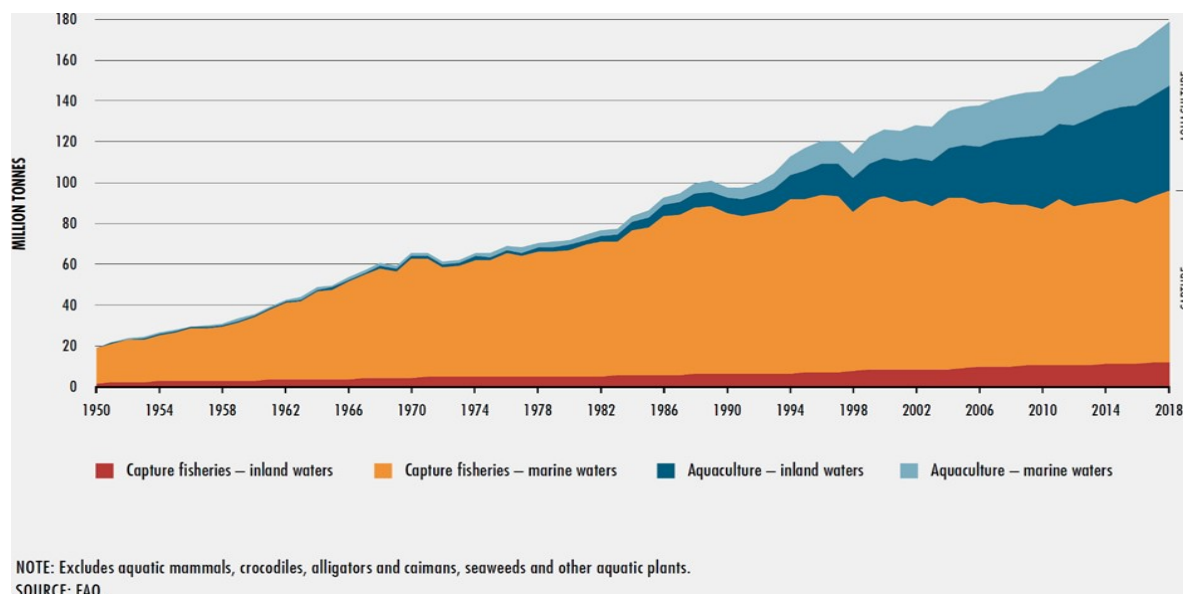


Fig. 1. World capture fisheries and aquaculture production (Source: FAO, 2020)

Later, fish farming spread to the Mediterranean countries and was transferred from the Roman Empire to Central and Western Europe (Klisarova, 2015). In Russia, fish farming has been known since the 13<sup>th</sup> century, where the first fishponds were used only to store live fish. Towards the end of the 15<sup>th</sup> century, several fish ponds were built in Ukraine, which are still used for fish farming (Zashev et al., 1958). Apart from food, hydrobionts are also used as a raw material for the production of various industrial products.

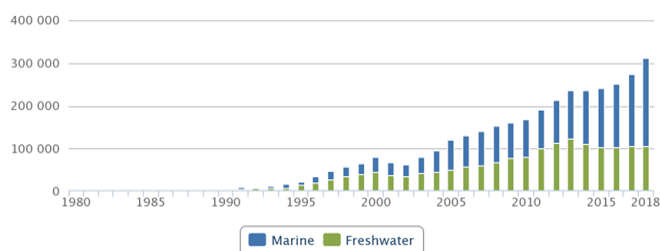
Unlike other countries, Bulgaria has relatively little experience in the field of aquaculture. The first steps in this area started at the end of the 19<sup>th</sup> century in freshwater aquaculture, in fishponds in Sadovo and Obratzov Chiflik villages (Klisarova, 2015). The predictable hydrological structure and the small size of the ponds, their easy maintenance, monitoring and troubleshooting were the advantages of this type of aquaculture farming (Boyadzhiev et al., 2011). Marine aquaculture has developed much later, but until the 1990s it occupied a small share of the total aquaculture production in the country. This branch of fish farming has developed more noticeably in the last 15 - 20 years, when a number of scientific experiments and introductions of some marine species in the Bulgarian Black Sea areas, funded by projects and grant schemes, have been conducted (Kolemanova & Manolov, 1977; Konsulov, 1980; Moncheva & Konsulova, 1983; Dilov, 1985; Bocheva, 2014; Klisarova et al., 2015).

Bulgaria is no exception to global trends and is developing aquaculture as a small, specific sub-sector of agriculture with great potential for development. A current analysis of the state of the Bulgarian Black Sea aquaculture and the prospects for its future development through the introduction of new native (autochthonous) and introduced (allochthonous) marine species, as well as the study and application of China's experience as a leader in the world aquaculture production were the subjects of this article.

### Aquaculture Production - Black Sea Countries and China

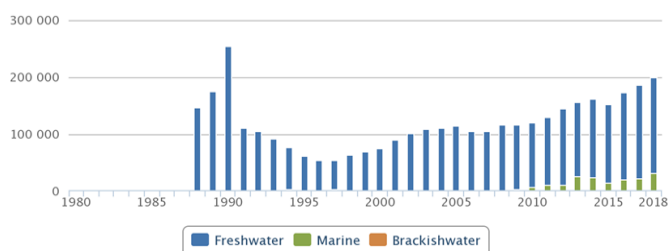
In the Black Sea countries, neighboring of Bulgaria, there are different trends in the aquaculture development after the 90s of the last century. In Turkey and Russia aquaculture production increased in the last decades (Fig. 2 & Fig. 3) (FAO, Turkey, Russia, 2020), while in Georgia, Bulgaria, Ukraine and Romania, the divergent trends were observed. In Georgia and Bulgaria, after a decline in the 1990s and the first decade of the 21<sup>st</sup> century, there is currently a tendency to recover production volumes (Fig. 4 & Fig. 5) (FAO, Georgia, Bulgaria, 2020). Unlike those countries, in Ukraine and Romania a decrease in the production of fish and aquatic organisms is observed from 80s of the 20<sup>th</sup> century until nowadays (Fig. 6 & Fig. 7) (FAO, Romania, Ukraine, 2020). After the 90s of the 20<sup>th</sup> century, China is a world leader in aquaculture production with sustainable growing trend of this production (Fig. 8), (FAO, China, 2020).

Aquaculture production by culture environment the Republic of Turkey (tonnes)  
Source: FAO FishStat



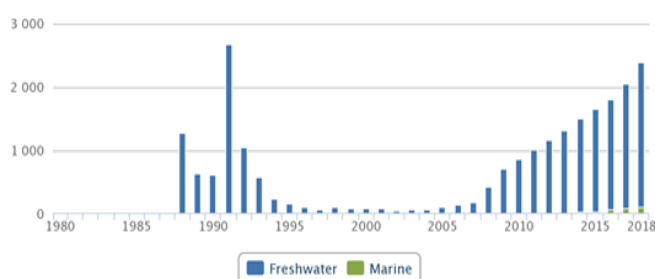
**Fig. 2. Aquaculture production in Turkey (t / y), 1980 – 2018)**

Aquaculture production by culture environment the Russian Federation (tonnes)  
Source: FAO FishStat



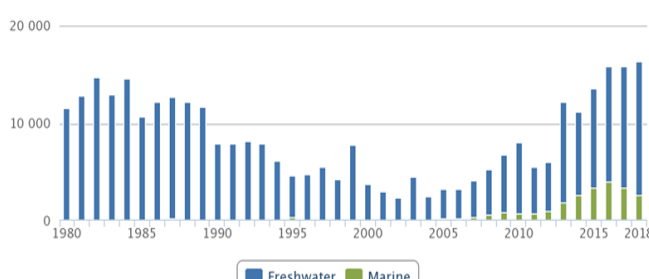
**Fig. 3. Aquaculture production in Russian Federation (t / y), 1980 – 2018)**

Aquaculture production by culture environment Georgia (tonnes)  
Source: FAO FishStat



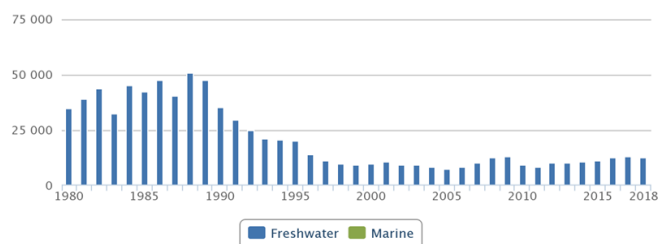
**Fig. 4. Aquaculture production in Georgia (t / y), 1980 – 2018)**

Aquaculture production by culture environment the Republic of Bulgaria (tonnes)  
Source: FAO FishStat



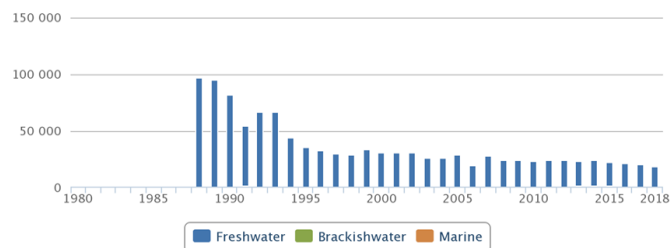
**Fig. 5. Aquaculture production in Bulgaria (t / y), 1980 – 2018)**

Aquaculture production by culture environment Romania (tonnes)  
Source: FAO FishStat



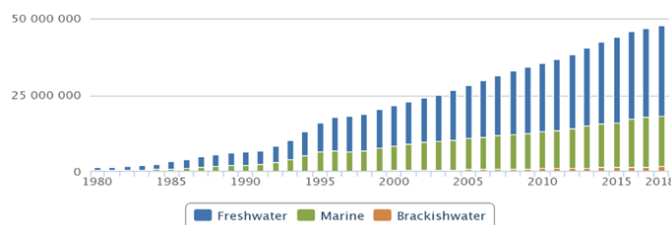
**Fig. 6. Aquaculture production in Ukraine (t / y), 1980 – 2018)**

Aquaculture production by culture environment Ukraine (tonnes)  
Source: FAO FishStat



**Fig. 7. Aquaculture production in Romania (t / y), 1980 – 2018)**

Aquaculture production by culture environment the People's Republic of China (tonnes)  
Source: FAO FishStat



**Fig. 8. Aquaculture production in China (t / y), 1980 – 2018)**

Data on the total aquaculture production and average per capita consumption of fishery products are quite heterogeneous, both between the countries in the Black Sea region and compared to China. In the Russian Federation aquaculture production amounted to 199,505 t (2018), of which 169,132 t from freshwater and 30,373 t from marine water, formed also from seas other than the Black Sea; the consumption of aqua products per capita was 11.3 kg (FAO, Russia, 2020). Aquaculture production in Turkey from the Black Sea and other seas was a total of 311,681 t in 2018, including 105,167 t freshwater aquaculture and 206,514 t marine aquaculture, a quantity which satisfies both national and international markets; the consumption per capita of marine products was 7 kg (FAO, Turkey, 2020). In 2018, in Ukraine the freshwater aquaculture production was 18,595 t (no data on brackish and marine production); the consumption of fishery products was relatively high - 11 kg per capita (FAO, Ukraine, 2020). Aquaculture production in Romania was a total of 12,529 t by freshwater and 44 t by seawater in 2016 and 12,298 t in 2018, by freshwater production only; the consumption of those products was low - 4.5 kg per person (FAO, Romania, 2020). In 2018, the production of aquaculture in Georgia was a total of 2,381 t of which 2,281 t from freshwater and 100 t from marine water; consumption of fish and other aquatic organisms (from catch and aquaculture) averaged 7 kg per person (FAO, Georgia, 2020). The situation in Bulgaria is close to that in Romania with total aquaculture production of 16,340 t in 2018 of which 13,809 t from freshwater and 2,531 t from marine water (81.7% vs 18.3%), formed mainly by mollusks

(*Mytilus galloprovincialis*); per capita consumption was 4.3 kg, when the products were purchased from the store and 5.9 kg in the restaurants (FAO, Bulgaria, 2020). The total production of aquaculture in the Black Sea countries was 560,800 t in 2018 with average consumption - 7.52 kg per capita. In the same year total aquaculture production in China was 47,559,074 t of which 16,381,672 t marine, 1,586, 660 t brackish and 29,590,742 t freshwater; the consumption of fish and fishery products from catches and aquaculture was impressive - 36.2 kg per capita. The average consumption per capita in 2018 has increased by 31.7 kg compared to 1970 (Hu et al., 2014; FAO, China, 2020).

The above cited data clearly show that the production and consumption per capita of fishery products in China is many times higher than the total production and average consumption per capita for all countries in the Black Sea region and for each individual country in this region. Of course, long-standing traditions in fish farming and breeding, and the consumption of fish products in China, as well as the country's larger population must be taken into account. Nevertheless, it should be noted that China has achieved undeniable success in aquaculture production.

Of all the Black Sea countries, only Bulgaria and Romania are EU members and comply with the European legislation (legal and administrative initiatives, laws and regulations, including these in the field of fisheries and aquaculture). The other countries have their own legislation, which is not always synchronized with the modern requirements for shared space and protection of water resources.

EU legislation also sets high standards in the fields of health, consumer protection and environmental sustainability that EU aquaculture activities must comply with.

These standards have an impact on costs for producers, but can be turned into a competitive advantage if consumers' attention is focused on quality, and can also contribute to the adoption of aquaculture at local level. At same time, the EU Science for Environment Policy pays attention how the aquaculture could develop in harmony with the environment (EC, 2015). With a view to the practice of marine aquaculture, as well as the use of natural stocks of marine molluscs, EU Directives on water quality for growing mussels have been implemented, identifying suitable areas for exploitation (FAO, 2020).

### China' Experience in Aquaculture

A very useful move for Bulgaria, in its efforts to create and develop modern, successful and sustainable systems for aquaculture production is to share the experience of the world leader in this field - China. Mariculture had a long history in China, but large-scale production began only after 1949 (CAID, 2003). From 1950 to 1970, the government began to fund the research of breeding valuable and excellent aquatic species, which played a vital role in developing Chinese mariculture, e.g. sea cucumber breeding research in 1954. During the period 1970-80, the culture of shrimp prospered greatly (Jilin, 1997). In the 1980s, the sector in China grew dramatically, becoming one of the fastest developing sectors of the country's agriculture. The ratio of valuable species increased from less than 1% in 1978 to over 40% in 2008. China ranks first in the world for fish production and exports. Income growth and transitional economic environment have dramatically changed the food consumption patterns in the country. Chinese people have learnt to consume significantly more seafood than they did in the past, which affected the intensive aquaculture development (Hu et al., 2014).

The Chinese government has made tremendous efforts to promote the advancement of the aquaculture industry through the technical resources of its extension system. China has established a relatively comprehensive aquaculture extension system under the leadership of the Ministry of Agriculture and Rural Affairs. The system includes the five-level state-owned extension organizations, the main body, and research institutions, universities, social organizations, and aquatic enterprises. The three popular aquaculture extension models are used: technical extension programs, demonstration zones, and technical consultation. However, problems such as insufficient funding, outdated staff structures, and inefficient management systems should be addressed to promote the prosperity of the aquaculture industry (Zhao & Shen, 2016; Wang et al., 2020).

In recent years, China has registered a total of 30.28 million t of farmed fish per year, representing 64.34% of the national fish production. Chinese aquaculture is much more diverse compared to that of all other countries in

terms of farmed species (over 200) and farming systems/methods. Chinese fish farmers contributed to 62% to the world's farmed food fish production in 2015. China harvested 13.9 million t of seaweeds from aquaculture in 2015 (FAO, China, 2020).

About 40 commercially marine and brackish water species are farmed. Traditional marine culture is largely limited to four groups of molluscs: oysters, calms, blood cockles (*Anadara granosa*) and Manila clams. Scallop (*Chlamys livida*) and abalone have developed in the 1980s. Seaweed production has developed in the 1950's. The shrimp culture industry started in the 1980s. *Penaeus chinensis*, *Penaeus japonicus*, *Penaeus monodon*, *Penaeus vannamei*, *Penaeus merguensis*, *Penaeus penicillatus* and *Metapenaeus ensis* are the major species farmed in China. In present days *P. vannamei* is the dominant species in terms of production. Extensive production of marine fish began in 1990s based on the sea bream, milkfish (*Chanos chanos*), sea perch, Japanese flounder, mullet, yellow croaker (*Larimichthys polyactis*), grouper and puffer fish. Species introduced from abroad such as seabass, large mouth bass, turbot (*Psetta maxima*), redfish (*Centroberyx affinis*) have also been successfully farmed (FAO, China, 2020). Nowadays, the goal of mariculture is to realize the genetic improvement of cultured species, ecological engineering of culture technologies and protection of marine environment (Fusui, 2003). Additionally, integrated mariculture is a more popular culture pattern with its priority of ecological benefits (Shuanglin, 2011). The rapid development of aquaculture in China has contributed to improving the supply of a variety of foods, but has also led to an increase in Chinese employment and income (FAO, China, 2020).

In world practice, a modern technology for building marine aquaculture is the use of integrated marine aquaculture, which is a more popular culture pattern prioritizing ecological benefits (Shuanglin, 2011). Integrated aquaculture is described as an aquaculture system sharing resources, water, feeds, management, etc. with other activities; commonly agricultural, agro-industrial, infrastructural (wastewaters, power stations, etc.). Integrated aquaculture has been widely practised by small households, mainly in Asia (FAO, 2009).

At present, there are several dozen types of integrated aquaculture in China that offer several ecological benefits, including waste reclamation through trophic relationship, maintenance of ecological balance by commensalisms of farmed species or production systems, optimization of resource use (time, space and food), and disease prevention. Integrated aquaculture can be divided into three forms: technical integration, species integration, and system integration, the latter consisting of two sub-groups (integration of aquatic systems and integration of aquatic and land systems) (Shuanglin, 2011). Nowadays, the goal for mariculture is to realize the genetic improvement of cultured species, ecological engineering of culture technologies and marine environment protection (Zhou et al., 2019).



Suggested filter-feeding bivalves in China are the Pacific oyster (*Crassostrea gigas*), black mussel (*Mytilus galloprovincialis*) (Zhou et al., 2014), scallop (*Chlamys farreri*) (Hawkins et al., 2002), blue mussel (*Mytilus edulis*), Chinese pleated oyster (*Crassostrea plicatula*), Chinese scallop (*Chlamys farreri*), Manila clam (*Tapes philippinarum*), razor clam (*Sinonacula constricta*), blood cockle (*Tegillarca granosa*) (Hawkins et al., 2013), that can effectively consume and consequently eliminate the phytoplankton.).

Furthermore, the faeces excreted by the mussels become food source for the deposit-feeders, e.g. sea cucumber (class Holothuroidea). Species from this class are *Apostichopus japonicus* (Kim et al., 2020), *Cucumaria frondosa* (Sun et al., 2020) and *Holothuria tubulosa* (Gunay et al., 2020). So, this pelagic and benthic coupling culture model became more and more popular in China and Japan (Takeda and Kurihara, 1994). The dried form of sea cucumbers has been a seafood and medicinal cure for Asians over many centuries.

There are about 20 types of edible sea cucumbers in China, which have long been used in traditional medicine and as a tonic food (Fig. 9). The protein content of dried sea cucumber is more than 50% in most edible species. In order to meet the growing demand and to protect natural resources, the highest priority is given to the seed production of the sea cucumber (*Apostichopus japonicus*) (Fig. 10), as well as to the development of cultivation and breeding techniques. Yields in recent years have reached over 5,800 t (dry weight) and the sea cucumber is sold directly to restaurants or processed as dried edible and medicinal products (Chen, 2004). China has become the world's largest producer of sea cucumber (Robinson & Lovatelli, 2015).



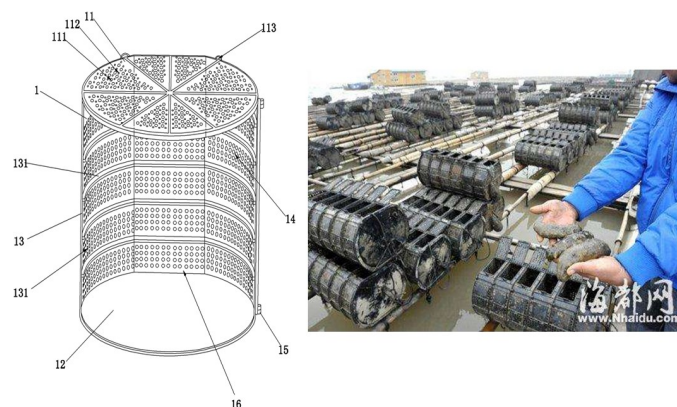
**Fig. 9. Traditional sea cucumber dish (Corresponding author's personal archive)**



**Fig. 10. Sea cucumber (*Apostichopus japonicus*) - general view**

(Source: e-health magazine, <https://theconversation.com/sea-cucumbers-are-so-popular-in-asia-they-face-extinction-24011>)

The suspended cages for culturing sea cucumber are a very popular system in China (Fig. 11). The suspended bivalve aquaculture is used since it is not only economically but also ecologically advantageous by functioning as a biofilter and potentially mitigating eutrophication pressures (Zhou et al., 2006). The economic value of sea cucumber has been recognized along with its nutritional value. Sea cucumber polysaccharide, including holothurian glycosaminoglycan and holothurian fucan, has a certain protective ability for normal cells. It can enhance the cellular immune function and inhibit the activity of tumor cells (Sun et al., 2006; Zhou & Xu, 2008). Though there is little direct reliable scientific evidence to support claims that sea cucumber is effective in treating cancer, arthritis and other diseases, its health care functions are widely recognized (Janakiram et al., 2015).



**Fig. 11. Suspended cage for culturing sea cucumber in China**

(Source: Qu Qinghui, 2006)

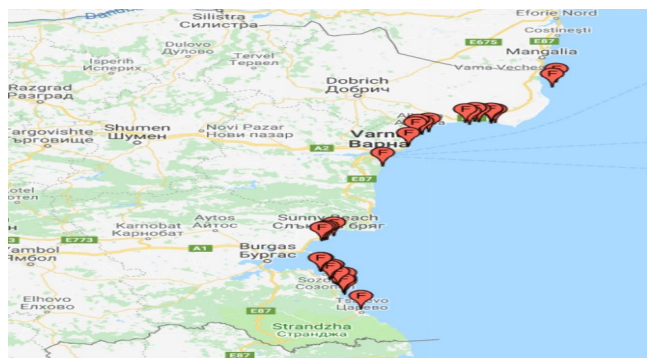
Like most sea foods, sea cucumber is low in fat and cholesterol and a good source of protein, it also lowers the blood pressure. In fact, 100 grams of sea cucumber provides 26% of the recommended daily protein intake. It also provides other nutrients, such as vitamin A, Ca, Fe, as well as amino acids and collagen, which are all essential nutrients for healthy growth. As a result, its economic value is much higher than that of other marine species. (Wen & Hu, 2010).

### **Bulgarian Marine Aquaculture – State, Development, Prospects**

Aquaculture is a relatively new activity in Bulgaria, although the cultivation of various aquatic species dates back many years. The aquaculture sector began to develop in the late 18th century, when the first state-owned fish farms for rainbow trout (*Oncorhynchus mykiss*) were built. The first carp farms were built in the 1940s. As early as the 1970s, methods for growing mullet and trout fish and mussels were tested in the Bulgarian Black Sea waters, but they did not progress into aquaculture production (Kolemanova & Manolov, 1977; Boyadzhiev et al., 2011).

In this period, semi-intensive production systems were normally used and intensive rearing systems were applied in the trout fish farms. The most popular fish reared are the rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792), common carp (*Cyprinus carpio* Linnaeus, 1758) and Chinese carps (*Hypophthalmichthys molitrix* Valenciennes, 1844; *Hypophthalmichthys nobilis* Richardson, 1836; *Ctenopharyngodon idellus* Valenciennes, 1844) whereas the main output of marine aquaculture is the black mussel (*Mytilus galloprovincialis* Lamarck, 1819). Fish farmers sell their aquaculture production mainly on the domestic market. The majority of the quantities exported are in the form of frozen fish products (FAO, Bulgaria, 2020).

The cultivation of black mussel (*M. galloprovincialis*) in the Bulgarian Black Sea waters began in 1971 thanks to studies of the scientists from Institute of Fish Resources (IFR) - Varna, who established the most suitable constructions of mussel farms for the sea conditions on the Bulgarian coast (Fig. 12) (Konsulov, 1980; 1983; Konsulova, 1984). Mussel farming installations are divided into two types: surface ("long lines", "star" and "fan" types) and underwater facilities (construction of collectors from the bottom up, below water surface (3 - 4 m) to avoid the destructive effects of waves and storm conditions (Boyadzhiev et al., 2011). A total of 3113.5 t of blue mussel were harvested from 34 marine aquaculture farms in Bulgaria in 2015 and 3376.3 t in 2016 - an increase of 8.4% compared to the previous year (Agrarian Report, 2017).



**Fig. 12. Map with the black mussel aquaculture farms location along the Bulgarian Black Sea coast, 2018**  
(Created by Dr. D. Gerdzhikov)

In 1980s, scientists from the Institute of Fish Resources (IFR), Agricultural Academy, Varna have conducted pilot experiments on fattening rainbow trout in sea water. The experiments were performed in two stages - laboratory and field experiments in Balchik and Sozopol bays. An easy adaptation of the rainbow trout to life in the salt water of the Black Sea and a good growth rate when temperatures were below 20°C (autumn - winter - spring fattening) were established, as well as the need to create storm-resistant cages and methods to combat summer diseases of the rainbow trout in order to ensure a year-round production cycle (Kolemanova & Manolov, 1977). In the same period, the

scientists have conducted another experiment for seaweed (microalgae) cultivation using the technology of the Southern Research Institute of Fisheries and Oceanography (YugNIRO) in Sevastopol, Ukraine. Apart from the scientific interest, this experiment was also dictated by practical needs as in the recent years, algal biomass off the Bulgarian coast and in aquaculture areas has declined because of different reasons. With this in mind, Dr. Klisarova and Dr. Gerdjikov (IFR – Varna) proposed an idea for feeding farmed aquaculture, in order to avoid crushing the shell of mollusks and to increase the taste quality of the mussels. Unfortunately, the idea was not shared by the business, although the laboratory experiments have shown that it was on the right track and that the artificial feeding of the mussels in marine aquaculture in order to increase their growth rate was a natural and gentle method of production with conservation of the mussels and fish populations (Dilov, 1985; Klisarova, 2015). In 1980-1982 in IFR-Varna attempts were made to grow mullets, which for a number of reasons (insufficient funding, low interest, underdeveloped market, etc.) did not end with the development of technologies to be offered to producers (Technical IFR Reports, 1980; 1982).

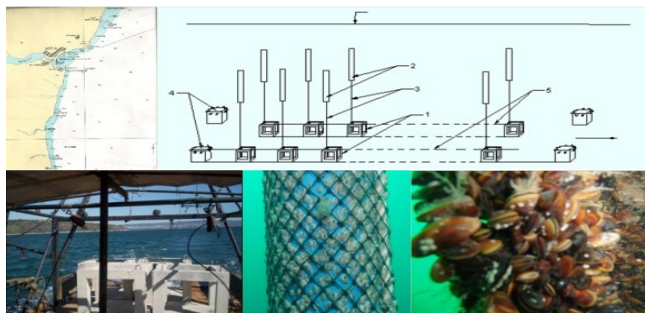
The 1990s marked the beginning of the transition of ownership in freshwater aquaculture from the public to the private sector, formed by both existing and newly built aquaculture production facilities. The fisheries and aquaculture sector has a specific position and role in the national economy. The sector is relatively small with a share of about 0.05% of the Gross Domestic Product (GDP), but provides employment at a regional level, especially in the coastal areas, where it has a significant impact on the local economies. The advantages of the sector are related to the presence of potential for aquaculture production in freshwater and sea waters, the availability of unused natural resources, combined with low labor costs and market opportunities (NSPFA, 2007). Currently, the main task of the authorities and associations in the fishery and aquaculture is to adapt the sector successfully in order to effectively apply the requirements of the Common Fisheries Policy of the EU, to stimulate expansion in the production of fish and fish products and to target foreign markets. It must be underlined that as a whole existing legislation in the sector has been harmonized as far as the rearing, processing and marketing of fish and other water organisms were concerned.

The development of aquaculture in Bulgaria is dependent on the successful application of efficient technologies, innovation and modernization, on the good interaction between fish farmers and research institutes, advanced information systems use as well as using the experience of leading countries such as China (FAO, Bulgaria, 2020).

The innovative mussel farm, developed by the research team of IFR-Varna in 2012, contributed to upgrading and using the scientific capacity of our marine science to test and introduce a new and more productive technology for growing the Black Sea black mussel.

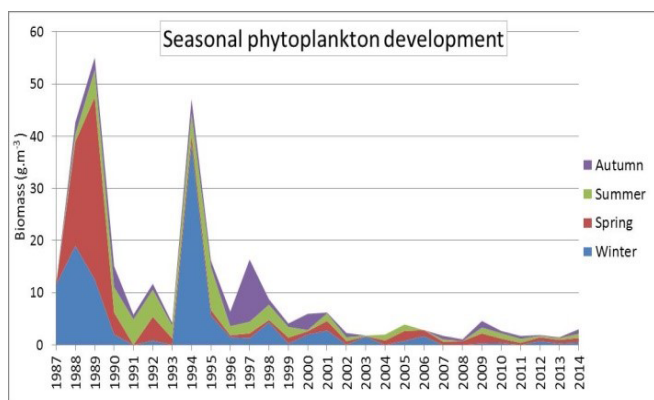


The collectors of the mussel farm were placed on specially designed anchors at the bottom, with removal to the water surface in a dynamic state (Fig. 13). Growth of mussels to commercial size is directly dependent on their diet. In this connection, the ecological conditions in the area of the mussel farm during the period 2010 - 2012 were studied (Klisarova et al., 2015).



**Fig. 13. Underwater experimental mussel farm at the Institute of Fish Resources - Varna, 2012**  
(Source: Klisarova et al., 2015)

Phytoplankton and detritus (dead organic matter) are the main ingredients in the diet of the black mussel (Moncheva & Konsulova, 1983). During the period 1992 - 2006 in front of the Cape Emine, Cape Galata and Varna bay a significant decrease in the level of the produced phytoplankton biomass was registered (about 30 times compared to the period 40 years ago) (Gerdjikov & Petrova, 2008). This negative trend continued until 2014 (Fig. 14), then a slight increase in the abundance and biomass of phytoplankton in front of the Cape Galata, Cape Ilandjik and Varna Bay was observed, especially in 2017, when the measured values were the highest for the last decade (Klisarova et al., 2019). The results are encouraging for the restoration of the food stocks in the Bulgarian coastal waters of Black Sea.



**Fig. 14. Long-term changes (1987-2014) in the seasonal phytoplankton biomass ( $\text{g.m}^{-3}$ ) in the Bulgarian Black Sea water area**

Attempts to diversify the species grown in marine aquaculture have been made by private Bulgarian companies. In the period 2007 - 2014, in Burgas the Australian fish barramundi (*Lates calcarifer* Bloch, 1790) was grown in intensive, closed recirculation aquaculture system, but in

small quantities (17 - 20 t per year). This is a delicacy fast-growing fish (it grows twice as fast as the turbot), with a very good taste and quite resistant to various weather conditions. The farm has a modern recirculation system that maintains the water purity, the required temperature and salinity (Fig. 15). Due to the high demand for that fish, the ambition of producers was to increase production to 50 - 100 t per year (Standartnews.com, 2014).



**Fig. 15. Farm with recirculation system for barramundi growing**  
(Source: Standartnews.com, 2014)

In the period 2008 - 2017, the state of fish stocks in the water basins of the country has deteriorated, mainly as result from the anthropogenic impact of unreasonable activities (deforestation, construction of hydraulic facilities, lack of adequate treatment plants, and inflow of heavily polluted rivers into Black Sea). In many ways this negative trend is more pronounced for the Black Sea due to the fact that the sea is isolated from the rest of the global hydroecosystem (Klisarova & Gerdzhikov, 2020).

Modern aquaculture production in Bulgaria is dominated by the production of carp and trout in freshwater aquaculture, followed by the black mussel - in marine aquaculture. An indicative fact is that out of 764 fish farms in 2018, 730 were for freshwater aquaculture, and only 34 - for marine aquaculture, i.e. there was a large imbalance between freshwater and marine aquaculture (Agrarian Report, 2019). Despite the increase in the number of the aquaculture farms and the quantity of the aquaculture produce, it cannot meet the needs of the local market. This leads to an increase in imports of fishery products, most often frozen, from other countries. Nevertheless, Bulgaria remains one of the lowest consumers of fish and fish products per capita in the EU - 7.0 kg per capita in 2013 (FAO, Bulgaria, 2020).

The existing large market niche for fish and other aquatic products can be successfully filled by increasing aquaculture production in the country. In this regard, Bulgaria has a great chance to benefit from China's experience in the fisheries and aquaculture, as the two countries have contractual relations for cooperation in this field. Within the frame of several Bulgarian-Chinese projects (including the initiative "One Belt, One Road") Dr. D. Klisarova and Dr. D. Gerdzhikov had the opportunity to get acquainted with technologies for fish farming and feeding ponds with selected strains of algae with a high nutrient supply.



This knowledge and contacts give a confidence for offering new, attractive species of hydrobionts that can be introduced in the Bulgarian aquaculture farming.

Diversification in the production of aquatic organisms in Bulgaria should be aimed at the inclusion of valuable species of both local fauna and imported species. In our marine waters, in addition to black mussels (*M. galloprovincialis*), there are opportunities for cultivating other economically valuable species, such as rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792), mullet (*Mugil cephalus* Linnaeus, 1758), turbot (*Scophthalmus maximus* Linnaeus, 1758), rainbow trout, bivalve mollusks, white mussel (*Chamelea galina* Linnaeus, 1758, *Donax trunculus* Linnaeus, 1758, *Mya arenaria* Linnaeus, 1758 and *Anadara kagoshimensis* Tokunaga, 1906). The reasons to offer these species are that they exist in neighboring countries, the conditions in the Bulgarian Black Sea water area are suitable for them, and that they are easily adapted for growing in aquaculture farms. In modern conditions it is necessary to establish the economic effect of using these species in aquaculture production systems.

The authors share the national experience and international knowledge, suggesting growing non-native species of echinoderms (class Holothuroidea), a genus of sea cucumbers in Black Sea coastal farms. For this purpose, special tanks, equipped to maintain the optimal for these marine species hydro-physical and biological parameters of the environment can be used. This will ensure their efficient and safe cultivation. Sea cucumber cultivation has an established economic effect (prices on international markets are high) and potential for business development. We offer the experience, scientific observations and tests from Chinese research institutes and universities (Wuhan, Xiamen). These species, which usually develop in waters with high salinity, subject to the conditions for safe cultivation in ponds / tanks of aquafarms, will not cause unwanted reproduction if they accidentally end up in the Black Sea, whose water is lower in salinity, i.e. unsuitable for preserving their vital functions. This will comply with the requirement that the introduction of non-native species does not endanger the local flora and fauna. It is possible to carry out studies on other new species in compliance with Regulation (EC) N708 / 2007. The document establishes a framework governing aquaculture practices related to introduction of alien species in the country. In recent years, there has been an increasing interest in the cultivation of grass carp as a means of combating the highly invasive species of zebra mussel (*Dreissena polymorpha* Pallas, 1771), (MNSPAB, 2013).

The future diversification in the production of hydrobi-

onts in Bulgaria can be aimed at including valuable species of local fauna: whitefish, perch, tench, Danube trout, sea-mullet, turbot fish and others, which for one reason or another have not been an object of cultivation in our country so far (MNSPAB, 2013). New innovative technologies and approaches for cultivation of non-native species from the high price segment, having proven their perspective in the world, can also be successfully applied. The enrichment of the range of harvested seafood would support the sustainable economic development of the coastal municipalities and improve the social status of people living along the Bulgarian Black Sea coast. Furthermore, it will enrich the Bulgarian market with the recent demand for environmentally friendly and healthy seafoods. The opportunities for export of part of produced aquaculture products will probably increase, which will generate additional income for the business and will provide financial resources for innovations and prosperity of the aquaculture.

## Conclusion

The analysis made gives grounds to draw the following conclusions: (i) in Bulgaria there is a large disproportion between freshwater and marine aquaculture in favor of the former (81.7% vs 18.3%); (ii) the main production of marine aquaculture in the country is due to the black mussel (*Mytilus galloprovincialis*); (iii) in Bulgaria consumption of fish and other aquatic organisms per capita is comparable to that of other Black Sea countries - Turkey, Georgia and Romania (about 7 kg per person), and lower than that in Russia and Ukraine (about 11 kg per person); (iv) Bulgarian marine aquaculture sector, despite the modest production volume so far, has a large economic potential and prospects for future development; (v) the marine aquaculture sector has great prospects for future development, both on native and introduced species; (vi) Bulgarian cooperation with China gives an opportunity to use the rich Chinese experience for successful development of the native marine aquaculture; (vii) market-oriented innovations in aquaculture are welcome and implemented by Bulgarian business.

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