“Piloting of eco-innovative fishery supply–chains to market added–value Adriatic fish products”

Priority Axis: Blue innovation

1.1- Enhance the framework conditions for innovation in the relevant sectors of the blue economy within the cooperation area

D.4.2.1. Brochure of product lines

WP4 -INNOVATING TOOLS AND PROCESSES FOR ADDED-VALUE ADRIATIC FISHERY PRODUCTS/
A 4.2. DESIGN, DEVELOPMENT FEASIBILITY OF SPECIALIZED POLYVALENT-MULTIUSE PROCESSING PACKAGING SOLUTIONS

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REPORT EVALUATION	mr.sc. Mario Lovrinov	
MEMBERS OF EXPERT TEAM	mr.sc. Mario Lovrinov	Maribu d.o.o.
	Ivan Matijašević,MBA, dipl. ing. Ana Brala Gospić, bacc. oec. Lovre Vidov	Omega 3
	dr.sc. Pietro Rocculi, prof. dr.sc. Luca Camanzi	University of Bologna
CONSULTATION	mag.ing. Valentina Andrić	Ministry of Agriculture- Fishery department
	dr. sc. Lav Bavčević	University of Zadar
PRODUCTION	MARIBU d.o.o. Marine consultancy company	

Content

Abstract

The study, with a technical description of the fishery's operational protocols, sublimated the basic commercial and technological preferences in fishing operations to preserve fish and other marine organisms on a fishing boat. Exclamation point in fishing operation was given for catching sardine and anchovy in the Adriatic Sea and selection of clams, while for demersal seasonal fish and other marine organisms will be given to processing. The analysis covered with documents, analyses the current state of the main stock, trends in catches, quality assessment, innovative process solutions as well as management recommendations, management measures and also sustainable management especially of the small pelagic resource. The complete operational flow from fishing to the landing of small pelagic fish is presented as also an advantage in processing. Emphasis was given to finding and identifying those parts of the operating procedure where the introduction of technological upgrades and innovative solutions of operational procedures, changes in techniques and technology, that could improve the quality of catching small pelagic from the Adriatic Sea as well as making effective selection of clams and processing innovation for seasonal catch of shrimps, musky octopus and mullets as a species of common interest.

Through the splitting of operations, an attempt was made to identify the level of operation in which quality could be affected. The most sensitive point found in small pelagic resources is within the final squeezing of the purse seine net and the harvesting or collecting- lifting fish on the boat. Specifically, it can be seen that in the process of collecting fish nearby the boat there is an extensive squeezing of catch, and later through the manipulation with crane and hand net fish can be damaged much more frequently. Operation is medium slow, which can significantly affect the quality of the fish. As all fish go through the same process and traditional techniques of lifting fish to the deck, the opportunity to change the catch manipulation option on board is opened as a bottleneck.

Considering that the use of harvesting pumps would be an innovation that has not yet been applied in the Adriatic to catches of small pelagic fish, it would be an important and comprehensive sound of innovation. Current operational procedures allow the integration and implementation of a new harvesting system through pumps whose adaptation and installation on board will be a pilot action to verify the efficiency of their use, in terms of raising quality and efficiency. This provides a complete operational point of process where quality product can easily withstand for further processing and packaging operations.

With the rapid increase in fleet capacity after World War II, the issue of fish conservation from catch to processing is also being raised. As a result, the use of ice is introduced, and daily surplus catches are frozen and used in processing during the time between two fishing darks or trawler voyage.

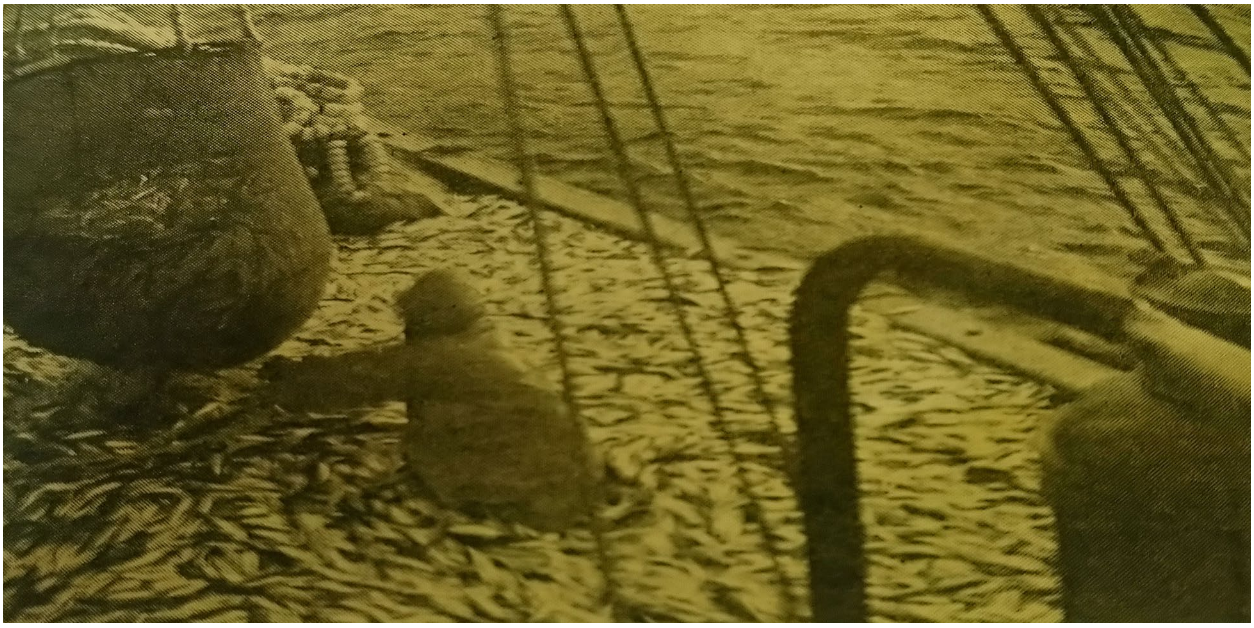

Figure 1: Fish handling on the boat-Source: Historical development of contemporary tuna fishing - A. Viličič

Freezing processes developed tremendously in the late twentieth century to the present days. The introduction of fast individual deep freezing (IQF) into processing small pelagic fish is completely changing the development opportunities and access to new and distant fish markets.

This brief introductory survey of small pelagic fisheries in Croatia indicates that sardine and anchovies have always been treated as commercial species that were not caught solely for their own use and the local market. This was only possible by finding the possibility of preserving fish from deterioration, which ultimately resulted in new products achievement. Sardine and anchovy processing are therefore an integral part of fishing for these species throughout history. These fish species are also recognized as high quality food and are a constant motive for innovative products and improvements in the process from catching to bringing them to the market and to final consumers.

Project participants and main product

OMEGA 3- The business is primarily based on the fishing activity of sardine and anchovy creating more than 20 % of Croatian catch by purse seine.

ISTRA- The business is primarily based on the fishing activity of demersal fish and other marine organisms, creating biggest catch on mullet (por. Mugilidae, muscy ostopus- Elodone moschata), shrimp on some occasions

BIVALVIA- The business is primarily based on the fishing activities of bivalve molluscs from the Adriatic Sea. The main species are the Striped venus (*Chamelea gallina*), Smooth callista (*Callista chione*), Warty venus (*Venus verrucosa*) and Razor clam (*Ensis minor*).

All three producer organisations also include commerce and product distribution activities

PROJECT BENEFITS-The project is structured in order to create possibilities for sustainable development and increased economic benefits in the Croatian/Italian fishery sector. A main task is to identify and recognise which “bottle necks” exist within organisation structure, technology innovation, investment, and ensuring quality aspects in primary production and processing.

The project is divided into several specific tasks, which all together bring efficiency through:

- Knowledge transfer
- Education
- Know-how
- Evaluation of opportunities and threats
- New organisational, technical and technological solutions
- New equipment/software

The Croatian fishery sector in sense of market mostly is in a transitional phase of adoption to achieving prices according to the EU standards and levels. Italian market is much more developed in sense of value-added products. A new market policy will cover the integration market process. The project will contribute to this strategy with its covered tasks.

The project has main tasks:

1. Catch management
2. Catch handling
3. Catch transformation
4. Catch recognition

A superior goal is to guide the Croatian and Italian fishery sector towards a more sustainable development, including well managed resources – supporting an efficient industry. This requires a sector with involved participants and focus on quality education and knowledge transfer to a widest possible range, including experts, cooperatives, fisherman associations, processing industry and others involved in the first stages of value chain for resources from the sea. Main issue is to increase value of product as an indirect measure on sustainable resources.

The main goal in the short run is to achieve a more sustainable, competitive and stronger sector relaying on quality and bigger prices with more responsible approach to marine resources, and better education to all stakeholders in the sector.

The immediate goal is the direct transfer of knowledge, experience and involvement to all industry participants, directly or indirectly.

Main result is capacity-building and transfer of knowledge and experience in fishery sector.

The main aim of the whole project is to develop more sustainable fishery sector value chains, based on technical/technological innovations. The specific aims are:

A1 To achieve a more sustainable fish resource management model, catch management and systems based on scientific research and practice, by technical and technological solutions

A2 Introduction of innovation techniques and technologies in on board quality handling of the catch and throughout the value-chain

A3 Introduction of innovation techniques and technologies and improved models in first-hand trade and processing of fish (logistics, value added products on board, new processing possibility on board as well as in landing facilities development)

A4 Education and dissemination

CATCH MANAGEMENT Present situation in Croatia and Italy is characterized by structured conservation and management measures. That needs to be improved in a way that all regulations are taken as a starting point for fishing operations. Those rules are introduction to management options.

Croatian commercial fisheries are characterised by a relatively old fishing fleet that is limited in terms of vessel length, engine size and equipment. The principal target fisheries are pelagic species (tuna, sardines, sprat), and demersal finfish (hake and red mullet), nephrops and cephalopods. On average, Croatian catch consists of 85 % pelagic fish.

A number of fishery management measures are in force (closed areas, technical restrictions in the use of fishing gears and minimum landing sizes). All vessels are licensed, and the licences specify the types of gear that may use.

Monitoring of catch distribution in Croatia is based on recorded fishery logbooks and catch reports for vessels under 10 m. Obligatory introduction of sales note is giving direct possibility for directorate of fishery to follow first sales price. There are no quotas except for ICCAT catch restrictions set for tuna.

Possibilities for improvement are recognizable in possible implementation of quota options, in developing a base for reporting and monitoring of vessels performance regarding catch quality and distribution and in technical gear adjustments in order to lower discard. This will be the base for sustainable model with profitability.

Experience in technical measure on gear adjustment can also lead to reach better profitability by reducing cost of operation as well as to have a lower impact on fish by-catch.

CATCH HANDLING

Due to the traditional selling channels, markets of fish and fisheries products in Croatia are underdeveloped. In addition to capture fisheries, Croatian fish farmers produced roughly 3 000 tonnes of tuna, 13 000 tonnes of sea bass and sea bream, and 2 000 tonnes of shells.

The main export market is Italy. Fish are mostly sold from individual wholesalers and processors to the HoReCa-segment or directly to consumers.

The main difficulties are represented by (a) disorganization of product supply and marketing, (b) price instability, (c) strong competition for the supply of export and national markets, (d) lack of infrastructure, (e) lack of efficient and systematic control of the market, (f) insufficient marketing promotion, (g) underdeveloped systems for utilisation of fish waste, and (h) limited access to support services.

Improvements can be made through development of more efficient operational management system. Achieving good practices, it will be a step towards sustainable, responsible and efficient use of fisheries with the emphasis on growth, innovation, adding value, etc. Primarily to implement the technological innovation to make production better by quality issue on the boats, harvesting models, size selection and eviscerating on the boats, filleting, vacuum-packing…. With possibilities of knowledge and experience from global innovative processes, this project needs to recognize and to propose in which segments fishery industry can be moved toward better environmental and economical sustainability. After assessing the level of possibilities, interests and objectives related to subprojects, the project will develop management and technological proposals which will be subjected to knowledge transfer and education process.

A key part of these evaluated proposals may be concrete recommendations for fisheries handling management measures provided through pilot programs.

The **overall objective** of this project is to implement a new model for operational management with improvement in competitiveness and productivity of fisheries cooperatives together with transferring knowledge to end users for all segments

CATCH HANDLING - overview

Goal 1: Implantation of new technical and technological solution in on board quality handling

Goal 2: Ensure new techniques and technological knowledge on selection
Goal 3: To obtain effective processing strategy and proposals for fishery diversification

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- Knowledge and experience transfer
- Study of best practice model in the EU and world fishery
- Specifying an updated catch handling structure
- Development of pilot model
- Education and dissemination
- Proposals for pilot projects in fish catch handling
-

Results CATCH HANDLING

- **R1**: Improved on board handling – new technical and technology solutions
- **R2:** Confirming safety, quality and origin of selected products introduced
- **R3**: Developed technical models
- **R4**: Developed operating systems
- **R5**: Improved processing (primary products, products, processing systems, logistics, waste treatment, know-how solutions, etc.)
- **R6**: New technical solutions proposed
- **R7**: Improved processing approach
- **R8**: Proposal for pilot project
- **R9**: Necessary equipment provided
- **R10**: Ensured publicity and availability of the information about the programme

1. Introduction

Fishing on the east coast of the Adriatic has a millennial tradition. Fishery targeting anchovy for salting on the island of Vis has been documented in 1553 (Božanić J. 1997, Millennium of Fisheries in the Vis Archipelago Islands, A Thousand Years of First Mention of Fisheries in Croats, pp. 289-

307). At that time, sardine fishing was carried out by “Vojga” and coastal seines. Shoreline fishing using light is mentioned in the Dubrovnik Statute as early as 1272. At the beginning of the twentieth century, Petar Lorini (1903) paid special attention to the fishing of sardines in his work "Fishing and fishing devices on the eastern Adriatic Sea", stating that sardine fishing was the most significant during the role of the first Venetian Republic. In particular, it describes the development of light used in fishing operations. Only salted sardines and salted anchovies are recorded in Lorini's published production data for small pelagic fish.

The catch of small pelagic fish has been modernized and technologically transformed by the introduction of surrounding fishnets mainly on boats. There is no accurate data on the introduction of this fishing gear. In Japan, the Lampara-type encircling net was used as early as the 14th century but was still drawn to the beaches (Iitaka Y. 1971 History and Global Review of Purse Seines), indicating the emergence of this tool as a modification of coastal drifters. The same author finds the first recorded nets in Rhode Island in 1826, but the true development of this tool occurs in California. However, due to the size of net, its true development is related to the emergence of developing synthetic mesh materials. The first patent for the net was reported in Norway in 1859 (Scofield 1951. Purse Seines and Other Roundhaul Nets in California, Fish Bulletin 81). Three types of surrounding nets are mentioned, and a combination called the "Ring Net". The use of these tools’ dates from the early twentieth century. Ante Domančić Tomin describes the use of a ring-shaped nets on the Croatian coast as an idea he invented and developed on the island of Hvar in 1929. There is no clear link between his innovation and the development of this tool in the world. In Croatia, at that time, there was an increase in the number of fishing vessels and in 1935 there were 108 fishing vessels fishing for small pelagic fish. The final development of fishing for small pelagic fish occurred thanks to the “Fish Power Block” invented by Mario Puratic in 1954 and the use of an echo sounder to search for fish.

After the Second World War, the Croatian fishing fleet for catching small and large pelagic fish grew in two directions. The first is shipbuilding for small boats and the second is for the construction of fishing vessels for companies, boats over 20 m in length, modelled on vessels donated by UNRRA (Basioli J. 1984, Fisheries in the Adriatic, Ognjan Prica Printing Office 392.) The last construction in the former state refers to fiberglass ships in Vela Luka. Most of these vessels go fishing with pelagic trawl net. The pelagic trawl net was pulled by steamboats and fishing was carried out to a depth of 50 meters. There were ten pairs of vessels in Istria, of which 8 in Croatia and two in Slovenia (Tičina V. and Kačić I. 1996. Fishing small pelagic on the western coast of Istria, One Thousand Years of the First Mention of Fisheries in Croatia, pp. 543-550).

The Homeland War in Croatia was followed by the privatization of the fishing fleet and adaptation to new market conditions. Cannery production is significantly reduced and the fishing period targeting anchovies for salting purposes and the catching of small pelagic fish used as food for tuna farming began. In 2003, the Government of the Republic of Croatia adopted the "National Program for Increasing the Production and Consumption of Fish in the Republic of Croatia" with the aim of increasing the catch from about 20,000 tonnes to about 45,000 tonnes of small pelagic. Under this program, a "Fleet Modernization and Reconstruction Project" was created and the fleet capacity targeting small and large pelagic fish was increased. As a consequence, the expected catch increase, which from 2003 to 2008, resulted in an increase in annual sardine catch from 20,000 tonnes to 30,000 tonnes. This is followed by a restriction on fishing for bluefin tuna in accordance with the prescribed quotas by ICCAT (the International Commission for the Conservation of Atlantic Tunas was established in 1966. Croatia has been ICCAT Commission member since 1997) and of the 36 tuna boats only nine vessels remain. This resulted in shifting some of the fishing effort to the small pelagic. After that, the sardine catch grew and the annual sardine and anchovy catch in 2014 exceeded seventy thousand tonnes. Thus, one-species-based management has put pressure on fishing for other species and measures are now being implemented to reduce the fishing effort of small-scale pelagic fish.

Until the end of the 19th century, fishing in the area of Zadar County was mostly conducted by the island population. The most frequently mentioned are the islands of Dugi Otok, Iž, Molat, Silba and Ugljan. Particular emphasis is placed on Sali and the island fishermen who are involved in the construction of the cannery factory in 1905. Kali, nowadays a symbol of industrial fishing in Zadar County, began its development at the end of the nineteenth and early twentieth centuries, when the number of fishing vessels increased from a dozen to a total of 30 in a period of 25 years (Reiter S., Bratanić M.,. 2017, Kali, University of Zadar, HAZU, 817-830, 987).

Historical records of sardine and anchovy fishing are linked to the conservation of fish. From the first written fishery documents on the eastern Adriatic coast to the end of the nineteenth century, fish preservation was largely based on the use of salt. Some records, however, also indicate the use of vinegar (Order of the Providence of Dalmatia by A.Civran in 1630). The Agricultural Institute, which opened in Gruž in 1887, teaches fishermen how to dry, salt and prepare fish in oil (Bašić Đ. Maritime Journal 43 (2005) 1, 261-283). According to these reports, drying and marinating fish were also known methods of preservation but were probably used only for smaller quantities of fish and for the local market, while salted fish was traded throughout the Mediterranean. The export of salted anchovy from the region of Dalmatia in 1887 amounted to over 38,000 barrels. Bašić also cites export data from the island of Zlarin from which salted fish was sold in the nineteenth century to "Trieste, Friuli, Lombardy, Vatican, Naples Kingdom and the Levant Islands".

In the late nineteenth century, a new way of canning fish was introduced. The first sardine canning factory in the eastern Adriatic coast was built in Komiža in 1885. At the end of the nineteenth century and the beginning of the twentieth century, 44 fish processing factories were built on the coast. During this period, two canneries were built in Zadar County, one in Sali and one in Silba (Buturić Š. 1997, 90 years of existence and operation of the Sali fish cannery, One Thousand Years of the First Mention of Fisheries in Croats, p. 247-260). Thus, besides salting, the sardines were processed and preserved in non-sterilized cans. In the 1950s, after World War II, steam heating and canning sterilization were introduced. With the development of factories that, in addition to processed fish, produce fish by-products, fish flour and fish oil production were also being initiated. During that period, 22 canned fish factories were built in Croatia. Production in Croatia peaked in 1983 when 32 789 tonnes of canned goods were produced.

After the Homeland War, there were significant changes due to a completely new market situation. The Yugoslav market collapsed, and the cans no longer had a proportionate number of consumers. Factories and a fishing fleet were being privatized. The catch decreased the amount of sardine and anchovy catches increased. As a consequence, the processing focused on salting the anchovy. Catches of other small pelagic are finding a partial new market in tuna farms where they are used as food.

With the rapid increase in fleet capacity after World War II, the issue of fish conservation from catch to processing is also being raised. As a result, the use of ice is introduced, and daily surplus catches are frozen and used in processing during the time between two fishing darks. Freezing has developed tremendously in the late twentieth century to the present. The introduction of fast individual deep freezing (IQF) into small pelagic processing processes is completely changing the development opportunities and access to small pelagic markets.

This brief introductory survey of small pelagic fisheries in Croatia indicates that sardine and anchovies have always been treated as commercial species that were not fished solely for their own use and the local market. This was only possible by finding the possibility of preserving fish from deterioration, which ultimately resulted in new products. Sardine and anchovy processing are therefore an integral part of fishing for these species throughout history. These types are also recognized as high quality food and are a constant motive for innovative product improvements in the process from catch to marketing to final consumers.

The processing of other white fish and other marine organisms on the eastern shores of the Adriatic by quality and quantity began with the opening of a number of plants during the adaptation to EU rules and the construction of processing plants co-financed by the EU.

After the Second World War, Italy was oriented towards building a very strong fishing industry and built strong and robust vessels that could fish in distant fishing areas as far as North Africa and stay for several days at sea. Fishermen were mostly associated with strong fisheries associations, and since then a system of auction sales and commodity exchanges has been established. Europe's central position, fisheries environment, strong commercial and industrial influence have put Italy at the forefront of Europe's fisheries as well as a succession of innovations to satisfy the market over time. The development of retail chains has led to the timely diversification and marketing of value-added products, so that today we can consider Italy as a country with a highly developed fishing range and a culture of consuming fish.

2. Target species market – overview

The majority of small pelagic fishing in the Adriatic catches represent Sardina pilchardus and Engraulis encrasicolus.

The small pelagic catches market consists of:

• Traditional canning processing market mainly including sardines

• Renewed salting processing market, which mostly includes anchovies, and a smaller part of the market is looking for sardines

• Newer market for anchovy processing by marinating

• Freezing processing market

• Fresh product market

• Fresh product market for animal nutrition (tuna farming)

The development of the IQF freezing technology should also include the fresh-frozen market in the above categories.

Some buyers on the market have the ability to process fish in many ways, as well as to ship it to tuna farms. The EU has a well-developed small-pelagic and other marine product processing industry, despite high production costs.

Sardine pilchardus is an important fishery species in catch areas in zones 34, 37 and 27 while most of the world's anchovy catches are Peruvian anchovy (Engraulis ringens), with a total catch of 4.3 million tonnes (2015). Most global anchovy catches are processed for fishmeal and fish oil. Along with Chile, Peru is the largest producer of fishmeal.

Table 1. - World sardine and anchovy catch 2007-2016 FAO stat

Year of catch	Sardina pilchardus in t	Year of catch	Engraulis enrasicolus in t
2016	1 281 391	2016	342 609
2015	1 174 611	2015	432 721
2014	1 208 478	2014	273 518
2013	1 003 097	2013	407 699
2012	1 021 129	2012	491 656
2011	1 037 161	2011	607 118
2010	1 245 956	2010	588 066
2009	1 244 822	2009	537 571
2008	1 064 599	2008	550 112
2007	1 012 842	2007	673 123

Catch trends by species throughout the GFCM are extracted from anchovy (Engraulis encrasicolus) and sardina (Sardina pilchardus) and continue to be the main landed species (270,000 tonnes and 189,500 tonnes on average), followed by sprat (Sprattus sprattus) (82 000 tonnes).

Table 2.: Landings (tonnes) of major commercial species (more than 1 percent of total landings) in the scope of the GFCM Source: FAO. 2018.

Common name	Species	2014	2015	2016	% share (2014–2016 average)
European anchovy	*Engraulis encrasicolus*	210 431	345 840	254 260	22.1
European pilchard (=sardine)	*Sardina pilchardus*	195 443	184 759	188 431	15.5
European sprat	*Sprattus sprattus*	56 744	109 198	79 097	6.7

The EU fleet landed almost 5.3 million tonnes of fisheries products in 2017, the highest amount since 2014 (these figures do not include Greece, which has not yet provided the data in the last report).

The most important species by weight was the Atlantic herring with 781 535 tonnes, followed by the Atlantic mackerel (460 000 tonnes). In terms of catches, Atlantic mackerel comes first with 459.5 million euros.

Table 3.: TOP 15 landing species on EU fisheries and GFCM applications Source: Facts and figures on common fisheries policy Basic statistical data 2018 EDITION; EC

Atlantic herring	769 376	15.0%
Atlantic mackerel	545 256	10.6%
European sprat	530 414	10.3%
Blue whiting	235 182	4.6%
Sandeels	218 956	4.3%
Sardine	197 618	3.8%
Atlantic horse mackerel	183 154	3.6%
Atlantic cod	147 151	2.9%
Yellowfin tuna	144 782	2.8%
Skipjack tuna	132 632	2.6%
European anchovy	129 760	2.5%
European hake	117 693	2.3%
Atlantic chub mackerel	109 415	2.1%
European plaice	92 402	1.8%
Blue mussel	61 545	1.2%

Trade in fishery products remains important for the region. Most coastal states of the Mediterranean and Black Sea are importers of fishery products, and only eight countries are exporters (Morocco, Russia, Turkey, Tunisia, Croatia, Malta, Albania and Greece). Also, the three countries depend almost entirely on imports of fishery products (Montenegro, Lebanon and the Syrian Arab Republic). Source: FAO. 2018. The State of the Mediterranean and Black Sea Fisheries. General Fisheries Commission for the Mediterranean. Rome. 172 pp.)

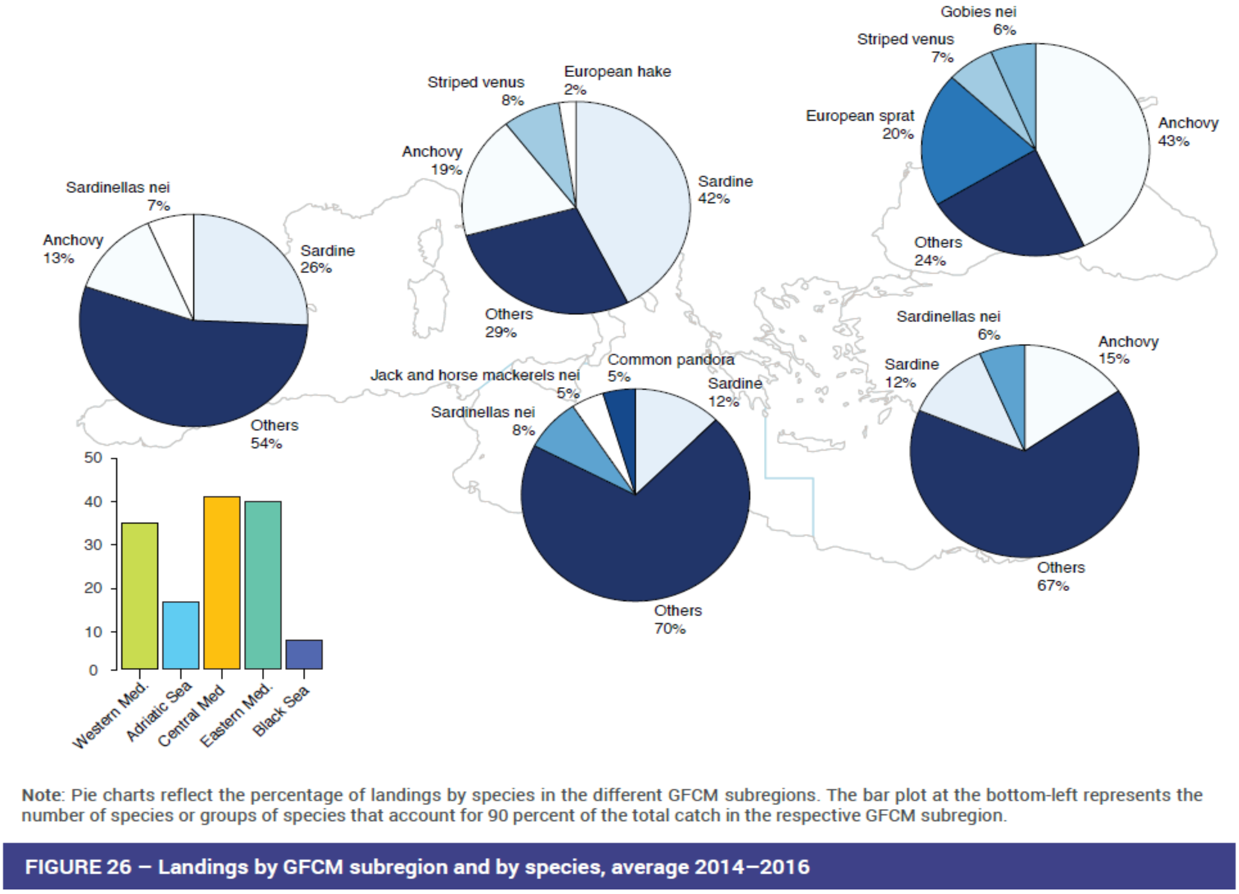


Figure 2. Concentrations and catch distributions of Mediterranean and Black Sea fisheries. Source FAO 2018. General Fisheries Commission for the Mediterranean. Rome. 172 pp.

Although more than 110 different types of fishery products are commercially fished in Croatia, 6 species account for more than 90 % of the total catch weight. The highest value among them is sardine with a catch value of € 18.1 million and an anchovy of a catch value of € 10.1 million in 2017.

Small pelagic fish are being fished by surrounding nets. The largest part of the fleet is 24 to 40 m (73 active vessels) and 18 to 24 m (49 active vessels) (SOURCE: STECF - Annual economic report 19-06).

Sardine (Sardina pilchardus) is widespread in the north-eastern Atlantic Ocean and the Mediterranean. In the Atlantic, sardines extend along the continental shelf from the islands of the Celtic Sea and the North Sea to Senegal, with a backward population from the Azores, Madeira and the Canary Islands (Parrish et al. 1989). The habitat is the Mediterranean and the Black Sea. Changing environmental conditions affect the distribution of sardines, (Corten and van Kamp, 1996; Binet 1998) Source: ICES stock annex

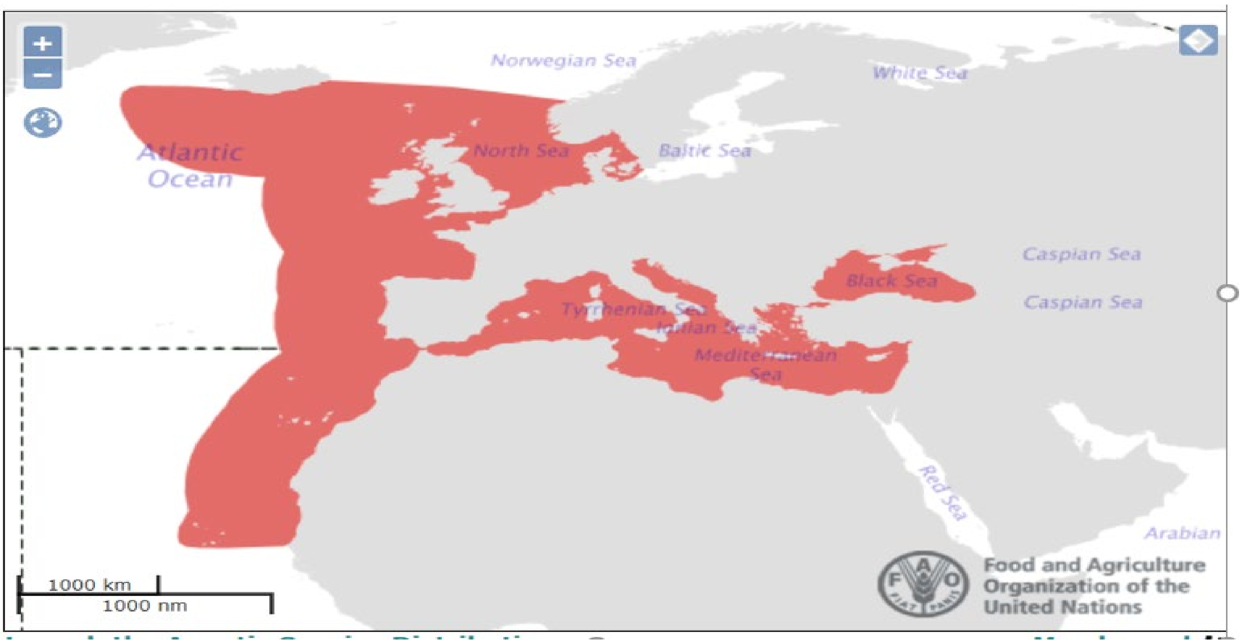


Figure 3. Geographic distribution of the species Sardina pilchardus

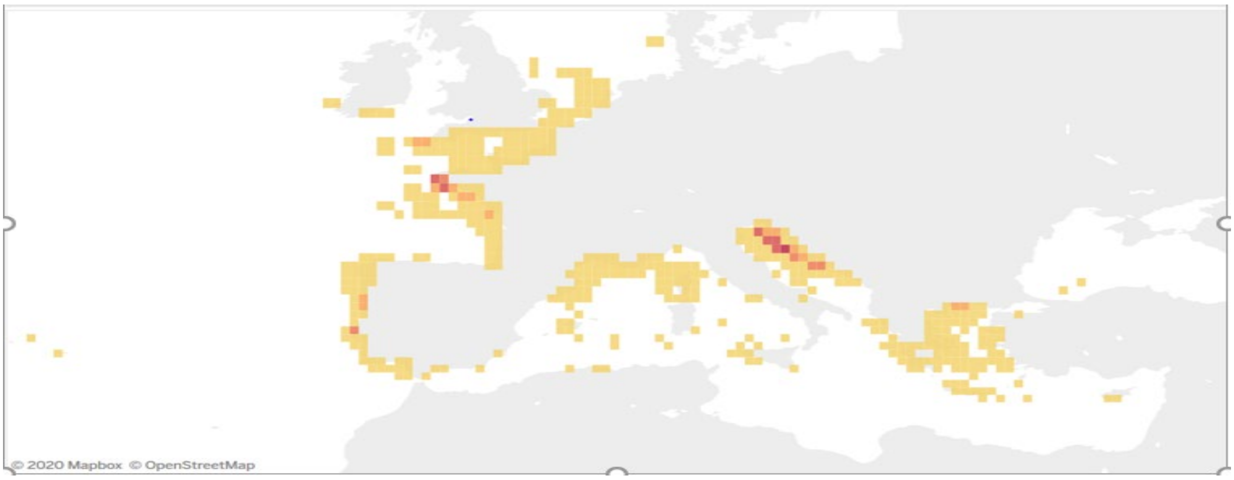


Figure 4. Spatial distribution of sardine catches Source:
https://stecf.jrc.ec.europa.eu/dd/fdi/spatial-land-map

About 200-250,000 tonnes of sardines are harvested in the EU annually (249,503 2014; 197,618 2015). About one million tonnes are fished worldwide, out of which over 800,000t in Morocco in 2014 (70% of the world's catch).

Out of these million tonnes, just under 200,000 are fished in the Mediterranean, so most of the sardine production comes from the equatorial Atlantic.

In 2006/2007, the largest producers of sardines in Europe were Portugal (91,000t) and Spain (60,000t) (source: EUMOFA Monthly highlights No 6/2016). Today, Portugal's catch has dropped to only about 14-16,000 tonnes, causing a huge damage to Portugal's fishing industry and fish processing industry. It is not clear why such a large decline has occurred, but it is believed that, in addition to intensive fishing, climate change and ocean circulation and changes in sea temperature also have an impact.

A sharp drop in catches in Portugal (-78 %) is caused by a sharp rise in first sale prices (+ 275 %). The result was a drop in catch value of only 18 %.

The EU produces around 21% of the world's sardine. Of the EU countries, Croatia currently leads the production with 22% of European catches (2014 data). The Netherlands is next behind Croatia, followed by Spain, Italy and Portugal.

The EU signed with Sustainable Fisheries Partnership Agreements with Morocco (and with Mauritania but it expired) back in 2005, which expired in 2011 but has been renewed several times since. In June 2019, EU fishermen returned to Morocco and details of the new treaty are that 138 fishing licenses have been granted, of which more than half (92) belong to Spain. Other 10 EU countries that are included in the Treaty are Portugal, Italy, France, Germany, Lithuania, Latvia, the Netherlands, Ireland, Poland and the United Kingdom. The total amount of the contract is 208 million euros to be paid to Morocco over 4 years. A significant part of this amount is earmarked for the sustainable development of fisheries in Morocco. This is the largest of all the agreements the EU has with other countries on fishing licenses, and the next largest is with the Seychelles in the amount of about 5 million euros. The total amount of the contract is divided into catch compensation (around EUR 15-20 million), support for Morocco's fisheries sector (an additional EUR 15-20 million), and one part is paid by the fishermen themselves to obtain a license (around EUR 10 million).

For comparison, the total value of fishery products landed in the Republic of Croatia for 2018 is estimated at around 59 million euros, from the check of about 18 million wastes for sardine catches.

Sardine caught by the EU fleet comes from 3 fishing grounds (source: EUMOFA Monthly highlights No 6/2016):

• Mediterranean Sea (43% of catches in 2014); most of the catches are from Croatia, Italy and Spain)

• North-East Atlantic (30%); Spain, France and Portugal have most of the catch

• East-Central Atlantic (27%) where the Netherlands and Lithuania hunt under Sustainable Fisheries Partnership Agreement

Each of these fisheries has different fishing conditions, so the highest catch is reached at different times of the year. In France, the most catches are done from July to September, while in Italy from May to June and from September to October. In the Republic of Croatia, the biggest catch is from September to November.

In 2015, Europe imported about 150,000 tonnes of sardine. Most of the imports are canned sardines and the rest is frozen for canning production within the EU. At the same time, the EU source was around 50,000 tonnes, so the total deficit was around 100,000 tonnes.

Table 4. EU and non-EU sardine trade in 2015. (value / 1000 euros) (source: EUMOFA Monthly highlights No 6/2016)

Extra EU	**Trade**	**Fresh**	**Frozen**	**Processed/caned**	**Total**
	Export	953	11.805	41.071	53.829
	Import	95	21.752	132.210	154.057

Most of the frozen and canned sardines were imported from Morocco (23,000 tonnes in 2015 frozen and 36,000 tonnes canned).

Within the EU, Spain and Croatia are the largest suppliers of fresh and frozen sardines, while Portugal dominates the sale of canned food within the EU.

It is important to emphasize that very little fresh sardines are imported into the EU (78 tonnes in 2015), which means that all fresh sardines on the EU market originate from the EU. Exports mostly relate to neighbouring countries: from Croatia to Italy, and from Spain to Portugal.

This is mostly because of the short shelf life. The closest ports in Morocco to land sardines are Dakhla and Laayoune, which are 1.500 and 2.000km away from Gibraltar, so it is not profitable to transport fresh sardines over such long distances.

Frozen imported sardines on the EU market are mostly from Morocco (EUR 20 million worth), Spain (EUR 15 million), the Netherlands and Croatia (around EUR 5.9 million).

Canned sardines are mostly imported from Morocco (about 120 million euros in value), Portugal (45 million euros), Spain and from Thailand.

The EU exports very little fresh sardine (worth around € 700,000). The most cans are exported to USA, Serbia and Australia, and frozen sardines are exported to Morocco, China and Canada.

When the sardine catches in Portugal began to decline sharply after 2012, their sardine processing industry needed to find a new source of raw materials. Companies have turned to imports from Morocco, France and Spain and today import about 50-60% of raw materials for processing. In addition, due to the lack of sardine, 19 canneries began to produce canned tuna and mackerel.

Countries in the Mediterranean (Italy, Spain and Croatia) have maintained a good position in the sardine trade, although they are also at risk of declining production to protect resources. Countries fishing in the Atlantic have significantly reduced their exports (France from 4,800 tonnes in 2008 to 800 tonnes in 2015 and Portugal from 19,300 t to 3,500 t), meaning that each country consumes almost all of its production.

Given the stock situation, the EU processing industry will largely depend on imports of frozen sardines in the future, and the fresh sardine market will depend on catches with a tendency to increase the price of fresh sardines. It is likely that for this reason an increasing proportion of EU sardine catches will be consumed fresh, due to the highest cost.

The only sardine products certified under the EU quality scheme is Cornish Sardines.
Some other products have quality certificates, especially in France where premium products are labelled “Label Rouge”.

The MSC certificate is held by two EU fleets fishing for sardines, but none is in the Mediterranean.

These are:

- "South Brittany purse-seine sardines" in France, about 20,000 tonnes per year,
- Cornish Sardines in the UK, about 1,000 tonnes a year.

Anchovy Engraulis encrasicolus is found in the East, North and Central Atlantic (Europe's coasts south of Bergen, Norway, but not the Baltic and rarely in the north; the entire Mediterranean, Black and Azov seas, with sporadic inlet in the Suez Canal and Gulf of Sue; south along the west coast Africa to Angola, also recorded by St. Helena).

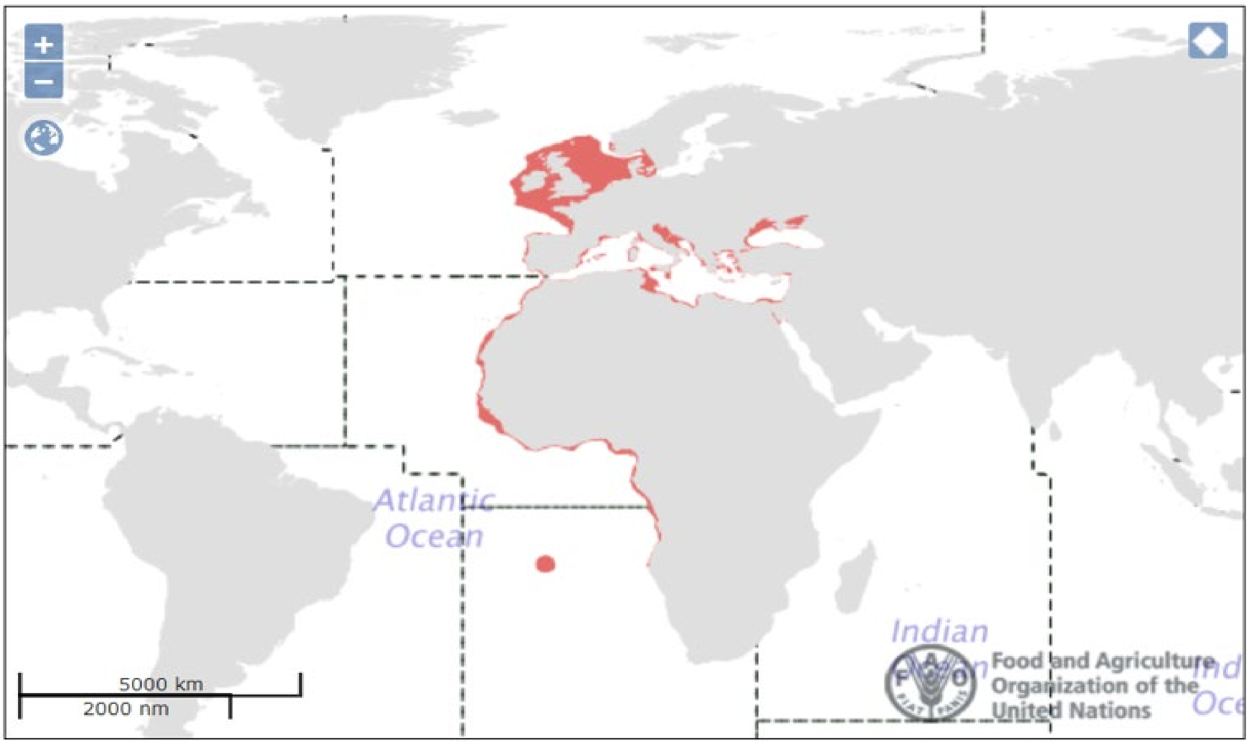


Figure 5. Geographical distribution of Engraulis encrasicolus

Spain is the largest processor in the EU and thus the largest exporter of processed products. Generally, the most of anchovy is traded. Spain and Italy import salted anchovy from Argentina, Peru and Morocco, and partly from Croatia and Albania.

Fresh anchovy is mostly traded within the EU, with Spain the largest importer with 13,270 t in 2016. It imports mainly from Portugal, Italy and France. Italy is also a major importer of fresh anchovies (3,500 t), with Germany and France importing less than 800 t.

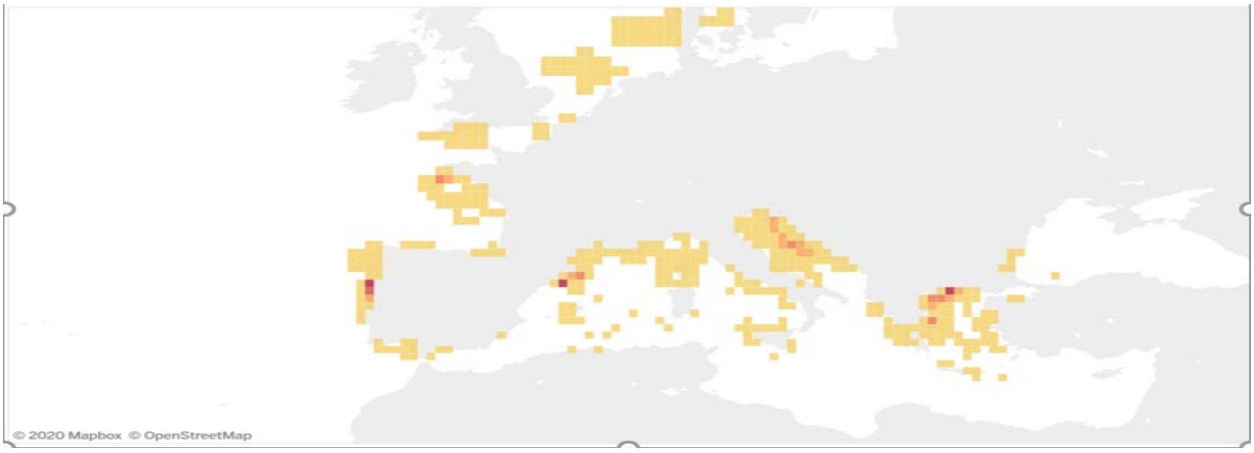


Figure 6. Spatial distribution of anchovy catches Source:
https://stecf.jrc.ec.europa.eu/dd/fdi/spatial-land-map

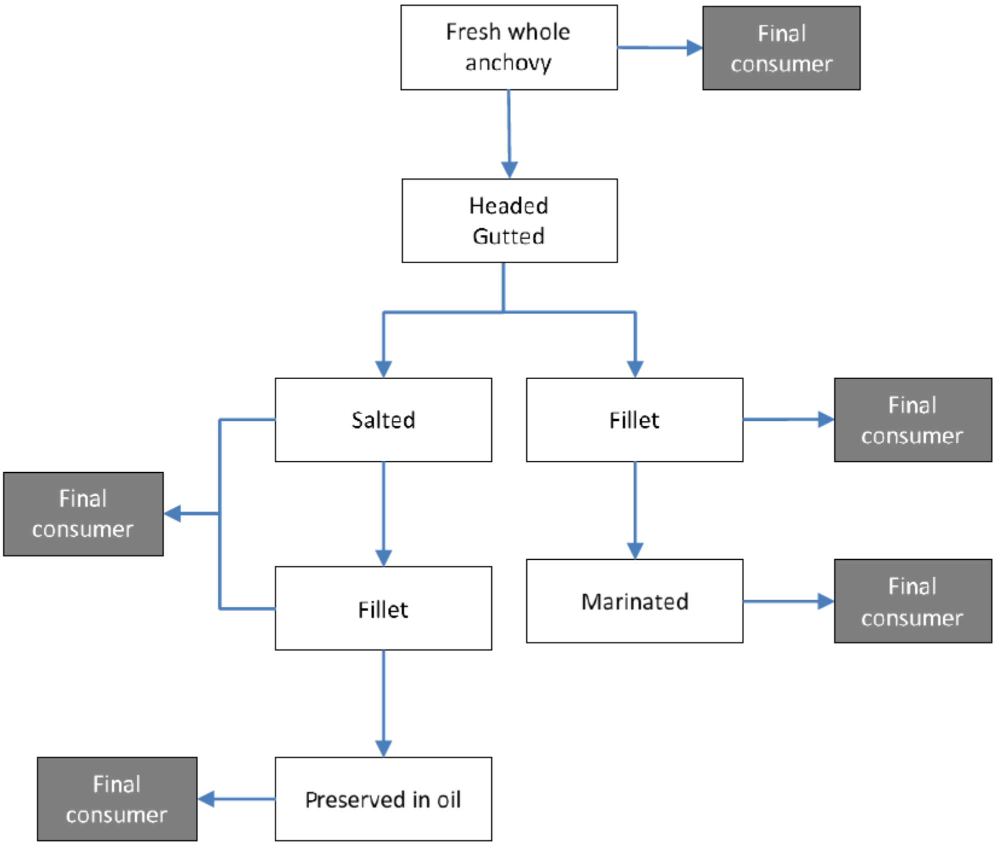


Figure 7. Processing and sales stages of anchovy (source: Case study: Processed anchovy in Italy, EUMOFA 2018)

The diagram shows that the trade in anchovies is complex because semi-processed products are traded both in retail and in individual countries.

Salty anchovy can be marketed as a final product for some destinations (for example, the United States) and raw material for the production of prepared/canned anchovy for other destinations (for example, Albania and Tunisia producing prepared/canned anchovy)

There are two geographical indications of anchovy in the EU:

• “Acciughe sotto sale del Mar Ligure” (Italy, 2008),

• “Anchois de Collioure” (France, 2004).

Both tags are used for processed anchovy. The Italian designation has not been used since 2017 because in the Ligurian Sea the size of the anchovy has fallen below the size limit specified in the specifications of the designation of origin.

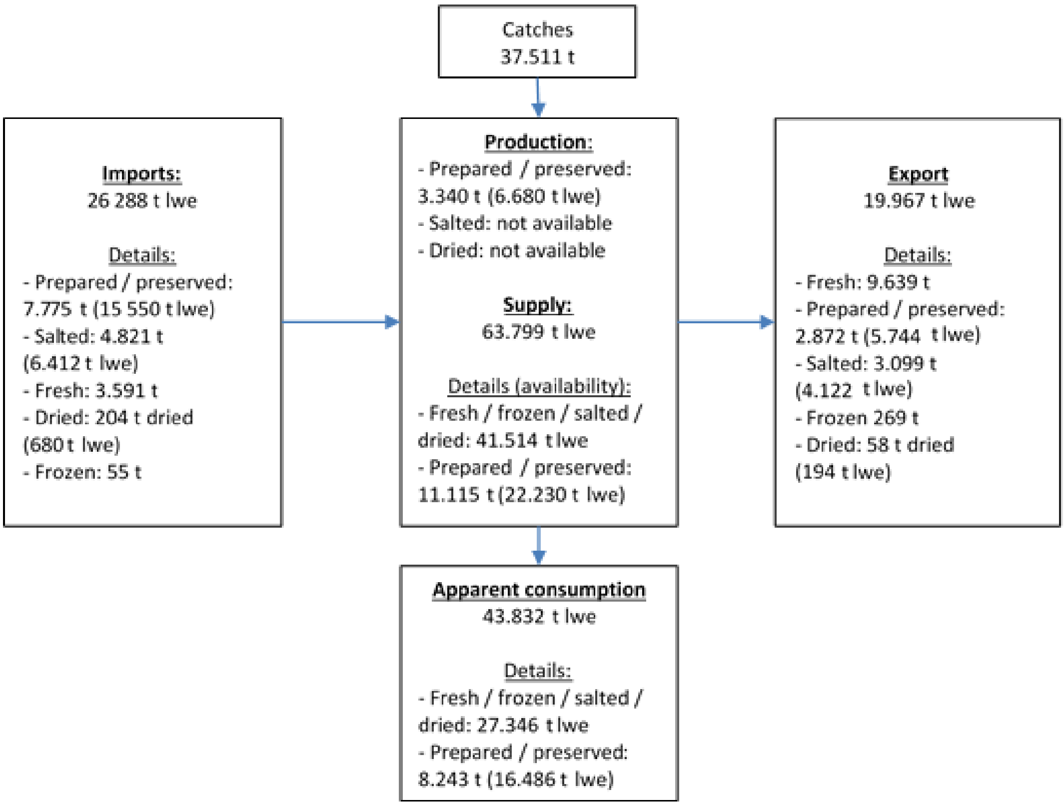


Figure 8. Anchovy trade in Italy (source: Case study: Processed anchovy in Italy, EUMOFA 2018)

The figure shows that despite the catch of 37,000 tonnes, Italy imports an additional 7,700 tonnes of fresh anchovy and exports 9,639 tonnes of fresh anchovy.

Imports to the EU in all product categories in 2015 amounted to around 188 million euros and 30,000 tonnes. The main supplier was Morocco with around EUR 108 million and 14,000 tonnes, followed by Peru with around EUR 29 million and 6,000 tonnes. The category of prepared or preserved products is the largest in terms of imports into the EU, reaching a value of EUR 162 million and 21,000 tonnes, which is 18% more than in 2014. The second largest product category, dried/salted/smoked anchovy imported into the EU, is delivered mainly by Argentina, Peru and Morocco, usually for further processing in the EU canning industry (Spain, Italy and France). The most valuable product category for export is anchovy.

In 2015, the value of exports of prepared and preserved products reached EUR 34 million. The most important in quantity was the dried-smoked category, which made up 32 % of the total. As the largest anchovy processor in the EU, Spain is naturally the largest exporter, accounting for 43% and 50% of total exports and volumes in 2015, respectively.

Morocco and Albania were the main markets for anchovy products exported from the EU in 2015, accounting for 23% and 22% of total exports, respectively. Products exported to Morocco are generally fresh and frozen products that are presumed destined for further processing in Morocco. The products exported to Albania are mainly dried, salted or smoked.

In 2014, apparent consumption of anchovies in Spain amounted to about 53,000 tonnes, with 64% being shipped from national landings and 36% from imports. Anchovies are consumed as canned, salted or processed, fresh and frozen.

In Spain, consumption of fresh anchovies per capita was stable at around 1 kg/year between 2012 and 2014(0.96, 1.12 and 1.09). Retail prices have remained stable over recent years.

In 2015, fresh anchovy was the third strongest consumed seafood product in Italy, with about 18,000 tonnes. Consumption in Italy has been steadily increasing since 2013, when total domestic consumption was 15,000 tonnes. The average annual wholesale prices reported by Mercabarna in Spain indicate that anchovies from the domestic fleet are the most attractive processing material over other foreign suppliers, i.e. France and Italy SOURCE: EUMOFA MONTHLY HIGHLIGHTS | NO. 3/2017.

The quality of the catches and seals determines the end use and the selling price, and the price of the fish also depends on the current quantity on the market. Source: https://www.prnewswire.com/news-releases/global-sardine-market-2019-2024-canned-frozen-and-fresh---canned-sardine-accounts-for-majority-shares-followed- by-frozen-sardine-

300880377.html DUBLIN, July 5, 2019 / PRNewswire / - The "Sardine Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2019-2024" report

Other relevant species

Figure 9: Fish offer in the French fish market

Catching of musky octopus in the Istrian County accounts for 40-45% of the total catch of marine organisms, except for the catch of small pelagic fish. The proportion of catches of musky octopus in the County of Istria compared to the Republic of Croatia ranges between 75-85%. The highest share of catches is in zone A, as the highest catch is recorded at 3-4 NM from the coast.

About 50% of the revenue of Istrian trawlers relates to the sales of musky octopus, which are categorized into 4 size classes and where the smallest individuals achieve the highest price. Depending on the time of the year, the structure of the catch varies, with prices ranging from HRK 8 for the largest specimens to HRK 36 for the smallest specimens for which the best season is in the spring months. The average price ranges from 12-15 HRK.

Figure 10 a,b,c,d,e. Raw material for added value product

3. Main findings in Producer organizations PO productive – marketing opportunity

Catch harvesting and handling is a crucial point for quality preservation in the value chain, involving both gear technology, vessel equipment as well as delivery and landing conditions and processing. This is knowledge possessed by industry professionals, some research institutes and by the lengthy experience achieved in organisations and by individual fishermen. Gear and equipment technology are to a great extent attended to by producers of equipment which have carried out specific projects of this kind.

In the context of strengthening export segment of economy, fishery sector must search for answers through the recognition of individual, regional and national advantages and through the creation of more effective working processes, new products and services in order to differentiate themselves from the competition. One of the ways to ensure differentiation on the market is by achieving excellence in high standards, product quality, variety of services and organization of work as well as a right managing with resources.

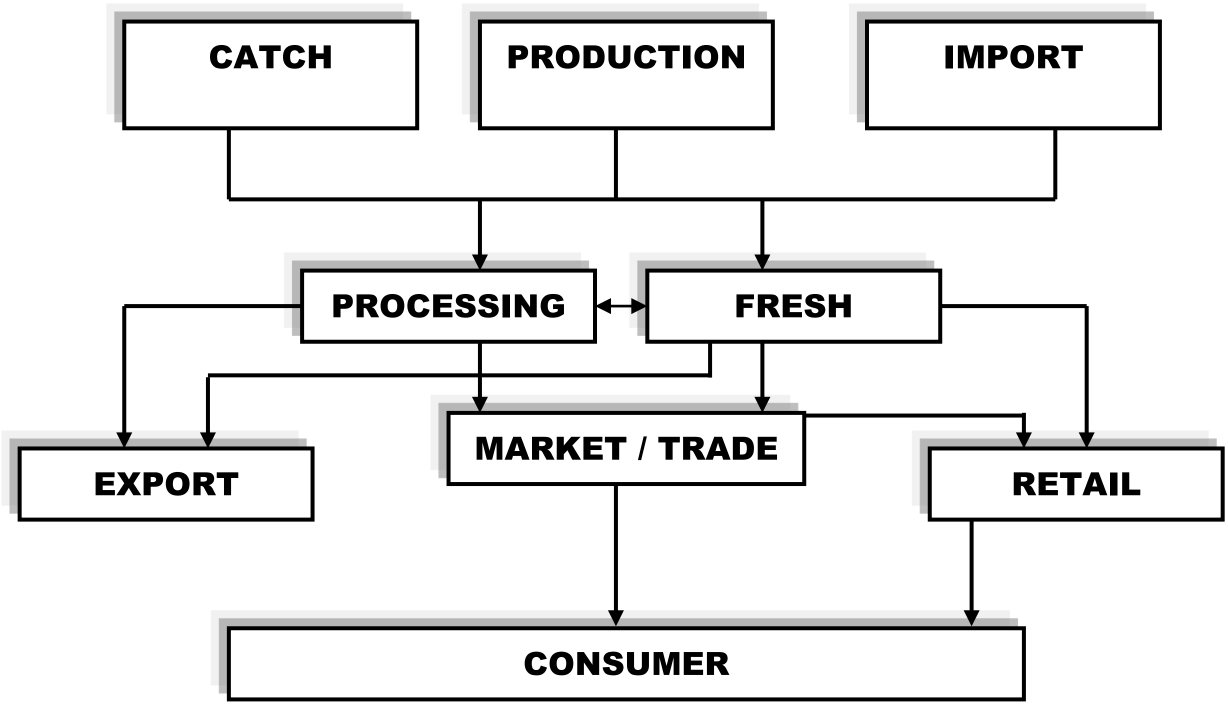


Figure 11-Product flow

For the purpose of the preparation of this study, a special marketing study was done to determine the possible raw material basis as well as the types of products that would be produced for the purpose of further evaluation of economic viability. The marketing study also looked at potential markets for product placement and determined that there was a justification in terms of demand for this type of product.

In addition to analysing consumption, consumer habits when selecting product types, imports/exports, target countries for potential markets, the marketing brief analysis included a review of the current distribution system.

The data used in the marketing study was downloaded, collected, sublimated, interpolated and verified from a number of official sources and primarily includes the data collected (Eurostat, FAO, USDA, and other sources such as CBI, World Bank, IMF, data from statistical offices and institutions of countries). It should be noted that some data differ, so some should be taken with caution, but certainly despite the differences, they show clear trends in individual countries.

A marketing analysis is an example of the importance of more thoroughly processing the market before starting any business process and can greatly assist in the quality assessment of opportunities and the ability to start new production in order to make good business decisions.

For the proper business positioning of fish operational, handling, processing and confectioning plants, it is necessary to consider the market opportunities in both raw material procurement (supply market) and product placement (sales market). This way the principle of completeness is satisfied before starting production. As a result of this producer organisations Omega 3, Istria and Bivalvia can properly consider the possibilities for successfully starting a new production or reorganizing a part of production related to the current marketing and processing of fish to reach new quality and processing level. High value-added products, new processes in terms of quality and degree of processing are crucial for increasing value of the present product.

In sardine and anchovy, there is a basis is to create the conditions for raising the quality of the catch on board and subsequently processing the fillets and promoting frozen headless sardines in the fresh produce category.

The dispose of seasonal large catches of shrimps, musky octopus, mullets as a low-value fresh and whole product are needed. This low value product needs to be directed to processing segment and transformed in products of the highest quality. In this case products of quality fillets as well as meat mixtures for further processing into ready-to-eat burgers after a short heat treatment can be achieved.

For shellfish, we talk about the Striped venus (Chamelea gallina), Smooth callista (Callista chione), Warty venus (Venus verrucosa) and Razor clam (Ensis minor) selection in the sea and the design of the entrance for the HORECa segment.

Mentioned points offers a complete range of ready-to-serve products in restaurants and hotels, open fresh markets as well as the ability to sell in wholesale chains. Modern lifestyle, extended working hours and the consequent lack of time to prepare fish place this category at the top of suitable quick preparation products.

The total EU market for fisheries products in 2006 was 10.2 million tonnes, or 10% of global consumption of fisheries products. While consumption in the successive 10 years increased by about 4 million tonnes, or up to 14.61 million tonnes on 2016. The five largest EU consumption markets are Spain, France, Italy, Germany and the United Kingdom, accounting for more than 70% of total consumption. The largest consumers in general are the Mediterranean and Scandinavian countries.

Central European countries and new member states do not have a strong tradition of eating seafood, but in some countries, there is a rise in consumption due to rising revenues and increased trade.

In the long term, the consumption of fisheries products in the EU is increasing. Consumers have an increased interest in specialty products, culinary delicacies, luxury products, value-added ones, fish fillets and fisheries products related to sustainable development, certified, and as one of the more important categories, those fish products for quick and easy preparation.

The new member countries do not have a strong tradition of consuming fishery products. Most of these countries are surrounded by land and lack a significant marine product sector and are governed by the consumption of freshwater species. However, in these countries there is an increase in consumption of marine fisheries products with the expansion of the market and an increase in personal income.

The Central and Eastern European countries have a poor tradition of consuming fishery products and are at the lowest end of their consumption levels, but this is partly why they represent an interesting development market.

Total consumer volume is projected to grow modestly, but prices and value are expected to increase through the delivery of high-quality value products and products for quick and easy preparation. FAO's predictions are that consumption for frozen fish will decrease. The consumption of crabs and molluscs is expected to increase. Markets in the countries such as Romania and Bulgaria together with Latvia and Slovenia show the highest growth rates in consumption. High growth rates are also present in Austria. Their growth values are above the EU average. Germany, Portugal and Slovakia also show good growth rates, in contrast to the markets of Poland, Ireland and the Netherlands rising below the EU average.

As countries' incomes slowly increase, so does the demand for fisheries products. Some countries that have a tradition of fishing and aquaculture, such as Poland, are also developing into a strong supplier to other EU Member States. Trade relations between surrounding countries in the EU are generally strong and reinforce the trade balance in the fishery product category.

Opportunities

- EU spending is a growing value, especially in the newer member states

- Consumption in the new Member States is growing strongly, the market is growing, and at the same time, it is driven by rising net personal income

-Increasing demand for added value, luxury and special fishery products such as the anticipated range

- Accepting new species of fish as a replacement for traditional species

- Fisheries products have a positive health image and match the health trend in almost all EU Member States

- Consumer demand for sustainable catches and aquaculture products is increasing

- Selected species can represent a good raw material base for penetrating new markets

The EU relies heavily on imports of fisheries products to meet demand. This change is structural as production in the EU is declining and consumption is rising.

- Imports from third countries are increasing strongly

-New tropical species are becoming more popular and may replace the more endangered traditional species and strike a balance in supply

-Demand for crabs and molluscs will remain strong, especially in southern European countries

-Demand for value-added products from third countries will increase, especially as they are priced very competitively compared to EU products

- Competition between third country suppliers will intensify as they lift their production

- Increasing demand for food safety and consistency will impose more rules and regulations on exporters from third countries.

Supply and demand estimation

The traditional market for fresh fish caught in the eastern Adriatic coast is Italy, where a significant share of the total catch is placed. But in recent years, there has been a partial reluctance of primary producers to find new markets from Spain, France, Austria, to the Eastern European bloc. One of the reasons is the low price of fresh fish.

When it comes to estimating the market in terms of demand for a planned type of product, we can conclude that demand and consumption are much higher than supply. Some distribution channels for planned products already exist and are very interested in the type of proposed product.

Competition for such products in relation to the target markets is not present and huge opportunities are being opened to win new markets without direct competition. On the contrary, with a wide variety of products, there are various possibilities in terms of selecting the target market and taking over and winning market shares.

4. Catch quality

Changes in the quality of fish occur immediately after its death.

The first change in fish is rigor mortis, which results from muscle contraction after death. After the rigor mortis loosens, the muscle becomes soft again, but is no longer as elastic as it used to be. The strength and duration of rigor mortis are influenced by the temperature, handling, size and physical condition of the fish. At higher temperatures, the rigor occurs abruptly and strongly, which can lead to muscle tissue separation in the fish fillet, which is visible upon further processing.

If the fish freezes before the rigor occurs, product quality may be good if the thawing is done slowly at low temperatures.

The next change is a change in the skin that is bright, vibrant in colour with live or recently killed fish, and the transparent parts are colourless and transparent. After death, pigmentation and vibrant colours disappear first, the translucent parts become cloudy, and dull mucus can form on the skin.

Eyes in fish also change colour and shape after death. With fresh fish, the eyes are bulging, transparent, and the pupil is completely black and clear. After dying, the eyes become dull, bloody or yellowish, and later on they may be recessed due to desiccation.

The flesh and muscles are firm and elastic at first, and after the rigors, the body becomes soft, the scales begin to fall off and the skin becomes dry and wrinkled.

Gills are light red in colour and smell of seaweed when the fish is completely fresh, and when the fish is older, they become burgundy, mucilaginous and have a sour odour.

The intestines and internal organs of fresh fish are solid and light in colour, and the mucus is shiny and translucent. In old fish, the walls of the internal organs crack, and the abdominal wall may rupture, and digestive juices may be released.

After the death of the fish, there is a gradual autolysis due to the activity of the enzymes contained in the cells, then the degradation by bacteria from the womb, but also from the environment, and the oxidation of lipids and hydrolysis which give rise to odour and taste compounds.

From the above it follows that in order to preserve freshness and quality it is necessary to:

1. Decrease enzyme activity
2. Decrease the activity of bacteria naturally present on the fish
3. Reduce contamination with new bacteria by humans, dirty surfaces, water, ice and everything in contact with fish.
4. Reduce oxidation and hydrolysis by modifying the atmosphere

The biotechnological assessment of fish quality is being developed in two basic directions:

• Assessment of fish quality from the aspect of food safety

• Assessment of fish quality in terms of organoleptic and nutritional properties

In the commercial sense, quality is a term that corresponds to the price that a particular type of fish can achieve on the market and the duration of quality within a framework recognized by end consumers.

The quality of unprocessed fish comes down to a freshness assessment and an assessment of the effects of the stress that results from fishing. Freshness begins to fade immediately after the death of the fish. There are 4 basic stages of deterioration, i.e. loss of freshness:

1. Autolytic changes 1. after fishing (the action of enzymes in tissues that are no longer alive). The fish is delicious, aromatic and has a good meat texture

2. Autolytic changes 2. (enzyme action). They lose their flavour and aroma, become more neutral, and the texture remains acceptable

3. Changes caused by the action of bacteria that reproduce in autolysed tissues. The already unpleasant odours and the smell of rancidity in oily fish are formed. The texture of the meat is no longer firm. This phase is referred to as the onset of deterioration and has a significant impact on end-user acceptability

4. The enhanced action of bacteria results in odours of putrefaction and is no longer edible

(Shawyer, M.; Medina Pizzali, A.F. 2003)

In areas that are poor in protein in human nutrition, they are still satisfied with the second and third quality categories. However, in developed countries, it tends to stay in the first quality category for as long as possible. To achieve this, it operates in two basic directions:

I. Stress reduction during fishing. Innovative solutions in fishing operations.
II. Retardation of autolytic processes in fish tissues. Cold Chain Maintenance.

Fish stress can be measured by changes in the concentration of certain chemical compounds in the body:

i. Primary stress is manifested in the increase in catecholamines and corticosteroids in tissues
ii. Secondary stress has a number of physiological manifestations that increase blood glucose levels, decrease blood glycogen, initiate anaerobic breakdown of carbohydrates and increase lactate concentration in muscles, increase haematocrit and alter hydromineral balance.
iii. Tertiary stress does not apply to fish in fishing, but only to live fish that have been exposed to stressors for a longer period of time.

(Portz D.E., Woodley C.M., Joseph J. Cech J.J. 2006)

Stress in trapped fish accelerates tissue degradation and supports accelerated autolysis in damaged organs. Stress also has visible consequences such as bleeding and vomiting, which speeds up the settlement and development of bacteria, which quickly lead to the third quality category.

Fish freshness is assessed by organoleptic sensory and non-sensory methods. Sensory methods for freshness of fish, for whole fish:

Table 5. - Scheme of freshness criteria

Freshness criteria - EU scheme for whole fish				
Category	EXTRA	A	B	UNDESIRABLE
SKIN	It is glossy, pigment colours are overflowing, or it is opalescent, no discoloration	The pigmentation is light, but the skin is not radiant	In the process of losing pigmentation and shine	Loss of pigmentation
EYES	Convex, black, glistening pupil, transparent cornea	Convex and slightly sunken, black, pupil is shiny, cornea is blurred	Straight, cornea blurred, and blurred pupil	Concave in the middle, grey pupil, milky cornea
GILL	Shimmering colours, numerous slips are visible	Weak coloured with translucent mucus	Greenish brown, swollen and blurry	Yellowish, covered with mucus of milky colour
FLESH	Firm, elastic, smooth surface	Less elastic	Less elastic, soft and shiny	Soft, the shells fall out, the surface wrinkled

Non-sensory methods include chemical analysis methods:

- The chemical composition of the edible part which, in addition to basic analysis (proteins, fats, carbohydrates, ash and water) can include the composition and amount of fatty acids.
- K value is a biochemical index for the quality assessment of aquatic organisms, based on the measurement of adenosine-5′-triphosphate (ATP) and its degradation products (AMP, IMP, HxR and HX)
- Total basic volatile nitrogen (TVB-N) resulting from the microbial breakdown of proteins and other organoleptic compounds.
- Trimethylamine (TMA), which is produced by the bacterial degradation of trimethylamine oxide (TMAO) that fish have in their tissues and gives a characteristic fish odour.
- Thiobarbituric acid (TBAR) is used in the determination of fat oxidation. Fat oxidation leads to fish rancidity.
- Biogenic amines (histamine, putrescine, cadaverine and tyramine) produced by bacterial degradation of histidine, ornithine, lysine and tyrosine. Tiny blue fish abound with the amino acid histidine. In the processes of bacterial degradation, histamine is produced from histidine. Histamine is toxic and causes a poisoning reaction in humans that resembles a severe allergic reaction. Therefore, it is imperative to keep the histamine concentration under control, or below the maximum prescribed level

In addition to chemical analysis, microbiological analyses are included in the assessment of fish quality. Microbiological analyses include bacteria that cause fish spoilage and bacteria that can be pathogenic to humans.

In order to preserve the quality of the catch, bacterial contamination that causes spoilage must be prevented. EU Regulation 852/2004 contains a so-called hygiene package that sets out all the necessary conditions for fishing vessels.

To prevent bacterial contamination, it is recommended that:

- The area of the fish handler must be separated from the crew rooms and propulsion system
- The area of the catch vessel must be protected from bilge water, exhaust gas, fuel or other hazardous substances.
- Seawater intake must be located far from sources of contamination
- All surfaces and equipment must be easy to clean, corrosion resistant, smooth and non-toxic
- The fish must be protected from contamination
- Ice must be made of clean drinking water or clean seawater
- Refrigerated vessels carrying fish for more than 24 hours must have equipment capable of storing fish at 0 to 2°C.
- Always keep the boat clean
- Clean drinking water or clean seawater should be used for cleaning
- Before fishing, clean the deck, fish tanks, water tanks and all equipment with water and non-toxic detergent
- All surfaces should be thoroughly rinsed after washing with detergent
- It is necessary to clean the fishing net from the residue of the catch
- Cabins, bathrooms and toilets need to be cleaned
- After returning from fishing, the deck, equipment and tanks of fish shells, blood and other dirt must be cleaned again
- Waste should be collected and disposed of far from where the fish is stored.
- Contamination from pests such as seagulls and seabirds should be considered. The tanks should have lids and the deck awning. The trash should have lids to keep pests out.
- All chemicals and detergents should be used according to the manufacturer's instructions.
- Keep all chemicals and detergents in a safe place separate from where the fish is handled.

(Huynh Nguyen Duy Bao, Sigurj´on Arason, and Krist´ın Anna I_´orarinsd´ottir., 2007

(Šimat V., Maršic-Lucic J., Bogdanovic T. , Dokoza M., 2009,

(Hus H.H., 1995., Quality and quality changes in fresh fish,

(Tahsin K. N., Soad A. R., Ali A.M., Moury I.J., 2017,

Shellfish has been an important part of human nutrition since ancient times.

There are a variety of edible shells on the market such as main important mussels (Mytilus galloprovincialis), oysters (Ostrea edulis), razor clams, etc.

By visual inspection as well as pressure, we determine whether the shells are alive and whether they have tightly closed shells. The shells which died, and which are open or which do not close firmly under pressure and touch are discarded. Shells that come from contaminated water and contain biotoxins are also discarded, as well as increased levels of bacteria.

The presence of E. coli is taken as an indicator of contamination of bivalve molluscs and water. With human and animal faeces, those and other bacteria that inhabit the gut contents, such as faecal coliforms, can enter the water.

The plan for monitoring the quality of the sea and shells in the areas of production, fishing and re-laying is a category that is mandatory in terms of production and/or harvesting and collection of shellfish. The purpose of the plan is to: - check the microbiological quality of live bivalve molluscs in relation to breeding, harvesting and re-laying areas - to check the possible presence of toxic plankton and potentially toxic plankton in water in the breeding, harvesting and laying area, and toxin in live bivalve molluscs - to check the possible presence of contaminants in live shells.

Shellfish filter large quantities of water through gills, keeping bacteria out of the water, so the total number of bacteria in grams of their tissues is much higher than in the same amount of surrounding water.

The bacterial species Clostridium botulinum type E and F, Vibrio parahaemolyticus, Salmonella spp, Escherichia colli, Streptococcus faecalis, Proteus spp, C. perfrigens are particularly important as shellfish poisoners. Many types of bacteria reproduce in the meat of the shell during their storage at temperature up to + 5ºC (Mašić, 2004).

The hygienic safety of bivalve meat can be compromised by deterioration microorganisms, especially autolytic bacteria. The meat spoilage caused by these microorganisms is very often accompanied by the formation of biogenic amines (muscarin, sepsin, neurin), which are highly toxic (Beganović, 1975). Shellfish may also contain so-called physiological toxins, which are particularly dangerous, namely mytilotoxin. Mytilotoxin is thermostable but is sensitive to alkalis. (Mašić, 2004). Biotoxins are toxic substances for humans that primarily produce eukaryotic microalgae and cyanobacteria, and are accumulated in shellfish meat by their diet, by sea filtration (Paralytic Shellfish Poison -PSP, Diarrhetic Shellfish Poison-DSP). Inorganic wastes in shells are metals (lead, iron, mercury, zinc, copper), radioactive isotopes, herbicides, insecticides, etc. (Mašić, 2004).

Shellfish are usually preserved by sterilization. First, they are well rinsed, then boiled in open-air boilers, autoclaves, in 3% salt solution for 10 to 15 minutes. Meat is removed from the shells carefully to minimize damage. It is further prepared depending on the product you want to get, usually as a can or in frozen form. The cans are filled with oil or various sauces. Mussels can be frozen, dried and preserved in sterilized cans, while oysters can be used dried or sterilized in cans (Soša, 1989).

5. Trends in raising the quality of small pelagic fish in catching operations

Throughout history, fishing for small pelagic fish went in two directions, fishing with stagnant nets (“vojge” “budeli”) and fishing with nets that encircle and compact the shoal od fish in order to catch on a vessel or shore (shore nets, shorebirds and trawl nets). For both fishermen, the quality of the fish caught was crucial, especially when it is known that the small pelagic fish species are a possible source of histamine that can cause serious damage to human health.

“Vojge” are single-headed nets and are also selective for the size of the fish caught. Fishermen with “vojge” targeted a certain size of sardine, which led them to very distant fishery grounds. Thus, the fishermen from Vis salted the fish immediately after the catch. However, fishing with such gear was limited by the number of people and the capacity to catch, which is why gears that achieve higher catches per fishing day with less work required on the vessel alone were prevalent.

The trap nets, by their catch of small pelagic fish, could not compete with the purse seine and pelagic trawler. Today, fishing for small pelagic fish is done with the surrounding networks (hereinafter referred to as the "purse seine") and the trawl net (pelagic trawler). In the Adriatic, fishermen on the east coast of the Adriatic use purse seine vessels, while Italian fishermen in the 1980s mostly switched to pelagic trawler and turned mainly to catching anchovy. There are only a few purse seine boats left on the west coast. Fishermen who fish with purse seine, target the primary or secondary processing market while fishermen with pelagic trawler turn to the fresh product market.

Fishing for small pelagic fish with pelagic trawler, focused on the fresh product market, developed in Italy after the decline of the processing industry (expensive labour). Priorities for entering the fresh product market were:

- Continuity of supply (fishing)
- The amount of catches that can meet demand
- Quality of the fish caught and duration of freshness in retail

Fishing with pelagic trawler does not use the fishing darkness, so it can ensure continuity of supply. Fishing is done by a pair of fishing vessels with a large net that provides the required catch size. The duration of the pull should not be too long and larger amounts should be avoided by the pull so that the fish caught do not cause damage due to the pull, that the stress does not last too long and that the fish do not suffocate in the net.

Pulling out live fish on deck allows for "shocking", killing in ice emulsion of water and ice, which interrupts all catabolic processes, including anaerobic digestion processes, which significantly affects the duration of the fresh product in retail. From catch to retail it is necessary to maintain a cold chain. Recently, IQF freezing technology has enabled the primary processing of fish caught in pelagic trawler, which has changed, or diversified, the market for small pelagic fish caught in pelagic trawler.

In terms of the quality of the fish caught, fishing for sardine fish differs from fishing for pelagic trawler by the amount of catches taken in one zone and by the target market. When fishing for purse seine, the fisherman "grazes" the fish usually once during the fishing day. Italian fishermen practiced more harnesses (2-3) in the night. Croatian fishermen have a tradition of fishing for small pelagic fish for processing, so the amount of daily catch has been linked to optimization, which includes the cost of fishing and the price that can be afforded by fish processors.

In recent years, Croatian fishermen have been turning to the fresh fish market as well as using IQF technologies to place frozen fish to distant markets. Hereinafter, we will pay particular attention to the connection between fishing operations in purse seine fishing and the quality of small pelagic fish as a product for the first sale market.

6. Catch trends and target species in purse seine fishing

The target species in the purse seine fishery in the Adriatic Sea are sardines and anchovies. Occasionally other pelagic species are also fished. For illustration, the graph below shows the composition of the catches made with a sardine in 2012, where catches of sardine and anchovy account for more than 94% of the total catch. By-catches prevail Atlantic horse mackerel and chub, while the participation of other species in the catch is negligible.

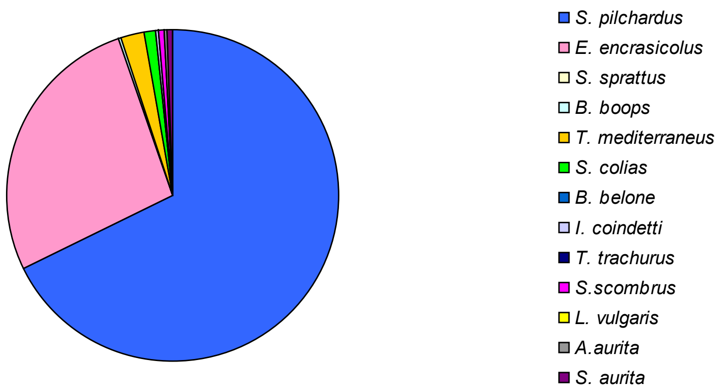


Figure 12. Species representation in srtdelara catches in 2012, in the Adriatic Sea (GSA 17), by species (from: Lucceti et al. 2014 Technical properties of purse seines targeting small pelagic species in the Adriatic Sea.)

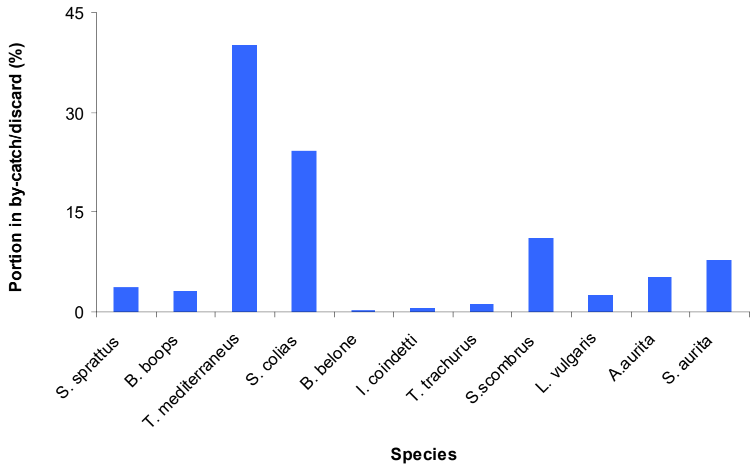


Figure 13. Species representation in the by-catch of purse seine 2012, in the Adriatic Sea (GSA 17), by species (from: Lucceti et al. 2014, Technical properties of purse seines targeting small pelagic species in the Adriatic Sea.)

The representation of species in catches by purse seine have a significant impact on the quality of the fish caught at first sale. The presence of Horse mackerel in the catch can significantly damage the sardine and anchovy. Anchovy is particularly sensitive to skin damage caused by scales on the side of the mackerel.

Targeting a particular species in a purse seine catch is not entirely possible, so the catch to a greater or lesser extent includes species not targeted by the fisherman. The following graph shows the annual composition of sardine and anchovy catches in 2017. It is evident that equal quantities of sardine and anchovy catches are rare. However, in the prevailing sardine catches, an average of about 7% of anchovies are fished and in anchovy catches on average 24% of sardine are found.

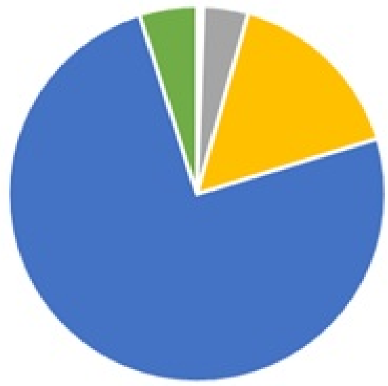


Figure 14. Composition of catches of sardine and anchovy - distribution of catches by share of each species in the 2017 annual catch. An average of 7% of anchovy was caught in sardine-dominated catches and an average of 24% of sardine caught in anchovy-catches. (Source: Ministry of Agriculture)

The targeting for each species depends on:

• Long-term fishing experience - boat captain's estimate of expected catch

This estimate comes to light at the beginning of the fishing dark when the fleet is looking for fish.

• Short-term experience in catching small fish. It is based on the catch information in previous days and the position of the vessels determined by the review of the vessel tracking system

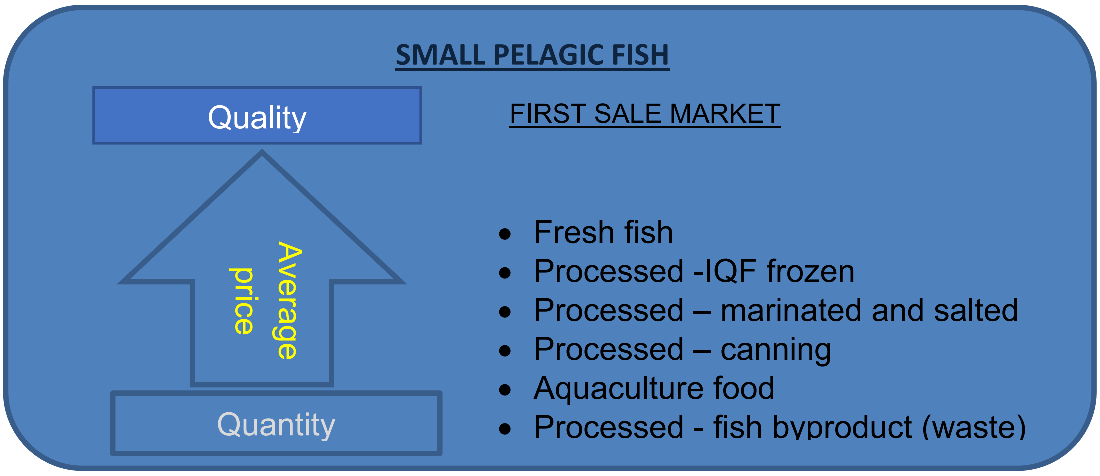
• Estimation of the amount of expected catch of each target species

• Assessment of the relationship between the cost of fishing and the value of the expected catch

• Weather. The captain estimates the certainty of the catch in the expected weather conditions, so he can choose the fishing area where he estimates the probability of catching

The cost of the fishing trip is proportional to the distance of the fishing area from the landing port, and the value of the catch depends on the catch structure (species, average size), the quality of the fish caught at the first sale and market situation.

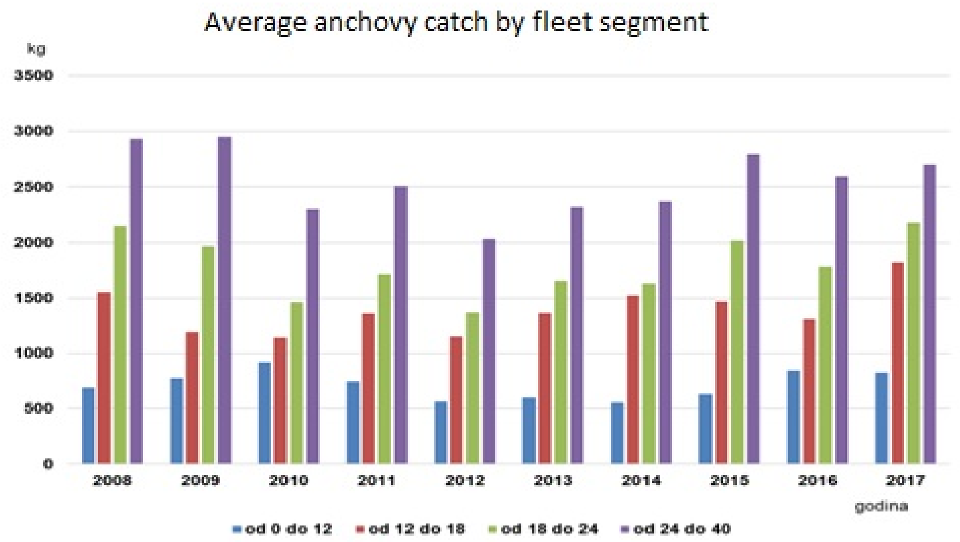
On the revenue side, decisions on fishing area selection and target catches are in the optimization of catches given the expected quality and quantity of catches:

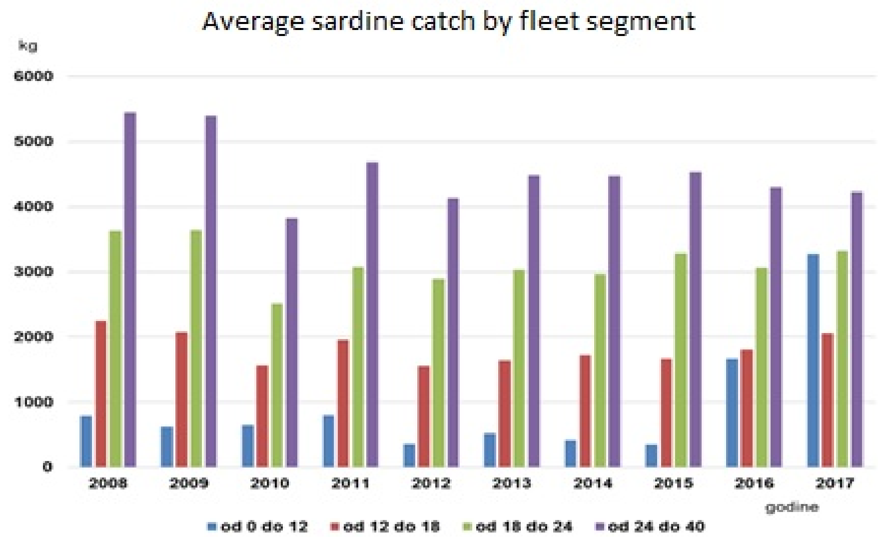


Maintaining quality is generally easier to achieve with fewer catches in the net, and the decline in quality is linked to excessively large catches and a lack of adaptability in fishing operations to the quality of fish (from species in catches through seals to fishing operations, shocking and preserving quality to landing). This means that the decline in the quality of the fish caught can be offset by the amount of daily catch, which is contrary to the EU Common Fisheries Policy.

The representation of species in the catch is reflected in the quality of the product because the species caught need to be separated (sorted), which represents one extra operation. The need to sort fish when it goes to market or processing is technologically and commercially based, but there is also an administrative obligation to record catches and weigh catch by species at first sale. A partial exception is in the use of small bluefin tuna fish where quantities of individual species are estimated on a sample basis.

Figure 15. Throwing fish in cassettes immediately after "shocking" in ice emulsion (Source: HRT / YouTube / Screenshot)





Graph 16 am. Average daily catches of anchovy and sardine by fleet segments from 2008 to 2017

As a rule, the daily catch amount is proportional to the size of the fishing vessel. The impact of daily catch quantity on quality is significant. The large quantity of fish caught should be gradually squeezed into the jacket and care should be taken to ensure that no anoxic conditions are created and that, due to stress, the fish do not die before being caught from the fish net. In large catches, including catches higher than average for vessels over 18 meters, the speed of fishing is crucial. The goal is to catch undamaged and live fish as quickly as possible on board a fishing vessel where shock is carried out in an ice emulsion. This way, the residence time of the fish is reduced, which contributes to the reduction of fishing stress.

7. Review of existing technological and operational procedures in catch-to-landing and processing with general recommendations

The Hazard Analysis Critical Control Point (HACCP) system serves to control food safety by analysing risks, recommending design for space, process and equipment safety to achieve optimal hygiene, and setting measurable standards and monitoring and control systems.

The HACCP system is aimed primarily at controlling the hygiene, process and maintenance of the cold chain and can be applied at all stages of production, from catch to retail.

Some of the critical control points in establishing better quality fish and other marine organisms processing are:

- Maintaining a cold chain during transportation and in the processing plant itself, recording temperatures
- Control when flushing fish and other marine organisms
- Removal of fish and other marine organisms that are infected with parasites, damaged or of poor quality
- Good plant hygiene and reduced bacterial contamination
- The shorter the process of cleaning, filleting and other manipulation of fish and other marine organisms

The quality and durability of fresh fish is raised by cleansing the intestines because it naturally contains many bacteria and enzymes. Small pelagic fish cannot be cleaned on board, and most often they are processed whole. If the fish were intensively fed just before the catch, belly burst could result in a significant decrease in fish quality (source: FAO FISHERIES TECHNICAL PAPER - 348, Quality and quality changes in fresh fish, 1995).

New packaging frameworks and technologies for preserving quality and freshness:

MAP packaging

The next step in improving quality is to control the atmosphere because the reduced amount of oxygen reduces the oxidative processes and bacterial growth. For meat products, the impact of the vacuum and the modified atmosphere on the durability of the product is much greater than that of fish, because the deterioration of meat is influenced by gram-negative bacteria such as Pseudomonas. Although gas mixtures involving about 30 % oxygen are used for MAP packaging of white fish, crustaceans and shellfish, carbon dioxide and inert nitrogen mixtures are used in the packaging of small pelagic and other fatty fish to reduce the oxidation of fatty acids in tissue. Too high a concentration of carbon dioxide causes acidification, which causes the water to drain from the fish.

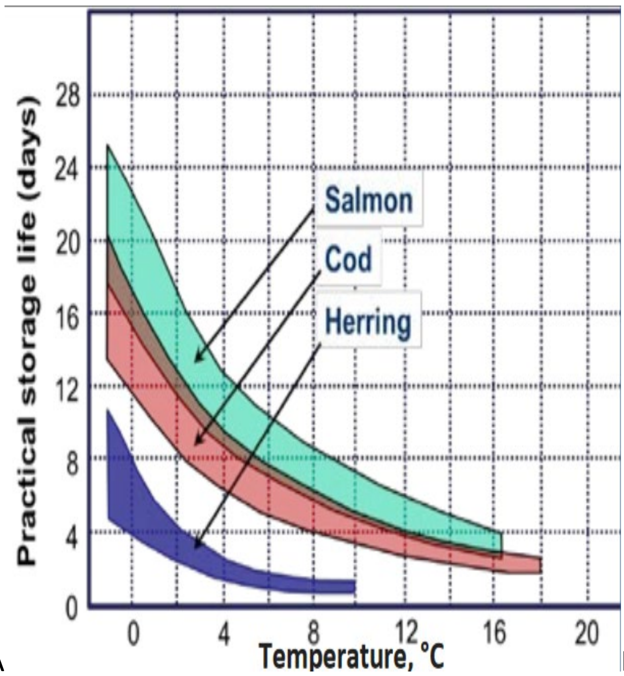
Özogul et al. (2004) experimentally proved that shelf life of sardine is 12 days if packed in MAP atmosphere with ratio 60% CO_2 : 40% N_2 at 4°C, and 9 days in vacuum packing while in ordinary atmosphere its duration is only 3 days. They measured several parameters, including histamine content, bacterial counts, trimethylamine concentration (TMA) and total volatile nitrogen (TVB-N) (F Özogul, A Polat, Y Özogul,)

Super chilling

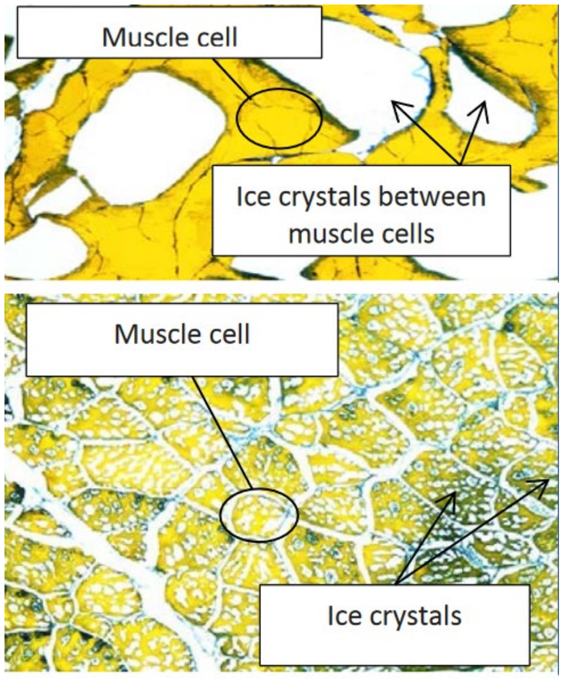
Storage at temperatures from 0 to -4°C is called super chilling or partial freezing. This storage method can extend shelf life by as much as 15 to 30 days for a portion of whitefish species, depending on temperature (source: FAO FISHERIES TECHNICAL PAPER - 348, Quality and quality changes in fresh fish, 1995), which gives additional time to resellers to place the product on the market.

The principle of super chilling is to keep the product at a temperature of 0.5 to 2 degrees below freezing. Although pure water is freezing at 0°C, the fluids in fish tissue contain salt, proteins and other solutes that lower the freezing point of body fluids. Depending on the type of fish, this temperature is different, but in most species, about 50% of body fluids are frozen at temperatures between -2 and -2.2°C (source: Fresh fish keeps up to two days longer, Eurofishmagazine.com). If the temperature drops to -2.8°C, almost all the fluid in the fish is frozen and shelf life is extended for up to 35 days, but then larger ice crystals are formed and, upon thawing, more fluid is lost and the destruction of fish tissue happens.

From the above it can be seen that this process is extremely sensitive and demanding and that the temperature should be maintained within a narrow range.



A



B

Figure 17. a.b.c The temperature-shelf-life ratio for the three fish species; B formation of crystals inside the muscle during freezing (Source: Super chilling of fish: long shelf life, superior quality, low transportation costs; www.sintef.no)

There are two ways to achieve super chilling. The first is that the product is cooled without any pre-treatment, while in the second method, the surface of the product is first frozen, followed by the equalization of the temperature inside. If the cooling is done incorrectly, large ice crystals can form inside the tissue, resulting in poor product quality as shown in the figure.

In addition to the extended shelf life, supercooling is also useful in filleting, as subcooled fish has firmer meat that is easier to process and reduces waste by about 2 to 3%. Additional savings are achieved because no ice is required for transport and storage. Supercooled fish are transported in Styrofoam boxes. In the case of longer transport, some dry ice may be added to the boxes to keep the temperature low.

Super chilling is a technique that pays off only for raw materials of exceptional initial freshness and quality.

Super chilling on fishing vessels was first used by Portuguese trawlers who had in their vessel's tanks filled with water and ice with bulkheads through which coolant tubes pass. This system maintains a controlled temperature of 0°C so that the fish comes into port supercooled and is ready for further processing.

As the Portuguese method of supercooling is demanding in terms of processing the hull of the ship, British trawlers use a simpler super chilling technique. They put the fish in boxes in such a way that there remains an empty space between them, through which cold air can be blown. However, it is much more difficult to maintain the same temperature throughout the warehouse with air than with water. Fish that are on the surface will freeze faster than those inside the box. Because of this, water is often accumulated at the bottom of the box and the bottom layer of fish is glued together. To separate this fish later, it needs to be warmed up, which causes the cold chain to break.

There are different super chilling techniques and one of them is to pass the fillet having a temperature of 1 to 4°C through a cold ice-water bath of 1 to 2.5% at -1.4°C for 8 minutes. The ribbon on which the fish is placed is made of Teflon and additionally serves to accommodate the heat of the fish. The fillets from the bath pass through the so-called Contact Chill Blaster (CBC) in which the air temperature is -8°C for 8 minutes, until their temperature drops to about -1°C (this is an example for cod fillets; Stevik, Astrid & Claussen, Ingrid., 2011).

Large fish processing plants located near the landing site can process tens of tonnes of fresh fish daily into super chilled products before they move on to the market.

Standard canning techniques

Traditional techniques for preserving fishery products are based on preserving or stopping bacterial and enzymatic degradation by:

- Salting (salting draws water from the flesh of the fish and prevents the growth of bacteria that do not tolerate high osmotic pressure)
- Smoking (smoking also dries fish, and chemical compounds in the smoke additionally act as a preservative. In addition, the fish must be salted or soaked in brine before smoking. During hot smoking, the fish is also heat treated, which kills microorganisms and denatures enzymes.)
- Drying (drying eliminates water from the tissue of the fish and thus inhibits bacterial growth. Before drying, the fish must be salted, which can be further preserved)
- Marinating (the marinade contains acid that denatures proteins and enzymes and stops the growth of bacteria. The fish are immersed in the oil and thus prevent access to oxygen which prolongs its life)
- Canning (boiling sterilizes the product and kills microorganisms)

8. Operational flow of catching fish until landing and processing

Fishing with purse seine involves a series of operations that can affect the quality of the fish. Fishing operations in fishing with sardine and anchovy are:

- Search for fish
- Attracting fish
- Laying the purse seine net in the sea
- Tighten, close and pull out the net
- Catching fish from the net to a fishing vessel
- Killing of caught fish (rapid freezing)
- Keeping quality from catch to landing

- Disembark the fish

Searching for fish using echolocators has significantly improved fishing for sardine fish. It can be heard among fishermen that some captains are able to estimate the biomass and species of fish. There is no scientific endorsement for this, so this opens the way to innovations that would increase the value of a catch, which by its characteristics is more suited to the objectives of sustainable fishing.

Attracting fish to light is a traditional technique that has no significant impact on the selectivity of fishing or on the quality of fish caught.

Deploying the purse seine net into the sea begins when ultrasound detection and visual observation determine that the school of fish is "ready" for the start of operation. The very process of laying a purse seine in the sea and stocking the school of fish has no significant effect on the quality of the fish caught.

Tightening, closing and pulling the net depends on the skill of the crew. In any case, the procedure should be carried out to reduce the stress of the surrounding fish. This is also affected by sea currents and eventual predators in the network. Today, we do not have the ability to monitor the behaviour of the surrounded school of fish, so the impact on fish quality in this operation is technologically very limited. **However, the last phase of netting can have a significant impact on fish quality**. The speed of net retrieval and the squeezing of fish into the sack should be matched by the density (catch amount) and the sack discharge rate (catch). Innovative fishing solutions can contribute significantly to the quality of the fish caught. **The goal is to get the fish out of the bag as quickly as possible with as little damage as possible.**

Figure 18 a,b. **Catching of fish from bag to fishing vessel (critical phase identified)**

Killing the fish after fishing (shocking) is carried out in an emulsion of ice and water. When shocking the fish, it is advisable to lower the temperature of the fish to approximately 0°C as quickly as possible. For the emulsion, combinations are used:

• Freshwater ice water

• Sea ice - sea water

• Chilled sea - ice

As the salinity decreases, the freezing point of the water decreases, that is, the water temperature decreases while it is in the liquid phase, and ice crystals begin to form in fish at temperature between -0.5 and -1.1°C.

Figure 19. Refrigeration of fish after fishing. The "shock" of the sardine and anchovy, which is then put into caches

The conservation of the cold chain then depends on a sufficient amount of ice to cache the caches, the temperature of the air, and the duration of transport until the landing of the fish.

After death, fish are unable to regulate osmotic conditions in body fluids. This means that if they are submerged in fluid that has less osmolarity than the osmolarity of body fluids, water will penetrate the body and the fish will swell. That is, if immersed in a solution of higher osmolarity, the fish will lose water and lose weight.

The following can be simplified approximatively. The body fluids of fish have a salinity of about 1 ppm and if the ice and sea emulsion had so much freshwater ice that its dissolution tends to lower the salinity below 1 ppm the fish will receive water. This is especially important if the fish are transported in chilled water where there is sufficient time for water to penetrate and swell.

In contrast, higher salinity of cold water (cold sea or sea ice and sea) should cause loss of water from fish tissue. However, by increasing the salinity of the fluid, the freezing point decreases and reaches a lower temperature than the freezing point of the body fluid of the fish. If the amount of fish entering cold water does not have enough heat to raise the temperature above the freezing point of body fluids, ice crystals form in the tissues of the fish. If these crystals are tiny then these crystals do not damage the tissues, but if the crystals are large, they can cause damage at the cellular level and accelerate autolytic processes when or if the temperature increases. This effect is used by fishermen who have to store fish for a long time (e.g. Pacific tuna) "Super chilling". Super chilling is the already described process of evenly lowering the water temperature below 0°C or -0.6°C depending on the type of fish.

In practice, super chilling is used to cool and store large fish (e.g. tuna) for longer periods. The process involves cooling the fish to -2.2°C. Then half of the water in the fish crystallizes and half of the water remains in the liquid state. As the temperature drops, large ice crystals gradually form, but at that temperature the amount of ice in the fish is insufficient to cause major tissue damage. Lowering the temperature below -2.2°C increases the amount of crystals and damages the fish as a product.

In small pelagic fishing, the situation is not completely analogous to the cooling of large fish. Tissues of small pelagic fish are softer and more susceptible to mechanical damage that can be caused by ice crystals. Furthermore, the sardines and anchovies are small in volume and therefore faster tissue cooling can be achieved which results in the formation of smaller ice crystals and potentially less damage.

In the fishing fleet, some of the vessels are equipped with either a sea ice machine or a cold sea machine. in practice, fish is often brought into the theoretical possibility of super chilling. However, this does not happen in practice. A large amount of fish is brought into the shock containers, which warms the cold sea or the cooled sea with its heat. The equilibrium temperature in the emulsion then usually ranges between 0°C and 4°C, so that the crystallization of ice in the fish does not occur.

The usual recommended mix of fish and ice seawater:

water: ice: fish = 1: 1: 4 - (kg).

In summer temperatures, it is necessary to increase the relative proportion of ice:

water: ice: fish = 1: 1.2: 3.5 - (kg)

The use of ice-cold chilled sea is not economical because latent heat of ice dissolution, which is 80 times the heat capacity of water, is not used. Therefore, for cooling the chilled sea, it is necessary to put 8 times less fish or it is more economical to add 10% less ice (preferably freshwater ice). Another option is large tanks with chilled sea that actively cool during fishing. The practical use of large refrigerated tanks must be calibrated for specific situations. This is especially due to the quantity of fish, the size of the tanks, the rate of entry of fish into tanks with chilled sea and the technical capacity of the cooling system. If a catch is anticipated that goes beyond the technical cooling capacity of the sea, a certain amount of ice should be loaded on board. Then the ice is added during the catch. To estimate the dynamics and amount of ice added, it is necessary to make measurements of fish temperature in tanks during the catch.

The use of chilled sea or sea chilled with sea ice has advantages and disadvantages:

Advantages	Disadvantages
1) Faster cooling 2) Ability to use a lower temperature than 0°C 3) Quick handling of large quantities of fish 4) In case of prolonged storage - longer low temperature preservation time	1) Fish salting 2) Loss of protein 3) Possibility of anaerobic spoilage 4) Changes in fish such as pale gills, rougher skin, blurred eyes

The choice of subcooling method depends on the target market for the first sale and the duration of the journey until the landing of the fish.

Maintaining quality from catch to landing of fish at the landing site depends on the method of temporary storage. The purpose of temporary storage on board is to maintain a cold chain, or to maintain the temperature of the fish during transport in the range -0.60°C to 0°C. They use two methods of temporary storage, traditional in fishing cages and more recently transported in thermally insulated containers.

Transporting in cassettes, usually on deck, can lead to overheating of the fish. The bigger the catch, the higher the air temperature. Preventive measures are extensive backfilling of ice caches (from ½ kg to 1 kg of ice per kg of fish), placing blinds above the crates to protect against direct insolation and adding ice during transport. Adding ice is difficult when the catch is high, and many caches need to be iced. The use of polystyrene cartridges is desirable because they are a good thermal insulator, but they have the disadvantage that they are brittle (polystyrene) and burst during manipulation. It is best to use freshwater flake ice shells to flush the fish cages, which dissolves into the fish by melting, cools the fish and prevents the fish from drying out.

In order to avoid problems and numerous combinations to be taken into account when using caskets, the use of thermally insulated containers is becoming more and more inevitable when fishing small fish. They prepare an ice water emulsion for shocking, carry out a rapid subcooling of the fish and use them as storage facilities for the transport of caught fish. In this case, there is no interruption of the cold chain, and the possibility of contamination of the fish as food during the transport by boat is minimized. The benefits and problems of using ice and chilled sea, which are listed in the shocking process, especially occur during the transport of fish in a bath of very cold water.

Containers, due to thermal insulation, can save some ice, but if the journey is long and the air temperature is high, additional amounts of ice must be brought in. Adding sea ice is desirable because cold seawater is heavier and sinks toward the bottom of the container, thus cooling the fish throughout the container. The use of freshwater ice results in two aspects. The first is the sweetening of the liquid in the container and the ability to lower salinity below 1 ppm. Another aspect is actually the problem of swimming cold water and ice that are lighter than the salt water in the container. Then the fish cannot be cooled uniformly without stirring. Excessive addition of ice does not solve the problem because then there is a lot of fresh and cold water on the surface and the heated salt water is at the bottom. Then there is a swelling of the fish on the surface and a faster deterioration of the fish on the bottom.

Landing fish is another manipulation from catch to target customer. The fish in the cassettes are unloaded one by one into the vehicle at the fishing port and ice is then added to each cage most often. Thus, the amount of ice in fishing for small pelagic fish exceeds 1 kg per kilogram of fish caught. Disembarkation in thermally insulated containers is fast and there is a significantly lower possibility of contamination of fish as food during disembarkation.

9. Innovations in the technological process of catching and processing fish and other marine organisms

Freezing and dissolving under high pressure

Ice is composed of water molecules linked by hydrogen bonds that give the ice an unusual property of 8.3% less density than water density. For this reason, by increasing the pressure, the ice is transformed into a liquid (because it has a smaller volume), but with further increase in pressure at certain temperatures, crystals of a different shape are formed again. Ice has 18 known crystalline forms. Nature's ice is composed of hexagonal crystals called Ih (Ice one h). Ice III (tetragonal crystals) is formed at a pressure of 300 MPa and a temperature of -25°C and is denser than water, i.e. smaller in volume. Other stages of ice have different crystals and volumes and each one has a different effect on the quality of the freezing of food.

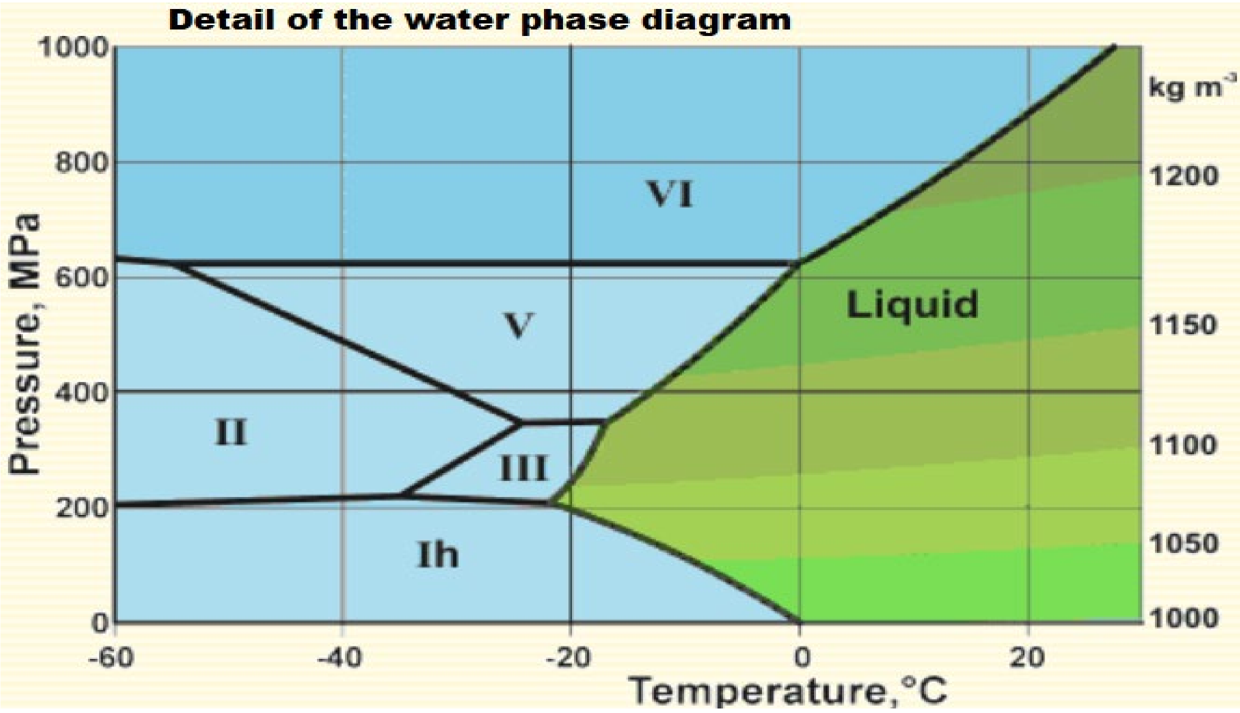


Figure 20. Water phase diagram showing the appearance of different types of water crystals (source: http://www1.lsbu.ac.uk/water/water_phase_diagram.html)

Under high pressure conditions, the freezing point of the water is lower, so that at an air pressure of 200MPa the water remains in the liquid state up to -21°C. At the moment when the pressure is suddenly released due to the isostatic properties of water, crystals of water that are uniformly distributed and of equal size in the tissue of the flesh of the fish are presently formed.

This freeze at the time of pressure release is called High Pressure Shift Freezing (HPSF).

The freezing-down property of water can be used for supercooling or storage at low temperatures without freezing, but also for the opposite thawing process whereby a frozen fillet of temperature below 0°C is placed in a high-pressure chamber and completely de-iced to reduce the freezing point (Pressure Shift Thawing).

Freezing food at temperatures below 0°C and pressurized from 50 to 200MPa perfectly preserves the quality of the food while slowing down bacterial growth and enzyme activity. As there is no formation of ice crystals, so the texture, taste or colour of the food does not change.

It has been established (Fuchigami et al., 1998) that freezing at pressure of 200 to 400 MPa preserves food best, while at pressure of 100Mpa and 700 MPa ice crystals are created which damage the food structure.

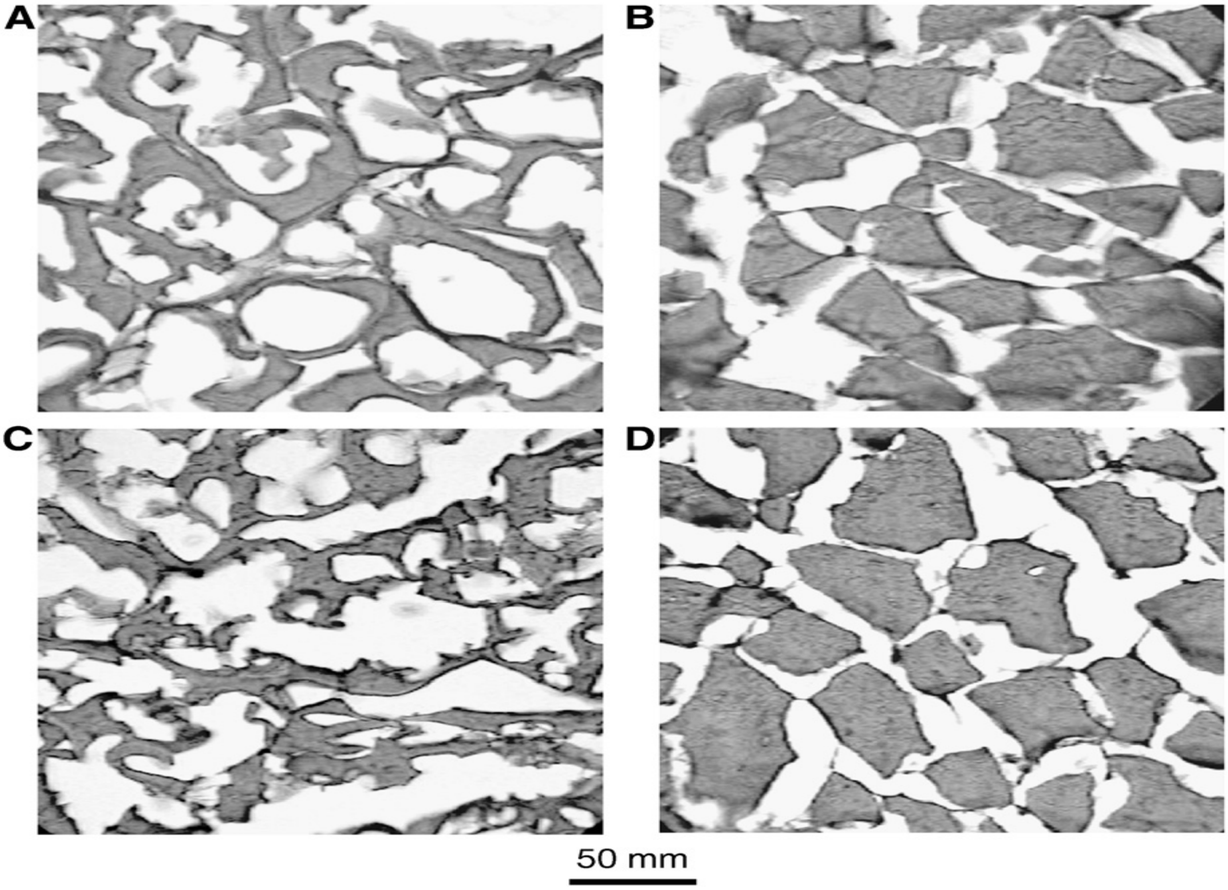


Figure 21. Transverse section of fennel muscle: A. conventionally frozen after 3 months at -15ºC, B. PSF after 3 months at -15ºC, C. conventionally frozen after 3 months at -25ºC, D. PSF after 3 months at -25ºC (Source: Tyrone , Valeria & Lamballerie, Marie & Le-Bail, Alain, 2010).

Picart et al (2004) investigated the inactivation of various types of bacteria during freezing under high pressure. They found that different combinations of pressure, temperature and time period had different effects on slowing down bacterial growth, and needed numerous tests and studies to determine the best technological procedure, which at the same time preserves the quality of the food and reduces the bacterial action. According to their research, a rise in pressure from 207 to 300MPa has a better effect on microbial inactivation than a decrease in temperature (from 20°C to 3°C) to 207MPa.

Innovation in the use of ozone (O3 generator SGC11; Lenntech B.V., Rotterdamseveg, The Netherlands), combined with supercooling, has shown an improved duration of sardine and anchovy.

High pressure processing

High pressure processing (HPP) is a technological process for the sterilization and preservation of food which, through very high hydrostatic pressure, results in the deactivation of microorganisms and enzymes in food. Unlike pasteurization, which uses heat to sterilize food and cause changes in taste and other food characteristics, HPP preserves the sensory and nutritional properties of the food.

This technology was proven by B. H. Hite back in 1899 with the first experiments, and was named after a French scientist Pascal, who studied the effect of pressure on liquids.

HPP is also called "cold pasteurization". The process consists of placing the products in their final packaging or in bulk in a hyperbaric chamber filled with water and increasing the pressure to 300-600MPa / 43,500-87,000psi at a temperature of + 4°C to 10 °C.

High pressure deactivates microorganisms such as Listeria, E. coli, Salmonella, Vibrio and some enzymes. However, as part of the enzyme remains active, the food has an extended shelf life, but must be kept cool. This technology is most useful for acidic food like yoghurt and fruits, because spores of high-pressure resistant microorganisms cannot live in low pH conditions.

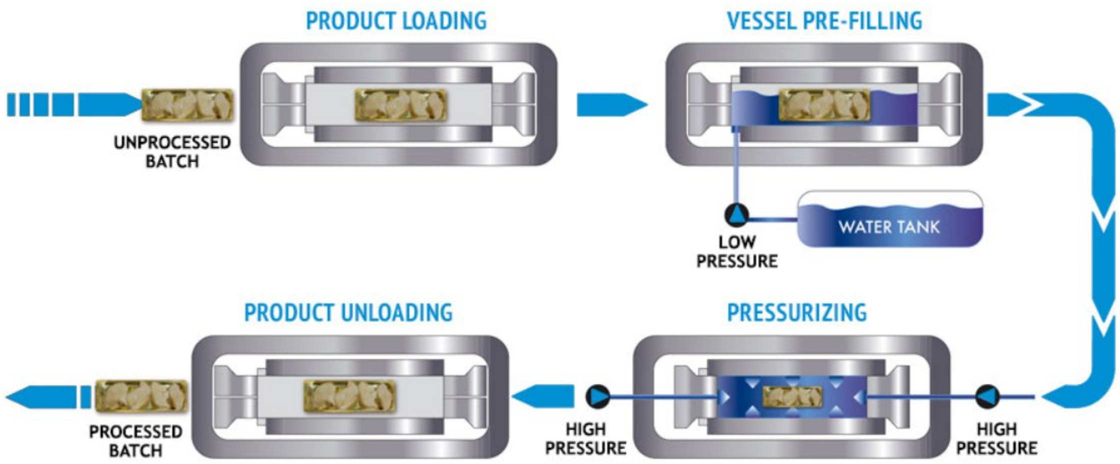


Figure 22. Diagram showing the HPP process (source: https://www.hiperbaric.com/en/high-pressure)

Advantages of HPP Technology:

- Better food quality, product characteristics remain intact, taste and nutrients unchanged
- Destruction of pathogens (Listeria, Salmonella, Vibrio, Norovirus) and food safety
- Extended shelf life
- Reduction of microbial spoilage - better quality over the shelf life
- No need for preservatives and food additives
- Responsible for products that cannot be heat treated - innovative technology
- If fresh bivalve molluscs are treated this way, they leave open shells from the chamber, making cleaning easier. It also makes it easy to clean crabs.

• The device consumes only recyclable water and electricity - it preserves the environment

Figure 23. Hyperbaric chamber for high-pressure food processing (source: https://www.hiperbaric.com/en/hiperbaric420)

Research on albacore tuna has proven to extend its shelf life to more than 22 days at 4°C and more than 93 days to -20°C (RamĂrez-SuĂˇrez, Juan & Morrissey, Michael, 2006).

Rode and Hovda conducted a research on salmon, cod and mackerel fillets and found different effects of elevated pressure (200 and 500MPa for 120 seconds) on the microbial composition, oxidation, pH and other parameters, which depended on the type of fish (Source: Rode, Tone & Hovda, Maria, 2016). This proves that more research is needed to justify application to a particular product.

Pulse electric field

Research into the application of pulse electric field PEFs of several microseconds or even milliseconds in the intensity of 10-80 kV / cm to the inactivation of microorganisms began in the 1960s. Electric fields up to 25kV were found to inactivate the following microorganisms: Escherichia coli, Staphylococcus aureus, Micrococcus spp., Sarcina lutea, Bacillus subtillus, B. cereus, Clostridium welchii, Saccharomyces cerevisiae and Candida utilis. The mechanism of action is that the charge created on the cell membrane causes it to burst, causing the bacteria to be destroyed.

The PEF food processing system consists of the following components:

1. High Voltage Pulse Generator

2. Treatment chamber

3. Temperature control unit

4. Control unit for parameter monitoring

5. Packing machine

Since electricity is a necessary guide, this technology is mostly used for liquid products such as juice, milk, yogurt, liquid eggs, soups, as well as for fruit and vegetable treatments used for further processing.

In terms of meat processing, PEF technology can be used to soften the texture as it induces proteolysis (Syed QA, Ishaq A, Rahman UU, et al.2017).

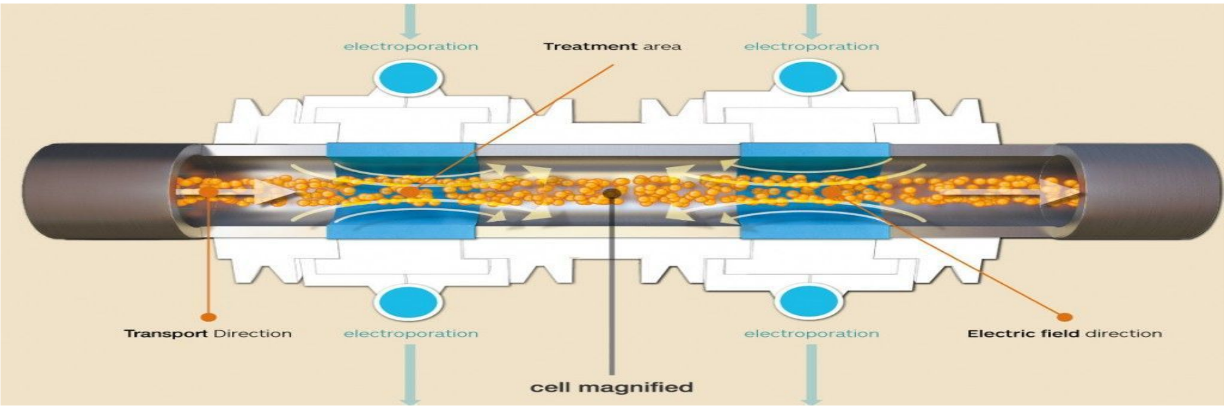


Figure 24. Schematic of the PEF process (source: http://i3food.eu/pulsed-electric-field-preservation/)

Ultrasound

Ultrasounds are sound waves, or rather pressure waves, mostly above the frequency that people can hear, starting at 20 kHz (20,000 cycles / second). Ultrasound energy is inversely proportional to the square of the frequency, so the "power" of ultrasound used to process food is 15-40 kHz, while frequencies greater than 100 kHz are used for imaging, medical diagnostics and other applications. People can hear frequencies up to 15 kHz and some up to 20 kHz, so workers in these ranges will need hearing protection and sound-absorbing enclosures.

Ultrasound is created by an electrical device called a generator, which can be adjusted to create vibrations at the desired frequency. These vibrations, of relatively low amplitude, are transmitted and amplified through another device, called a coupling. Finally, the vibration is delivered to a third device, called a horn or tool, which actually comes in contact with the material being treated. Sound waves dampen rapidly in the air, i.e. they lose energy quickly, so the horn must be in physical contact with the treated material, which may be solid or liquid. In addition to direct application, the product can be immersed in so-called ultrasonic bath.

Depending on the frequencies used, ultrasound can cause cell decay, heating due to viscous friction, emulsification, mixing, accelerating chemical and biochemical reactions, small bubbles and cavitation, enhanced oxidation, dispersion and homogenization.

Ultrasound can be used to digest plastic, to cut products such as frozen fish, to peel, extract, but also to inactivate enzymes and germs.

Ultrasound accelerates product de-icing and can be used in salting and marinating to achieve uniform permeation with reduced concentrations of solutions (Chemat, Farid & Zill-e-Huma, & Khan, & Muhammad, 2010).

In Asia and the Middle East, where cane beans are consumed, ultrasound can be used to hydrate dried cane meat. (Zhang, Longtao & Huang, Xuhui & Miao, Song & Zeng, Shaoxiao & Zhang, Yi & Zheng, Baodong, 2016)

Radiation

Electromagnetic radiation of different frequencies is used to reduce the number of pathogens or even completely sterilize the product. Radiation causes the formation of ions and free radicals and enhanced oxidation, which is undesirable for products rich in fatty acids because the oxidation of fat produces compounds that give a burnt taste. Because the presence of oxygen is required for oxidation, meat and fish are exposed to radiation in a vacuum package.

ICGFI (International Consultative Group on Food Irradiation) has made recommendations for maximum radiation doses for fishery products:

- Reduction of pathogenic microorganisms - 5.0 kGy
- Shelf life - 3.0 kGy
- Parasite control - 2.0 kGy

Intensive pulse light

Pulse light includes wavelengths from 200 to 1100nm and includes UV (200-400nm), visible (VIS - 400-700nm) and edge infrared light (IR - 700-1100nm). Pulse light is used to sterilize the outer surfaces and has the advantage of UV sterilization due to the shorter action time.

Table 6. Effect of Pulse Light on Surface Decontamination (M L Bhavya, H Umesh Hebbar, 2017)

Product	Microorganism	Treatment	Log reduction	Reference
Tuna Carpaccio	*V. parahaemolyticus* *L. monocytogenes*	Pulse time lapse 250 µs, 30% UV light, 30% IC 40% visible spectre; 0.7–11.9 J/cm2	0.2–1.0 log CFU/cm 20.2–0.7 log CFU/ cm2	Hierro *et al.* (2012)
Fish products	*P. phosphoreum* *S. liquefaciens* *S. putrefaciens* *B. thermosphacta* *Pseudomonas* *L. innocua*	Highly intensive pulses in time lapse range 325 µs; wavelengths 200 to 1100 nm, around 20% UV-C, 8% UV-B, 12% UV-A spectra; 0.053 J/cm2	5 log CFU/cm2 3.9 log CFU/cm2 2.1 log CFU/cm2 <1 log CFU/cm2	Lasagabaster and De Marañón (2012)
Salmon fillets Sole fillets	*L. monocytogenes*	1.75 mJ/cm^2/puls; duration -1.5 µs; frequency-5 Hz; 6.3 to 12.1 J/cm^2	2.2–2.4 log CFU/g 1.9–2.1 log CFU/g 1.7–1.9 log CFU/g	Cheigh *et al.*, (2013)

Limitations on the use of pulse light:

• Unequal exposure

• Shadow effect on uneven products

• Change the colour of the product

• Sample heating

• Surface softening

• High cost of the device (300-800,000 euros)

To correct these deficiencies, a cooling system and surface treatment with various antioxidants such as vitamin C is recommended.

Omni heating

Omni heating is a process in which electricity is converted into thermal energy due to the resistance of the conductor through which it passes.

Some food products have good current conductivity such as eggs, milk, yogurt, juice, wine and so on. Products that do not have good conductivity (e.g. frozen food) require a stronger electric field.

In a study on mussels, Bastias et al found that osmotic warming reduced concentrations of bacteria, but also of lead and cadmium. (J.M. Bastias, J. Moreno, C. Pia, J. Reyes, R. Quevedo, O. Munoz,)

Microwaves

Microwaves are electromagnetic waves of frequency from 300MHz to 300GHz.

Microwaves are used for heating, drying, blanching, baking and defrosting.

Microwaves act on the water molecules in the product and increase their kinetic energy, thus generating heat.

In fish processing, microwaves can be innovatively used for drying (Darvishi, Hosain & Azadbakht, Mohsen & Rezaeiasl, Abbas & Farhang, Asie, 2013)

Innovative packaging

The classic packaging for the transport of fishery products must have many layers to protect the product and keep the chain cold, while also preventing straining from the package. The options are:

- Plastic wrap around the product
- Ice or cooling gel in bags; or dry ice
- Bottom to absorb liquid
- Insulation layer, usually of Styrofoam
- A layer of additional waterproofing
- Exterior layer - a cardboard box with declarations on it

Figure 25. FedEx Packaging Perishable Shipments

https://www.fedex.com/content/dam/fedex/us-united-states/services/Perishables_fxcom.pdf

Active packaging

Innovative active packaging creates special conditions within the packaging to extend the shelf life of the product.

Active packages may have:

• Absorption system for undesirable substances such as oxygen, carbon dioxide, ethylene, excess water, dyes or other substances

• A system for adding desirable substances such as carbon dioxide, antioxidants and preservatives

• Additional systems such as cooling

Table 7 Active Packaging Modes and Their Application Mohan, C.O. & Ravishankar, C. & Gopal, T. & Kumar, Ashok & Lalitha, K. (2009).

Type of substance	Description	Application
Oxygen-reducing substances	Chemical compounds (iron oxide powder, iron carbonate, iron sulphite, ascorbic acid, etc.) Enzyme systems (glucose oxidase, alcohol oxidase)	Fresh and dry fish, sausages, dried fish
CO2-emitting systems	Ascorbic acid, ferrous carbonate and metal halides	Fresh fish and shellfish
Moisture absorption systems	Silica gel, propylene glycol, polyvinyl alcohol, diatomaceous soil	Fresh and dry fish
Ethanol emission	Ethanol in capsules	Fresh and semi-dried fish products
Release of antibacterial substances	Sorbates, benzoates, propionates, ethanol, ozone, peroxide, sulphur dioxide, antibiotics, silver zeolite, ammonia salts	Fish and various processed products

Mohan et al found that the addition of an O2 scavenger system prolongs the shelf life of fresh blue fish from 12 to 20 days and reduces the production of histamines, putrescins and cadaverine (Mohan, CO & Ravishankar, C. & Gopal, T. & Kumar, Ashok & Lalitha, K (2009).

There are foils of non-oxygen-permeable material on the market and are used for packaging instead of the metal foils that were used in the past.

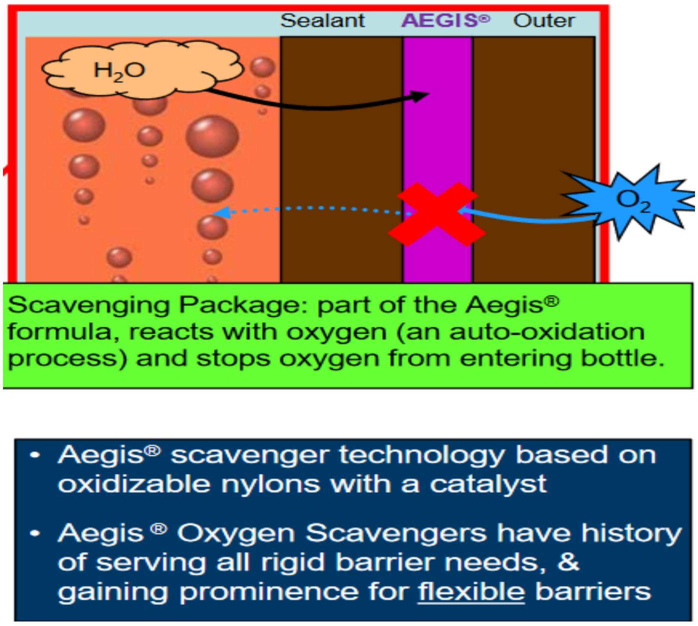


Figure 26 a,b. Drawing describing the operation of the O2 scavenger sheet (Source: https://www.packagingstrategies.com/ext/resources/Events/Global-Pouch-Forum/presentations-gpw/Tom-Clark_AdvanSIX_GPWest18.pdf).

Intelligent packaging

Intelligent packaging is one that can provide information on the condition of packaged food and its quality during transport and storage.

There are various indicators on the market today that, based on the principle of mechanical, chemical or enzymatic processes, can collect and provide various information. Cold chain indicators are important indicators of time and temperature. These are usually external indicators.

TTI (Time Temperature Integrator) remembers and records the total time when the temperature was higher than a certain number of degrees. Thus, 3 or 5ºC stickers can be purchased. If the product was at a temperature lower than specified all the time, there is no coloured indication. If the specified temperature was higher for a period of 2 hours, colouring will appear in the first window and after 4 hours in the next. The indicator is precise and irreversible and allows the customer to assess the risk of the product.

Figure 27. TTI indicator (source: https://www.jri-corp.com/products/temperature-indicators/irreversible-temperature-indicators/234-time-temperature-integrator-3)

Indicators indicating the amount of oxygen or carbon dioxide in the package are contained within the package and may indicate that the packaging may break by changing its colour.

Indicators for germs work on the principle of changing the pH or reacting with certain metabolites.

Indicators for pathogens, such as E. coli, may respond by immunochemical methods.

Packaging with antimicrobial properties

Some of the systems for reducing the number of microorganisms in the package are:

• Organic acid supplement - benzoates, parabens, sorbates and propionates

• Enzyme supplement - lysozyme, nisin, glucose oxidase

• Fungicides and bacteriocins

• Polymers - chitosan and nylon

• Natural spices - mint, oregano, cumin, clove

• Other - silver, zeolite, antibiotics

Wang and co. tested an edible collagen and lysozyme surface coating on salmon fillets and found that it significantly improves the durability and quality of fresh fillets without unwanted discolouration or pH over ordinary fillets (Wang, Zhe & Hu, Shuaifeng & Gao, Yupeng & Ye, Chen & Wang, Huaiyu, 2017). Collagen is a protein that builds connective tissue in animals, while lysozyme is an enzyme with antimicrobial properties that has a particular effect on gram-positive bacteria. The authors investigated the effect of different combinations of concentrations of these two substances on the durability of salmon fillets.

10. Choosing an innovative operating process with the ability to transform -pilot

OMEGA 3 and ISTRA case -It is important to manage the catch and cool the catch to raise the quality of the small pelagic fish and white fish and other marine organisms. Small pelagic fish are particularly vulnerable to poor handling and storage, but with good manufacturing practices, spoilage at all stages of production and processing can be assessed and minimized.

In fishing operation, we will make put focus on small pelagic fish due to several reasons. There is complete comprehensive operation while lifting fish on the deck which make inappropriate handling of big quantity of fragile fish. The small pelagic fish is delicate in structure and has thin skin. Because of this, it is easily damaged during handling, and since it has a relatively larger surface area relative to body volume and is thus more exposed to bacteria, it is more susceptible to bacterial spoilage. Blue fish in tissues contain large amounts of fat, which soon after the fish is taken out of the sea begin to oxidize and significantly alter the organoleptic properties and quality of the fish meat. In addition, blue fish meat is rich in the amino acid histidine, which is an integral part of its protein. The histidine-decarboxylase enzyme, which is found in the fish itself and in bacteria that cause fish spoilage, converts histidine to histamine, especially if the fish is not shocked and cooled to the optimum temperature. At temperatures above 10°C, a large amount of histamine is produced rapidly. This is because the highest activity of this enzyme is at 24°C, while at temperatures below 0°C and above 50°C the histidine decarboxylase activity is significantly slowed down and there is almost no risk of histamine formation.

Histamine is an organic compound that plays a role in the human body's immune response and allergic reactions, but if it enters the digestive system in large quantities, it can cause symptoms of poisoning and have toxic effects. Symptoms of histamine poisoning in humans are facial redness, rash, headache and gastrointestinal disorders. Once created, the toxin in fish meat cannot be removed by processing or cooking. Histamine is thermostable and can withstand temperatures up to 200°C. Because of this, the meat of heat-treated fish still contains histamine in the amount it was in the fish even before processing.

Temperature also affects the appearance of rigors in the fish caught. Rigor is a natural process of muscle contraction, which occurs after dying. At lower temperatures, contractions are milder, and the rigor lasts longer, which slows down enzymatic activity and spoilage. At higher temperatures, the rigor occurs abruptly and strongly, which can lead to muscle tissue separation in the fish fillet, which is visible upon further processing.

Fish are cold-blooded animals and their body temperature depends on the sea temperature, which usually ranges from 10 to 20°C in the Adriatic. Additionally, during the summer, it should be taken into account that the air temperature is even higher and may further heat the catch. In any case, in winter and summer, it is important to lower the temperature of the caught fish to 2-3°C as soon as possible. Cooling is most easily achieved by dipping catches into chilled seawater or into a mixture of seawater and ice (RSW) and refrigerated seawater (RSW). The water should be cooled to 0°C and the fish-water ratio should be 80%: 20%.

Cooling - coverage in operations

FAO General Recommendations:

• If there is no possibility to cool the fish on the vessel, it should be returned to the port as soon as possible - very small unpowered vessels

• Cooled seawater or a mixture of water and ice should be prepared in the fish tanks and should have a temperature of about 0°C depending on the medium.

• The ratio of fish to chilled water in conventional thermal insulation tanks should be no more than 80:20, so for 80 kg of fish 20 or more litres of water, that is, 100 litres of chilled water should be placed in a 500 litre tank and a maximum of 400 kg of fish should be added.

• Fish in the tank should be cooled to 2-3°C, and if the temperature of the fish is higher than 4°C, the fish should not be disembarked at all until it is further cooled to mix the layers

• It is possible that in the future, fish tanks may have a cooling system or system for circulating cold water such as fixed-tank vessels

• Sensors and data loggers should be in the containers. The sensor display should be in an easily visible location so that temperature information is easily accessible.

• The cooling system inside the tank should cool the entire tank uniformly

• The cooling capacity should be such that a temperature of 3°C after 6 hours and 0°C after 16 hours can be reached.

• Fish should be transported to processing factories in heat-insulated containers with cooled water to maintain a low temperature during transport.

• Continuous monitoring of tank temperature, even during transport, is necessary.

• If dry storage is used, ice should be placed on the bottom, centre and top of the container to ensure the best possible cooling.

• Each tank should be labelled and numbered, and the content of each tank should be separately recorded to identify which catch is from which tank if the "breakthrough" occurred.

• The temperature of the fish should be re-measured at the processing plant and additional cooling should be carried out if necessary.

• In the processing plant, it is necessary to keep records of the origin of the fish from the individual tanks as well as the cold chain information from the vessel to the plant. In the case of a consignment of inadequate quality, the origin of the catch and the transport information must be known.

Due to its small size, small pelagic fish are not individually handled, but larger quantities are grabbed and transmitted using shovels, rakes, nets, crates, strainer or other tools. Careful handling reduces damage to fish and loss of quality**.**

Source: http://www.fao.org/3/V7180E/v7180e08.htm
http://www.fao.org/3/V7180E/V7180E00.HTM#Contents

The handling of catches should be such as to ensure maximum quality of raw fish. Excessive squeezing of fish should be avoided to avoid increased stress and consequent spoilage of meat. It is also necessary to respect the welfare of animals and to ensure a quick "painless-unconscious" death. Surface damage and inclinations should be avoided in a different and more efficient way of transferring fish.

In addition, the procedures for landing catches should be such as to facilitate the work of the crew and reduce the physical strain of the fishermen. The use of human force in lifting heavy loads should be avoided as well as precarious and inappropriate positions for workers.

Recommendations for raising the quality in today's catchment system are:

• Choose as small a volume as possible to pull the net - floating bones - a possible category - a question of efficiency

• Reduce the duration of the pull-hovering skin - a possible category

• To draw fish out of the net with less sack filling to prevent kneading due to heavy weight - category delays fish collection - adverse category

• Use pumps when removing fish from the net, instead of lifting sake - possible category - recommendation for pilot testing in the surrounding swimmer nets in the Adriatic

The pumps for lifting fish from the net to the fishing boat have an underwater suction and the ratio of water to fish during pumping must be monitored and the water should be separated from the fish as much as possible in order to maintain the temperature in the cooling tanks.

Recently, the so-called P / V pumps (pressure / vacuum) have been used. The principle of operation of this pump is to place the reservoir of about 500 to 1500 litres alternately under vacuum and under pressure. The fish, together with water, are sucked in through the tube and valve into the tank. When the tank is filled, a mixture of fish and water is pumped into another tube and into a strainer. The P / V pump handles the fish relatively gently as it alternately uses vacuum and pressure but has a low capacity as well as interruptions to operations. For this reason, two tanks connected to one pump are often used. The disadvantage of such pumps is the oversized rigid components for mounting on smaller vessels as well as possible damage to fish. Submersible pumps, by their metal structure, damage the fish when squeezed.

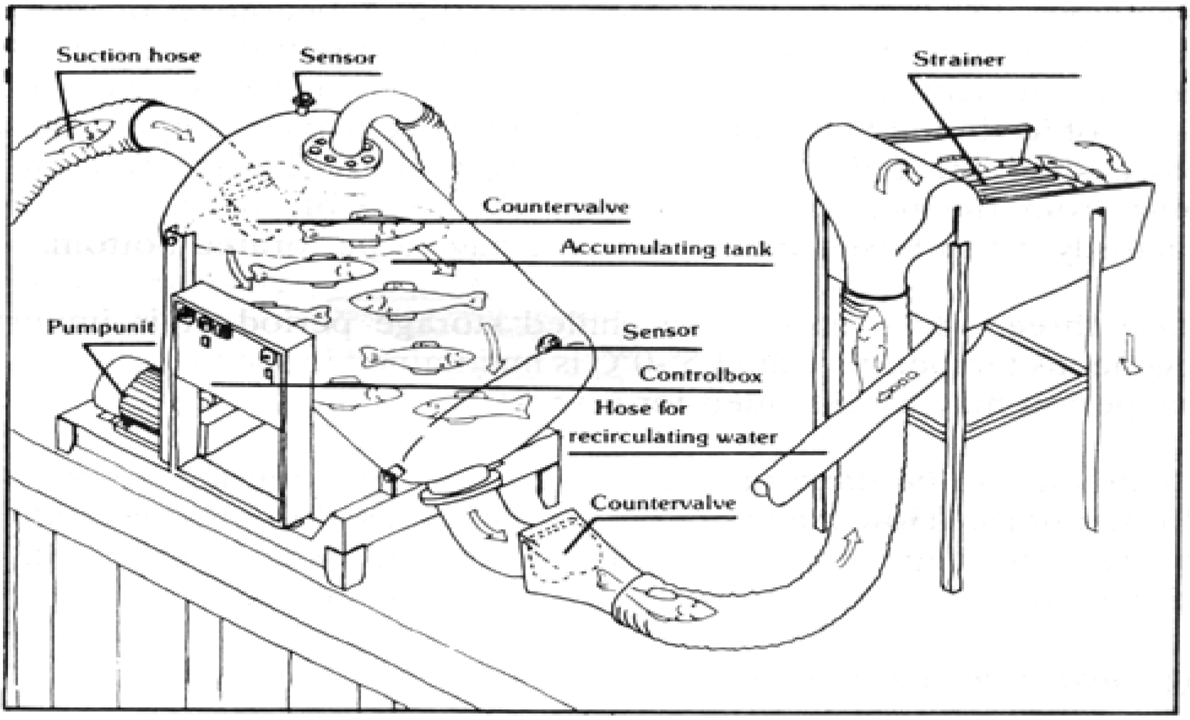


Figure 28. P / V pump operating principle (source: FAO Improved fresh fish handling methods http://www.fao.org/3/V7180E/v7180e08.htm)

Handling the catch using the bag

Recommendations:

• If the fish is overloaded dry (where water is drained), a maximum of 400kg of fish may be raised in one operation to avoid crushing the catch (bad weather and waves greatly hinder this operation in terms of jerking on the crane and further damage the fish)

• Containers in which fish are kept dry should never be overcrowded to avoid crushing catches. When the fish is in water, it floats due to buoyancy and does not press other fish by its weight, which is not the case for dry storage.

BIVALVIA CASE-The Striped venus represents the most important specie for organisation. The main fishing technique for catching the specie is dredging. For that purpose, the fishing vessels are equipped with a hydraulic dredge gears, constituted by a large water pump and a metallic dredging cage with water jet nozzles for catching the specimens. The metallic cage has an edge followed by an inclined sieve structure made of evenly spaced metallic bars. Additional sorting equipment is placed on-board, following the collection bin. That equipment is used for separating the Striped venus specimens above the minimum conservation reference size (MCRS) defined in the Common Fishery Policy (CFP) from undersized specimens, other by-catch species and debris (Morello et al., 2005). At first, an upward rotating sorting screw with longitudinally equally spaced rods separates most of the debris and smaller by-catch species, discarded directly into the sea. The separated material is transported to the vibrating screen for the final selection. The separation unit has several vibrating selection screens placed at different levels for separating different size classes of clams. The selection screen uses primarily two patterns, either equally spaced longitudinal bars or perforated plates with round holes.

Figure 29. A view of the upward rotating sorting screw (above) and the vibrating sorting sieve (bellow) used for sorting the catch from the hydraulic dredge. [source: ISPRA, 2016]

Therefore, the caught clams go through a two-step selection process, first on the metallic dredge and later on the on-board sieve system. The current regulation (UE, 2020/3) sets the minimum conservation reference size of *Venus spp.* in the Italian territorial waters to a total length of 22 mm. However, the current sorting process is not flawless and sporadically some specimen below

MCRS remain within the on-board product, which needs an additional sorting process in the production facilities. The main difficulty during sorting processes is given by the variable ratio between the clam's length, height and thickness. Sorting sieves with parallel equally spaced bars use the clam's thickness as a sorting criterion, while perforated plates with round holes are based on clam's height, and neither one of these measures is the one prescribed (length) in the regulation for determining the MCRS.

Figure 30. An example of a mechanical vibrating sorting sieve used for clams. [source: www.cocci.it]

Each sorting process adds some stress to the products due to the vibrations or tumbling and can cause some damage to the shell (Moschino et al., 2003, 2008). Studies conducted by Moschino et al. (2003) assessed the effect of different collection methods: i) low water pressure (inlet pressure 1 bar) without sorting, ii) dredging at high water pressure (inlet pressure 2.5 bar) without sorting and iii) dredging at high water pressure (inlet pressure 2.5 bar) and mechanical sieving for sorting as in commercial fishing. The results indicate that there is an increasing physical impact and mortality as water pressure is increased and mechanised sorting added, since the highest levels of damage were always detected in commercially dredged clams (Moschino et al., 2003). The provided information is useful since the by-catch samples, considering that all undersized clams captured by fishing gear, sieved and then rejected into the sea, may contribute to restocking of natural populations. Discarded animals thrown back into the sea may die as a direct consequence of physical damage incurred during fishing or indirectly due to predators or disease. Damage levels increase proportionally with increasing clam size: small sized samples (length <17 mm) were less damaged than medium-sized samples (25mm < length <17 mm) and samples fished using both high water pressure and mechanical sieving (<25 mm) showed the highest damage levels (Figure 3; Moschino et al., 2003). Moreover, additional studies of physiological indices of *C. gallina* in the Adriatic Sea show the effects of hydraulic dredging in field surveys (Moschino et al., 2008). Both high water pressure and mechanised sorting affected clearance and scope for growth, which generally showed decreasing trends as mechanical stress increased at the sampling sites, although significant differences among treatments were not always detected (Moschino et al., 2008). Respiration rate was less responsive, not being clearly affected by differing stress levels (Moschino et al., 2008). The decrease in both filtering and scope for growth in dredged clams provided a short-term response to the acute stress undergone by *C. gallina*, although these parameters are generally recognised as indicating long-term stress (Smaal and Widdows, 1994). The survival in air times of dredged animals also decreased with increasing stress (Moschino et al., 2008).

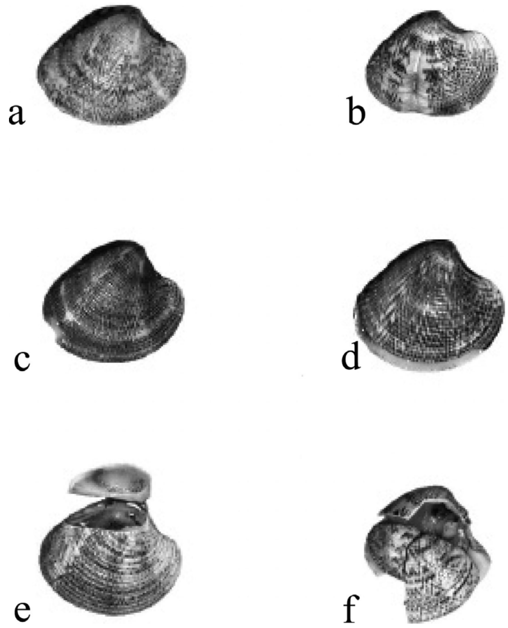


Figure 31. Various types of damage detected in *C. gallina*: (a) intact shell, (b) shell with previous damage repaired, (c) shell with both valves scratched, (d) shell with edge chipped, (e) crushed umbo and (f) crushed shell. [source: Moschino et al., 2003.]

OMEGA 3-

Given that the transfer of fish from the closed net via sacks to ships or tanks has been recognized as the most risky and heavy „bottle neck" category in small pelagic fish handling that can significantly affect the quality of fish, piloting the use of pumps will be selected for further project continuation. Harvesting small pelagic in the Adriatic is defined by traditional catch models which significantly deteriorate the quality of fish, negative influence of fish welfare, and use enormous effort on human work and create inefficient operation.

Figure 32- Traditional catch handling

Pumps used in aquaculture transfer live fish vertically and horizontally and it is an imperative that they do not damage the fish. For the purposes of this project, an aquaculture pump model with a special adaptation will be proposed for ejecting or separating water and coping with elevation differences. It is also planned to use pumps without a vacuum tank to provide smaller dimensions on board and facilitate manipulation. Given that such a pump model is not used in the catch operation, the same system will represent a certain innovation as it will need to be communicated and adapt to the fishing vessel.

The main objectives of this project development are:

- Test the possibility to implement novel-innovative fish pump on different construction and size of boat- design testing
- Testing that new fish transferring practice can replace those currently used
- Test the improvement of pumps while replacing the existing harvesting methods,
- Conduct a comparison study of on-board fish harvesting machines with classical methods and replacement cost
- Increased quality product to fresh market (fillets, cleaned)

BIVALVIA

The first objective of the present pilot activity is to improve the selectivity and reduce the physical damage and physiological stress of the clams. Such activities should improve the survivability of the discarded undersized clams to the sea, therefore improve the management of the resources and maintain a responsible fishery behaviour. Reaching this objective should allow maintaining a balance between sustainable fishing activities and the available resources at sea, as well as safeguard the marine ecosystem by reducing the impact on non-target species and the habitat. Moreover, a decreased induced stress on bivalve molluscs from sorting procedures would also allow increasing the shelf life of the fresh products and increasing the quality of the distributed products. An improvement of the fishing gear selectivity and a reduction of induced stress on clams is also in line with the EU Regulations and Italy's Discard Plan for *C. gallina* to reduce the discards and improve the survivability of discarded specimen.

The second objective of the piloting activity is to reduce the stress of processed fresh products in the production facility by improving the cold chain of the production process. This measure will further allow to increase the quality of the fresh products and extending its shelf life.

P.O. Bivalvia, in synergy with the Management Consortiums, has set itself the goal to test technological solutions to increase the selectivity. The approach consists of two steps: i) the improvement of the fishing gear and ii) the improvement of the on-board sorting processes. The plan is to not only improve the existing fishing gear, but also test new typologies of fishing gears that would increase selectivity by reducing the quantity of undersized *C. gallina* specimen and other by-catch species.

The main objectives of this project development are:

- Test the selectivity of a new fishing gears to replace those currently used,
- Test the selectivity of a new or improved sorting machines replacing the existing ones,
- Conduct a comparison study of on-board sorting machines with the ones off-board and in the future standardize and provide sorting machines throughout the production chain (from the fishing vessel until the production facility) with the same characteristics as one used on land.

Further objectives are to improve the quality of fresh products by creating a distinct cold-chain processing section within the facility and placement of live bivalve molluscs in the domestic market placement of possible heat-treated shells as a separate or assembled product in fresh or frozen state in Horeca segment.

ISTRA

The main objective of the PO Istra project is to initiate new processing procedures within the existing facility and to dispose the excess fish, thereby expanding the range and entering production from ship to table. The main guiding principle is the diversification of production in terms of consolidation of the company's business due to the decline in fish catches and falling prices in recent years and the realization of favourable financial effects from new production. A solid basis for starting the project is stability in the resources of musky octopus, mullets, shrimp, which would form the basis of much of the production, but in a significant part in processed form in the preparation of ready meals that are not present in the processing industry of the Republic of Croatia, and are rare among the EU producers.

After the construction of the facility and the installation and implementation of equipment for the primary processing of fish and other marine organisms and the commencement of production, one of the key effects in terms of different valuation of fishery products in the Republic of Croatia would come processed product. By treating fish and other marine organisms, the company will be able to achieve added value for primary products while reducing pressure on the market at times of saturation, thereby ensuring well-being for the fishing community.

Musky octopus, mullet and sole are the major species caught by the “Istra” PO but there are also significant landings of red mullet, sardine, anchovy, sea bass and cuttlefish.

Most of the vessels are operating all year round and they are multi species catchers. The predominant landings in the winter months are musky octopus, mullet and sole and in the summer month musky octopus and sardine.

Quantitative questionable / price questionable species

-shrimps, musky octopus, mullets

These species continue to show, through calculations, quantity and present value, the potential competitiveness in raising the price while being processed.

Production begins with the primary processing of fish required to produce the final product and refers to the following basic technological units in the processing itself:

1. Evisceration and filleting of white fish (mullets)

-cleaning and processing fish to fillets

- Finishing the fillets- novel machinery

- Substrate for further production

2. Cleaning, washing shrimps

- Shrimp meat separation- novel machinery

-Cooking shrimps

- Substrate for further production

3. Cleaning, washing and cutting cephalopods

- Cleaning and cutting of cephalopods

-Cooking cephalopods

- Substrate for further production

4. Fish burger line, dumpling from substrates standards and approach

Figure 33. a,b Separating meat

REVIEW- DESCRIPTION OF THE PILOT PRODUCTION PROCESS (PILOT PRODUCTION CYCLE)

The pilot production and marketing process is planned to be developed in five of the following production units and lines:

1. Raising the quality of small pelagic fish by changing the catch methods

2. Sardine fillets and cleaned frozen sardine for HORECA and alternative market

3. Production of fish burgers and dumplings (shrimps, musky octopus, mixed small white fish-mullet fillets) for HORECA and alternative market

4. Innovations in raising of the selectivity catches for razor clam

5. Preparation of shellfish packaging and processing for HORECA and alternative market

Project objectives

With the production of the proposed innovative range, the cooperative would also touch on and meet several general objectives required to receive a funding proposal and subsequently relate to the production of a new type of product at:

- Improving marketing channels for primary producers in the fisheries sector is foreseen by an improved approach to manipulating fish on board. This opens up an additional quality market for primary producers.

- Improving overall performance in processing and marketing. This goal is met by the production of products of the highest value added in terms of the production of ready-made appetizers and main dishes ready for consumption immediately or after a short heat treatment.

- Facilitate competition in the internal market by introducing new technologies and innovations. The technology envisioned is an absolute innovation not yet recognized in the domestic market.

- The process and application of new technologies would be made according to criteria that meet all EU standards related to hygiene, public health, animal welfare, occupational safety and environmental conditions.

11. Cost-effectiveness of fishing small pelagic fish in the long-term function of sustainability

The success of small pelagic fishing is the easiest to disassemble in the context of fishing economics. Cost-effectiveness is the result of the ratio between the output achieved and the costs that were required for the output achieved. Business efficiency can be achieved by:

- Increasing production output with unchanged costs
- Achieving higher sales prices for products and services
- Reducing costs in the production process per unit of product
- Lower purchase prices per unit of cost realized

Each of these items can be individually analysed and used as a parameter to improve business efficiency, but the overall result in changes in cost-effectiveness gives the sum of the results of all the mentioned elements of cost-effectiveness.

At the EU level, socio-economic monitoring of fisheries is carried out in individual Member States. The presentation of the overall condition of the fishing fleet of the Republic of Croatia from 2012 to 2019 indicates the unprofitable fishing until 2016, after which the situation is improved.

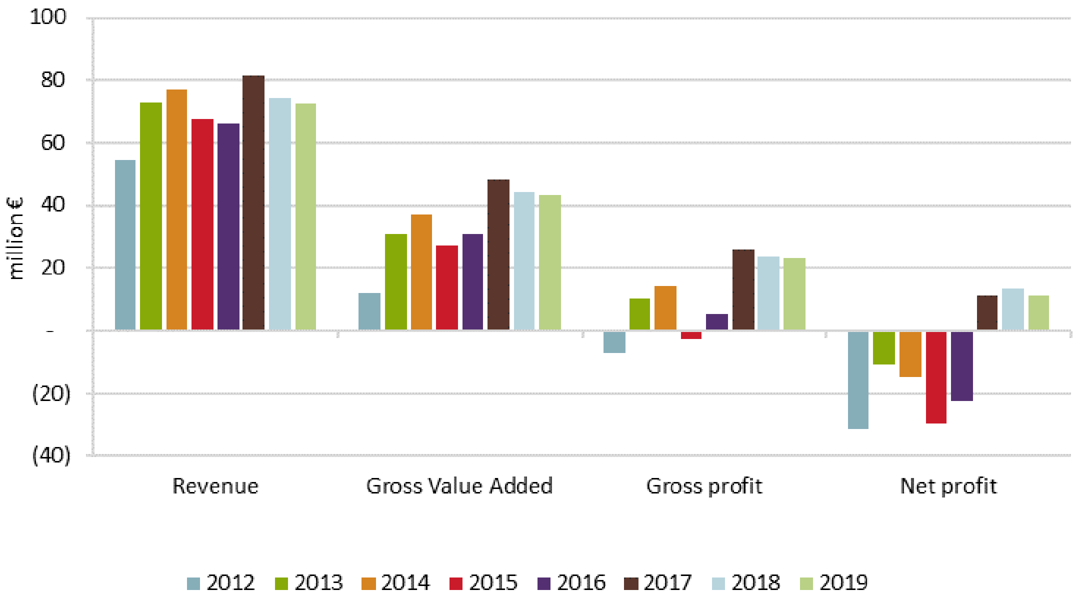
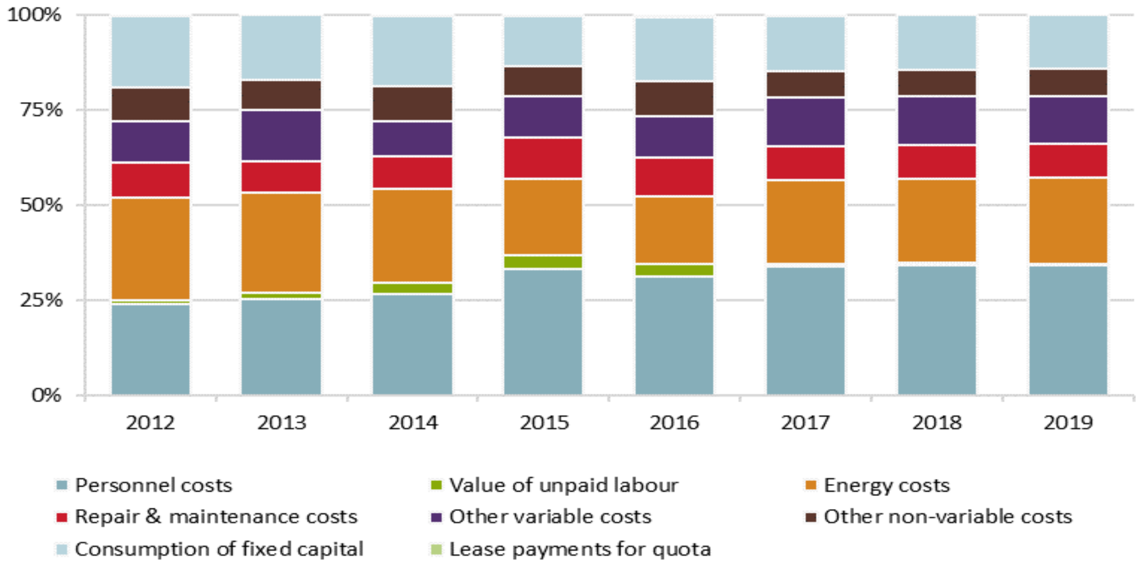


Figure 34. Economic indicators of the fishing fleet of the Republic of Croatia (source: copy - The 2019 Annual Economic Report on the EU Fishing Fleet (STECF 19-06))

Cost of labour and costs of energy (fuel) prevail in the presentation of the costs of the fishing fleet of the Republic of Croatia.



Graph 35. Costs of the fishing fleet of the Republic of Croatia according to STECF 19-06. (source: copy - The 2019 Annual Economic Report on the EU Fishing Fleet (STECF 19-06))

Socioeconomic monitoring is also conducted by fleet segments. In the segmentation of the fleet for this purpose, the vessels fishing with the surrounding fish nets are not separated according to the criterion of the target species, but are processed according to the criterion of the length of the vessel (length over all).

In fishing for these fleet segments, small pelagic fish predominate in quantity, but it also includes tuna catches and catches made by vessels fishing with nets “ciplara and palamidara”. Given that the tuna are subject to significant fishing restrictions, that only 9 vessels have been fished and that the catches of small pelagic fish are significantly prevalent in both quantity and value, STECF data can serve as an indicator of the small pelagic fish status which is the vessel fleet.

Table 8. Part of the statistical and economic indicators for the fishing fleet segment of vessels fishing with the 2017 fishing net (STECF 19-06).

Fleet segment	No. of vessels	No. of fishing days	Energy per catch tonnes	Quantity of landed catch	Value of landed catch	Gross income	Net income	Profitability
6-12 m	35	3.413	507	300.174	388.957	212.824	108.073	Acceptable
12-18 m	31	4.052	121	5.187.947	2.421.353	440.842	-60.656	Weak
18-24 m	49	7.856	147	19.796.245	9.544.590	10.882.799	-1.856.369	Weak
24-40 m	73	11.578	125	34.458.157	17.548.801	18.914.240	1.220.750	Acceptable

According to STECF data, the economic performance of individual fleet segments is not encouraging. The presented situation is not sustainable in the long term, especially not in the context of management measures, which, due to the assessment of the sardine and anchovy stocks, tend to reduce fishing mortality (read reduced annual catches).

The average catch price € / kg can be calculated from the table data. The boat category 6-12 meters has a higher average price (1.2 € / kg) because in this category there are small boats fishing with small nets. Other categories 12-18 m, 18-24 m and 24-40 m have significantly lower average prices (0.47; 0.48; 051) € / kg. The slightly higher average price for the largest vessel's category is due to their involvement in tuna fishing for 30 days.

In the same document we find the prices for sardines and anchovies in the Republic of Croatia in the period 2012-2017. The average price for sardine was unchanged at € 0.4, while the price of anchovy varied between € 0.7 and € 1.0. According to EUMOFA, the price of sardine in the Italian market, between 2010 and 2015, ranged between € 0.7 and € 0.9, while in Portugal it varied from € 0.5 to € 2. According to the annual report issued by EUMOFA 2108, the prices of sardines at the first sale in 2015 and 2016 ranged from € 0.38 in Croatia to € 2.19 in Portugal, and anchovies from € 0.85 in the Republic of Croatia up to € 1.87 in France.

Table 9. Prices of sardines and anchovies on first sales in the EU in 2015 and 2016. Source: (https://www.eumofa.eu/documents/20178/132648/EN_The+EU+fish+market+2018.pdf

Prices in €/kg	2015.		2016.	
State	Sardine	Anchovy	Sardine	Anchovy
Croatia	0,38	0,85	0,38	0,94
Italy	0,78	1,68	0,77	1,73
Spain	1,37	1,72	1,24	1,77
Portugal	2,19	1,90	2,03	1,70
France	0,85	1,85	0,97	1,96
Greece	1,87	1,50	1,25	1,58

This short overview does not capture the characteristics of the first sale market for the types listed, nor the global market opportunities for value added products. Therefore, the conclusion that a possible increase in prices in Croatian fisheries cannot be applied analogously. However, the differences in prices are significant and indicate the possibility of finding solutions through innovative positioning in the first sale market. Increasing the price on the first sale is the basis for economically sustainable catches in the Adriatic Sea, which scientists advise, which will be discussed in the next section.

The cost of a fishing vessel fishing for a sardine fish depends on fishing activities. Fleet costs for 2012, 2103 and 2014, are shown in the Small Pelagic Fish Fisheries Management Plan surrounding the 2017 sardine fishing net (Ministry of Agriculture). The costs shown are divided into fixed and variable costs by segments of the fleet fishing for sardine. The cost of gross wages and salaries is divided by 70% into variable cost and 30% into fixed cost. Maintenance costs are due to wear and tear and are split 50% into fixed costs and 50% into variable costs. The average of fixed and variable costs is shown in Table 3.

Table 10. Summary of average fixed and variable costs of the fishing fleet fishing for sardine, for the period 2012-2014. and an indication of the costs per fishing day.

Fleet segment	Fixed cost €	Variable cost €
6-12 m	343100	313700
12-18 m	1953400	1912800
18-24 m	5817867	5571267
24-48 m	11799933	11618400
	€/ fishing day	€/ fishing day
6-12 m	284.0232	259.6854
12-18 m	515.3183	504.6078
18-24 m	780.2235	747.1524
24-48 m	1147.184	1129.535

In the event of a catch reduction in the future, two extreme scenarios can be cost-predicted. In a scenario that seeks to rationalize costs, in which the catch reduction is proportional to the reduction in fishing days, the relative reduction in total cost corresponds to approximately half of the relative reduction in fishing effort. In this scenario, the burden of reducing revenue is evenly distributed to reduce costs and the necessary increase in prices on the first sale. In a scenario that seeks to ensure continuity in the market by allocating the target catch amount to as many days in the year as possible, the cost of fishing remains the same and all the burden must be borne by an increase in the price of the catch at first sale.

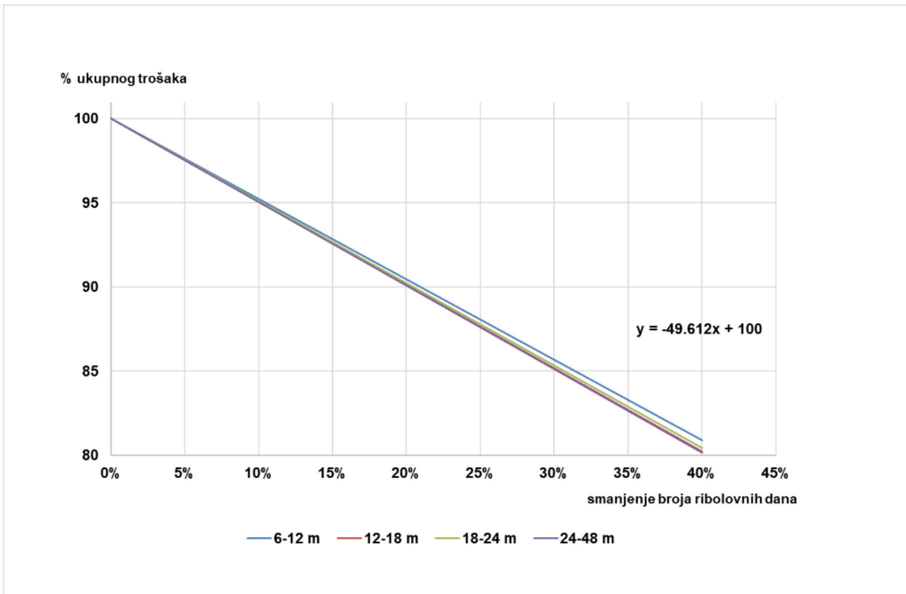


Figure 36. Change in the total annual cost of vessels (by fleet segments) engaged in fishing with sardine fish as a function of reducing the number of fishing days.

The situation is somewhat more complicated if the catch limits by species are separated. Some fleet segments (in the same years 2012-2014) have different ratios of sardine and anchovy per fishing day

Table 11. Average daily catch of anchovy and anchovy in 2012-2014 by fleet segments.

Fleet segment	Sardine kg/day	Anchovy kg/day

from 0 till 12	425.3193	562.9964
from 12 till 18	1585.729	1302.349
from 18 till 24	2817.863	1472.171
from 24 till 40	4057.601	2080.682

In larger vessels, the sardine anchovy catch ratio corresponds to the price ratio on the first sale, so a smaller impact of the catch reduction of each species on the overall business is expected. In smaller vessels the catches of sardine and anchovy per fishing day are equal, and the price of anchovy is twice the price of sardine. This is why the category of smaller vessels is particularly sensitive to the reduction of anchovy catches, that is, limiting anchovy catches has twice the effect on business than the proportional reduction of sardine catches.

12. Management measures implemented in the Republic of Croatia and Italy for target species and their effects

According to EURSTAT data, in 2016, Croatia exported sardine and anchovy worth EUR 54 million, accounting for 29% of all Croatian fish exported (caught and farmed).

Measures to prohibit fishing in areas where younger age groups were located were to prevent a drop in average catch size and to shift fishing mortality towards older ages. Due to the spatial and temporal regulation of fishing, the catch shifted towards the high seas.

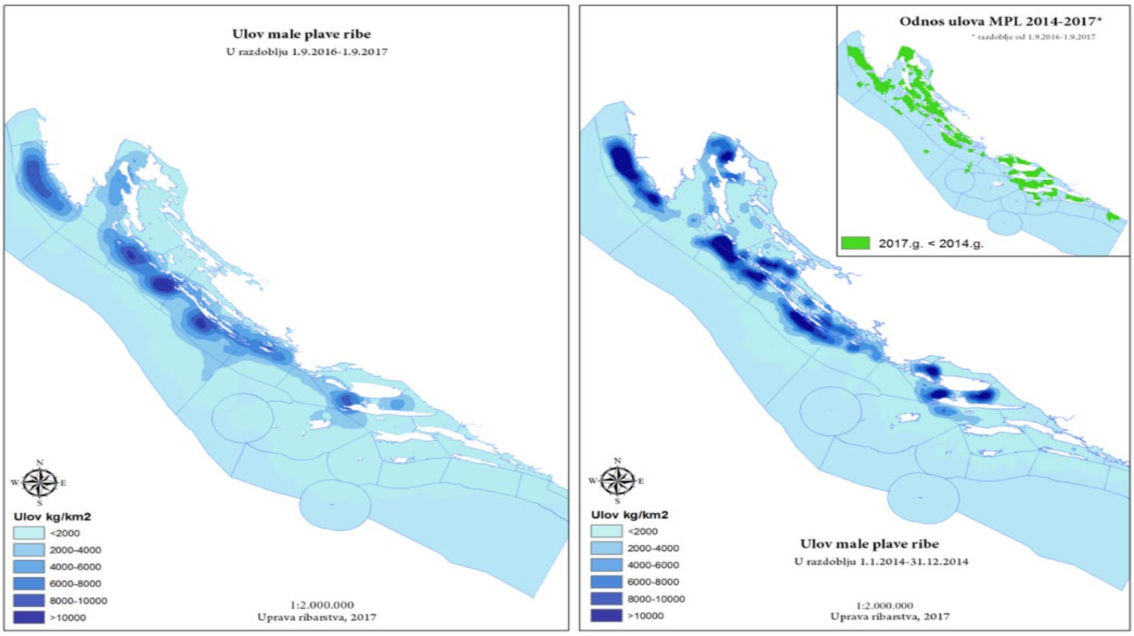


Figure 37 a,b. Comparison of catches of small pelagic fish before the introduction of spatial and temporal regulation (2014 right) and in the period after the introduction of spatial and temporal regulation (September 2016 -2017 left). (Source: Ministry of Agriculture)

An overview of the distribution of catches of sardine in the period September 2016-September 2017 shows that large sardine is kept far from the coast, especially in distant fishing grounds along the Istrian coast, the water rising zone on the north-western edge of the Jabučka basin and less frequent catches outside Lastovo and Mljet.

It is located on hunting grounds that are very remote and on which fishing was once based. Grubisic says in a popular science book (Fish, Crustaceans and Shellfish of the Adriatic) in 1967 that anchovies are spread all over the coast, where two areas "the Central Dalmatian and South Dalmatian" area with a centre around Vela Luka and the "Istria-Kvarner-North Dalmatian area" bounce.

It is interesting that among the density-bouncing areas, it places emphasis on Vis, Palgruza, Peljesac, Mljet and Lastovo, which are no longer the dominant fishing areas. It went there not only because of the quantities in the catch, but because of the seal that met market requirements. Today, these areas are underutilized because they are far removed from the market, which raises costs and has an impact on the quality of the fish caught. In addition, the anchovy is fished mainly in the fall when the weather is more likely to miss a catch, while travel costs are increased. This is due to the developed market for smaller seals, for which there is a greater certainty of catches.

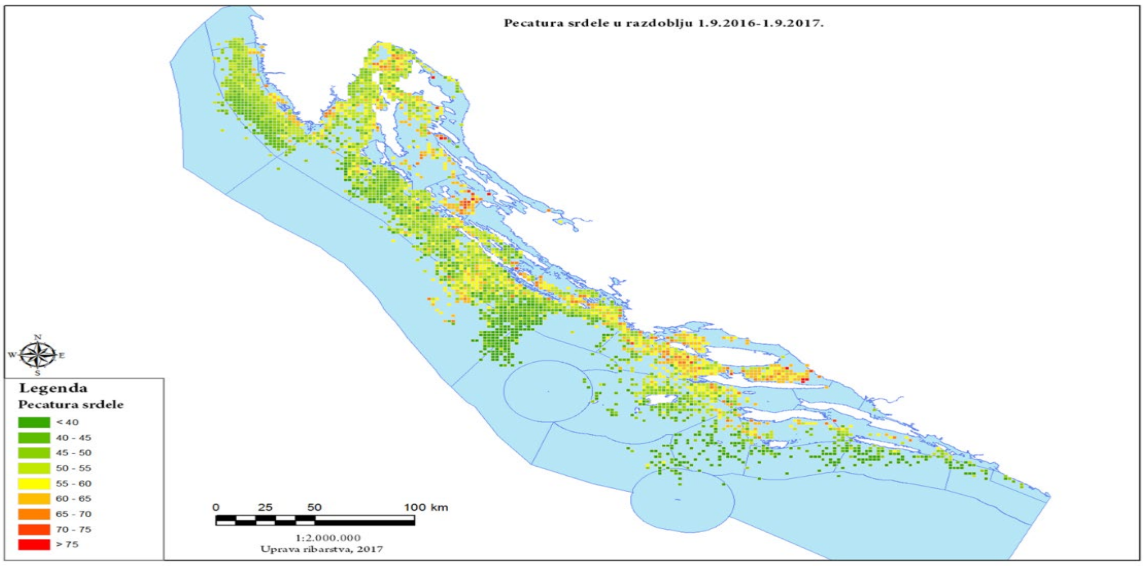
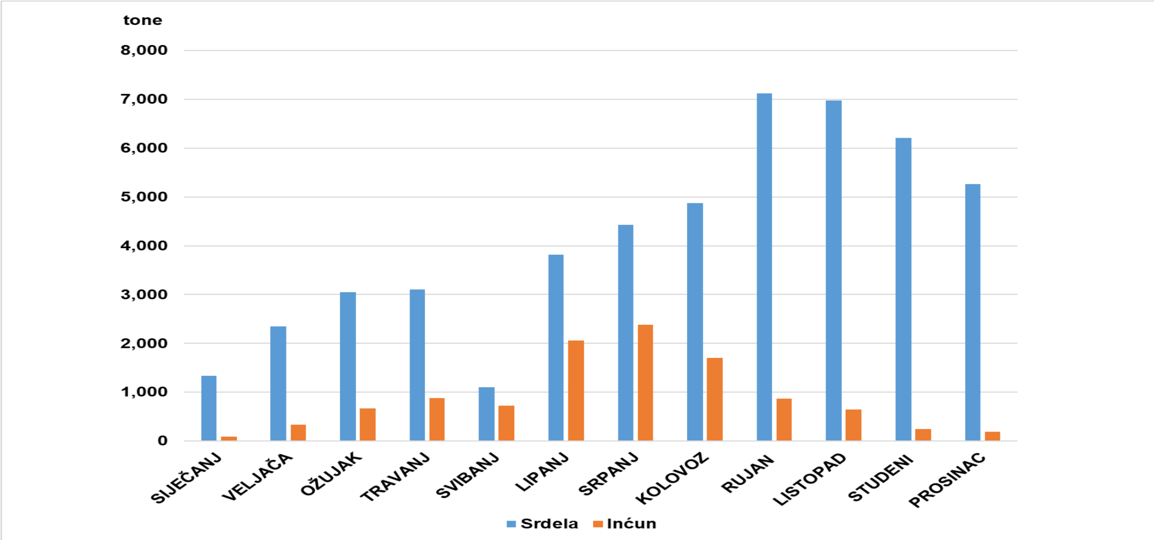


Figure 38. Distribution of catches (pcs / kg) of sardine in the period September 2016 - September 2017 (Source: Ministry of Agriculture)



Graph 39. Distribution of sardine and anchovy catches by months (average for 2016 -2018)

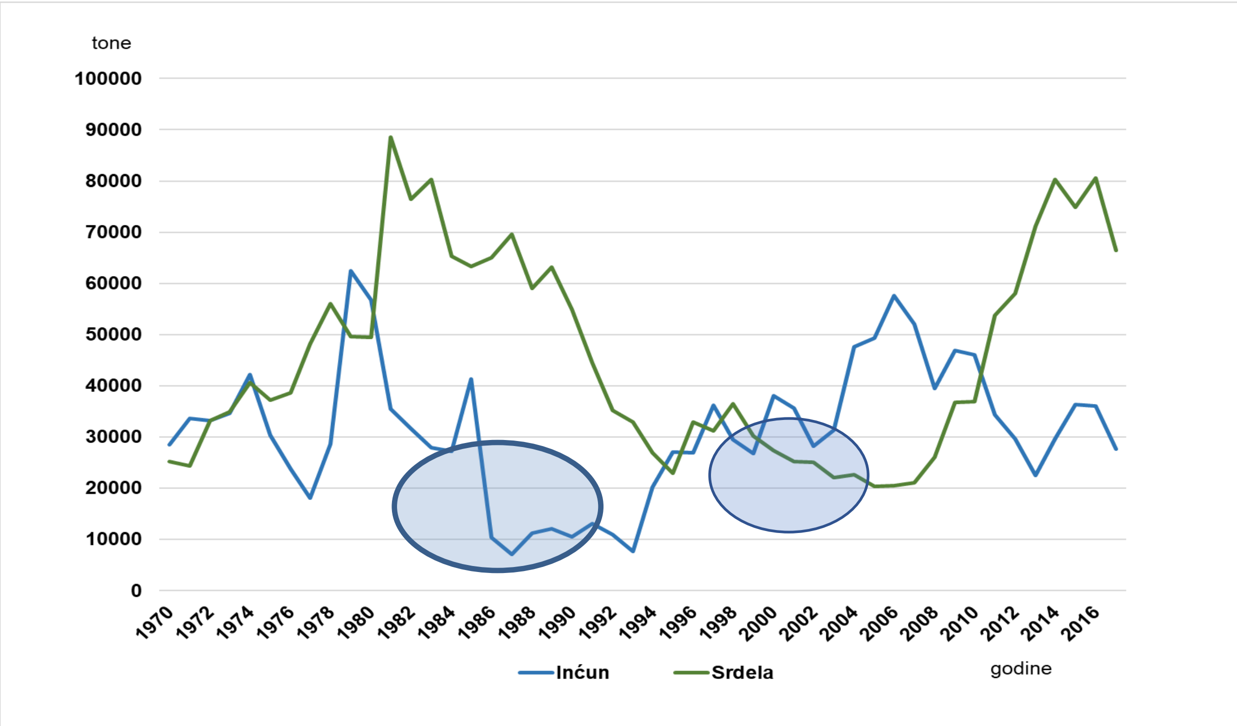
The decline in catches in May is related to the temporary cessation of fishing conducted at the time of the anchovy spawning.

Anchovy has been fished since spring culminating in July and August. The anchovy fishing by the Croatian fleet goes mainly for processing, so larger anchovies are appreciated, especially for salting. Daylight duration in summer permits trips to remote – distant area with an acceptable catch margin. Larger anchovies are caught in distant fishing grounds, where one can often find sardines above average fishing size.

It is interesting that the Italian fleet that fish anchovy with pelagic trawler does not come to international waters, although they have information that the Croatian fleet finds a large anchovy there. In addition, there is no spatial overlap since the Croatian fleet is open at night and the Italian can fishing at daytime. The Italian fleet fishing with the surrounding fish net is the only that comes far from the coast. Explicit information is not easy to find, but according to an oral statement, Italian fishermen switched to small-scale blue fish in the 1980s from driftwood to pelagic trawlers that remain closer to the Italian coast. According to Croatian experience with pelagic trawlers, only fishing shallower than 50 meters can be successful.

Catching of small pelagic fish in the Adriatic Sea

The Fish-Stat (http://www.fao.org/fishery/statistics/gfcm-capture-production/en) has been keeping records of catches since 1970. The picture shows a time shift in the periods of increase and decrease of catches of sardine and anchovy. The large drop in catches from 1980 to 1994 coincides with the transition of the Italian fleet from small boats to floating trawlers.



Graph 40. Fluctuations in the catch of small pelagic fish in the Adriatic Sea from 1970-2017 (Source: http://www.fao.org/fishery/statistics/gfcm-capture-production/en). The figure shows the catch that should be avoided according to management measures.

Considering all the above, one can expect a faster or slower decrease in the catch of small pelagic fish in the Adriatic. Therefore, it is necessary to act strongly and quickly, to provide mitigation instruments and to innovate, which will contribute to the ecological and economic sustainability of small-scale fisheries in the Adriatic Sea. One of the more significant roles in resource conservation can be indirectly assured by quality, in addition to existing management systems that monitor both the resources and the socioeconomic segment. By achieving higher quality, it is possible to ensure the higher price for the same and even reduced fishing capacity, which is of benefit to the existing fisherman as well as to conserving resources.

Since 2013, the Common Fishery Policy (CFP, EU, 1380/2013) has among other objectives to promote the reduction of discards and stimulate more selective fishing by introducing the landing obligation for catches of species subject to catch limits. Furthermore, the regulation empowers the Commission to adopt discard plans by means of delegated acts for a period of no more than 3 years on the basis of joint recommendations developed by Member States in consultation with the relevant Advisory Councils. Discard plans may also include technical measures regarding fisheries. Italy, as the single Member State with a direct management interest in the mollusc bivalve Venus spp. fisheries, in the Italian territorial waters, submitted a recommendation to the Commission in line with the procedure of Article 18 of Regulation (EU) No 1380/2013. This recommendation was submitted in the form of a national management plan for discard of the Venus spp. stock, after consultation with the Mediterranean Advisory Council (MEDAC). Upon submission of this recommendation, the Scientific, Technical and Economic Committee for Fisheries (STECF) reviewed the scientific contributions presented by Italy. Therefore, in accordance with the Commission delegated Regulation (EU) 2016/2376, Italy created a Discard Plan containing: i) the status of the Stripped venus clam fishery in Italy; ii) the description of the biology of the specie; iii) a study of survival of discarded specimens; iv) the application status of the Discard Plan; v) a scientific survey program; vi) the fishing effort; vii) the study of hydraulic dredge selectivity; vii) a study about discards and ix) a pilot study of restocking (Piano di Gestione Nazionale Rigetti per la risorsa Vongola *Chamelea gallina*). In particular the Discard Plan shows that the use of current on-board mechanical sorting sieve using a perforated plate with 21 mm round holes leaves less than 1% of individuals smaller than 22 mm (Figure 3, 4).

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