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Eduardo Spers
(Organizador)
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INTRODUÇÃO

O campo das Ciências Agrárias e Ambientais é vasto e dinâmico, abrangendo uma diversidade de abordagens, técnicas e inovações essenciais para o avanço da agricultura, da pecuária e do manejo dos recursos naturais. Em um mundo em constante mudança, em que a sustentabilidade e a busca por soluções eficientes para os desafios ambientais são cada vez mais urgentes, a contribuição dos profissionais das agrárias se torna fundamental para a construção de um futuro mais equilibrado e saudável.

O Volume III de **Estudos em Ciências Agrárias e Ambientais** reúne pesquisas de autores de diversas partes do mundo, contribuindo com uma série de investigações que exploram desde os fundamentos da agroecologia até as complexas interações entre os seres humanos e o meio ambiente. A primeira parte aborda questões cruciais relacionadas à sustentabilidade, desde a utilização de biopreparados como soluções ecológicas até a medição de emissões poluentes em processos produtivos, refletindo o compromisso com práticas agrícolas que buscam respeitar os ciclos naturais e minimizar impactos negativos no planeta.

Em seguida, somos conduzidos a uma viagem pelo campo da genética e do melhoramento de plantas, uma área essencial para garantir a segurança alimentar global e o uso mais eficiente dos recursos naturais. Através de uma análise detalhada, os estudos nos apresentam a diversidade genética e os avanços que permitem o desenvolvimento de culturas mais resilientes e produtivas.

O livro também nos convida a refletir sobre os diferentes aspectos do manejo de cultivos, abordando desde as propriedades físicas das madeiras tropicais até as técnicas agrícolas adaptadas a regiões semiáridas, sempre com o olhar atento para as melhores práticas agrícolas, que promovem uma integração harmoniosa entre o ser humano e a terra.

Por fim, encontramos uma seção dedicada à produção animal, que explora o papel fundamental da pecuária na alimentação e economia global, além das questões relacionadas à saúde animal. A conexão entre a produção e a saúde dos animais é uma chave para garantir a qualidade e a sustentabilidade dos sistemas produtivos, abrangendo desde práticas de manejo até o desenvolvimento de estratégias veterinárias inovadoras.

Através destes trabalhos, buscamos oferecer uma visão abrangente e integrada de diversos aspectos das ciências agrárias, com o objetivo de contribuir para o avanço do conhecimento, da pesquisa e da prática no campo. Este é um convite à reflexão sobre o papel fundamental que a ciência e a inovação desempenham na construção de um futuro agrícola mais sustentável, saudável e próspero para todos.

Desejo a todos uma proveitosa leitura!

Eduardo Eugênio Spers

SUMÁRIO

AGROECOLOGIA E SUSTENTABILIDADE

CAPÍTULO 14

A REVIEW OF THE STUDIES ON BLUEFIN TUNA (BFT) IN THE EASTERN ADRIATIC SEA[1]

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ABSTRACT: The aim of this paper is to provide a review of studies related to bluefin tuna (BFT) made in the eastern Adriatic Sea. BFT is an important food source and early studies were mostly related to fishing. BFT has wide spatial distribution, and for management purpose the International Commission for Conservation of Atlantic Tunas (ICCAT) was established in late 1960s. After the development of BFT farming, many studies were made on BFT in captivity. Croatian participation in ICCAT enabled participation of Adriatic scientists in common BFT studies on wide regional scale and stimulated local BFT research in the Adriatic Sea such as studies on fish parasites, molecular & genetic and nutritional studies.
KEYWORDS: Bluefin tuna. Studies. Fishing. Biology. Adriatic Sea.

[1] This Book Chapter is a republication of an article published by Tičina V. et al. in Proceedings of the 58 Croatian and 18 International Symposium of Agriculture, 11-17 February, 2023, Dubrovnik, Croatia.

UNA REVISIÓN DE LOS ESTUDIOS SOBRE EL ATÚN ROJO (BFT) EN EL MAR ADRIÁTICO ORIENTAL

RESUMEN: El objetivo de este artículo es proporcionar una revisión de los estudios relacionados con el atún rojo (BFT) realizados en el mar Adriático oriental. El BFT es una fuente alimentaria importante y los primeros estudios son mayormente relacionados con la pesca. El BFT tiene una amplia distribución espacial, y con fines de gestión, se estableció la Comisión Internacional para la Conservación del Atún Atlántico (ICCAT) a finales de la década de 1960. Después del desarrollo de la acuicultura de BFT, se realizaron numerosos estudios sobre el BFT en cautiverio. La participación croata en la ICCAT permitió la participación de científicos del Adriático en estudios comunes de BFT a escala regional amplia y estimuló la investigación local sobre el BFT en el mar Adriático, como estudios sobre parásitos de los peces, estudios moleculares y genéticos, así como estudios nutricionales.
PALABRAS CLAVE: Atún rojo. Estudios. Pesca. Biología. Mar Adriático.

UMA REVISÃO DOS ESTUDOS SOBRE O ATUM-RABILHO (BFT) NO MAR ADRIÁTICO LESTE

RESUMO: O objetivo deste artigo é fornecer uma revisão dos estudos sobre o atum-rabilho (BFT) realizados no mar Adriático oriental. O BFT é uma importante fonte alimentar e os primeiros estudos estão principalmente relacionados à pesca. O BFT tem uma ampla distribuição espacial e, para fins de gestão, foi estabelecida a Comissão Internacional para a Conservação do Atum Atlântico (ICCAT) no final da década de 1960. Após o desenvolvimento da aquicultura de BFT, foram realizados vários estudos sobre o BFT em cativeiro. A participação croata na ICCAT possibilitou a participação de cientistas do Adriático em estudos conjuntos sobre o BFT em grande escala regional e estimulou a pesquisa local sobre o BFT no mar Adriático, como estudos sobre parasitas de peixes, estudos moleculares e genéticos, assim como estudos nutricionais.
PALAVRAS-CHAVE: Atum-rabilho. Estudos. Pesca. Biologia. Mar Adriático.

1 INTRODUCTION

Bluefin tuna (BFT), *Thunnus thynnus*, L. (Fig. 1), is one of the large pelagic fishes that have been the focus of interest of fishermen and researchers in the Mediterranean, especially in the Adriatic Sea, for decades due to their exceptional biology and economic value.

Figure 1. Bluefin tuna on FishBase (https://fishbase.se/photos/PicturesSummary.php?resultPage=1&ID=147&what=species)

Tuna farming brought dramatic changes in the fishing strategies as the majority of fish caught are transfered to rearing cages for further breading rather than landed and/or sold directly. Such a practice also had an impact on stock management. In this review

some specific information on fishing and farming practice with its socio-economic and environmental impacts are discussed with special emphasises on Adriatic environment. Considering the long tradition of fishing for BFT and the great importance of this species for commercial fishing and farming in the eastern part of the Adriatic Sea, the Republic of Croatia has simbolicaly presented the silhouette of this amazing fish on its coins of 2 HRK (Fig. 2).

Figure 2. Croatian coin of 2 HRK with silhouette of bluefin tuna.

2 MATERIAL AND METHODS

In this paper, the authors describe the historical work of fisheries experts on the eastern Adriatic coast and review the most of available information on various aspects related to bluefin tuna fishing practices, its biology, ecology, management and farming. A large number of older references, describes the great importance of BFT for local fishing society and scientific communities. Recent PhD Thesis and studies on BFT, published in collaboration with scientists from other regions, are reviewed also and continued interest and research efforts of scientists in the eastern Adriatic dedicated to the study of BFT are documented.

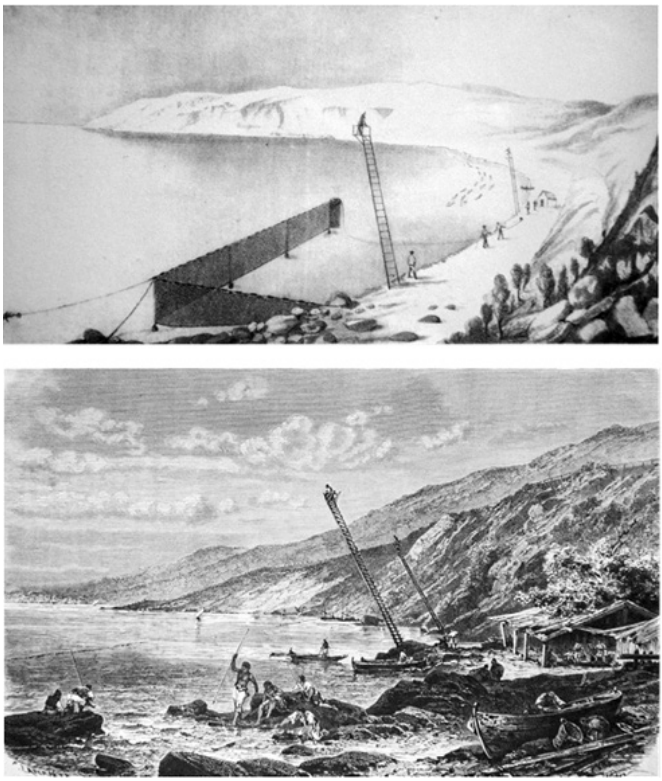
3 RESULTS AND DISCUSSION

3.1 STUDIES ON BLUEFIN TUNA IN 19TH AND AT THE BEGINNING OF THE 20TH CENTURY

A significant amount of knowledge concerning BFT life history and tuna fishing in the eastern Adriatic Sea by the ancients does exist. Some biological studies of the sea fauna and the fisheries of the Adriatic, during Austro-Hungarian presence, were published by foreign scientists (Faber 1883). Many important scientific documents dealing with BFT

trap fishery as the most ancient industrial acitvity in the fisheries of Adriatic were updated by Di Natale (2018). Concerning the trap fishery activities along the north-eastern Adriatic, Kirsch (1900) provided very useful information on how the trap fishery operated between the XIX and the XX centuries, with a detailed description of methods and techniques applied (Fig. 3). Due to geomorphological characteristics of the north-eastern Adriatic rocky coast (e.g. Kvarner and Rijeka Bay, Velebit channel, Cres and Krk islands) tuna's migration occured along the coast and more than 75% of tuna catches in 10-year period before II Wold War were obtained by trap fishery in this area. At the beginning of II World War 28 active tuna traps operated in this area, while after the war the number of active tuna traps decreased (Basioli, 1962).

Figure 3. The coastal tuna trap fishery along the north-eastern Adriatic between the second part of the XIX century and the first part of the XX century (Kirsch, 1900).



One of the first Croatian fisheries scientists to devote part of his work at the Institute of Oceanography and Fisheries in Split (IOR) before World War II, describing the BFT fishing on the eastern Adriatic coast, was Tonko Šoljan (1930). In his book "Fishes of the Adriatic" Šoljan (1948), morphometric and meristic characteristics necessary for the identification of tunas and other fish species are available. Fishing techniques with

different fishing gears targeting BFT in the Adriatic Sea were also the subject of studies conducted after the World War II by other fishery experts and scientists in Croatia (Basioli, 1962; Morović, 1971).

Josip Basioli, in his book "Tuna fishing on the Adriatic" (1962, in Croatian), described in detail all local fishing gears used for tuna fishing, including the appearance of the first purse seiners used for catching tuna and other large pelagic fish in the open sea. He also presented statistical data on their catches in certain areas and on certain islands along the eastern Adriatic coast, as well as the legislation in force at that time for catching large pelagic fish.

Morović (1971) in his book "Tuna and its Life" (in Croatian) has collected most of the current biological knowledge about tunas, including their geographical distribution and systematic classification, and describes for the first time the biometric characteristics of tuna body, as well as their growth, sexual maturity and reproduction. He also describes the predators, parasites, migrations, and feeding habits of BFT. The aroused scientific interest in studing the biology and ecology of BFT helped and enabled the research vessel "PREDVODNIK" owened by Institute of Oceanography and Fisheries in Split (IOR) equipped with purse-seine net and the so-called "Puratić block" or power block for fisheries research on pelagic fish (Fig. 4).

Figure 4. Research vessel PREDVODNIK of Institute of Oceanography and Fisheries with Puratić-block and purse-seine net (From: Morović, 1971; Foto: M. Alajbeg).

Otherwise, “Puratić block” is an invention of the Croatian emigrant to the USA, M. Puratić, from the Adriatic island of Brač who worked as a fisherman on tuna fishing vessels in the Pacific. He invented how to facilitate the demanding operation of purse seine nets lifting out of the sea on the fishing vessel, and his novelity is now an indispensable device in BFT purse seine fishing (Viličić, 1985).

Another Croat living in the USA, Ante Viličić, worked as a fisherman in the purse seine tuna fishery in the Pacific, where he gained valuable experience and became an expert in purse seine tuna fishing. After returning from the Pacific to the Adriatic Sea, he transfered his knowledge and experience on the eastern Adriatic. He published the book “Historical development of modern tuna fishing” (Viličić, 1985), describing the construction of the first fishing vessel in the Adriatic equipped with a purse seine net for tuna fishing, as well as experiences and statistical data of the tuna catches obtained. He pioneered the further development of BFT purse seine fishing in the open Adriatic Sea.

However, competition between modern fishing vessels equipped with purse-seine nets and traditional tuna fishing gears (e.g. tuna traps, beach seines etc.) resulted in many conflicts among fisherman (Basioli, 1962). Purse-seine fishing vessels were catching tuna schools far from the shore and therefore impacted abundance of tunas near shore. Consequently, development of purse seine fishing fleet resulted in gradual decline of tuna trap fishery and other old traditional tuna fishing gears used only in near shore areas. These old traditional fishing gears targeting large pelagic fish, together with modern, more effective fishing gears and techniques targeting BFT and other marine species, were described in “Fishing gears and techniques” by Cetinić and Swiniarski (1985).

The wide spatial distribution and long-distance migrations of BFT and other tuna species in the Mediterranean Sea and Atlantic Ocean highlighted the need for an international approach to further studies and management, and eventually the International Commission for the Conservation of Atlantic Tunas (ICCAT) was established in the late 1960s. As a BFT scientist D. Morović participated in the first ICCAT meeting hold in Rome, December 1-6, 1969 (Morović, 1971). After him, the monitoring of tuna catches on the east coast of the Adriatic Sea at the IOR in Split was taken over by the Chilean-born scientist Alegria-Hernandez (1984; 1990). After her return to Chile, fisheries scientist V. Tičina was engaged in more detailed studies of BFT biology and fisheries in the 1990s. These studies eventually resulted in his master’s thesis “Morphological and nutritional characteristics and fishing of tuna (*Thunnus thynnus* L.) in the Adriatic Sea” (Tičina, 1994) and publications (Tičina, 1993, 1997, 1999), including study on the age and growth of tuna caught in the Adriatic Sea (Tičina and Kačić, 1998). However, there were no studies

on sport-fishing of BFT during the XX century. At the end of 20th century, in 1997 the Republic of Croatia became a full member of the ICCAT, and V. Tičina became a member of the Standing Committee on Research and Statistics (SCRS) and served as the national BFT scientist of the Republic of Croatia in SCRS until 2010.

3.2 STUDIES ON BLUEFIN TUNA AT THE BEGINNING OF THE 21ST CENTURY

Starting from 1st decade of XXI century, Katavić headed Croatian delegation to ICCAT in period 2001-2013, and in parallel was involved in coordination and research activities focused on BFT related studies. Thanks to his involvement two hystoric ICCAT sessions were held in the Republic of Croatia (Dubrovnik, 2006 and 2018 respectively). Providing the Vice –Chair to the General Fisheries Commission for the Maditerranean (GFCM) he also strenghten regional studies on BFT at ICCAT sessions, acting on behalf both respectve regional bodies.

At the very beggining of XXI century, Tičina and Kačić (2001) studied usefulness of hydroacoustic devices (e.g. commercial searchlight sonar) in tuna fishing operations in the Adriatic. V. Tičina as a leading BFT scientist from IOR, dedicated great part of his career to BFT research and together with his coleauges from the eastern Adriatic, published a large number of research papers in ICCAT publication - Collective Volume of Scientific Papers during the first decade of the XXI century (Katavić et al., 2002; Miyake et al., 2003; Tičina, 2007; Tičina et al., 2002, 2003, 2004a, 2005, 2006). They joined the work of an international group of BFT scientists under the framework of ICCAT Bluefin Year Program (BYP). Acting as BYP tagging coordinator, Tičina and his colleagues conducted research related to captive BFT tagging to investigate the post-tagging mortality and growth performance of BFT during aquaculture activities (Tičina et al., 2004b, 2007). Following BYP, the ICCAT launched Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) in which Katavić served as an external expert aiming to improve knowledge and understanding of the Atlantic BFT stocks and migrations.

Croats returning 1996 to their homeland from Australia brought with them their experience in tuna aquaculture and decided to start this activity on the eastern Adriatic coast. Since the end of the 20th century, this extremely profitable activity has developed very rapidly on the eastern coast of the Adriatic Sea. In the first decade of the XXI century, fisheries-based BFT aquaculture became an important new activity in marine aquaculture, spreading rapidly throughout the Mediterranean (Miyake et al., 2003; Tičina, 2008). Given the domestication of tuna as a new species in Mediterranean aquaculture and the fact that caught live bluefin tuna is gaining importance as seed fish in cage

farming, the need to study the relationship between the economic activities of fisheries and aquaculture is coming to the fore (Katavić and Tičina, 2005). As a result, there has been very good cooperation between the Croatian Ministry of Agriculture and scientists from the Laboratory of Fisheries Science and Management of Pelagic and Demersal Resources and the Laboratory of Aquaculture of the IOR. This eventually led to their joint participation in a larger number of ICCAT studies (e.g. BFT stock assessments), as well as in many international scientific meetings and a larger number of jointly published scientific papers on this topic.

Katavić et. al. (2002) undertake a pioner studies with caged juvenile BFT in the Adriatic Sea indicating a significant increase of average daily weight gain compare to wild fish. In the later studies, the research provides important information on the growth performances of BFT juveniles caged in the Adriatic under specific conditions (Katavić et al., 2003a, 2003b, 2003c; Tičina et al., 2007). However, due to the fact that fish were not landed in the same year when they were caught, BFT farming caused difficulties in terms of catch statictics (i.e. gap in data collection) and consequently difficulties to BFT stock assessment and management measures based on multi-year catch data. IOR's scientists studied this catch data issue, and eventually in close cooperation with country administration in 2005 developed projects (called: PUT and PRUT) aimed to monitor and follow captured small BFT used as seed fish in farming process up to their harvest/landing. Outcomes of studies made within framework of projects PUT and PRUT improuved accuracy of ICCAT BFT catch statistics from the Adriatic Sea.

In the second decade of XXI century, the biometric characteristics of BFT originating from the Mediterranean Sea (Tičina et al., 2011), and migration pattern of tagged BFT juveniles were studied. Further research efforts were made on use of a stereoscopic underwater camera system, as a non-invasive tool, in estimating the number and biomass of caged live BFT (Grubišić et al., 2013a; Katavić et al., 2016; Tičina et al. 2016). In respecting specifity of BFT stock in the Adriatic and farming practice applied, a novel Adriatic L-W algorithm were determined (Katavić, et al., 2018). Comparing size and weight distribution of caged fish large variation among farms were adressed to difference in husbandry and environmental conditions (Katavić et al., 2013, 2017).

Considering that BFT farming highly depends on the availability of small pelagic fish used as feed, studies were made with the aim of estimating the type and amount of food needed (Miletić, 2011; Miletić et al., 2019), as well as possible improvements in feeding zootechnics and sustainability of tuna farming (Mišlov Jelavić et al., 2012). The spontaneous spawning of BFT in cages and the spatial distribution of the earliest developmental stages were studied also (Grubišić et al. 2013b; Džoić at al. 2017).

Successful ICCAT management measures related to BFT stocks resulted in increased small BFT abundance in the Adriatic Sea. Eventually, scientists and fisherman noted also that behavior of numerous BFT affect other fishing activities, particularly small pelagic purse-seine night fishing with artificial lights. The influence of presence of BFT within purse-seine fishing grounds affecting the catch of small pelagic fish and damage of fishing nets was studied (unpublished). However, on the other hand, increased abbundance of BFT in the Adriatic Sea acted in favour of sport and recreational tuna fishing, known as Big Game Fishing (BGF). BGF tournaments become very popular events in Croatia, but given a very low quota allocated to BGF, this type of fishing is mainly based on the catch-and-release practice. In cooperation with ICCAT-GBYP and the Croatian Association for Sport Fishing at Sea and BFT farmers, in 2017 IOR's scientists studied effects of different types of hooks used in BGF with aim to reduce post-hooking mortality and suffering of BFT relesed (Grubišić et al. 2018).

Research on the impact of BFT farming on the marine ecosystem (Matijević et al., 2012; Stagličić et al., 2017; Šegvić et al., 2011; Tičina et al., 2020) were also important contributions to overall BFT studies on the eastern Adriatic Sea. Within framework of international cooperation, scientists from IOR also contributed to various international studies on tuna biology and ecology at large spatial scale in the Atlantic and the Mediterranean (Rooker et al., 2008; Brophy et al., 2015; Druon et al., 2016; Deguara et al., 2017; Corriero et al., 2020). In addition, it should be mentioned that BFT has also been used as an object for the study on fish parasites that it also hosts (Mladineo at al., 2008; Stanić and Mladineo, 2020).

Recently, BFT has been often used as object in various genetic studies in the Adriatic Sea, resulting in PhD thesis of young IOR's scientists. In her studies on BFT, Trumbić (2015) established a normalized mixed tissue of BFT cDNA library, pyrosequenced, assembled and annotated. It was used as a proposal for the construction of a BFT-specific DNA microarray. The relationship between the BFT host and the digenean trematode *Didymosulcus katsuwonicola* was further investigated using DNA microarrays and transmission electron microscopy. Furthermore, Lepen Pleić (2018) cloned the first full-length mRNA and gDNA sequences of BFT in order to obtain molecular characterization and expression analysis of three pro-inflammatory cytokines IL-1β, TNFα1 and TNFα2 in cage-reared BFT. The expression analysis was performed in peripheral blood leukocytes stimulated in vitro with LPS, Poly I:C and parasite protein extract; and in gill tissue during natural parasite infection. In order to find out whether survival or mortality through the BFT farming cycle can be monitored at the genetic level and linked to several genes related to

immunity and stress response, IOR's researchers defined a set of 13 EST-SSRs for BFT, analysing wild vs. farmed adult BFT specimens (Radonić et al., 2020).

Finally, considering the fact that bluefin tuna is an important food for human consumption, special attention was paid to the fact that BFT is a long-lived species whose tissues are susceptible to bioaccumulation of various organic pollutants and heavy metals present in the marine environment. Therefore, IOR's scientist in collaboration with scientists from the Institute of Medical Research and Occupational Health in Zagreb and the Department of Marine Sciences and Applied Biology in Alicante, were studying this issue also (Fernandez-Jover et al., 2020; Klinčić et al., 2020; Kljaković-Gašpić and Tičina, 2021). This is particularly important for BFT from the Mediterranean Sea, highlighting importance to study BFT produced by tuna farming aquaculture activities in the Adriatic Sea, as one of the most enclosed parts of the Mediterranean. This is one of the reasons why BFT from eastern part of the Adriatic Sea should be better studied than those from other areas. Doing so, further studies may also reveal other ecological patterns of BFT.

4 CONCLUSIONS

Based on the review made, it is understood that BFT inspired a large number of experts and scientists working in the eastern Adriatic Sea to study its morphology, behaviour, biology, ecology and its life traits. Since ancient times BFT represented an important food source for coastal fishing communities, at the beggining studies on different fishing practices and types of fishing gears targeting BFT were the in the focus. The importance of studies in XX century related to BFT fishery was emphasized by high commercial value and the ability for capture BFT.

Due to BFT's long distance migrations very wide spatial distribution and multiple stock-users, need for an international management of this valuable sea resource resulted in establishment of ICCAT in 2nd half of XX century, higlighting the necessity for international stock assessments. Therefore, emphasis was given to studies that monitored BFT fishing activities in order to obtain regional statistical catch database and eventually provide management measures for sustainable BFT fishing.

Development of BFT farming practices in the Adriatic Sea at the begginning of XXI century, opened to Adriatic scientists a new study area, with a lot of chalenges and research opportunities coupling fisheries and aquaculture scientists. Therefore, many studies made in XXI century were mostly related to captive BFT kept in growth-out floating cages. Croatian active participation in ICCAT and SCRS offered to the Adriatic scientists' possibilities for developing international cooperation, enabling their participation in

common BFT studies on regional, wide spatial scales, as well as fueling BFT research in the Adriatic environment.

More recently, BFT in the Adriatic Sea is ferquently used as an object of studies on fish parasites, molecular and genetic studies, as well as a studied food item important in human consumption. As a comercially very important large pelagic fish, BFT will certainly continue to play important role in fishery-based aquaculture (e.g. tuna farming) and sport fishing and inspire scientist and experts in their future studies.

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SOBRE O ORGANIZADOR

EDUARDO EUGENIO SPERS realizou pós-doutorado na Wageningen University (WUR), Holanda, e especialização no IGIA, França. Possui doutorado em Administração pela Universidade de São Paulo (USP). Foi Professor do Programa de Mestrado e Doutorado em Administração e do Mestrado Profissional em Comportamento do Consumidor da ESPM. Líder do tema Teoria, Epistemologia e Métodos de Pesquisa em Marketing na Associação Nacional de Pós-Graduação e Pesquisa em Administração (ANPAD). Participou de diversos projetos de consultoria e pesquisa coordenados pelo PENSA e Markestrat. É Professor Titular no Departamento de Economia, Administração e Sociologia, docente do Mestrado em Administração e Coordenador do Grupo de Extensão MarkEsalq no campus da USP/Esalq. Proferiu palestras em diversos eventos acadêmicos e profissionais, com diversos artigos publicados em periódicos nacionais e internacionais, livros e capítulos de livros sobre agronegócios, com foco no marketing e no comportamento do produtor rural e do consumidor de alimentos.

ÍNDICE REMISSIVO

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