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Use of Local Ecological Knowledge on the Natural Recruitment of Bivalve Species of Commercial Exploitation in a Natura Area

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Abstract: The current study provides valuable insight into the ecological risks and decline of the bivalve fishery and biodiversity in the Amvrakikos Gulf over the last 50 years through a triangulation of information from in situ surveys and expert judgment, supplemented with historical archives. In situ sampling showed that bivalve species composition was a typical composition of benthic fauna consisting of the olive green cockle, *Cerastoderma glaucum*, the grooved carpet shell, *Ruditapes decussatus*, and the Mediterranean mussel, *Mytilus galloprovincialis*. Interviews confirmed the dramatic decrease in the abundance of striped venus clam, *Chamelea gallina*, and noble pen shell *Pinna nobilis*, both of which might be attributed to human-induced impacts, habitat degradation and climate change. Official data depicted a gradual reduction of bivalve catches since 1980 and massive degradation of the resources after 2000. As a result, the bivalve fishery was abandoned, having a negative impact on the local socio-economic community. The present study fills in a gap in knowledge for preserving species biodiversity that is critical to the health of the coastal environments.

Keywords: biodiversity loss; mass mortalities; historical reminiscence; Ionian Sea

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1. Introduction

Biodiversity loss directly affects ecosystem functioning, ecosystem processes and services' complexity [1]. Coastal environments are under increasing pressure by a wide variety of impacts, originating from human activities and environmental variability. In this context, the Natura 2000 network aims to protect most of the valuable and threatened species and habitats in Europe, where Mediterranean biodiversity hotspots are characterized by higher levels of threat and endemism than the rest of Europe [2]. The main problem in disentangling the impact from these factors is the lack of historical baseline information for comparison with present conditions to evaluate massive alterations [3]. The integration of historical experience on Mediterranean community-based fisheries with in situ field observations has significantly increased recently in fostering the sustainability of coastal resources and subsequently social cohesion [4].

Certain bivalve species such as the noble pen shell *Pinna nobilis* (Linnaeus, 1758), and European date mussel *Lithophaga lithophaga* (Linnaeus, 1758) are listed as "species for which there is a prohibition to fish for, retain on board, transship, land, store, sell, display or offer for sale" under the article 10(2) and the Annex I of the European Regulation 1241/2019 [5]. However, people involved in the bivalve fishery in the southern Mediterranean countries are not aware of the above-mentioned regulation [6]. In the Greek Seas, scientific information on the exploited bivalve species is also scarce and limited to a few species such as the brown venus *Callista chione* (Linnaeus, 1758), olive green cockle *Cerastoderma glaucum* (Bruguière, 1789) and warty venus *Venus verrucosa* (Linnaeus, 1758) [7]. The problem gets aggravated by discrepancies in the official fisheries data reported by the Hellenic Statistical Authority (HELSTAT). Despite the fact that these records are the most consistent data available in terms of spatial and temporal resolution [8], data reported are biased due to

misreporting estimates and limitations in the sampling methodology, thus creating a gap in the collected data, and masking potential shifts in less-resilient species [9]. Although these species are rarely targeted because of their scarcity, it is possible that when other species of the bivalves are caught, they are often deliberately or unintentionally misreported and recorded within another group of pelecipoda, jeopardizing accurate data reporting about these species.

Since the 1950s, bivalve fishery conducted in a Natura 2000 protected, semi-enclosed embayment, Amvrakikos Gulf, was one of the most systematic and profitable fishing activities with a significant socio-economic impact in the local communities [10]. The main bivalve of commercial interest in the gulf is the Mediterranean mussel *Mytilus galloprovincialis* (Lamark, 1819) [11], whereas other species with potential exploitation interest are smooth scallop *Flexopecten glaber* (Linnaeus, 1758) and variegated scallop *Mimachlamys varia* (Linnaeus, 1758) [12], *Striped venus* clam *Chamelea gallina* (Linnaeus, 1758), grooved carpet shell *Ruditapes decussatus* (Linnaeus, 1758), Noah's ark *Arca noea* (Linnaeus, 1758), *P. nobilis*, *C. glaucum* and several other bivalves such as the grooved razor clams *Solen marginatus* and *L. lithophaga*. Since the beginning of the 1980s, bivalve catches have severely declined followed by an analogous decline of the vessels licensed for bivalve fishing [10]. From this temporal point up to the present, gulf fjord characteristics (i.e., an enclosed bay with freshwater discharges and extended depth: [13]) accompanied by the high degree of human (e.g., increased fishing pressure, urbanization and aquaculture discharges, reduced water exchange with the Ionian Sea) and environmental (e.g., regulated river drainage by river dams, mean air temperature increase: [14]) impacts degraded ecosystem status and coastal resources' sustainability [15].

The aim of the present work is to assess through a multi-level approach the long-term (50 years) changes in bivalve biodiversity in a traditional fisheries-dependent area, the "National Park" of Amvrakikos Gulf (Eastern Ionian Sea, Greece). Local Ecological Knowledge (LEK) was implemented in parallel with field bivalve qualitative surveys and historical information found in old archives, grey literature and official reported data. The compilation of historical and 'forgotten' science with modern natural observations have significantly increased nowadays, under the framework of Marine Historical Ecology and Marine Environmental History [16]. This mixture of methods has been successfully contributed: (a) to a better understanding of the ecosystem baselines [17], (b) to identify changes in bivalve species biodiversity [18], and (c) to determine the effects of socio-ecological interactions on bivalve fisheries [19]. Findings of this study would be particularly important in the economy of fisheries dependent coastal areas of the European Union [20], especially under the frames of the new reform of the Common Fisheries Policy [21] (EU REG 1380/2013), which seek to encourage the representative participation of small-scale producers.

2. Materials and Methods

2.1. Study Area and Exploitation Pattern

Amvrakikos Gulf (Figure 1) has been characterized as a "National Park" through the Greek legislation [20]. Despite being protected by national, European and international regulations for its diverse wildlife and wetlands, the gulf is affected by fish farms, agriculture, livestock and sewage discharges from surrounding coastal towns and villages [22]. Seasonal hypoxic and anoxic seawater masses gradually expanded over the years, which resulted in more than 50% of habitat loss on the seafloor [23]. Along the coastline of the gulf, there is a complex of 14 lagoons covering approximately 20% of the entire surface of the gulf, which consists of Natura 2000 reserves for wildlife and nursery grounds for demersal fish species.

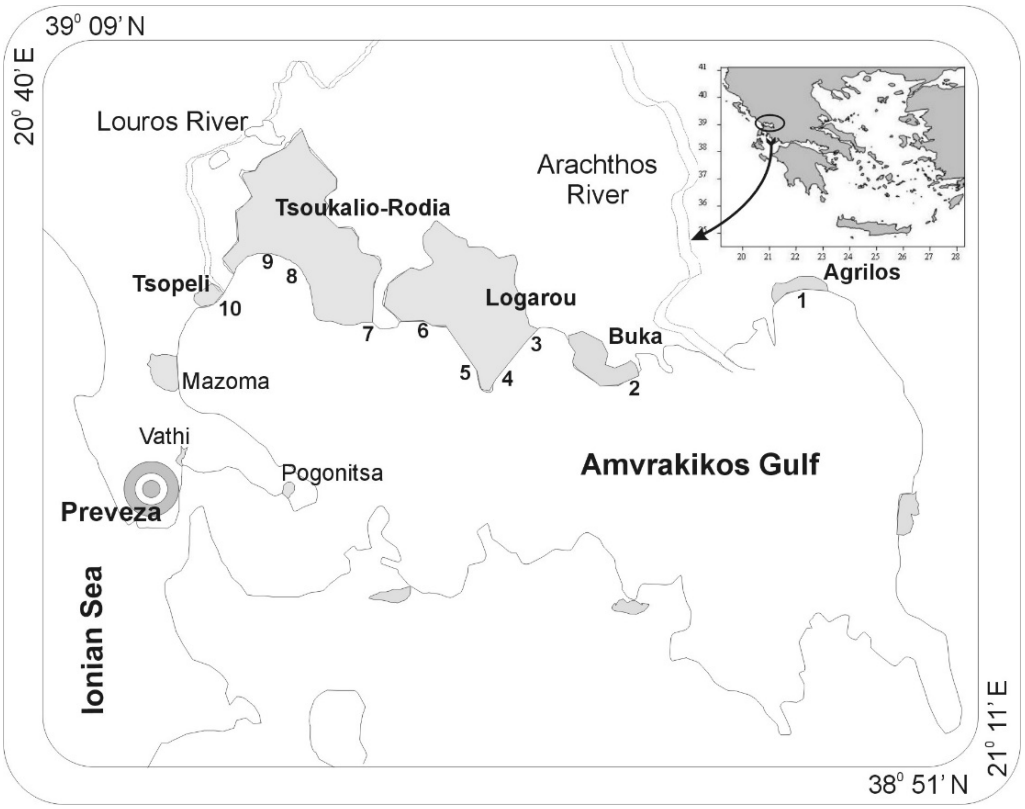

Figure 1. Map of Amvrakikos Gulf (lagoons in dark grey) showing the 10 sampling stations and the interviews sampling sites at the Northern part: Tsoukalio-Rodia, Tsopeli, Logarou, Bouka, and the city of Preveza.

Since 1953, bivalve harvesting has been operating within the gulf with small-size fishing boats using mainly set nets, whereas dynamic fishing gears such as trawling and purse-seining are prohibited all year round [10]. Fishing tools and dredges used on-board the traditional fishing vessel type called "priari" (lower part in Figure 2A), including the "pinologo" for the harvesting of *P. nobilis*. The most common fishing gear (apart from the collection by hand) for the exploitation of bivalves is the "fish net" (butterfly net) when the waters are clear in depths from 0.5 m to 3 m. Fishers used "gagamo" (dredge) (80 cm long), which is a triangular gear with an iron perimeter and a triangular net. When fishing by "priari", bivalves are caught in nets with a length of 1.5 km and a mesh size of 32–34 mm at 8 to 10 m depth.

The active fishing fleet currently includes almost 280 fishing vessels operating exclusively inside the Amvrakikos Gulf and targeting mainly (70% of the total landings within the gulf) European pilchard (*Sardina pilchardus*, Walbaum, 1792), red mullet (*Mullus barbatus*, Linnaeus, 1758), caramote prawn (*Melicertus kerathurus* (Forskål, 1775)), mugillids, *Mugil cephalus*, Linnaeus, 1758, and *Chelon* spp., and soles, *Solea* spp. [10]. The vast majority of the fishing vessels (80%) are concentrated in the city of Preveza and to a lesser extent in the city of Amphilochia (15%) (data from the Department of Fisheries, Regional Unit of Preveza).

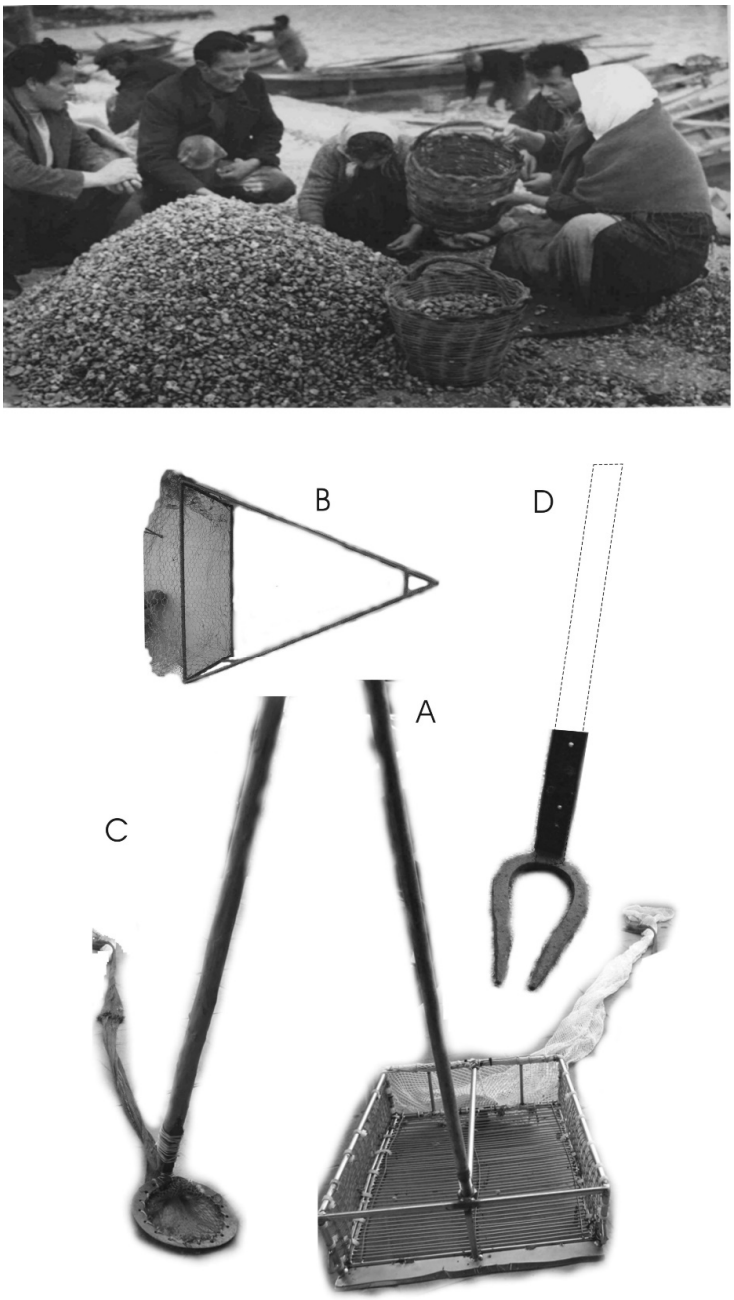

Figure 2. (**upper**) Photo from the post-World War II period (mid 1950s) from the dock of the Preveza port, with fisher's women contributing to the clean and grading of the harvested *Chamelea gallina* (original photos by Spiros Meletzis 1955), (**lower**) Bivalve harvesting tools and dredges used on the traditional fishing boat called "priari" for exploit bivalves in the Amvrakikos Gulf: (**A**) Dredge; (**B**) "gagamo"; (**C**) Benthic bivalve harvesting tool; (**D**) "pinologos" for harvesting *Pinna nobilis*.

2.2. Targeted Interviews

Due to data-limited issues, and in order to supplement the data availability, a type of qualitative research methodology was adopted on exploring perceptions and knowledge of the local professional fishers that are closely related to the bivalve fishery in the studied area. This research methodology is flexible and offers the opportunity for an in-depth investigation of perceptions, attitudes, intentions and experiences [24]. This stems from the fact that quality methods are based on the inductive research approach, which offers exactly this ability, in-depth internal analysis [25]. The use of qualitative research methods highlights differences of opinions between groups and in this way generates a wide range

of ideas that individuals express facts and issues [26]. Over two months (May–June 2016), seven highly prolific and experienced professionals working in the fishery sector in the Amvrakikos Gulf were selected based on their experience in fisheries and their willingness to be interviewed. The selected professional fishers were past and current presidents of the local small-scale fishers associations representing all the professional fishers that are members of the associations and fish within the gulf. Thus, their opinion and knowledge covered the majority of the professional fishers in a long-term base. All the interviewed fishers were middle-aged males (42 to 64 years old) having long fishing experiences (>25 years), being dependent on fishing (i.e., the portion of their total annual income derived exclusively from fishing), and they are still exclusively operating within the gulf. The methodological approach is based on expert opinion knowledge rather than on statistical sampling, in cases where the classical survey does not give reliable results due to high complexity and lack of credible data. The exclusion of women in the sampling design did not introduce any type of sampling bias into the overall results because their contribution was supplementary to bivalve fishery and mostly focused on peripheral activities such as cleaning and grading the bivalves before reaching the market and not on the core of the bivalve fishing activity (i.e., organization of the fishery, planning of the trials and of the quantities of the catch). Thus, we assume that the exclusion of women in the sampling design provides no bias in our survey.

Interviews were carried out in the mooring/landing sites privately (one-to-one sessions) to prevent influences by others, especially by the fisher's colleagues and in Greek by one person to ensure that questions were presented identically to minimize sampling bias. All fishers were interviewed voluntarily with the interviews based on a semi-structured questionnaire, resulting in free-flowing conversations guided by a set of a priori questions that were later recovered in specific coding covering four code analytical "spawning areas" over the last 30 years (Table 1): (a) seasonality of the fishery, (b) the number of species targeted, (c) number and frequency of fishing gears used, (d) peaks and minima of catches, and (e) reasons for moving away from the profession and site distribution. Interviews were carried out close to lagoons' "mouth" gates, where fishers act as members of the local fisher association and they are responsible for protecting the lagoon ecosystem and for exploiting the fisheries resources in a sustainable way.

2.3. In Situ Field Sampling

A bivalve sampling was carried out at 10 stations on the beach and the sub-littoral zone up to a depth of 0.5 m of the northern coastline of Amvrakikos (Figure 1) from June to August 2016. The northern part of the gulf (Figure 1) was selected for sampling because of the high heterogeneity of the ecosystem; i.e., two of the largest lagoons are located in this part, estuaries of the two rivers discharged in the gulf and significant fishing activity occurs. Samples of bivalves and dead shells were collected at stations and the presence and relative abundance of the species were assessed in both live and dead animals. At each station, substrate volume was taken up to 25 cm depth of a 30 × 30 cm frame. The substrate was sieved with a 5 mm sieve and the entire shells were collected and transported to the laboratory, where they were measured and taxonomy assessed. No ethical approval was required.

2.4. Official Data and Archive Information

The methodology applied for the collection of data is in line with international practices (e.g., [27] including an extensive archival search on bivalve fishery in the gulf within the 20th century based on academic-digital libraries, museums and online sources. Since 1964, fisheries data for bivalves are also routinely collected by the Hellenic Statistical Authority (HELSTAT) that is monitoring all professional fishing vessels with engine power greater than 19 HP from 16 fishing subareas of the Greek Seas (sub-area S4, Amvrakikos Gulf, [28]. Data analyzed included the up-to-date annual landings of bivalves from the

gulf for the period 1964–2019, whereas landings of bivalves were also recorded by the local Fisheries Department during 1979–2001 and were presented herein.

Table 1. Bivalve fishing operational characteristics among professionals based on data derived from interviews.

Questions	Statements				
In which seasons were bivalves fished?	March–April (25%)	Spring and September–October (25%).	From March (50%).		
When bivalve fishery has been stopped?	0–5 years ago (60%)	7–10 years ago for *Pinna nobilis* (20%).	Before 10–15 years (20%).		
Why bivalve's fishery has been stopped?	At 20 m of depth, massive mussel mortalities were observed (35%).	Prohibition of fishery (20%).	Illegal fishery from recreational fishers that caught young *Pinna nobilis* (15%).	No commercial interest (need of a license for the marketing) (25%).	Water pollution due to fish farms (5%)
Why bivalves are not fished?	There are not any bivalves (60%).	Fishing has been stopped since 7 years ago (20%).	Fishing has been stopped since 15 years ago (20%).		
How and where the bivalve production was directed?	Home consumption (33%).	Wholesale market (33%).	Retail market (33%).		

3. Results

3.1. Historical Evolution through LEK

Coded statements are presented in Table 1 and the most prominent patterns observed from all interviewed fishers were: (a) the disappearance of the most commercially important bivalve species from the gulf almost two decades ago (i.e., end of 1990s–early years of the 2000s), (b) the massive reduction in the bivalve catches since 2000, (c) the absence of bivalves within the lagoons and (d) the abandonment of the family-based profile of the bivalve fishery during the 1980s.

In Amvrakikos Gulf, about 25 fishing boats are currently employed partially for bivalve exploitation as a supplementary activity to their main fishing activities. The annual total harvested bivalve biomass was estimated about 25–100 metric t. Professionals stated that the current catches of *C. gallina*, *R. decussatus* and *A. noea* ranged between 100 and 400 kg/fishing boat/harvesting day, usually staffed by 2–3 fishers each. In contrast, between 10 and 20 years ago, *F. glaber* and *M. varia* catches ranged from 100 to 500 kg/fishing boat usually staffed by 2–3 fishers per harvesting day, whereas, currently, bivalves have disappeared and the exploitation has been stopped. Pollution, ineffective fishing patrolling and absence of marketing interest were the main reasons for the abandoning of the bivalve fishery.

The bivalve harvesting conducted before the decline in the bivalve populations was seasonal, about twice a week, and only after the ordering request of the merchants mainly during the Easter fasting season (40–50 days before the Greek Orthodox Easter in late spring). At that time, Greek-Orthodox followers avoid eating meat and dairy products, but they preferred to consume vegetarian and bivalve meals. Despite the minor interest for commercial exploitation, *P. nobilis* was also harvested sporadically by the fisher for their home consumption (up to 2–3 kg for 5–6 individuals). Concerning the spatial expansion of the bivalves, the most representative species that existed within the lagoons was the *C. glaucum*, whereas *S. marginatus*, *C. gallina*, and *L. lithophaga* were all harvested outside the lagoons on the rocks at depths ranging from few centimeters to 10 m.

3.2. Bivalve Sampling

Common and scientific bivalve names used in the survey are in accordance with the recent nomenclature [29,30] (Table A1). Overall, 1023 valves of dead and 325 live individuals were collected at 10 stations (Figure 1) and 13 species/taxa were identified: *A. noae*,

C. glaucum, *C. gallina*, *F. glaber*, *L. lithophaga*, Mediterranean Mussel *M. galloprovincialis*, edible oyster *Ostrea edulis* (Linnaeus, 1758), *P. nobilis*, *Pholas dactylus*, *S. marginatus*, *R. decussatus*, and *V. verrucosa*. The most representative species were *C. glaucum* (34%), *R. decussatus* (28%) and *M. galloprovincialis* (18%), with the remaining species, each contributed from 2% (*P. dactylus*, *P. nobilis* and *F. glaber*) to 7% (*O. edulis*) (Figure 3A). The highest relative abundance of dead bivalve specimens with shell length smaller than 20 mm were estimated for *C. glaucum* (135.54 ind./m^2) and *O. edulis* (109.99 ind./m^2) followed by *R. decussatus* (75.55 ind./m^2), whereas the corresponding relative abundances for live bivalve specimens were estimated for *M. galloprovincialis* (144.43 ind./m^2) and *C. glaucum* (129.99 ind./m^2) (Figure 3B). For the large specimens (shell length > 20 mm), the highest relative abundance for dead specimens were estimated for *R. decussatus*, (279.97 ind./m^2) and *C. glaucum* (225.53 ind./m^2), followed by *M. galloprovincialis* (108.88 ind./m^2). For live specimens, the highest relative abundance was estimated for *R. decussatus* (61.11 ind./m^2), followed to a lesser extent by *C. glaucum* (21.11 ind./m^2) and *M. galloprovincialis* (6.67 ind./m^2) (Figure 3C).

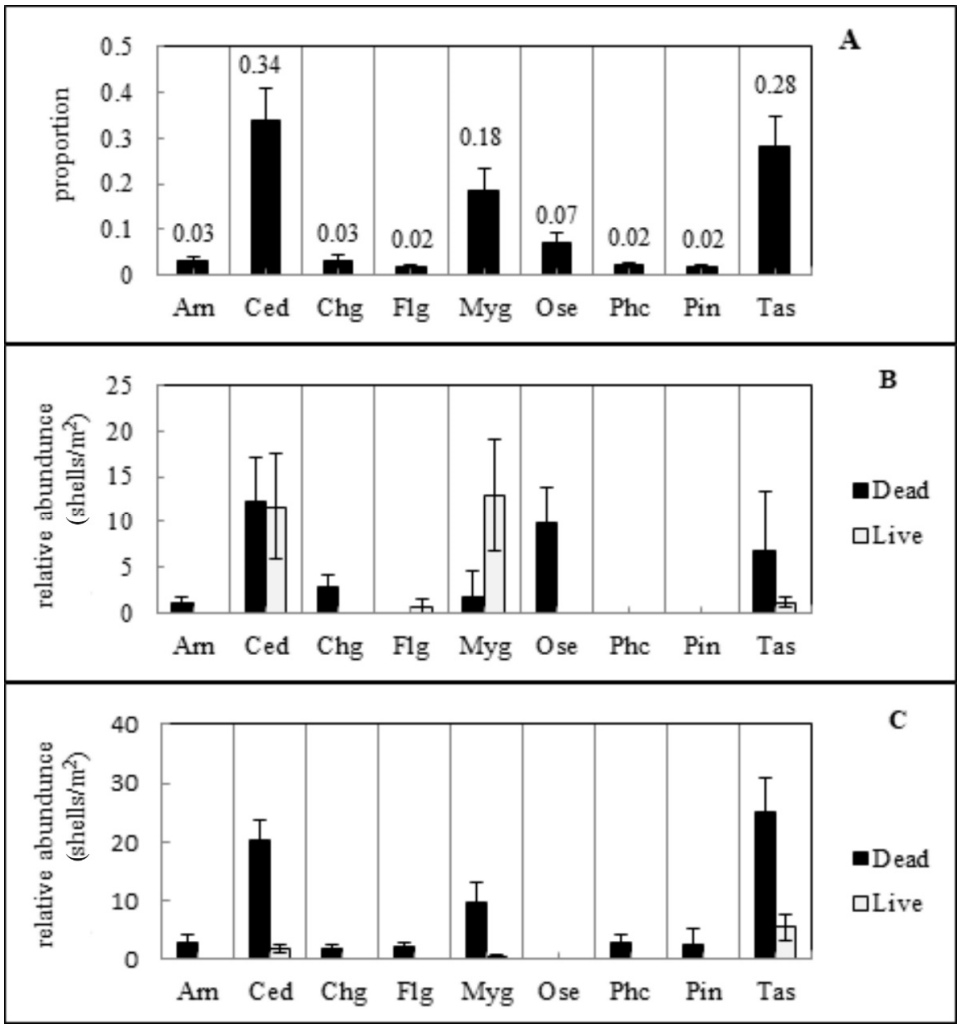

Figure 3. Bivalve species composition (**A**), relative abundance per species for death and live individuals with shell length < 20 mm (**B**) and with shell length > 20 mm (**C**). Data pooled from ten sampling stations in the northern coastal line of Amvrakikos Gulf during June–August 2016. Vertical bars show standard errors. Arn: *Arca noae*, Ced: *Cerastoderma glaucum*, Chg: *Chamelea gallina*, Flg: *Flexopecten glaber*, Myg: *Mytilus galloprovincialis*, Ose: *Ostrea edulis*, Phc: *Pholas dactylus*, Pin: *Pinna nobilis*, Tas: *Ruditapes decussatus*.

3.3. Official Data

Only a few bivalve species are specifically recorded by HELSTAT (i.e., *M. galloprovincialis*, *O. edulis* and *V. verrucosa*), whereas the rest are aggregated as 'other bivalves' [24]. Landings exhibited non-zero values for 22 out of 56 years of the 1964–2019 data series of landings (Figure 4a). Two periods were observed with landings greater than one metric t, one during 1964–1976, ranging from 0.5 t to 85.3 t, and the other during 1993–2001, ranging from 1.2 t to 16.4 t (Figure 4a). An extremely high value of landings was reported in 2014 with 420.8 t. Concerning the bivalve landings reported by the local Department of Fisheries (Figure 4b), a peak was exhibited in 1981 (358 t) followed by a gradual decrease to a low value of landings in 1984 (45 metric t) and then a stable pattern was observed up to 2001 (Figure 4b). In these data, landings per species exhibited various trends: (a) increasing, for *M. galloprovincialis* that was reached 60 t in 1999, (b) decreasing, especially during the first years of the data-series, for *F. glaber* and *P. nobilis*, with their landings almost minimized in the mid-1980s, and (c) drastic changes, decrease and increase of landings, in the first decade of the data-series, with a subsequent restoration to the first year landings', for *C. gallina*.

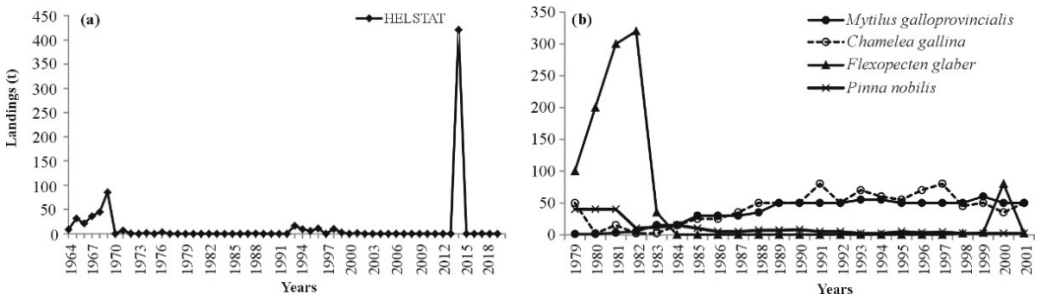

Figure 4. Bivalve landings based on: (**a**) species combined data reported by the Hellenic Statistical Authority during 1964–2019; and (**b**) species data reported by the local Department of Fisheries during 1979–2001.

4. Discussion

The present study provides, through a triangulation of information from in situ surveys and interviews complementing with historical archives, valuable insight to ecological risks and decline of bivalve fishery and biodiversity in the Amvrakikos Gulf during the last 50 years. Such a time-depth perspective represents a wealth of information on the ecology and the history of human impacts on marine ecosystems and exploitable resources. It is notable that the commercial exploitation of most bivalve species was abandoned almost two decades ago (e.g., *F. glaber*) due to a severe decrease in species abundance. The causes of the above-mentioned issues, as reported by the fishers and extracted by the historical archives, seemed to be attributed to overfishing and degraded environmental quality of the gulf.

Half of century ago, bivalves were sold together with fish species on the local fish market, and they were both packed in wet burlap bags, allowing them to be preserved alive for 4–5 days before reaching the wholesale markets of big cities such as Patras and Athens. The packing of the bivalves into burlap bags significantly expanded the product shelf-life due to moisture retention by the fibers of the bag. The rise in living standards and changes in living conditions following Greece's accession to the European Union (1981) have resulted in the abandonment of a declining complementary activity such as bivalve fishing, particularly during periods when other professions (e.g., agriculture) are more profitable. Since the 1990s, coastal communities involved in traditional small-scale fisheries have gradually 'decomposed' due to a decrease in fishing income due to catchment decline [31].

Up until the early 1980s, women, usually family members of professional fishers, worked as part-time workers in the post-harvesting process (e.g., cleaning and grading the bivalves before they reached the market) and thus made a significant contribution to

the family's income (Figure 2 upper). The family base of the participation of women in bivalve exploitation and packaging was abandoned in the 1980s due to modernization of bivalve sorting and cleaning using metallic nets. The uncertain future of fisheries is exacerbated further by young people's unwillingness to enter the fisherman's profession, a fact that reflects an insufficiency of a long-term strategy throughout the fisheries sector, which subsequently poses risks to the fishery's future [32]. These facts may explain the chronic shortage of young people in Europe's fishing industry [33] and particularly that of the women bivalve harvesters, issues that are also in line with other small-scale southern European fisheries [34].

Environmental degradation has also impacted the bivalve abundance. During the last 30 years, dysoxic and anoxic conditions that occurred in the gulf resulted in habitat loss on the seafloor spanning over 50% of the total area [13,23]. This largely impacted the sustainability of bivalve stocks. Mass mortality of olive green cockles is usually reported along with temperature increase from March up to August [14]. Local short-term events have also impacted the bivalve resources, as observed by the flood of the Arachthos River in February of 2015, leading to mass mortality of olive green cockles, as also mentioned by the fishers. The same is also observed in the adjacent estuary of the Louros River, a traditional fishing ground for bivalves (i.e., *F. glaber*, *V. verrucosa*, *P. nobilis*), because bivalve survival strongly depends on environmental conditions [35].

The integration of data from various official sources and field sampling revealed that only the latter of the high abundant species found in field samplings, *C. glaucum*, *R. decussatus*, and *M. galloprovincialis*, is specifically recorded by Greek statistical authority, while the others are aggregated with catches of other bivalve species. Major changes in certain bivalve landings have also been described in the corresponding statistics reported by the local Department of Fisheries. The historical decrease in bivalve landings in the Amvrakikos Gulf in the mid-1980s is, to some extent, consistent with the generalized decrease in small-scale fisheries landings observed within the gulf [10] and the surrounding lagoons [36]. Drop-in species catches were also in line with the analysis of the official reported catches made in the present study and fisher's statements, especially for *P. nobilis* and might be explained by the prohibition of *P. nobilis* fisheries due to its status as endangered species [37].

Although official fisheries' statistics constitute the baseline information for the documentation of fishing pressure on ecosystems, the actual impact of fisheries on the bivalve resources in the Gulf is also hard to be evaluated due to misreporting estimates and serious limitations in the sampling methodology followed by HELSTAT [9]. For instance, the unusual landing data reported by the HELSTAT for the "other bivalves" category in 2014 (420.8 t) seem to be underestimated and/or unreliable because frequently bivalve landings are largely derived from aquaculture [38]. A serious drawback, based on the bivalve species composition found in field samplings and fishers' statements, is the intentional or unintentional misreporting of congeneric bivalve species due to the sharing of the same common name or similar taxonomic characters that are often difficult to distinguish by non-experts.

Bivalve species composition found in the present study is representative of the composition of commercial benthic bivalves (or hard for sandwich species) in shallow waters. Recently, Ref. [39] identified bivalves from 41 bivalve species, which consisted of 46% of species recorded earlier in [40] for the Amvrakikos Gulf. These species are distributed in the shallow depth zone (0–20 m) [41], covering about 20% of the gulf surface. Bivalve fauna of this zone induces dead shell accumulations in the northern coastal line of the Amvrakikos Gulf. There is no way to compare the changes because there is no prior reference on the region's bivalve quantitative composition. Mussel mortality might be explained by the rising temperature above 26 °C during the summer [14] in combination with the air exposure of the animals at low tides [42].

The above checklist and relative abundance do not include species living on hard rock substrates (e.g., *L. lithophaga*), whereas, in the soft sub-surface zone, thirteen species/taxa of bivalves were recorded, with *C. glaucum* and *R. decussatus* being the most commercially

important. Dead shells need further examination by taphonomy methods to identify the causes of massive mortality. The analysis of growth rings also determines the climatic and environmental conditions that prevailed in the Amvrakikos Gulf. In this context, interviews revealed the spatial difference in the fishing behavior observed between western and eastern parts of the Amvrakikos Gulf. In the western areas (i.e., the city of Preveza), bivalve harvesting has a more traditional character compared to other areas, where this activity was fragmentarily conducted. This could be explained by the potential availability of adequate fishing grounds with substrate suitable for the growth of benthic bivalve. However, the bivalve fishing grounds have to be further investigated in Amvrakikos Gulf.

Health safety issues are the main reason for the absence of bivalve fishing within the lagoons because the exploitation within these systems requires consistent monitoring of the water quality and hygienic controls similar to that implemented in coastal areas and bivalve culture farms. Bivalve harvesting should be limited to sanitary zones, which must be demarcated and monitored weekly for water quality, microbial load, and biotoxins in order to be certified before dispatching [43,44]. According to the EU legislation, the harvesting of wild or farming bivalves must be conducted only from certified approved zones designated for the exploitation of bivalve resources by the veterinary authorities. In Amvrakikos Gulf, this zonation is limited to areas near 14 licensed mussel farm sites [45], and has not yet been determined whether the bivalve fisheries' standards will remain at a pro-EU legislative status in the entire area. This is one of the current issues which have a restrictive effect because the monitoring of the zones is unsustainable and makes sense only during the catch period. Bivalve fishing is a difficult task for fishers because existing hygienic safety standards exhibited high costs and complicated handling procedures [46]. The latter includes sampling for continuous water and bivalve quality monitoring, veterinary health inspections and documentation for each batch, and packing at a dispatch center prior to distribution [11,47].

Existing legislation is both inadequate to protect stocks and therefore poorly implemented, illegal fishing/trade of bivalves is taking place within the gulf. Fragmented and complex fisheries legislation in force also make the accuracy and validity of the monitoring very difficult. Fishers also stated that illegal fishing from recreational fishers, with catches usually ranging between 5 and 10 kg/day, was one of the major problems that professionals faced. This issue was amplified since the Greek economic crisis (from 2009 onwards) [48]. According to the official fisheries' infringement data derived from the coastguard authorities of Preveza from 1999 to 2013 [49], illegal bivalve fishery represents 5.9% and 9.0% of the total number of infringements and penalties imposed in the gulf, respectively, most of which (80%) were attributed to illegal fishing gear used, whereas only 10% was attributed to illegal fishing of endangered species, and the rest were related to illegal fishing in a protected area and fishing of undersized specimens.

5. Conclusions

In conclusion, such historical data and traditional ecological knowledge of local communities are particularly important in the absence of conventional datasets, especially for less-studied species, to promote conservation measures and to enhance legislation and policy. Results highlight the need to integrate up-to-date scientific knowledge with the experience of professional experts who have long-term multi-species knowledge of changing fisheries. Our study enhances the use of multi-disciplinary methodologies that can contribute as a valuable complementary tool supporting future research in detecting major changes in the biodiversity due to human impacts, especially in cases that funding is limited. Professional fishers and competent authority staff are not fully aware and thoroughly knowledgeable of the complicated relevant legislation that regulates the bivalve fishery. They also lack training in species identification, which may result in widespread misreporting of landings. Thus, a close collaboration with professionals is required for securing the dissemination of accurate information.

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Appendix A

Table A1. Bivalve species identified in the Amvrakikos Gulf.

Species	Common Name	Local Name
Arca noae (L., 1758)	Noah's ark	"Kalognomi"
Cerastoderma glaucum (Poiret, 1789)	Olive green cockle	"Kokori" or general "achivada"
Chamelea gallina (L., 1758)	Striped venus clam	"Chavaro" or "Pseudokidono"
Mimachlamys varia (L., 1758) and *Flexopecten glaber* (L., 1758)	Variegated scallop and smooth scallop	"Kaposanta" or "Chteni"
Lithophaga lithophaga (L., 1758)	European date mussel	"Spitonixia" or "Petrosolinas"
Mytilus galloprovincialis (Lamarck, 1819)	Mediterranean mussel	"Mydi"
Ostrea edulis (L., 1758)	Edible oyster	"Stridi"
Pinna nobilis (L., 1758)	Noble pen shell	"Pinna"
Pholas dactylus (L., 1758)	Common piddock	"Pholas"
Solen marginatus (Pulteney, 1799)	Grooved razor clam	"Solinas"
Ruditapes decussatus (L., 1758)	Grooved carpet shell	"Achivada"

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