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A Comparison of Traditional and Locally Novel Fishing Gear for the Exploitation of the Invasive Atlantic Blue Crab in the Eastern Adriatic Sea

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Abstract: The Atlantic Blue Crab *Callinectes sapidus* has been recognized as invasive in the Mediterranean Sea, where it now provides a significant contribution to artisanal fisheries. In this study, we compared the efficiency, selectivity, and productivity of American wire crab traps and traditional fyke nets for the capture of Blue Crabs in a study conducted from June to December 2019 in the Parila Lagoon (River Neretva Estuary, Croatia). A total of 7707 specimens were caught in 15 wire traps, comprising 6959 males and 749 females. The total catch using 50 traditional fyke traps was 1451 crabs, of which 1211 were males and 240 were females. In general, wire crab traps showed a higher capture selectivity and economic performance compared to fyke nets. The catch per unit effort (CPUE) was 102.76 kg for the American wire crab trap and 5.96 kg for the traditional fyke net. The CPUE of gravid female Blue Crabs was lower for the wire traps than the fyke nets. Herein, the utility of crab traps as selective fishing gear for the capture of Blue Crabs, and management tools for control of the reproductive and recruitment phases of the crab, are discussed, with the perspective of future exploitation of the species as a commercially valuable shellfish product in the Mediterranean.

Keywords: Atlantic Blue crab; traditional fyke nets; American wire crab traps; small-scale fisheries; Croatia

1. Introduction

The Atlantic Blue Crab (*Callinectes sapidus* Rathbun, 1896; hereafter Blue Crab) is a portunid brachyuran native to the Western Atlantic Ocean from Nova Scotia to Uruguay and Argentina [1]. In Europe, the Blue Crab appeared in the Eastern Atlantic Ocean in 1901 [2], probably introduced by ballast waters [3]. In the Mediterranean Sea, the species was recorded in 1947, but may have arrived as early as the 1930s in the Aegean Sea [3]. Subsequently, the Blue Crab has greatly expanded in the north-western sectors of the Mediterranean and in the Adriatic Sea [4–6].

In native areas, the Blue Crab supports important fisheries, representing a commercially valuable shellfish product [7–9]. The total catch along the western Atlantic coasts in 2016 was 97,896 metric tons (FAO statistics, http://www.fao.org/fishery/species/2632/en; accessed on 20 May 2021); in the same year, in the United States landings were 74,171 metric tons for an asset value of USD 234.8 million [10]. In invaded Mediterranean countries, the economic interest in the Blue Crab has progressively increased during the past decade. For example, annual landings of the species in Turkey fluctuated from 17 to 77 metric tons in

2008 and 2009 and from 0.6 to 10.5 metric tons between 2015 and 2018 (Turkey Statistical Institute http://www.tuik.gov.tr/PreTablo.do?alt_id=1005, accessed on 4 April 2020). In northern Greece, 50–80 metric tons per year were landed between 2010 and 2011 [11], and since 2016 the Spanish Ministry of Fishery has included the Blue Crab in the list of commercial fish species (VV.AA. 2016; BOE-A-2016-3357).

Crab wire traps (patented by Lewis in 1938; n. US2731761A) represent the standard fishing gear adopted for the commercial capture of Blue Crabs in their native range, although trotlines are still used in recreational fisheries [12,13]. Conversely, in Mediterranean waters, the species is currently caught using different traditional professional gear, including trawls, fyke nets, gillnets, and traps [14,15]. A study was performed in the Beymelek Lagoon (Turkey), in which Blue Crab catch composition, mean weight, and size-frequency distribution were compared among ellipsoid traps, collapsible box-type traps, and hoop nets [16]. In general, besides the aforementioned exception, investigations have mainly focused on evaluation of alternative designs and characteristics of crab traps (e.g., mesh size effects on size selectivity) [17], and no comparative information is available on the capture efficiency of different fishing gear in Mediterranean waters.

The goal of the present study was to compare the performance of American wire traps and traditional fyke nets for the capture of Blue Crabs in the Parila lagoon (Croatia). The lagoon is located in the Neretva River Estuary, where the first occurrence of the crab in Croatia was recorded in 2004 [18]. Subsequently, its establishment in the area has been repeatedly confirmed [19,20], together with a general expansion of the species along the whole Eastern Adriatic coast [21]. In 2010, the total fishery capture in the Parila lagoon and adjacent waters was cumulatively estimated at 30 tons per year and was dominated by finfish species, significantly contributing to the local economy [22]. More updated estimations are currently unavailable, also because fishers presently operating in the lagoon use different artisanal gear (e.g., gillnets, eel and fish traps, and angling), often not officially assigned by their fishery licenses. However, the Blue Crab has become a predominant component of by-catch in recent years, stimulating an increasing interest of local traditional stakeholders as a new shellfish product (B. Glamuzina, University of Dubrovnik, pers. comm.), and providing an unprecedented opportunity for the development of efficient and ecologically sustainable exploitation strategies [23,24]. The aim of this study was to perform a quantitative survey in order to compare gear efficiency, gear selectivity, and the CPUE of each of the two types of fishing gear, and evaluate their capacity to produce an income for the small-scale fishermen of the region by comparing the value of the landings from each type of gear minus their cost of use. In addition, special emphasis was placed on evaluating the CPUE of gravid females for each type of gear, as an indicator of gear efficiency. In this manner, we may propose the most efficient gear to be used within an effective population control management plan targeting the minimization of the reproduction of the species by removing gravid females from the population before spawning.

2. Materials and Methods

2.1. Terminology

Gear efficiency is the probability of catching a particular fish within the area affected by a given type of fishing gear during a single operation [25]. Gear selectivity in the context of this study is defined as the proportion of crabs caught by each fishing gear type [26,27]. Finally, gear productivity is the CPUE of each type of gear for Blue Crabs (in units, kg/gear/day).

2.2. Study Area

The study was performed in Parila Lagoon located within the Neretva River estuary in Croatia (Figure 1). Complete details on the area are provided elsewhere [20,28,29]. In brief, the lagoon is located northward of the main river mouth (Figure 1); the basin is a shallow (1.5 m maximum depth) water body characterized by muddy and sandy bottoms with extended stands of seagrass *Cymodocea nodosa* with a surface area and a perimeter of approximately 2 km^2 and 6 km, respectively. Both water temperature and salinity are characterized by strong seasonal variations, ranging between 7.2 °C and 33.4 °C, and from 11.4 to 34.6 Practical Salinity Units (PSU) in winter and summer months, respectively [30]. The dominant fish species in the area are grey mullet species (mainly the thinlip grey mullet *Chelon ramada*), the sand smelt *Atherina boyeri*, the European eel *Anguilla anguilla*), the grass goby *Zosterisessor ophiocephalus*, and the gilthead sea bream *Sparus aurata*. In addition, the major by-catch species are the Mediterranean green crab *Carcinus aestuarii* and, during the past decade, the Blue Crab [29–31].

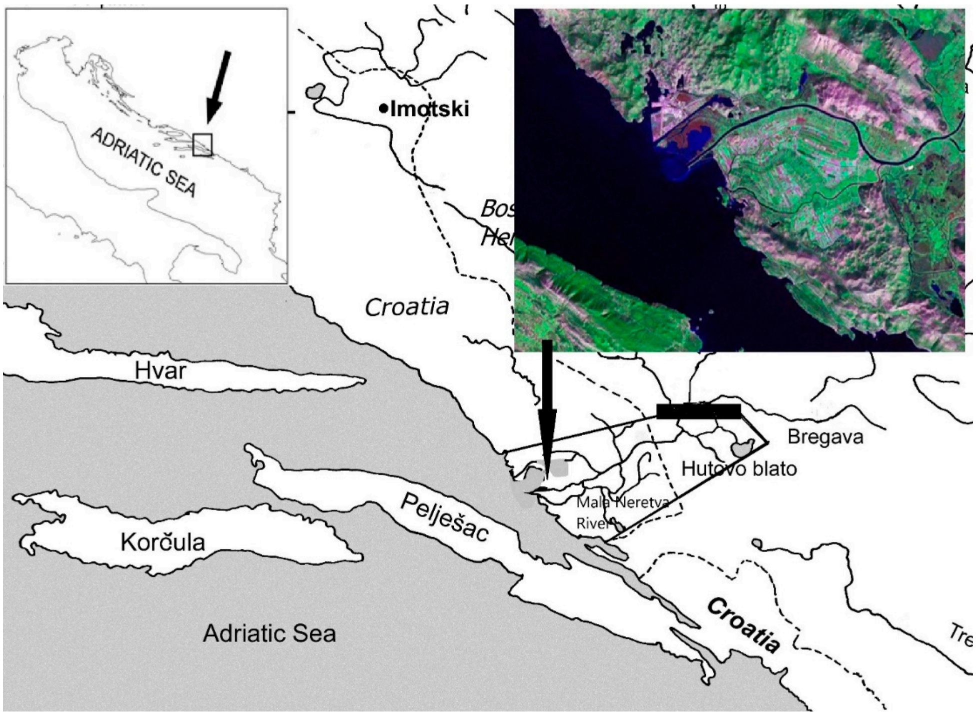

Figure 1. River Neretva Estuary (Eastern Adriatic, Croatia) with Parila lagoon (arrow) where the study was conducted.

2.3. Sampling Procedures

Sampling operations were conducted using two types of fishing gear. The first was represented by wire crab traps of American/Louisiana design [7] and locally adapted in Croatia by Mr. Stanko Glamuzina, a retired oyster fisher from Louisiana, USA, of Croatian origin (Figure 2a). The gear was characterized by a rectangular shape and was 0.6 m long, 0.6 m wide, and 0.4 m deep, and had a mesh size of 40 mm, two entrances, and a compartment for bait storage (Figure 2b). The second type of fishing gear used in the study was fyke nets, which are traditionally used to capture European eel. A fyke net is a fish trap and consists of cylindrical or cone-shaped netting bags mounted on rings or other rigid structures. It has wings or leaders that guide the fish towards the entrance of the bags. The fyke nets used in this study were fixed on the bottom by stakes. The fyke nets had a 6 mm mesh size and consisted of several net chambers, that conveyed the fish towards the terminal, closed cod end of the device (Figure 2c,d). Wire crab traps were baited using discards of non-commercial or low-value fish species such as *Chelon ramada*, but the gibel carp *Carassius gibelio* and the pumpkinseed *Lepomis gibbosus* were also used. No bait was used in fyke nets. A total of 15 wire crab traps and 50 traditional fyke nets were deployed in the lagoon on 1 June 2019, when the Blue Crabs appeared in the lagoon and were recorded by visual census and fisher's information. All pieces of gear were placed at a minimal distance of 100 m from each other, ensuring that the nearest device was a different type. Both types of fishing gear were sampled three times per week (Monday, Wednesday, and Friday) after deployment; consequently, an identical procedure was adopted until 30 December 2019, for a total of 84 samples per device.

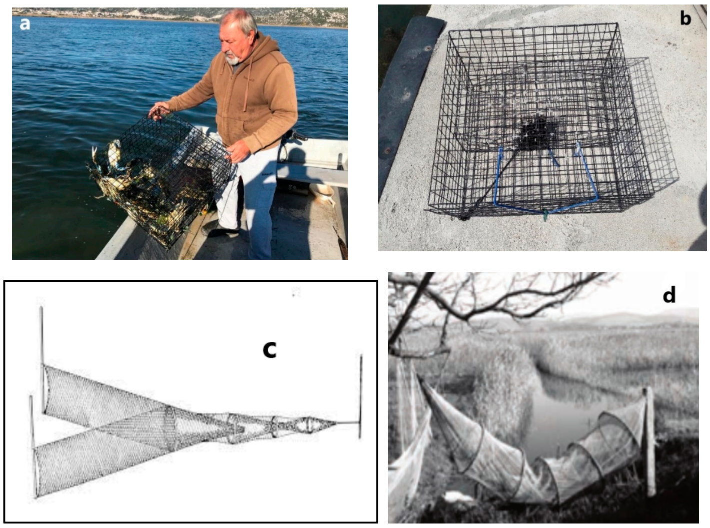

Figure 2. Mr. Stanko Glamuzina, retired oyster fisher from Louisiana, USA (**a**), and sampling gear: (**b**) American wire crab trap/and (**c**,**d**) traditional eel fyke net (**a**–**d**: photos by Branko Glamuzina).

2.4. Gear Economic Valuation

The economic evaluation of each type of gear was based on the net profit produced (per wire trap or per fyke net) as gross profit minus fishing costs. The gross profit was estimated from the monetary value of the landings based on the local retail market price of Blue Crabs during the main crabbing season (June–December 2019). Fishing costs for both types of gear were estimated based on invoices for gasoline, raw materials for gear repair, cost of bait-fish, and labor. For all currency exchange between Croatian Kuna (HRK) and US Dollars, the ratio of 1 USD = 6.75 HRK was used (in international prices, during the crabbing period between June and December 2019, 1 USD ranged between 6.67 and 6.84 Croatian Kuna).

2.5. Data Analysis

Landings were collected 3 times per week. CPUE was estimated on a monthly basis by adding the landing data collected during the month (in terms of number of individuals and weight). All landed Blue Crabs were weighed (using a digital balance to the nearest 1 g) and sexed. In general, to compare 2 different types of gear (or more) based on their CPUE performance, the prevailing model-based analytical methods assume either a Poisson model or a negative binomial model for each pair of gear sets [25,32].

Accordingly, in this study a comparison between the gear efficiency of the two types of gear was performed based on a Poisson distribution between the probabilities of having a catching event (percentage of days per month during which Blue Crabs appeared in the wire traps or fyke nets) and CPUE expressed as the number of crabs caught per wire trap or fyke net per month. The Poisson distribution was selected with the assumption that the crab population in the target area was randomly distributed because both the area and depth of the study site are uniform, indicating that Blue Crab population likely exhibits a non-random, aggregated pattern of distribution in Parila lagoon [25]. The Poisson model formula used was:

$$\text{Poisson}\ (\mathrm{N_i}|\lambda) = \frac{\lambda^{\mathrm{N_i}}}{\mathrm{N_i}!}e^{-\lambda} \quad (1)$$

where λ is the catching events (average days of Blue Crab appearance in the traps) per month, and N_i is the number of individual Blue Crabs caught per wire trap or fyke net.

Both Poisson models were run with the λ variable taking values between the numbers of days per month during which there were catching events for both type of gear ($5 < \lambda < 24$).

Monthly average CPUE data per gear were used to examine differences in gear efficiencies based on Principal Components Analysis using the CPUE values of the crabbing season only because, for the remainder of the year, the landings were 0. ANOVA and the one-tailed paired *t*-test were used to examine differences between means, such as the monthly CPUE data, the percentage of females, and the percentage of gravid females in the wire traps and fyke nets [33]. The monthly CPUE values (time-series) between the 2 types of gear were correlated using the Cross Correlation Function in SPSS [34].

3. Results

3.1. Fishing Gear Capture Performance

The number of productive days (number of days within month reporting crabs captured in fishing gear, n) and the probability of a capture event (n/total month days, %) showed that wire traps were characterized by a performance that was comparable with that of the static fyke nets (11.71 ± 6.11 days and 15.0 ± 6.56 days within a month that crabs appear in the traps, respectively), although qualitatively they show a 10% lower catchability (in terms of probability of a capture event; 38.26 ± 21.28% and 49.01 ± 23.71% of the days during one month). Comparison of the models using the Cross Correlation Function method showed that they were statistically identical because the overlap of the standard deviations shows that both types of gear have a similar capture efficiency for Blue Crab.

3.2. Catch Structure and CPUE

The results of an explorative PCA analysis showed that the CPUE of the two types of gear performed differently. In particular, fyke nets showed consistency in CPUE throughout the fishing period, whereas the CPUE of the wire traps changed significantly on a monthly basis. The catching season started in June and lasted until the end of the 2019. A total of 1541.4 kg, representing 7707 specimens, was captured in the 15 wire traps; 6959 were males and 749 females (Figure 3). Among the 749 females caught in total, 67 gravid females were recorded (9%). These were captured mainly in June (35) and July (26) and, to a minor extent, in August (6). Noticeably, the wire trap showed an extreme selectivity, because no other native crabs or fish species were captured. The average individual wet weight of Blue Crabs captured in wire traps was 200 g (±54.48 SD). However, these values fluctuated during the catch season, with minimum and maximum captures in July (301 specimens of total catch) and October (2256 specimens of total catch), respectively.

The total Blue Crab catch during the June-December period of 2019 using 50 traditional eel fyke nets was 298.2 kg, comprising 1490 Blue Crab specimens: 0 in June, 35 in July, 236 in August, 206 in September, 202 in October, 472 in November, and 339 in December. On average, the individual wet weight of Blue Crabs was 200.1 g (±89.58 SD). The average Blue Crab number in a single fyke net during a six-month capture period was 29.8 specimens and, at a two-day inspection interval, 0.25 Blue Crabs per fyke net.

In total, 246 females were caught and 43 gravid females were recorded (16.54% of total catch); and they were captured exclusively in June and July (14 and 29, respectively). The females represented 9.72% of Blue Crab captured in the wire crab traps and 16.54% in the fyke nets, with a sex ratio female:male of 0.11 and 0.2, respectively. The gravid females represented 0.87% of the total catch in wire crab traps and 2.88% in traditional fyke nets. The differences in percentage capture of total and gravid females between the two types of gear were statistically significant (t-test $t = -6.7$, d.f. 2; $p = 0.02$), and for female numbers caught and for gravid female numbers caught (t-test $= -18.8$, d.f. 2; $p = 0.00 \leq 0.01$), indicating a higher efficiency of fyke nets compared to wire traps as regards the capture of females, whether gravid or not.

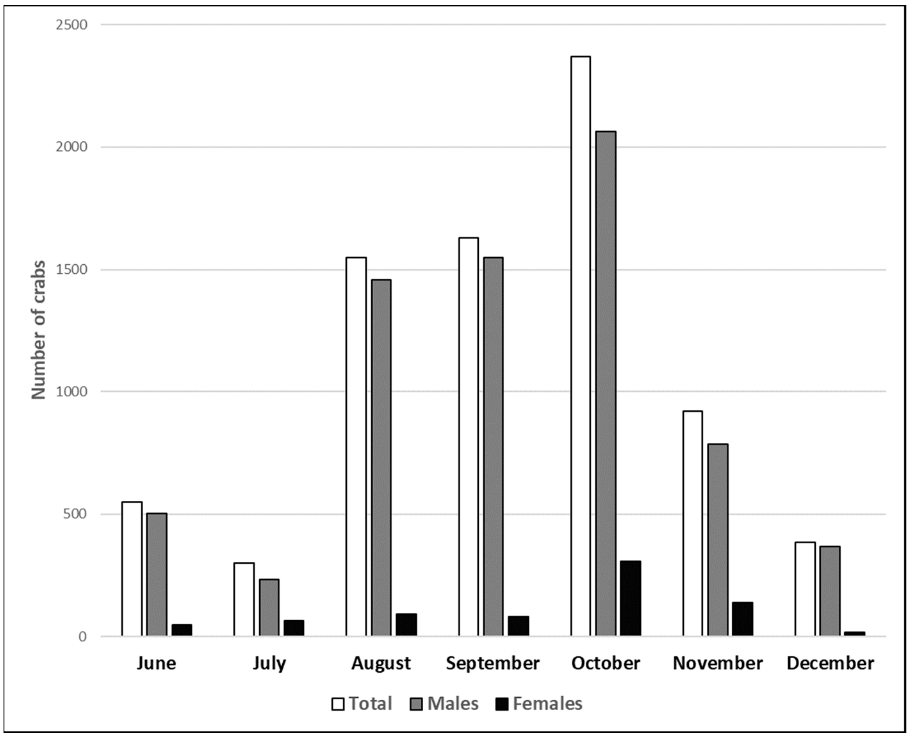

Figure 3. Monthly capture (total number, total males, and total females) of Blue Crab *Callinectes sapidus* in 15 wire crab traps in the Parila lagoon (Eastern Adriatic, Croatia) during June-December crabbing season.

The results from the landings for both types of gear showed that they exhibit statistically different catchability in terms of attracting and catching crabs during the crab fishing season in the lagoon. A qualitative evaluation of the patterns indicated that landings showed a limited similarity during the start and the end of the fishing season, when the crabs enter or leave the lagoon to migrate towards the sea or back (July and December respectively). The CPUE for the wire traps was highest in October (150.4 crabs per single trap) and lowest in July (20.1 crabs per single trap) (Figure 4). This follows the pattern of the start of lagoon heating in July and the increase in freshwater flows in the lagoon with a decrease in temperature and salinity after October, and subsequent Blue Crab migration in and out of the lagoon to marine waters.

3.3. Economics and Viability

During 2019, a Blue Crab market was developed locally by the restaurants in major tourist locations for live, cooked, and extracted meat. The fixed price for one whole live crab individual was 5 HRK and ≈USD 0.75. The average price per kilo was set at 20 HRK (≈USD 3.00). Based on the landings data of this study, the gross income for a traditional fisher for Blue Crab with a fyke net was USD 1117.50 for the crabbing season (July–December), whereas income from the wire traps was USD 4392.99.

Fishing costs were estimated by accumulating the expenses for fuel, servicing and maintenance of both traps, and the bait used for the American wire traps. Fuel consumption related to visiting the locations of the traps and collecting crabs is the same for both types of gear because Parila lagoon has a very small area (an average route within the lagoons does not exceed 2 km in any direction and most vessels originate from the port of Ploče nearby, which is around 4 km to the north of the Parila lagoon). Based on information received from fishers (in person), the cost was estimated at 2680 HRK (USD 400) for the crabbing period in 2019 (June–December).

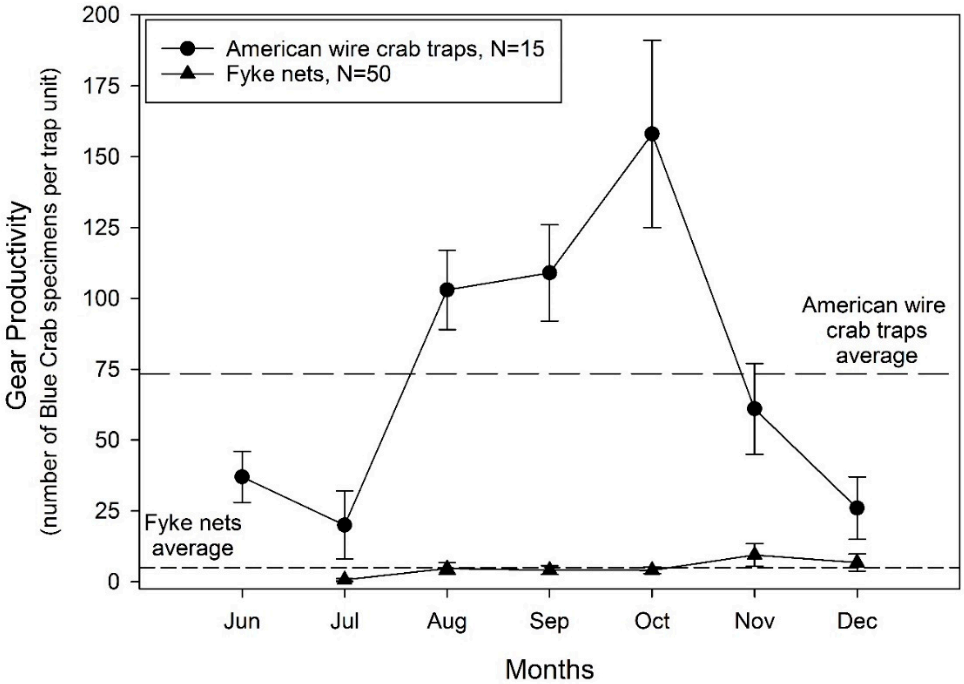

Figure 4. Comparison of the average monthly capture rate (number of specimens per trap) of Blue Crab *Callinectes sapidus* in the wire crab traps and traditional fyke nets from the Parila lagoon (Eastern Adriatic, Croatia) during the period June–December 2019. The black circles are average monthly numbers of Blue Crab per wire trap (n = 15) and the black triangles are average monthly numbers of Blue Crab per fyke net (n = 50). The vertical bars represent standard deviations.

Due to their robust construction, wire traps were not damaged by Blue Crabs. Conversely, crabs damaged and tore the fyke nets so that periodic retrieval and repair procedures were needed on a weekly basis. According to the fishermen, this cost (including materials and labor) was estimated at 130 HRK per week (USD 20) and for the whole crabbing season of 2019, this cost was estimated at 3216.00 HRK (USD 480).

The cost of bait was related only to wire traps. Each wire trap required 200 g of discarded fish and, in total for 15 traps, the bait requirement was 3 kg every two days. Bait was renewed in wire traps every two days; therefore, the total amount of fish discards for the 2019 crabbing season was estimated at 319.5 kg. Bait was composed of specimens of thinlip grey mullet having an average cost of 16.75 HRK/kg (2.5 USD/kg) and specimens of other species with no commercial value. In terms of bait cost, only the value of thinlip grey mullet was considered (at 2.5 USD/kg) because other species of baitfish/non-commercial fish were provided free. In addition, the cost of bait handling and transportation was estimated at 10 HRK/kg (1.5 USD/kg). We estimated that the cumulative cost of bait in the 2019 season for the fifteen wire traps was 4020.00 HRK (USD 600) or 268.00 HRK (USD 40) per trap.

The comparison of the economic performance of both types of gear showed that they exhibit different operational costs for the whole season, i.e., 5896.00 HRK (USD 880) for the fyke nets, and 6700 HRK (USD 1000) for the wire crab. The final net income from the Blue Crab fishery (see details in Table 1) was estimated for a fyke net fisher at −201.87 HRK (USD −30.13), whereas for a wire crab fisher it was 22,733.03 HRK (USD 3392.99).

Table 1. Results on the fishery, economic, and financial performance of American wire traps and fyke nets in Parila lagoon during the crabbing season from July to December 2019 (currency exchange rate: 1 USD = 6.7 HRK; June–December 2019).

Indicator	Wire Traps	Fyke Nets	Wire Traps	Fyke Nets
	(Prices in USD)		(Prices in Croatian Kuna)	
Number of devices used	15	50		
Total Catch, kg	1541.4	298.2		
CPUE, kg/device	102.76	5.96		
Average retail price, $/kg	≈USD 3	≈USD 3	HRK 20	HRK 20
INCOME				
Gross Total Income	USD 4392.99	USD 849.87	HRK 29,433.03	HRK 5694.13
Gross Income per trap	USD 292.87	USD 17.00	HRK 1962.20	HRK 113.88
COSTS				
Fuel	USD 400.00	USD 400.00	HRK 2680.00	HRK 2680.00
Repairs	USD 0.00	USD 480.00	HRK 0	HRK 3216.00
Bait	USD 600.00	USD 0	HRK 4020.00	HRK 0.00
Total	USD 1000.00	USD 880.00	HRK 6700.00	HRK 5896.00
Average	USD 66.67	USD 17.60	HRK 446.67	HRK 117.92
Balance, Total	USD 3392.99	USD (−30.13)	HRK 22,733.03	HRK (−201.87)
Balance, Total per single device	USD 226.20	USD (−0.60)	HRK 1515.54	HRK (−4.04)

4. Discussion

The results of this study indicate that wire traps have a high potential in supporting the establishment and development of a Blue Crab fishery in the Neretva Estuary area and the Mediterranean Sea, showing remarkable selectivity and capture efficiency, coupled with their relatively low maintenance and labor costs, and higher capability of generating economic income. Wire traps showed (i) a higher selectivity, because native invertebrate and fish species were only captured in fyke nets and (ii) a higher capture efficiency, with crab catches being approximately 17-fold those determined for fyke nets. By comparison, Blue Crabs captured in fyke nets showed a female:male ratio twice that determined in wire traps. Furthermore, a higher percentage of gravid specimens was observed among females in the fyke nets (Table 2).

The effectiveness of wire traps has been widely demonstrated in native US habitats. After their development in Louisiana and Texas in 1948, in the Gulf of Mexico and the Atlantic Coast, Blue Crab fisheries gradually evolved from a trotline to a trotline-drop net to a trap-dominated fishery [35–37]. However, in the case of the Neretva Estuary, the extreme selectivity of traps may negate a complete substitution of traditional fishing gear by the local community of fishers, because it may eliminate catches of other species of economic interest, such as the European eel. Contemporaneous use of the two types of gear, conversely, may maximize the catch of Blue Crabs and decrease the probability of capturing the species in fyke nets. In turn, this may simultaneously decrease the probability of damage to the nets and to other captured fish species, because Blue Crabs can consume and impact the quality of marketable fish captured in the same fishing type of gear [23].

Noticeably, the results of a similar comparative investigation performed in Turkey reported higher Blue Crab catches for traditional hoop nets (similar in shape and mesh size (1 cm or less) to fyke-nets used in this study, but larger) compared to collapsible box-type traps [16]. However, the wire traps used in the present study were baited by fish discards, thus being far more attractive to crabs, particularly under conditions of limited resource availability. This highlights the importance of bait for the Blue Crab fishery and the need to use it even when traditional fishery gear is used.

Table 2. A summary of the technical and fishery characteristics of the two types of gear.

	Fyke Net	Wire Trap
Material	Nylon/cotton net	Metal wire
Dimensions	Wings—1.5 m each Body—2 m	0.6 m long, 0.6 m wide, 0.4 m deep
Mesh size	6 mm	40 mm
Method of catching crabs	Crabs actively enter fyke net attracted by live fish inside	Crabs actively enter trap to get at bait
Selectivity	Blue Crab, Grass goby, European eel, Leaping grey mullet, other fish	Only Blue Crab
Size selectivity	All sizes of crab	Crabs > 75 mm carapace width
Sex selectivity	16.54% females	9.72% females
CPUE crab numbers	29.8	513.8
CPUE crab kg	5.96	102.76

Regarding the profit and loss analysis performed in this study, it is obvious that the wire traps are significantly more profitable than the fyke nets. The large difference in the profitability is based on the manner in which each type of gear interacts with the Blue Crabs, with the wire traps positively attracting the crabs using baitfish. Better management of the fyke nets in terms of positioning them in the Parila lagoon along the known Blue Crab movement corridors may eventually result in a small increase in capture, thus enabling the break-even point (production levels where costs = profits) for the fyke nets to be overcome. If the total production is able to increase to 309 kg rather than the figure of 298.2 kg (an increase by 3.26%) recorded for the 2019 crabbing season, the overall balance would be 0.0 HRK. Similarly, the break-even point for American wire traps for the same period was estimated to be 350.88 kg. Another management recommendation would be the simultaneous use of wire traps and fyke nets so that the cost of using both types of gear would be optimized, because the wire traps exhibit an operational cost of 446.67 HRK per trap (USD 66.67), whereas the fyke nets exhibit a cost of 117.92 HRK per trap (USD 17.60). Finally, it can be also advised that a minor redesign of the fyke net and the use of baitfish located in the last compartment may increase its performance. This can be the subject of further research in the use of Blue Crab fishing technology in the area.

One last aspect for discussion is the lower female: male ratio observed in wire traps and the relatively lower occurrence of gravid females. The Blue Crab in Mediterranean and Adriatic Seas represents an invader with negative impacts on local ecosystems [4,20]; the commercial exploitation of populations may represent a virtuous, cost-effective approach to control their abundance and minimize impacts on local native communities [23]. Once fertilized, Blue Crab females leave brackish habitats and move to the open sea for spawning [12]. Accordingly, an effective control strategy may be to implement use of multiple types of fishing gear to maximize capture efficiency for the whole population (i.e., wire traps) and for females (i.e., fyke nets).

This strategy would be consistent with recent recommendations for the development of a market-based approach to the management of marine invasive species, such as invasive Lionfish *Pterois volitans* in Belize, where fishing offers a cost-effective means to control the invasion and improve food security in rural fishing communities [38]. Another example is the newly developed lucrative Red King Crab *Paralithodes camtschaticus* fishery in Norway. In the Arctic Ocean, the species is managed as a sustainable fishery, whereas in the North Sea, where it is considered an invasive species, fishers are paid to reduce their abundance in order to preserve native species [39]. In 2004, the Norwegian government established the Red King Crab fishery management in two different zones. In one zone, harvesting is accessible to anyone, both commercial and non-commercial entities. In the second zone, only commercial fisheries can operate within a quota-regulated fishery. The objective of this management regime is two-fold: to limit the westward expansion of the Red King Crab via the free harvesting zone, where all crabs, including males and females of all sizes, are landed; and to establish viable, long-term harvests in the quota-regulated area [39]. Market and financial success in this mixed management approach, accompanied by good conservation measures and protection of native ecosystems, should also be suitable in the control of Mediterranean marine invasions.

In conclusion, the results of the present study showed that new gear and the development of the sustainable Blue Crab fishery may transform invasive Blue Crab populations in the Mediterranean from a threat to biodiversity and native ecosystems, to an opportunity as a new valuable fishery resource with real market value and demand. Increasing the artisanal harvest may also contribute to the efficient control of Blue Crab populations, by reducing ecosystem damage and lowering governmental costs associated with potential eradication.

Author Contributions: Conceptualization, B.G. and G.M.; methodology, A.C., and L.G.; formal analysis, L.G.; investigation, L.G.; resources, L.G.; data curation, L.G. and A.C.; writing—original draft preparation, L.G.; writing—review and editing, A.C., G.M. and B.G.; funding acquisition, B.G. All authors have read and agreed to the published version of the manuscript.

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References

1. Kennedy, V.S.; Cronin, L.E. *The Blue Crab: Callinectes sapidus*; Maryland Sea Grant College: College Park, MD, USA, 2007.
2. Bouvier, E.L. Sur un *Callinectes sapidus* M. Rathbun trouvé à Rocheford. *Bull. Mus. d'Hist. Nat. Paris* **1901**, *7*, 16–17.
3. Nehring, S. Invasion History and Success of the American Blue Crab *Callinectes sapidus* in European and Adjacent Waters. In *The Wrong Place—Alien Marine Crustaceans: Distribution, Biology and Impacts*; Galil, B.S., Clark, P.F., Carlton, J.T., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp. 607–624.
4. Mancinelli, G.; Chainho, P.; Cilenti, L.; Falco, S.; Kapiris, K.; Katselis, G.; Ribeiro, F. The Atlantic blue crab *Callinectes sapidus* in southern European coastal waters: Distribution, impact and prospective invasion management strategies. *Mar. Pollut. Bull.* **2017**, *119*, 5–11. [CrossRef]
5. Mancinelli, G.; Bardelli, R.; Zenetos, A. A global occurrence database of the Atlantic blue crab *Callinectes sapidus*. *Sci. Data* **2021**, *8*, 111. [CrossRef]
6. Cerri, J.; Chiesa, S.; Bolognini, L.; Mancinelli, G.; Grati, F.; Dragičević, B.; Dulčic, J.; Azzurro, E. Using online questionnaires to assess marine bio-invasions: A demonstration with recreational fishers and the Atlantic blue crab *Callinectes sapidus* (Rathbun, 1986) along three Mediterranean countries. *Mar. Pollut. Bull.* **2020**, *156*, 111209. [CrossRef]
7. Guillory, V.; Prejean, P. Blue crab, *Callinectes sapidus*, trap selectivity studies: Mesh size. *Mar. Fish. Rev.* **1997**, *59*, 29–31.
8. Mendonça, J.T.; Verani, J.R.; Nordi, N. Evaluation and management of blue crab *Callinectes sapidus* (Rathbun, 1896) (Decapoda-Portunidae) fishery in the Estuary of Cananéia, Iguape and Ilha Comprida, São Paulo, Brazil. *Braz. J. Biol.* **2010**, *70*, 37–45. [CrossRef]
9. Huang, P.; Woodward, R.T.; Wilberg, M.J.; Tomberlin, D. Management evaluation for the Chesapeake Bay blue crab fishery: An integrated bioeconomic approach. *N. Am. J. Fish. Manag.* **2015**, *35*, 216–228. [CrossRef]
10. National Marine Fisheries Service 2017. Fisheries of the United States, 2016. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2016. Available online: https://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus16/index (accessed on 14 September 2021).

11. Kevrekidis, K.; Antoniadou, C.; Avramoglou, K.; Efstathiadis, J.; Chintiroglou, C. Population structure of the blue crab *Callinectes sapidus* in Thermaikos Gulf (Methoni Bay). In Proceedings of the 15th Pan-Hellenic Congress of Ichthyologists, Thessaloniki, Greece, 10–13 October 2013; pp. 113–116.
12. Millikin, M.R.; Williams, A.B. Synopsis of biological data on blue crab, *Callinectes sapidus* Rathbun. In *NOAA Technical Report NMFS, 1*; FAO Fisheries Synopsis: Rome, Italy, 1984; Volume 138, p. 38.
13. Ashford, J.R.; Jones, C.M.; Fegley, L. Independent estimates of catch by private and public access fishers avoid between-group sources of error in a recreational fishing survey. *Trans. Am. Fish. Soc.* **2013**, *142*, 422–429. [CrossRef]
14. Carrozzo, L.; Potenza, L.; Carlino, P.; Costantini, M.L.; Rossi, L.; Mancinelli, G. Seasonal abundance and trophic position of the Atlantic blue crab *Callinectes sapidus* Rathbun 1896 in a Mediterranean coastal habitat. *Rend. Lincei-Sci. Fis.* **2014**, *25*, 201–208. [CrossRef]
15. Gökçe, G.; Saygu, I.; Eryaşar, A.R. Catch composition of trawl fisheries in Mersin Bay with emphasis on catch biodiversity. *Turk. J. Zool.* **2016**, *40*, 522–533. [CrossRef]
16. Atar, H.; Ölmez, M.; Beckan, S.; Seçer, S. Comparison of three different traps for catching blue crab (*Callinectes sapidus* Rathbun 1896) in Beymelek Lagoon. *Trans. J. Vet. Anim. Sci.* **2002**, *26*, 1145–1150.
17. Özdemir, S.; Gökçe, G.; Çekiç, M. Determination of size selectivity of traps for blue crab (*Callinectes sapidus* Rathbun, 1896) in the Mediterranean Sea. *Tarım Bilim. Derg.* **2015**, *21*, 256–261. [CrossRef]
18. Onofri, V.; Dulčić, J.; Conides, A.; Matić-Skoko, S.; Glamuzina, B. The occurrence of the blue crab, *Callinectes sapidus* Rathbun, 1896 (Decapoda, Brachyura, Portunidae) in the eastern Adriatic (*Croatian coast*). *Crustaceana* **2008**, *81*, 403–409.
19. Dulčić, J.; Tutman, P.; Matić-Skoko, S.; Glamuzina, B. Six years from first record to population establishment: The case of the blue crab, *Callinectes sapidus* Rathbun, 1896 (Brachyura, Portunidae) in the Neretva river delta (South-Eastern Adriatic Sea, Croatia). *Crustaceana* **2011**, *84*, 1211–1220.
20. Mancinelli, G.; Glamuzina, B.; Petrić, M.; Carrozzo, L.; Glamuzina, L.; Zotti, M.; Raho, D.; Vizzini, S. The trophic position of the Atlantic blue crab *Callinectes sapidus* Rathbun 1896 in the food web of Parila Lagoon (South Eastern Adriatic, Croatia): A first assessment using stable isotopes. *Mediterr. Mar. Sci.* **2016**, *17*, 634–643. [CrossRef]
21. Župan, I.; Karaga, A.; Šarić, T.; Kanski, D. Blue Crab *Callinectes sapidus* Rathbun, 1896 continues invasion: First case of entering into freshwater ecosystem in the Mediterranean (Nature Park Vransko Lake, Adriatic Sea). *Cah. Biol. Mar.* **2016**, *57*, 81–84.
22. Glamuzina, B. Neretva Fishery- history and perspectives. In *Proceedings: Fish and Fishery of River Neretva*; Glamuzina, B., Dulčić, J., Eds.; University of Dubrovnik and Dubrovnik-Neretva County: Dubrovnik, Croatia, 2010; pp. 20–30. (In Croatian)
23. Mancinelli, G.; Chainho, P.; Cilenti, L.; Falco, S.; Kapiris, K.; Katselis, G.; Ribeiro, F. On the Atlantic blue crab (*Callinectes sapidus* Rathbun 1896) in southern European coastal waters: Time to turn a threat into a resource? *Fish. Res.* **2017**, *194*, 1–8. [CrossRef]
24. Glamuzina, B.; Tutman, P.; Glamuzina, L.; Vidović, Z.; Simonović, P.; Vilizzi, L. Quantifying current and future risks of invasiveness of non-native aquatic species in highly urbanised estuarine ecosystems—A case study of the River Neretva Estuary (Eastern Adriatic Sea: Croatia and Bosnia–Herzegovina). *Fish. Manag. Ecol.* **2021**, *28*, 138–146. [CrossRef]
25. Zhou, S.; Klaer, N.L.; Daley, R.M.; Zhu, Z.; Fuller, M.; Smith-Anthony, D.M. Modelling multiple fishing gear efficiencies and abundance for aggregated populations using fishery or survey data. *ICES J. Mar. Sci.* **2014**, *71*, 2436–2447. [CrossRef]
26. McClanahan, T.R.; Cinner, J.E. A framework for adaptive gear and ecosystem-based management in the artisanal coral reef fishery of Papua New Guinea. *Aquat. Conserv.* **2008**, *18*, 493–507. [CrossRef]
27. Humphries, A.T.; Gorospe, K.D.; Carvalho, P.G.; Yulianto, I.; Kartawijaya, T.; Campbell, S.J. Catch composition and selectivity of fishing gears in a multi-species Indonesian coral reef fishery. *Front. Mar. Sci.* **2019**, *6*, 378. [CrossRef]
28. Glamuzina, L.; Conides, A.; Prusina, I.; Ćukteraš, M.; Klaoudatos, D.; Zacharaki, P.; Glamuzina, B. Population structure, growth, mortality and fecundity of *Palaemon adspersus* (Rathke 1837; Decapoda: Palaemonidae) in the Parila Lagoon (Croatia, SE Adriatic Sea) with notes on the population management. *Turk. J. Fish. Aqua. Sci.* **2014**, *14*, 677–687.
29. Glamuzina, L.; Conides, A.; Mancinelli, G.; Dobroslavić, T.; Bartulović, V.; Matić Skoko, S.; Glamuzina, B. Population dynamics and reproduction of the Mediterranean green crab in the Parila lagoon (Neretva Estuary, Adriatic Sea) as fishery management tools. *Mar. Coast. Fish.* **2017**, *9*, 260–270. [CrossRef]
30. Prusina, I.; Dobroslavić, T.; Glamuzina, L.; Conides, A.; Bogner, D.; Matijević, S.; Glamuzina, B. Links between epibenthic community patterns and habitat characteristics in the Parila lagoon (Croatia). *J. Coast. Conserv.* **2017**, *21*, 813–828. [CrossRef]
31. Glamuzina, B.; Bartulović, V.; Glamuzina, L.; Dobroslavić, T. Records of new fish species in the River Neretva estuary: Potential threat to coastal Adriatic nursery. *Nase More* **2017**, *64*, 86–89. [CrossRef]
32. Miller, T.J. A comparison of hierarchical models for relative catch efficiency based on paired-gear data for US Northwest Atlantic fish stocks. *Can. J. Fish. Aquat. Sci.* **2013**, *70*, 1306–1316. [CrossRef]
33. Jolliffe, I.T.; Cadima, J. Principal component analysis: A review and recent developments. *Philos. Trans. R. Soc. A* **2016**, *374*, 20150202. [CrossRef] [PubMed]
34. Derrick, T.R.; Thomas, J.M. Time-Series Analysis: The cross-correlation function. In *Innovative Analyses of Human Movement*; Stergiou, N., Ed.; Chapter 7; Human Kinetics Publishers: Champaign, IL, USA, 2004; pp. 189–205.
35. Guillory, V.; Perry, H.; Steele, P.; Wagner, T.; Hammerschmidt, P.; Heath, S.; Moss, C. The Gulf of Mexico Blue crab fishery: Historical trends, status, management, and recommendations. *J. Shellfish Res.* **1998**, *17*, 395–403.
36. Hammerschmidt, P.; Wagner, T.; Lewis, G. Status and trends in the Texas blue crab (*Callinectes sapidus*) fishery. *J. Shellfish Res.* **1998**, *17*, 405–412.

37. Sharov, A.F.; Vølstad, J.H.; Davis, G.R.; Davis, B.K.; Lipcius, R.N.; Montane, M.M. Abundance and exploitation rate of the blue crab (*Callinectes sapidus*) in Chesapeake Bay. *Bull. Mar. Sci.* **2003**, *72*, 543–565.
38. Chapman, J.K.; Anderson, L.G.; Gough, C.L.A.; Harris, A.R. Working up an appetite for lionfish: A market-based approach to manage the invasion of *Pterois volitans* in Belize. *Mar. Policy* **2016**, *73*, 256–262. [CrossRef]
39. Lorentzen, G.; Voldnes, G.; Whitaker, R.D.; Kvalvik, I.; Vang, B.; Solstad, R.G.; Thomassen, M.R.; Siikavuopio, S.I. Current Status of the Red King Crab (*Paralithodes camtchaticus*) and Snow Crab (*Chionoecetes opilio*) Industries in Norway. *Rev. Fish. Sci. Aquac.* **2018**, *26*, 42–54. [CrossRef]