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Perspectives

Economic Effects of Fisheries Exclusion Zones: A Sicilian Case Study

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Abstract *Spatial approaches to fisheries management in the form of total or partial exclusion zones have attracted much interest in recent years, though relatively little is known in practice about how such measures impact fishermen or other groups of stakeholders. The present paper hopes to shed light on this issue by reporting the results of a recently completed EU project investigating the effects of a trawl ban introduced in the Gulf of Castellammare, NW Sicily, in 1990. The results indicate that the prohibition on trawling led to stock recovery and improved financial returns for the artisanal fishermen who have been permitted to operate within the restricted area. There is evidence, however, that the displacement of trawlers to the outer periphery of the exclusion zone has impacted adversely on artisanal operators located immediately outside the trawl ban area.*

Key words Exclusion zone, trawl ban, artisanal fishery, effort displacement.

JEL Classification Code Q22.

Introduction

Marine exclusion zones (MEZs) may serve a variety of functions, and are increasingly being used as a way of protecting vulnerable coastal habitats from the adverse

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effects of human activity. Their role in fisheries management has been extensively discussed in the literature, with a number of recent papers focussing on the bioeconomic implications of spatial relative to non-spatial approaches to management (Holland and Brazee 1996; Hannesson 1998; Conrad 1999; Sanchirico and Wilen 1999, 2001; Pezzey, Roberts, and Urdal 2000; Milon 2000; Li 2000; Armstrong and Reithe 2001). Much of the debate has centred around the supposed advantages of complete no-take marine reserves, but it must be remembered that zones where preferential access is allowed to certain types of vessel but not others have a long-established place in fisheries management. Such access arrangements are often justified on the grounds that they eliminate user conflict through the separation of incompatible gear types (*e.g.*, active and passive fishing methods), or because they help to maintain artisanal fishing communities that are dependent on a natural resource which is under threat from harvesting pressure. While this way of managing fisheries may be criticised for failing to tackle the open-access problem, with the added complaint that controls which discriminate against more powerful catching methods are just another form of 'regulated inefficiency,' there may be occasions when it represents the only politically acceptable way of regaining control of a fishery whose sustainability is jeopardised by overexploitation.

The present case study, based on a project funded by the European Union (EC 97/0063), provides an illustration of this type of 'partial' exclusion zone approach to fisheries management, namely one involving the areal separation of passive and active gear types. In 1990, the Gulf of Castellammare (NW Sicily, Mediterranean) was the location for a year-round trawling ban, the objective of which was to reduce fishing pressure on the severely depleted demersal resources of the Gulf while permitting small-scale artisanal operators to fish in safer conditions and enjoy the benefits of stock recovery. An earlier EU-funded study (MED 92/011) carried out by CNR-IRMA in 1993–95 demonstrated that the conservation objectives had been achieved, with demersal stocks having increased dramatically within the exclusion zone four years after the trawl ban was imposed. Specifically, the biomass estimated from experimental trawl surveys was estimated to have increased eight-fold between 1987-89 and 1994 (Pipitone *et al*. 1996, 2000). The latest project (EC 97/0063), carried out jointly by CNR-IRMA and CEMARE in 1998–99, aimed at updating the biological data, specifically to see whether demersal stock abundance had continued to increase and whether fish assemblage had changed (Pipitone, Badalamenti, D'Anna, Whitmarsh, James, and Pickering 2000). It was also undertaken, however, to establish how the trawl ban had impacted the artisanal fleet and, more generally, to identify the relationship between the biological condition of the resource and the financial performance of commercial operators. In this paper, we report some of the findings of this study, focussing in particular on the differential effects of the trawl ban on artisanal operators according to their location either within or on the periphery of the management area.

The Artisanal Fishery in the Gulf of Castellammare

The Gulf of Castellammare occupies approximately 400 km^2, with the exclusion zone extending over some 200 km^2 to a depth of about 500 metres in its central part (figure 1). During the survey period (1998–99), there were 147 vessels registered to fish from the four ports in the Gulf: Castellammare del Golfo, Balestrate, Trappeto, and Terrasini. Of the total 147 vessels, 96 were registered artisanal fishing boats, while the remainder consisted of trawlers, purse seiners, and unlicensed craft. The main gear types employed by the artisanal fleet are trammel nets and set gillnets, with occasional ad hoc use being made of bottom lining, FAD seining, and squid jig-

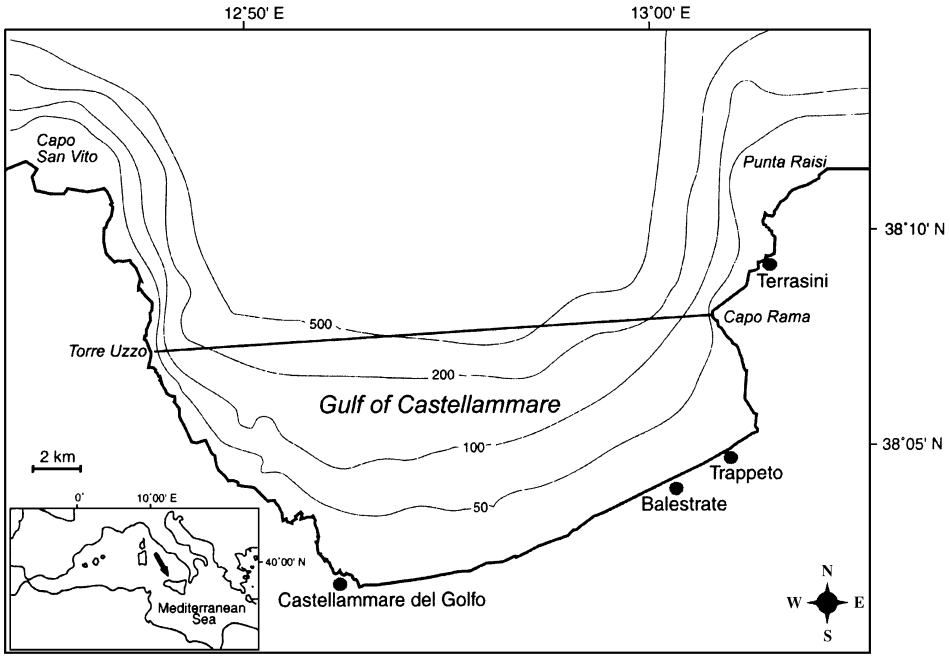

Figure 1. The Gulf of Castellammare, NW Sicily

ging. Artisanal fishing is a year-round activity, though fishermen commonly observe a voluntary tie-up of 45 days per year during the period from October to January. The number of artisanal fishing vessels in the Gulf operating on a fully commercial basis has shown no evidence of expansion since the trawl ban was introduced, in contrast to recreational and angling boats whose numbers have increased rapidly in recent years. Most of the trawlers are based at the port of Terrasini in the NE corner of Gulf, and while their activity is now concentrated outside the exclusion zone, it is common knowledge that a certain amount of illegal trawling takes place inside the prohibited area, notably in the eastern sector.

The majority of fish are sold commercially, though some of the very low-value species are retained for home consumption. In common with other Mediterranean fisheries, a very wide variety of species make up the catch, some of the more important being: red mullet (*Mullus barbatus*), picarel (*Spicara flexuosa*), sea breams (*Diplodus sargus*, *D. vulgaris*, and *Pagellus spp*.), hake (*Merluccius merluccius*), amberjack (*Seriola dumerili*), and dolphinfish (*Coryphaena hippurus*). The fish find their way to the consumer via a somewhat complicated distribution channel; the highest-value species command individual prices, while the low-value species are typically sold as a 'mixed bag.'

There are no quotas limiting the quantity of fish that can be landed, but a number of institutional arrangements are in place that influence the conduct of artisanal fishing operations. For fishing to be undertaken as a professional enterprise, the fisherman and his boat must be registered as such. Once registered, the fisherman is then able to catch and sell fish for a living. The vessel must be registered as a professional fishing boat before fish can be sold from it, and in fact, most of the restrictions on fishing apply to the vessel rather than to the fisherman. There is no licence

fee as such, but certain costs are likely to be incurred in relation to the number of registered crew per vessel. The fishing licence specifies what gear may be carried and used as well as the maximum distance from the shore that an artisanal vessel may operate (currently three miles). Though the law makes provision for the suspension of new licence issues, the practice of recent years has effectively been to grant licences *ad lib* to eligible applicants. Of the various financial instruments, arguably the most influential have been the 'biological rest payments' made each year between 1987 and 1997 which accompanied the 45 days per year cessation of fishing. Though this had been discontinued by the time the present survey commenced, the annual tie-up was still apparently being practiced by the majority of artisanal fishermen — evidence, perhaps, of the strength of informal rules and conventions within the fishing community concerning the management of the natural resource.

Data Used in the Economic Assessment

The collection of primary economic data on the artisanal fisheries of the Gulf involved the cooperation of fishermen, fish traders, and equipment suppliers. With respect to fishermen, three major survey instruments were employed during 1998–99:

(*i*) A *landings survey* designed to obtain information on the operating performance of fishermen.
(*ii*) A *fishing characteristics survey* aimed at identifying gear use, fishing patterns, and markets.
(*iii*) A *motivations survey* intended to elicit fishermen's attitudes and opinions, particularly with respect to the trawl ban.

The assessment of commercial landings consisted of two main elements, commencing with a preliminary survey carried out in 1998 aimed at developing a complete picture of the structure and composition of the fishing fleet in the Gulf. Vessel registers at the Port Authorities of Castellammare del Golfo and Terrasini were consulted, and these records were validated by field trips to the four main fishing harbors. The second element of the landings survey involved the fortnightly collection of catch data from the artisanal fishermen at these ports on a census basis from July 1998 to June 1999. The data included the weight of each species fished and the effort employed in their capture, the effort measure being defined in terms of net length and trip duration. The landings survey was also the main source of costs and earnings data. While the procedure for generating this information broadly followed custom and practice used elsewhere (Davidse *et al*. 1993; Pascoe, Robinson, and Coglan 1997; European Commission 1998; Whitmarsh *et al*. 2000), the methodology used in our study had two distinctive features. Firstly, the collection of data on a 'real-time' basis at fortnightly intervals over a 12-month period contrasted with the approach more commonly used in cost and earnings studies involving the one-off return of annual financial data at a specified point in time. The advantage of the approach used here, we would contend, was that it permitted the monitoring of fleet activity and performance throughout the year, as well as enabling us to generate aggregate data once the survey was completed. Secondly, fishermen's gross revenue was calculated indirectly by using the physical weight of fish caught and then imputing a value obtained by asking traders the prices they were offering the catchers. In this way, the reluctance of fishermen to divulge information about their income was side-stepped. These costs and earnings data were corroborated by interviews with the two accountants representing fishermen in the area.

Data collected primarily for the biological component of the project were also

used in the economic assessment as part of our aim of identifying a link between the state of the demersal stocks and the performance of the artisanal fishery. Four seasonal experimental trawl surveys were carried out between June 1998 and March 1999 on the trawlable areas of the continental shelf using a stratified random sampling design based on depth strata. The non-trawlable areas were assessed using 12 trammel-gillnet surveys at three locations within the infra-littoral zone of the Gulf from June 1998 to May 1999 in order to examine the state of shallow water resources. Comparative data from trammel-gillnet surveys carried out in earlier years were also used. While the surveys aimed to monitor both fish assemblage and stock abundance, it was the latter information that was of most relevance to the economic assessment. The important indicator for our purposes is catch per unit of effort (CPUE), which in the trawl surveys was measured as weight per haul and in the trammel-gillnet surveys as weight per standard net per trip. For us, the main interest is to see whether the CPUE data would enable any inferences to be drawn regarding the impact of the trawl ban on vessel operating performance.

Analysis and Results

Profitability of the Artisanal Fishery

Data on the costs and earnings of the artisanal operators in the Gulf provided the basis for assessing current profitability and also for seeing how financial performance would change if operating conditions were to deviate from the 1998–99 baseline levels. Fishermen cooperated well with the landings survey, and the costs and earnings results represented just under 50% of the total number of registered artisanal vessels. Here we report the results for trammel netting, the most widely used method in the artisanal fishery.

Net financial profit (boat income) in 1998–99 averaged 8.7 million lira (4,493 Euros) per vessel, though as figure 2 shows, there were large inter-vessel variations in performance. Just over 15% of operators incurred losses, while some 9% earned profits in excess of 25 million lira (12,911 Euros). To investigate whether it would be financially worthwhile to invest in the fishery, a capital budgeting model was constructed based on the returns expected from a representative one-crewman trammel netter. Data were derived from the landings survey and also from information regarding the purchase and replacement of capital items (boat, gear, and equipment) supplied by manufacturers. Using a 20-year planning horizon produced an internal rate of return (IRR) of 30%, substantially in excess of the opportunity cost of capital (6–12%), which fishermen might realistically incur for such a venture. This is an important result because it suggests that, if the operating conditions that existed during the survey year were to be maintained into the foreseeable future, it would be rational to invest in the fishery rather than in the next best alternative use of funds. As such, the artisanal fishery has the potential to be economically sustainable, since the capital necessary for its long-term continuation would be expected to earn a competitive return. The assumption of unchanged operating conditions would, of course, no longer be satisfied if the trawling ban were to be relaxed. It might also be argued that the prospects for investment might be similarly jeopardised if, even with the trawl ban still in place, profits attracted significantly more artisanal vessels into the area. Whether this happens, and how rapidly, clearly depends on the strength of both the formal and informal barriers to entry into the artisanal fishery. However, the fact that over the previous decade there has not been a conspicuous increase in the number of artisanal operators, despite the favourable conditions induced by the trawl ban, seems to suggest that such entry barriers are non-trivial.

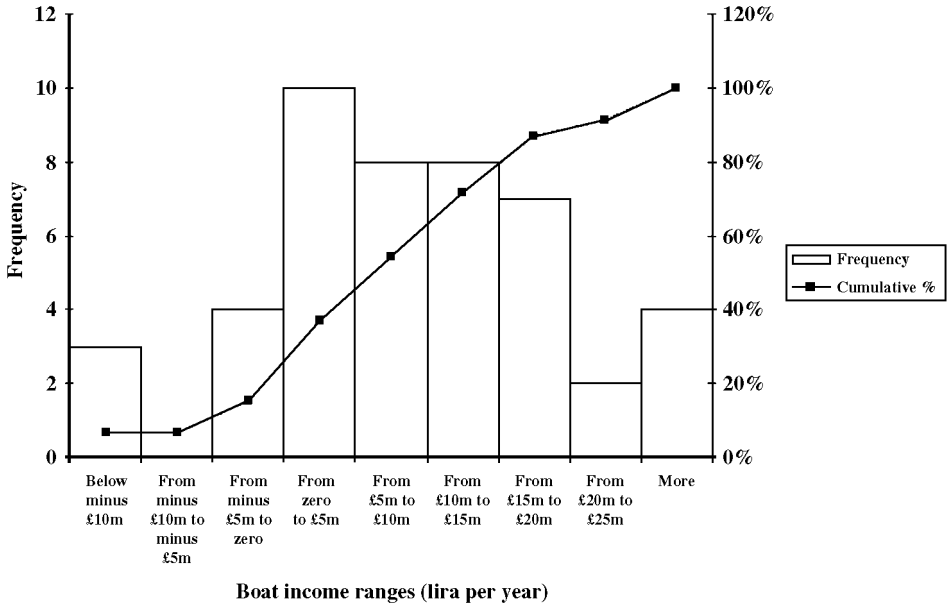

Figure 2. Profitability of Artisanal Fisheries in the Gulf of Castellammare, 1998–99

Implications of Variation in Catch Rates

We were also concerned to see by how much financial performance would change if vessel catch rates deviated from their baseline levels. Though catch rates are only one of the factors affecting profitability, they are an important policy variable and an indicator of the success of fisheries management in maintaining fish stocks. Table 1 compares the actual 1998–99 financial results with those which would have been obtained if catch rates had been 25% higher or lower. The simulated results are derived from a simple financial model of the revenue and cost structure of vessels, the key assumptions of which are:

(*i*) For boats which employ extra crew, labor costs are based on an agreed share of net revenue (total revenue minus running costs) and that in the short run, this share rate remains constant.
(*ii*) Running costs vary directly with the vessel utilisation rate (*i.e.*, days fishing per year).
(*iii*) Supplies from this one fishery represent only a small part of the total market; therefore, prices will be unaffected by localised variations in catch rates.

Accordingly, the profit function may be written as:

Profit = total sales revenue
minus running costs
minus labor costs
minus fixed costs

Table 1
Profitability of Artisanal Vessels in the Gulf of Castellammare
Under Alternative Assumptions Regarding Catch Rates

	Distribution of Vessels According to Income Range		
Boat Income	Actual Results for 1998–99	Results Assuming a 25% Fall in Catch Rates	Results Assuming a 25% Rise in Catch Rates
Below minus 10 m. lira	3	3	3
From minus 10 m. to minus 5 m. lira	0	1	0
From minus 5 m. lira to zero	4	7	1
From zero to 5 m. lira	10	11	7
From 5 m. to 10 m. lira	8	13	6
From 10 m. to 15 m. lira	8	6	9
From 15 m. to 20 m. lira	7	3	6
From 20 m. to 25 m. lira	2	2	8
More than 25 m. lira	4	0	6
Average boat income	8.71 m. lira	4.20 m. lira	13.22 m. lira

Note: 'Boat income' is a measure of financial profit, which is defined as total sales revenue minus running costs, minus labour costs, minus fixed costs.

i.e.,

$$\Pi = pEK - cE - w\left[pEK - cE\right] - F$$

where:

Π = profit (lira per vessel per year)
p = price (lira per kg)
E = utilisation rate (days fishing per year)
K = vessel catch rate (kg per day fishing)
c = average running cost (lira per day fishing)
w = crew share rate (percent)
F = vessel fixed costs (lira per boat per year)

It is clear from table 1 that a change in vessel catch rates causes a major shift in the frequency distribution of profits. Starting at the 1998–99 operating levels, the results suggest that a 25% change in catch rates (K) would lead to approximately a 50% change in profits in the same direction. This highlights the sensitivity of financial performance to variations in fish stock abundance which, as the biological assessments of the Gulf have clearly demonstrated, is linked with the effectiveness of the trawl ban.

Effects of the Trawl Ban on Artisanal Fleet Performance

Since no detailed costs and earnings data of artisanal fishermen in the Gulf are available for the years prior to 1998–99, it has not been possible to give an explicit demonstration of any improvement in financial performance over the period of the trawl ban. The evidence for such an improvement can be inferred, however, from a comparison of the results of the trammel-gillnet survey undertaken in the most recent period with those of earlier years. These demonstrate a 77% increase between 1990 and 1999 in the abundance of shallow water species, which are the main target of the artisanal fishermen in the Gulf, and this increase can be expected to have positively affected catch rates and profits. It should also be added, however, that over this period the species composition changed, with most of the biomass increase being for varieties of fish classed as only 'moderately' commercial (Pipitone, Badalamenti, D'Anna, Whitmarsh, James, and Pickering 2000). What this means in effect is that the increase in the *economic* abundance of the stocks has been less pronounced than the increase in physical abundance, and as such, the gains to the artisanal fishermen, though positive, will have been partially attenuated.

To investigate further whether there was a connection between the trawl ban and the performance of the artisanal fleet, a comparison was made between vessels located at the three ports inside the exclusion zone (Castellemmare del Golfo, Balestrate, and Trappeto) and those located at the port immediately outside (Terrasini). Though artisanal vessels based outside the trawl ban area earned positive profits, on average, evidence that trawling may have adversely affected their productivity is revealed by the comparative catch data for trammel netters at the four ports derived from the landings survey (table 2). At Terrasini, standardised catch rates (weight of fish caught per 1,000 metres of net per trip) were between one-half and two-thirds of those achieved at the ports within the trawl ban area, indicative of the lower abundance of shallow water species on grounds where trawling remains unrestricted. Interviews with fishermen suggest that the incursion of trawlers forced an adaptation in their fishing behaviour. Of particular note is that, in contrast to the other three ports, artisanal fishermen at Terrasini travelled, on average, a greater distance (and spent correspondingly more time) to reach suitable fishing grounds in order to avoid conflict with displaced trawlers which, in recent years, have tended to concentrate on the periphery of the banned area. This avoidance tactic seems to have impacted on costs, since expenditure on fuel as a proportion of total expenses was higher at Terrasini than elsewhere (table 2). It is worth noting that artisanal vessels at Terrasini spent fewer days at sea per year, on average, than at the other ports, which again, based on interviews with fishermen, can be interpreted as a response to the congestion externalities (*i.e.*, a 'crowding out' effect) and stock externalities caused by the presence of trawlers.

The evidence of differential productivity is corroborated by results from the biological assessments carried out as part of the earlier EU project (MED 92/011) and the present one. Experimental trawl surveys undertaken at defined sampling locations within the Gulf enable us to compare stock abundance of demersal species inside and outside the exclusion zone. A summary of the data is given in table 3 from which it becomes clear that, in each of the four seasons in 1993–94 and 1998–99, stock abundance within the trawl ban area was higher than in the corresponding season outside the area. Though the experimental trawl surveys do not include all shallow water species and, as such, are not fully representative of the catch of the typical artisanal trammel netter, they nevertheless give a strong indication of the differential impact of the trawl ban on the fisheries resources of the Gulf. The abundance of demersal stocks within the exclusion zone has generally been maintained or increased throughout the period 1993–94 to 1998–99, despite the fact that illegal

Table 2
Operating Performance of Artisanal Vessels at Ports in the Gulf of Castellammare, 1998–99

Port	Physical Productivity		Fuel Costs as a Proportion of Total Expenses		Utilization Rate		Boat Income	
	Kg per 1000 Metres of Net per Trip		Percentage		Days Fishing p.a.		Million Lira	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Castellammare	10.255 (*n* = 241)	8.341	15.6 (*n* = 17)	9.3	229 (*n* = 17)	26.7	11.95 (n= 17)	7.60
Balestrate	9.212 (*n* = 89)	7.316	18.9 (*n* = 10)	13.1	213 (*n* = 10)	11.6	14.69 (n= 10)	13.34
Trappeto	7.578 (*n* = 72)	5.412	14.5 (*n* = 12)	9.3	179 (*n* = 12)	54.7	- 0.12 (n= 12)	12.72
Terrasini	5.128 (*n* = 51)	4.392	23.0 (*n* = 7)	10.6	169 (*n* = 7)	25.5	7.44 (n= 7)	5.23

Table 3
Comparative Stock Abundance Inside and Outside the Trawl Ban Area

	Inside			Outside		
Date	Mean CPUE (kg per 30 Minute Haul)	S.D.	Number of Valid Hauls	Mean CPUE (kg per 30 Minute Haul)	S.D.	Number of Valid Hauls
Autumn 1993	33.82	21.04	24	24.39	20.92	9
Winter 1994	45.16	31.42	20	29.88	23.62	11
Spring 1994	32.52	21.00	24	25.53	14.01	6
Summer 1994	34.33	19.31	19	23.16	16.62	11
Spring 1998	39.09	22.50	17	26.31	18.26	9
Summer 1998	54.93	33.77	22	37.40	28.71	4
Autumn 1998	59.74	31.63	19	35.00	15.45	7
Winter 1999	33.14	27.03	20	11.70	3.34	7

trawling is known to occur. There is no obvious sign that stocks in the unrestricted part of the Gulf have fallen between these dates, though it is interesting to note that in the most recent season (winter 1999) CPUE was down to 40% of what it had been five years previously. While a number of factors may have contributed to this, the evidence is consistent with claims made by fishermen of increased trawling effort and decreased catches on coastal grounds in the Eastern sector of the Gulf. When considering the period as a whole, however, evidence suggests that the trawl ban had a positive impact on demersal stocks. This is supported by the regression results given in the Appendix showing that the CPUE differential between the protected and unprotected zones was unlikely due to chance.

Concluding Remarks

The partial exclusion zone introduced into the Gulf of Castellammare in 1990 has undoubtedly benefited the artisanal fishermen who have been permitted to operate within the prohibited area. The evidence for this comes from two main sources. Firstly, there are the biological survey results, which have demonstrated a large increase in demersal biomass since the ban was imposed. While there are indications that species composition may have changed over the period, the higher overall stock abundance can be expected to translate into improved catch rates for artisanal vessels. The second main source of evidence is derived from the observed differences in the physical productivity of vessels according to their location, with artisanal operators based at ports inside the trawl ban area achieving higher catch rates than those outside. The finding is supported by the experimental trawl surveys demonstrating that CPUE is markedly higher on fishing grounds presently located inside the prohibited area. These empirical observations are consistent with the theoretical expectations of bioeconomic modelling studies of marine reserves, notably the model by Hannesson (1998) showing *inter alia* that stock density within a zone where fishing is restricted will be higher than in an adjacent area where fishing is uncontrolled. What our case study has also revealed, however, is that artisanal fishermen based outside the management area have not simply failed to capture the benefits of stock recovery, but seem to have become worse off as a consequence of increased activity by displaced trawlers.

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Appendix

To establish whether there was a statistically significant difference between CPUE inside and outside the trawl ban area, an ANOVA was carried out using data from the experimental trawl surveys undertaken in 1993–94 and 1998–99. For analytical purposes, the Gulf was divided into four radial sectors corresponding to the fishing zones of each harbor. The rationale for this design was that there was the expectation of a decreasing gradient of fish stock abundance from the core of the banned

area (*i.e.*, the westernmost sector, the port of Castellammare) to the unrestricted area (*i.e.*, the easternmost sector, the port of Terrasini). Data were also disaggregated into two bathymetric depth strata, 51–100 metres and 101–200 metres.

Initial results of a three-way ANOVA suggested no significant difference between the years, and the CPUE data were then pooled to detect any possible difference between the sectors and depth strata. This revealed that CPUE in the sectors adjacent to the three inner ports (Castellammare, Balestrate, and Trappeto) was significantly higher than CPUE in the outside sector (Terrasini), and also that CPUE in the 51–100 metre depth stratum was greater than in the 101–200 metre stratum. Further analysis was conducted within a multiple regression framework using binary (*i.e.*, dummy) variables to represent the different sectors and strata. These were defined as follows:

Variable	Value
CM	1 for Castellammare, 0 for all other ports
BA	1 for Balestrate, 0 for all other ports
TR	1 for Trappeto, 0 for all other ports
STRATUM	1 for depth stratum 51–100 metres, 0 for stratum 101–200 metres

This procedure, therefore, takes the reference category as CPUE in the deeper of the two depth strata within the sector corresponding to Terrasini (*i.e.*, outside the protected zone). The model then tests to see whether departures from this arbitrary reference point in respect of either fishing zone or depth stratum cause a significant shift in the constant term in the regression equation. To preserve the degrees of freedom we assume for simplicity that there is no interaction between the independent variables.

The results are presented in appendix table A. The model explains about one-third of the observed variations in CPUE, with the value of the Durbin-Watson statistic implying that there are no unusual patterns in the residuals. For our purposes, the important result is given in the t-statistics, which confirm that the three sectors inside the trawl ban area each have significantly higher CPUE than the sector immediately outside, and that the shallower of the two depth strata is more productive than the deeper area.

Appendix Table A

Results of a Multiple Regression Model to Test for the Effects of the Trawl Ban on CPUE

Variable	Regression Coefficient	t-statistic	Significance
Constant	14.38	2.12	0.04
CM	27.36	3.19	0.00
BA	20.85	2.43	0.02
TR	20.00	2.33	0.02
STRATUM	28.33	6.07	0.00

N = 64
R^2 = 0.36
Adjusted R^2 = 0.32
S.E.E. = 24.27
Durbin-Watson = 2.12
F = 8.304