Case Study

Economic valuation of ecosystem services in Bivalve shellfish aquaculture

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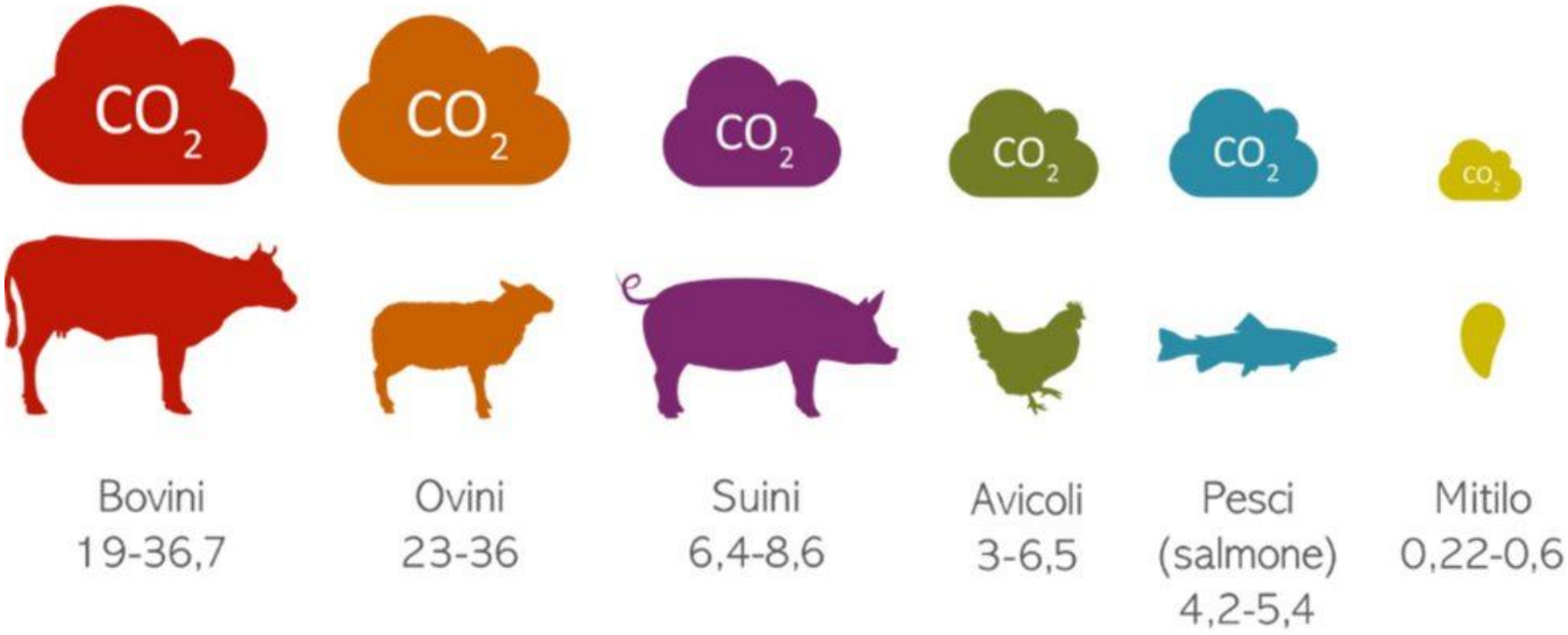
Ecosystem services provided by mussels

Ecosystem service	Function	Examples
Gas regulation	Regulation of the chemical composition of the atmosphere.	CO_2/O_2 balance
Environmental regulation	Biological processes regulation	Habitat's response to environmental variability; mussel shells increase the retention of fluorine and reduce the risk of environmental pollution due to excessive concentrations
Water regulation	Regulation of hydrogeological flows	Contribution to seawater filtration; there is no use of freshwater in the production or supply chain phases
Nutrient cycling	Reduction of organic matter, nutrients, chemicals, bacteria, and viruses	Regulation of carbon, nitrogen, and phosphorus
Life cycle maintenance	Habitat	Mussel farming promotes and enhances biodiversity by creating structures and habitats for other marine species
Food provision	High-quality animal protein production system	Promotion of a healthy diet
Recreation	Opportunities for recreational activities	Ecotourism
Genetic resources	Biological and raw materials	Fertilizers: Mussel shells are a byproduct rich in carbonate that can be used in wastewater treatment.

Ex. mussel benefits

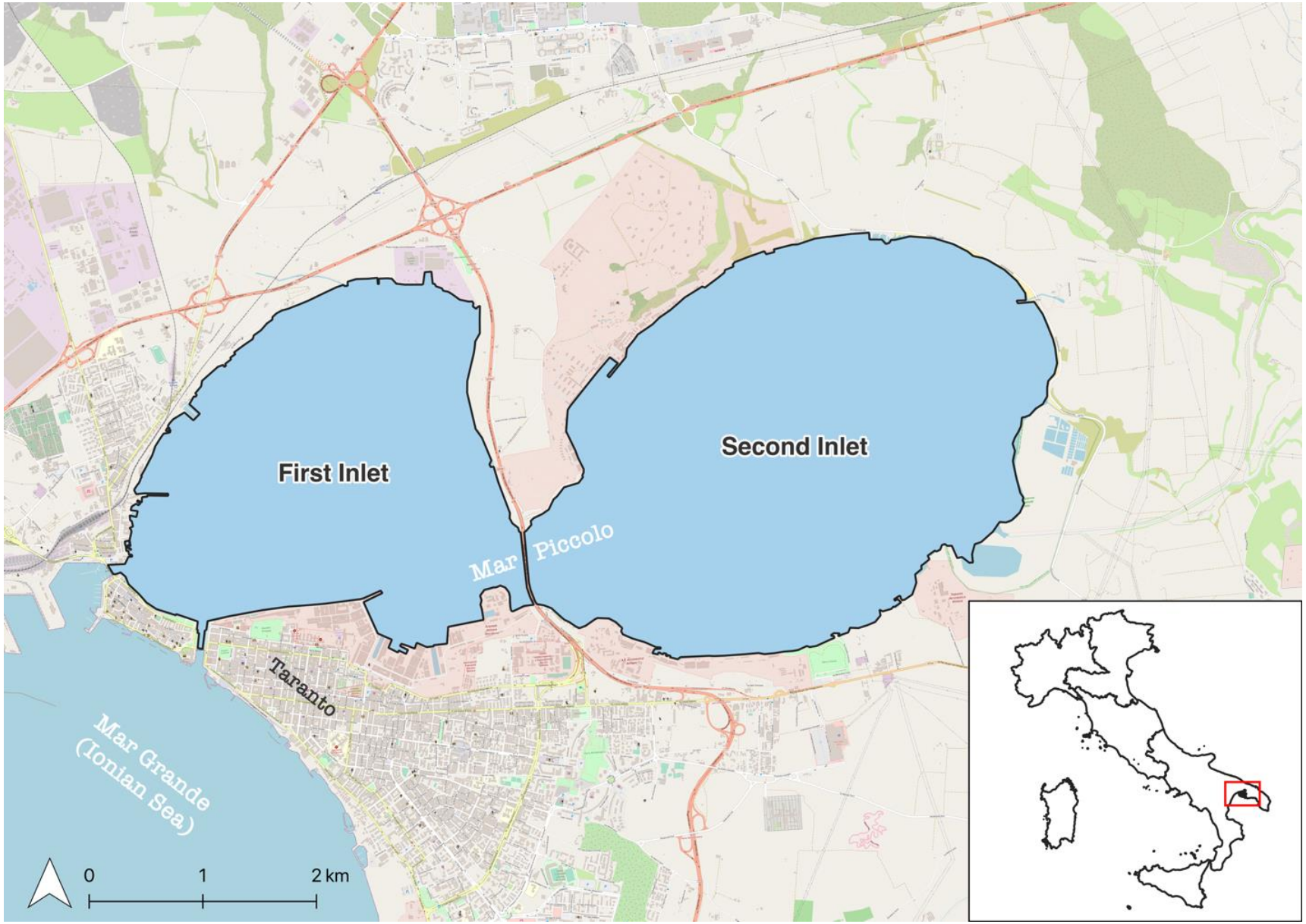
Mussels are linked to the *European Green Deal* and *Farm to Fork* strategies because they are **sources of protein with low carbon footprints,** and increased production would help to mitigate the effects of climate change and preserve biodiversity.



Mussel-provided ecosystem service, benefits for humans and economic evaluation

Ecosystem service class	Mussel-provided ecosystem service	Benefits for humans	Economic Evaluation
Regulating	Biofiltration	Water quality	*Market price; replacement cost; lower cost evaluation*
	Carbon sequestration	Climate change mitigation	*Market price; replacement cost; lower cost evaluation*
	Nitrogen and phosphorus reduction	Eutrophication reduction	*Market price; replacement cost; lower cost evaluation*
Supporting	Nutrient cycling and storage	Water quality	*Production function*
	Habitat/Habitat modification	Fish habitat	*Contingent valuation*
	Environmental monitoring	Water quality	*Production function; choice experiments*
	Food webs	Biodiversity	*Market price*
Provisioning	Feed for other species	Feed provisioning	*Market price*
	Food for humans	Food provisioning	*Market price*
	Product from mussels' shells	Pottery, art, fertilizer, purification	*Substitute cost*
Cultural	Cultural value	Historical and traditional value	*Travel cost; hedonic price*
	Existence value	Conservation value	*Contingent valuation; substitute cost*

Case study area: Taranto



Data collection

Average investment/plant value per linear meter (€/m)	**50**
Average boat and equipment value (€)	60.000
Number of boats per enterprise	2
Total area of adult mussel production installations (Iha)	141.518
Total linear meters of adult mussel production installations (II basin)	55.759
Number of enterprises	12
Linear meters per enterprise	4.646
Area per enterprise	117.932
Number of employees per enterprise	3
Number of working hours per day	8
Average number of days at sea	280
Yield per linear meter (Kg/m)	70
Average price per Kg (€)	0,8
Existing market forms	wholesalers

Ecosystem services provided by mussels in the Mar Piccolo of Taranto

Category	Ecosystem services	Technique
Provisioning	Food provisioning	Market prices
Regulating	Carbon sequestration	Market prices
	Phosphorus and nitrogen removal	Replacement cost
Cultural	Existence value	Contingent valuation

Economic data

Production area (m^2)	**1.415.184**
Production (t/anno)	3.902,64
Average capital value (€)	4.435.570,45
Revenues (€/anno)	3.122.112
Variable costs (€/anno)	415.240,90
Value added (€/anno)	2.706.871,10
Depreciation (€)	566.795
Salaries (estimated) (€)	967.680
Interests on capital (€)	177.422,82

Economic valuation of ecosystem services

1. Food provision

$$Food\ supply\ value\ \left(\frac{€}{year}\right) = Revenues - (variable\ costs\ + depreciation + wages + i \times capital)$$

The economic estimate of the ecosystem service related to food supply is 994,973.29 €/year.

The contribution of ecosystem to the food production = rent

Economic valuation of ecosystem services

2. Carbon sequestration

The carbon sequestered by mussels generates carbon credits which can be implemented within existing carbon credit programs (Van den Burg et al., 2022).

The reference carbon price considered is the European Union Allowance (EUA), the official carbon credit under the European Union Emission Trading Scheme (EU ETS)

The valuation was based on the mean of the daily EUA prices covering the period 01/01/2023–1/06/2023. = 90 €ton

$$Carbon\ \ sequestration\ value\ (€/year) = production\ \left(\frac{Kg}{year}\right) \times$$

$$net\ sequestration\ rate\ CO_2\left(0{,}08\ \frac{CO_2}{Kg}\right) \times\ \ average\ EUA\ price\ (€)$$

Rate 0,08 KCo2/Kg mussels according to Martini et al. 2022

The economic estimate of the value of this ecosystem service is €28,058.82/year.

Economic valuation of ecosystem services

3. Nitrogen and phosphorus reduction

An important marine ecosystem service provided by bivalve production is the regulation of water quality associated with filtration and nutrient extraction

Budget of N and P removed for a typical North Adriatic mussel farm over the life cycle(600 t/year production)
by Porrello et al 2018

Lyfe cicle	N (t)	P (t)
Input at seeding	0.8	0.07
Ingested	- 16	- 2
Removed by harvesting	- 3.3	- 0.3
Excreted	4.7	-
Released as faeces	7.8	1.7
Released as pseudofaeces	0.9	0.1

The amounts of nutrients fixed are found to be -33.2 t N and -2.8 t P.

Economic valuation of ecosystem services

Costs for the removal of one ton of nitrogen and phosphorus from wastewater (€/t)

Method	Removal cost N	Removal cost P
Coarse solids separation	979,94	990,09
Coarse and fine solids separation	843,31	891,52
Biological nitrogen removal	1.376,30	1.360,73
Extraction of nitrogen as mineral fertilizer	3.657,03	3.736,95

$$Replacement\ cost\ N, P_{method}(€) = Removal\ cost\ N, P_{method}\left(\frac{€}{t}\right) \times Quantity\ removed\ N, P_{mussels}\ (t)$$

Method	N (€ 2008)	P (€ 2008)
Coarse solids separation	32.506,96	2.769,18
Coarse and fine solids separation	27.974,76	2.493,48
Biological nitrogen removal	45.655,30	3.805,81
Extraction of nitrogen as mineral fertilizer	121.312,67	10.451,86
Mean	**56.862,42**	**4.880,08**

Economic valuation of ecosystem services

4. Existence/cultural value

Taranto is one of Italy's oldest traditional areas for mussel production. The production vocation is part of the local cultural system, so mussel farming provides ***cultural ecosystem services of existence and traditionality***.

Based on the findings of the focus groups, ***an online questionnaire*** consisting of 12 questions was developed, through a Likert scale of 1 to 10. The questionnaire was divided into three sections: (i) respondents' perceptions of the benefits provided by mussels; (ii) WTP question; and (iii) respondents' socio-economic profiles.

Willingness to Pay (WTP), which represents the maximum monetary amount an individual is willing to pay for a given benefit from ecosystem services, or for a change in their quantity/quality;

The bid amount was randomly assigned to each respondent within a vector of ten values ranging from €5 to €50

Economic valuation of ecosystem services

The data were analyzed in order to estimate the households' *WTP per year*.

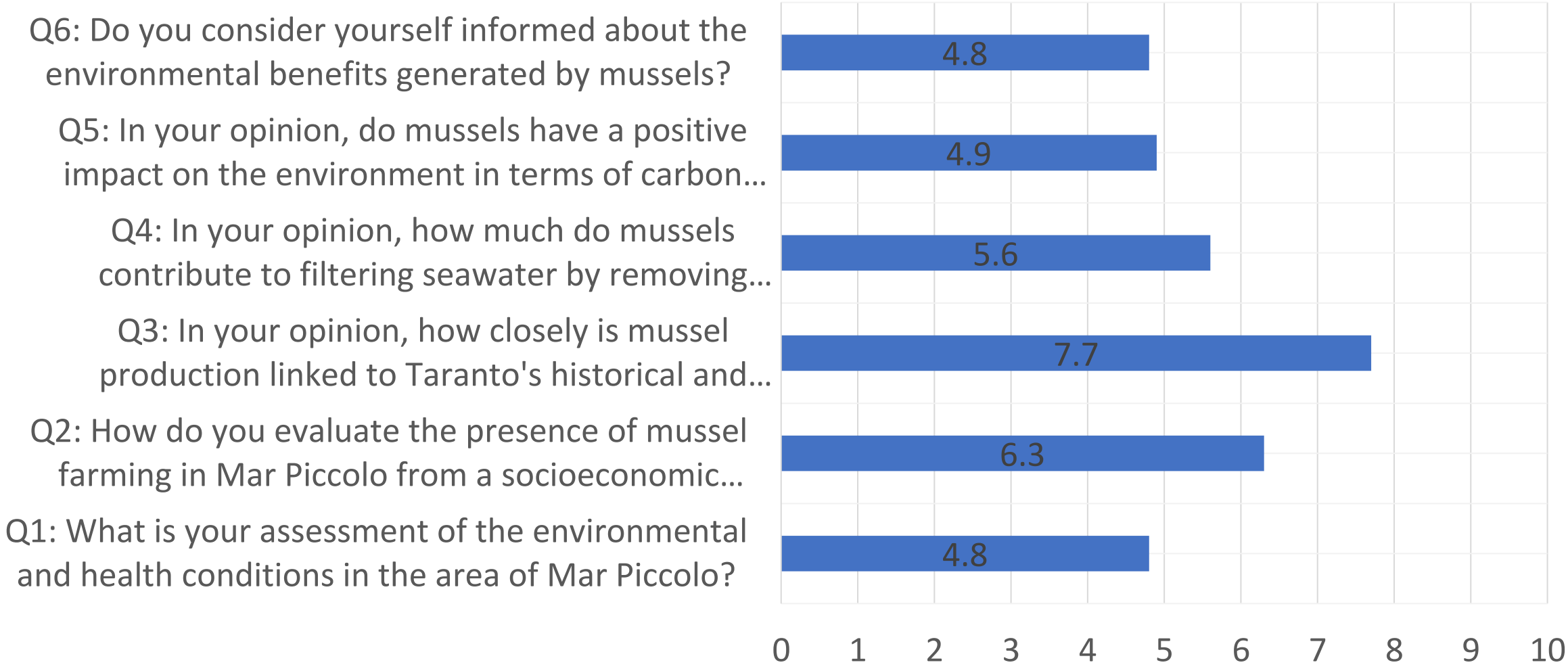
According to Hanemann (1984), the respondents' attitude toward choosing to pay the proposed bid can be described by an indirect random utility function

$$U_i = U(y_i; z_i) + \epsilon_i$$

where U_i is the utility level of the individual i, y_i is the respondent's income level, z_i is a vector of individual's characteristics (e.g., age, education), and ϵ_i is the identically, independently distributed random variable with zero means.

Results of the perception survey section

(Likert Scale 1 = "very negative" / "not at all" to 10 = "very positive" / "very much")



Results ***Economic valuation of ES***

c. Existence value

WTP question:
«Would you be willing to pay €X as an annual donation to be allocated to a local association or organization to ensure the protection and preservation of practices and traditions related to mussel farming over time?»
❑ Yes ❑ No

- 228 valid respondents
- Data were assessed to determine the mean of WTP using the Hanemann (1984) approach.
- A dichotomous choice logit model was applied in STATA, in which the dependent variable is the Yes/No answer given by the respondent, while the independent variable is the proposed price.

Mean annual citizens WTP for traditional value provided by mussel farming in the Little Sea of Taranto

	Amount (€)	St. error	Confidence interval (95%)	
Mean WTP	32.78	3.06	26.78	38.78

- Aggregate WTP was calculated by considering the mean WTP and the number of families in the city of Taranto, which are the user base for the cultural ES assessed

→ **Aggregate WTP = 2,709,562 €/yr.**

Economic valuation of ecosystem services

Total economic value of goods and services

Value type	Good & service	Value	Value per unit
Direct use	Food provision	994,973 € yr^{-1}	7,056 € ha^{-1} yr^{-1}
Indirect use	Carbon sequestration	28,059 € yr^{-1}	199 € ha^{-1} yr^{-1}
Indirect use	Nutrient removal	79,524 € yr^{-1}	564 € ha^{-1} yr^{-1}
Non-use	Local-meaning making	2.709 million € yr^{-1}	32.78 € $household^{-1}$ yr^{-1}