LE FORESTE DEL MARE

28 NOVEMBRE 2025

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Conferenza Finale
LIFE SeaForest

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Implementazione di un modello BlueCarbon in Europa: Il progetto SEAForest LIFE

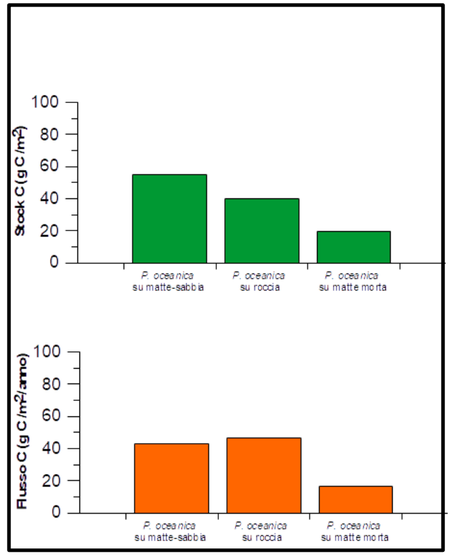
UNIVERSITÀ DEGLI STUDI DELLA Tuscia

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Collection and analysis of *Posidonia oceanica* data

Above-ground and below-ground biomass pool

PNAS



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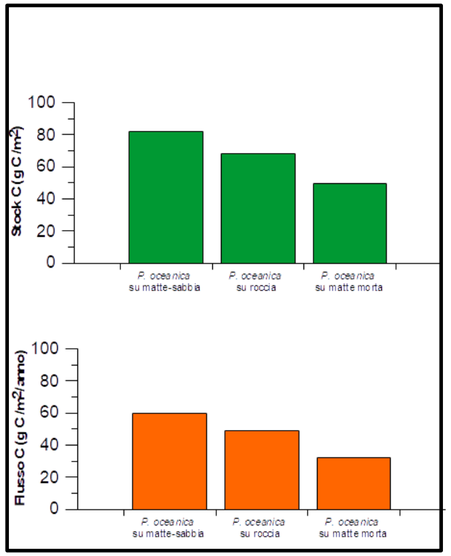

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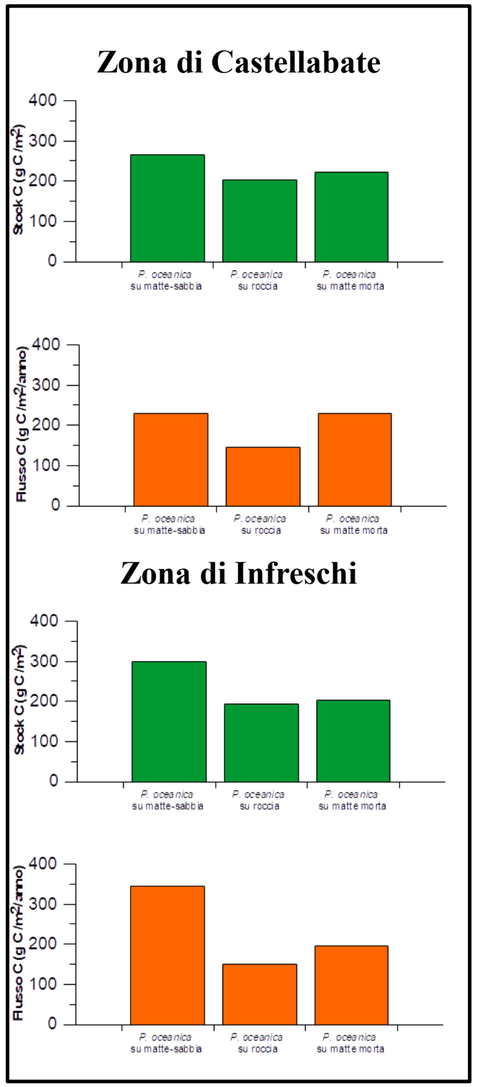
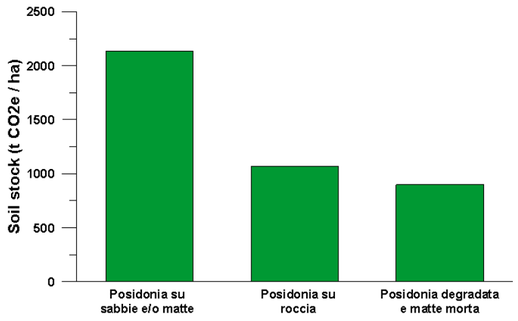


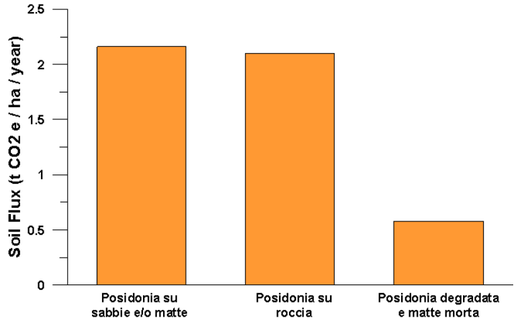
Soil pool (*matte*)

LIFE BLUE NATURA

lobal CO_2 stocks and fluxes. SE: Standard error of the mean.

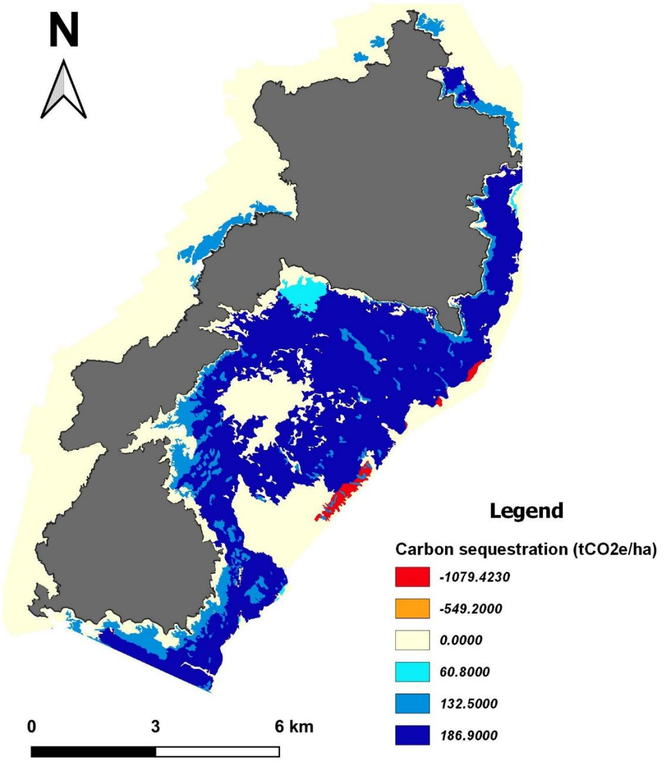
Type of bottom	Depth (m)	Area (ha)	tCO₂/ha	se	tCO₂/ ha yr	se	ktCO₂/ Andal.	tTCO₂/ Andal. yr
P. oceanica stable	<5	183.2	566.5	126.3	2.7	0.3	158.8	495.1
	5-10	706.2	814.4	94.6	3.1	0.4	575.2	2168.6
	10-15	841.1	906.7	259.7	2.2	0.4	762.6	1813.0
	15-20	658.2	4051.0	2396.2	1.4	1.6	2666.2	896.7
	>20	665.3	4051.0	2396.2	1.4	1.6	2694.9	906.3
C. nodosa stable (open sea)	<5	48.4	79.6	9.5	0.1	0.2	3.9	7.1
	5-10	897.6	79.6	9.5	0.1	0.2	71.5	131.8
	10-15	1560.4	79.6	9.5	0.1	0.2	124.3	229.1
	15-20	989.6	79.6	9.5	0.1	0.2	78.8	145.3
	>20	356.2	79.6	9.5	0.1	0.2	28.4	52.3
C. nodosa semi-enclosed	0.1	249.6	104.2	14.8	0.1	0.0	26.0	33.2
C. nodosa and *Z. noltei*	<5	0.3	91.9	12.2	0.1	0.1	0.0	0.0
P. oceanica regression	<5	2.2	632.6	308.6	1.7	0.5	1.4	3.6
	5-10	48.1	594.5	272.4	1.9	0.5	28.6	91.8
	10-15	170.0	661.9	416.1	0.7	0.4	112.5	113.6
	15-20	61.0	2957.2	2761.0	0.4	0.6	180.5	25.8
	>20	287.7	2957.2	2761.0	0.4	0.6	850.7	121.5
P. oceanica and *C. nodosa*	<5	70.7	566.5	126.3	2.7	0.3	51.3	191.1
	5-10	94.2	814.4	94.6	3.1	0.4	76.7	292.0
	10-15	410.7	906.7	259.7	2.2	0.4	372.4	885.4
	15-20	280.4	4051.0	2396.2	1.4	1.6	1136.0	382.1
	>20	36.3	4051.0	2396.2	1.4	1.6	147.2	49.5
P. oceanica, *C. nodosa* and *Zostera* spp.	<5	1.7	566.5	126.3	2.7	0.3	1.5	4.6
	5-10	35.2	814.4	94.6	3.1	0.4	28.7	109.1
	10-15	19.5	906.7	259.7	2.2	0.4	17.7	42.0
P. oceanica and *Caulerpa cylindracea*	10-15	1.4	4051.0	2396.2	1.4	1.6	5.7	1.9
	15-20	40.8	4051.0	2396.2	1.4	1.6	165.3	55.6
P. oceanica mixed bottom	5-10	7.9	814.4	94.6	3.1	0.4	6.5	24.6
	10-15	21.1	906.7	259.7	2.2	0.4	19.1	45.4
	15-20	26.8	4051.0	2396.2	1.4	1.6	108.6	36.5
	>20	1.0	4051.0	2396.2	1.4	1.6	3.9	1.3
P. oceanica dead mat	<5	3.8	1064.4	107.4	1.1	2.6	4.1	4.1
	5-10	15.6	900.0	230.4	0.6	1.3	14.0	8.6
	10-15	51.2	735.6	353.4	0.0	0.0	37.6	1.9
	15-20	24.6	900.0	230.4	0.6	1.3	22.1	13.5
	>20	29.0	900.0	230.4	0.6	1.3	26.1	15.9
P. oceanica on rock	<5 to >20	2299.2	1069.0	1054.6	2.1	0.9	2457.7	4911.8
C. nodosa on dead mat	<5	0.1	1224.0	394.2	1.2	2.6	0.1	0.1
Z. noltei stable (semi-enclosed)	<5	473.7	18.6	8.4	0.1	0.1	8.8	52.2
Zostera marina stable	<5	0.1	18.6	8.4	0.1	0.1	0.0	0.0
	10-15	1.2	18.6	8.4	0.1	0.1	0.0	0.1
Total / Mean		11671.2	**1393.6**	736.2	**1.3**	0.7	**13085.4**	**14384.1**





Preliminary analysis of sequestered CO_2 based on the comparison of two P. oceanica maps in the project areas

PNAS



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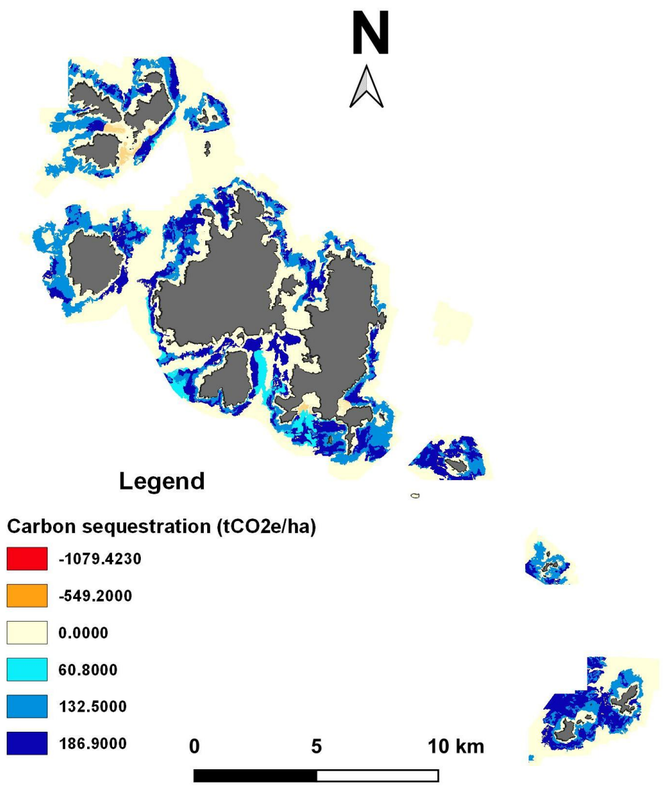

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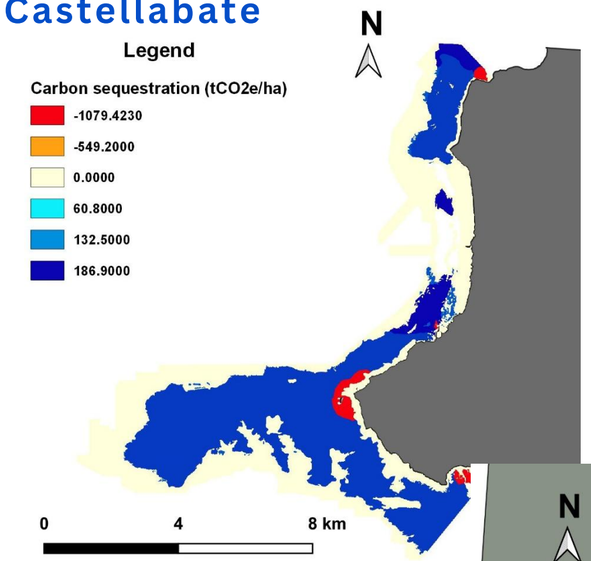
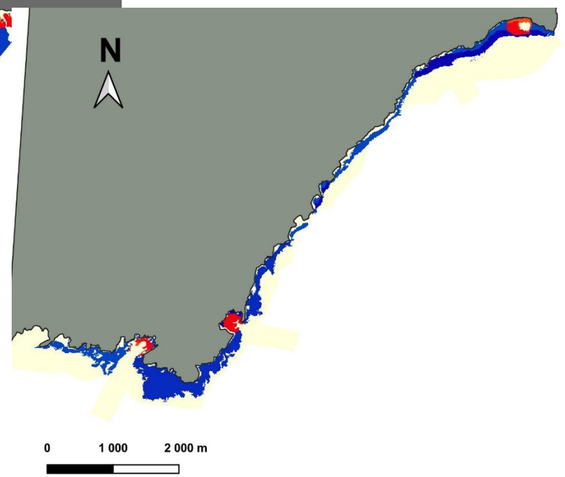
Castellabate



Infreschi



Dapueto et al.(2023)

Pergent-Martini et al.(2022)

Literature Review on the Assessment of Anchoring Damage

Large vessels (L > 50 m)

A 50 m yacht can destroy up to 1,500 m² of *Posidonia oceanica* meadow per anchoring cycle (Recommendation for leisure boating – Interreg PHAROS4MPAs project).

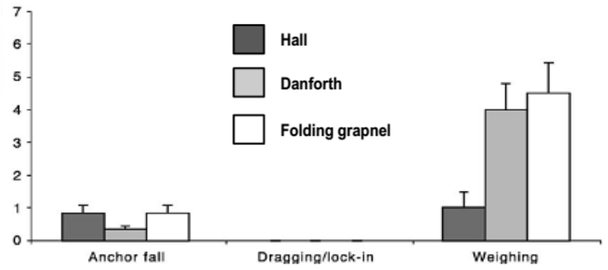
ANCHORING CYCCLE

Locking-in

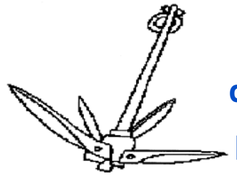
Retrieving

Total

Small vessels (L < 20 m)



Milazzo et al. (2004)



Folding grapnel

The folding anchor causes damage of approximately 5.5 bundles per anchoring cycle on small vessels.

Medium vessels (20 m < L < 50 m)

Number of shoots	Locking-in ($n = 30$)	Retrieving ($n = 100$)	Anchoring cycle
Uprooted	15.6 (3.7)	12.0 (1.4)	27.6
Broken	4.3 (0.8)	1.6 (0.2)	5.9
Total	19.9 (4.3)	13.6 (1.5)	33.5

Francour et al. (1999)

Vessel type	Biomass damage	Soil damage
Small vessels (< 20 m)	0,16 m²	Irrilevant
Medium vessels (> 20 m e < 50 m)	2,38 m²	0,37 m³
Big vessels (>50 m)	296 m²	0,74 m³

Dapueto et al.(2023) Pergent-Martini et al.(2022)

Methodology for Mapping Anchor Activity

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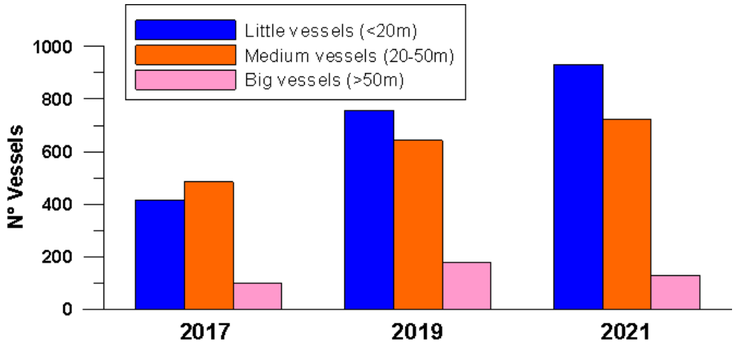

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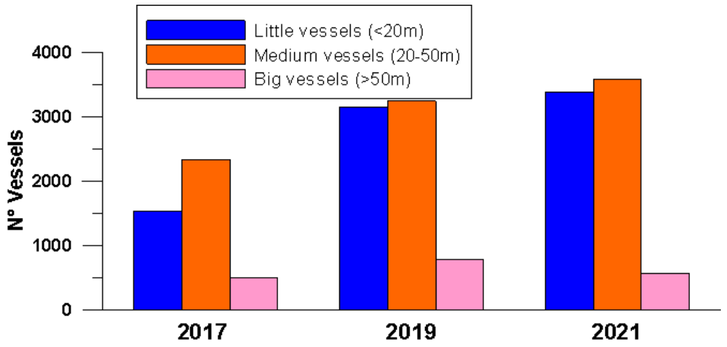

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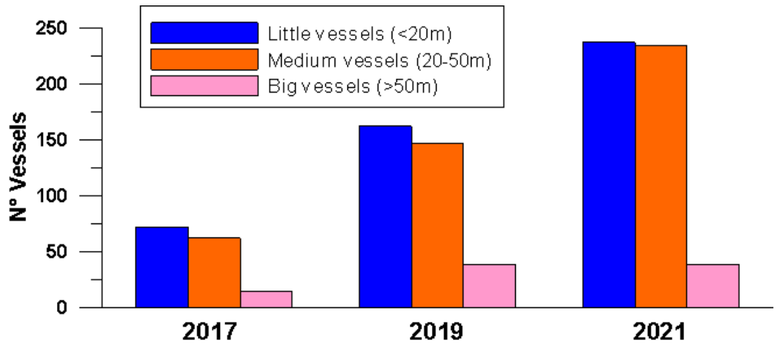

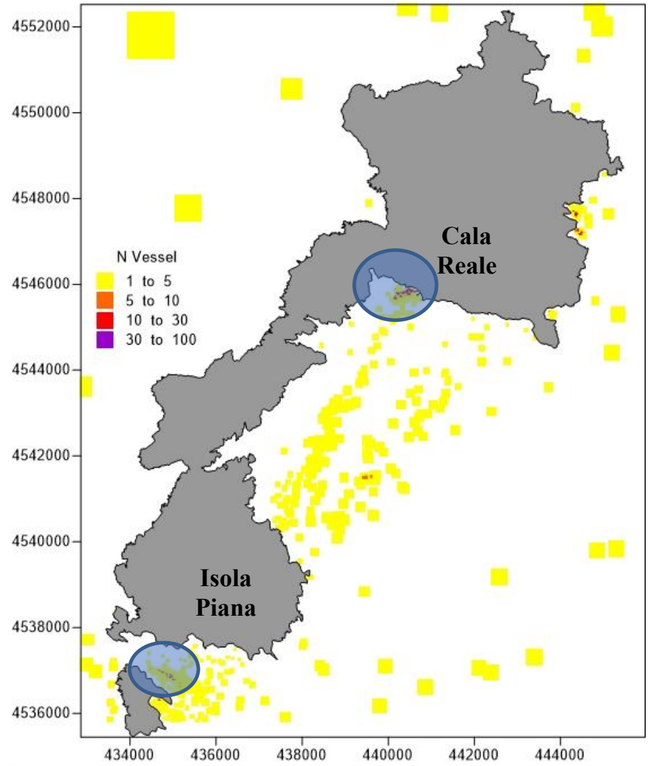

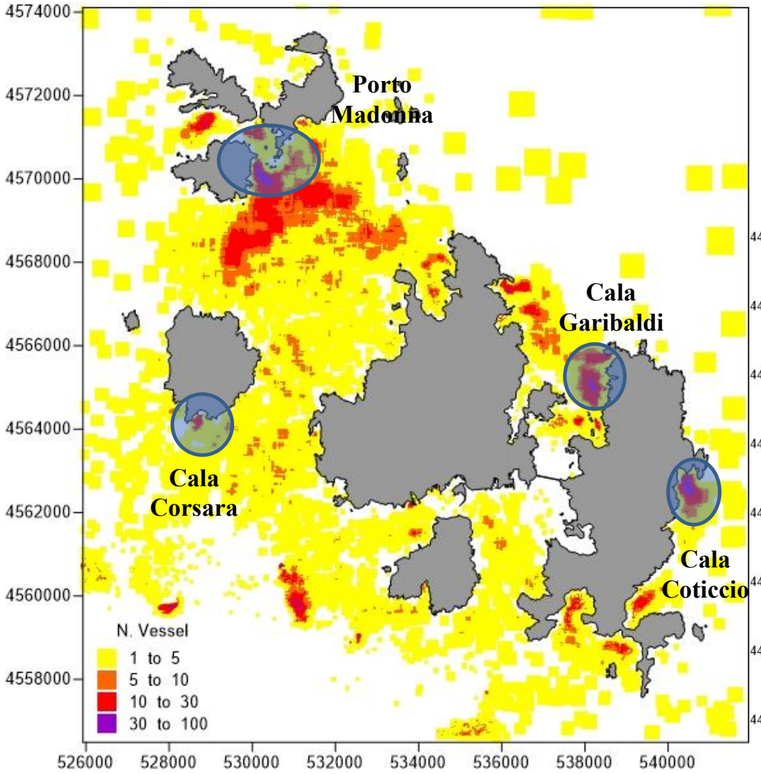

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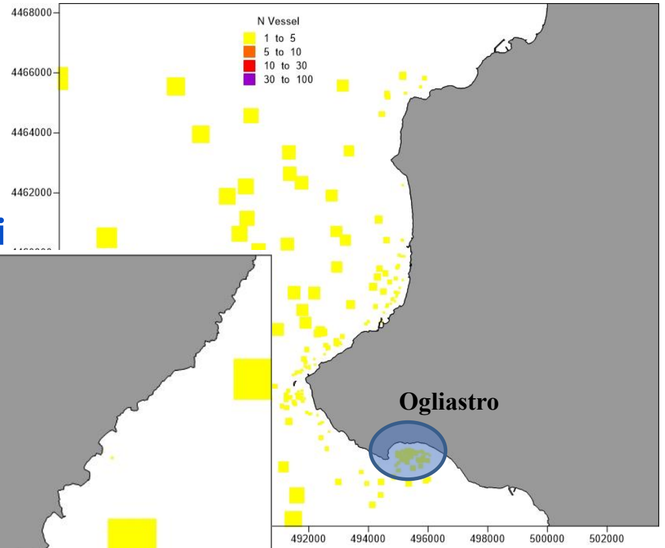

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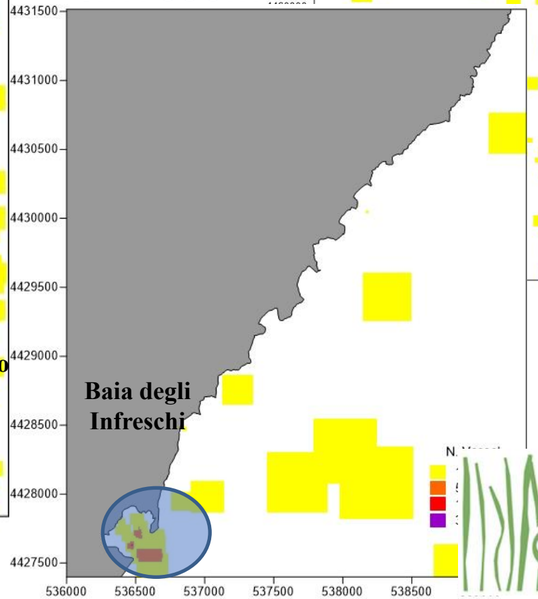


Metodologia SeaForest – Tappe principali

- Sviluppo del metodo di baseline (AIS + PlanetScope) e Identificazione e quantificazione dei danni dell'ancoraggio
- Scenario di progetto (piani ormeggi + ormeggi sostenibili)
- Calcolo NER (Net Emission Reduction)

$$\mathbf{NER = GHG_{BSL} - GHG_{PRJ} - GHG_{LK}}$$

*Where **NER** = Net Emission Reductions [tCO_2]; **GHG_{BSL}** = Total CO_2 emissions in the baseline scenario [tCO_2]; **GHG_{PRJ}** = Total CO_2 emissions in the project scenario [tCO_2] **GHG_{LK}** = Total CO_2 emissions due to leakage [tCO_2]*

$$GHG_{BSL} = GHG_{BSL\text{-}biomass} + GHG_{BSL\text{-}soil}$$

*Where **GHG_{BSL}**= Total CO_2 emissions in the baseline scenario [tCO_2];**$GHG_{BSL-biomass}$**=Total CO_2 emissions of biomass in the baseline scenario [tCO_2]; **$GHG_{BSL\text{-}soil}$**= Total CO_2 emissions of soil in the baseline scenario [tCO_2]*

$$GHG_{PRJ} = GHG_{PRJ\text{-}biomass} + GHG_{PRJ\text{-}soil}$$

*Where **GHG_{PRJ}**= Total CO_2 emissions in the project scenario [tCO_2]; **$GHG_{PRJ-biomass}$**= Total CO_2 emissions of biomass in the project scenario [tCO_2]; **$GHG_{PRJ\text{-}soil}$**= Total CO_2 emissions of soil in the project scenario [tCO_2]*

$$GHG_{LK} = GHG_{LK\text{-}biomass} + GHG_{LK\text{-}soil}$$

*Where **GHG_{LK}**= Total CO_2 emissions due to leakage [tCO_2];**$GHG_{LK-biomass}$**=Total CO_2 emissions of biomass due to leakage [tCO_2]; **$GHG_{LK\text{-}soil}$**= Total CO2 emissions of soil due to leakage [tCO2] [tCO_2]*

Metodologia SeaForest

Calcolo delle emissioni nello **scenario di riferimento (baseline)** della CO_2 contenuta nella biomassa epigea e nel suolo

$$\Delta C_{BSL-biomass\ i,t} = \sum_{b=1}^{B} \left(IA_{i,t,b} * \Delta C_{b,i}\right)$$

Cambiamento del carbon stock nello scenario BSL per layer *i* e tempo *t [tC/yr]*

Numero dei tipi di barche *b* nell'anno *t* sullo strato *i*

Carbonio emesso per ciclo di ancoraggio attraverso la tipologia di barca *b* sullo strato *i* [tC/boat]

Lo stesso tipo di calcolo è stato effettuato per l'emissione di CO_2 nel suolo nello scenario di baseline: $\Delta C_{BSL\text{-}soil\ i,t}$

Calcolo delle emissioni nello **scenario di progetto** della CO2 contenuta nella biomassa epigea e nel suolo.

$$\Delta C_{PRJ-biomass\ i,t} = \sum_{b=1}^{B} \left(IA_{i,t,b} * \Delta C_{b,i}\right) * ERF$$

Fattore di riduzione delle emissioni (Stimato ex-ante)

Calcolo del **Leakage** (5% delle emission dello scenario di baseline):

$$GHG_{LK} = GHG_{BSL}\ \text{emissions} * 0{,}05$$

Calcolo del NER (GHGbsl-GHGprj-GHGlk -10% buffer):

$$NER = GHG_{BSL} - GHG_{PRJ} - GHG_{LK} - \underbrace{(GHG_{BSL} - GHG_{PRJ} - GHG_{LK} * 0{,}1)}_{\text{Buffer}}$$

Metodologia SeaForest: Punti di forza, Potenziale e Urgenza

Urgenza

- Pressione crescente della nautica su Posidonia
- Degrado rapido delle praterie
- Emissioni elevate da perdita di biomassa e matte
- Non-azione = perdita irreversibile di stock di carbonio

Punti di forza

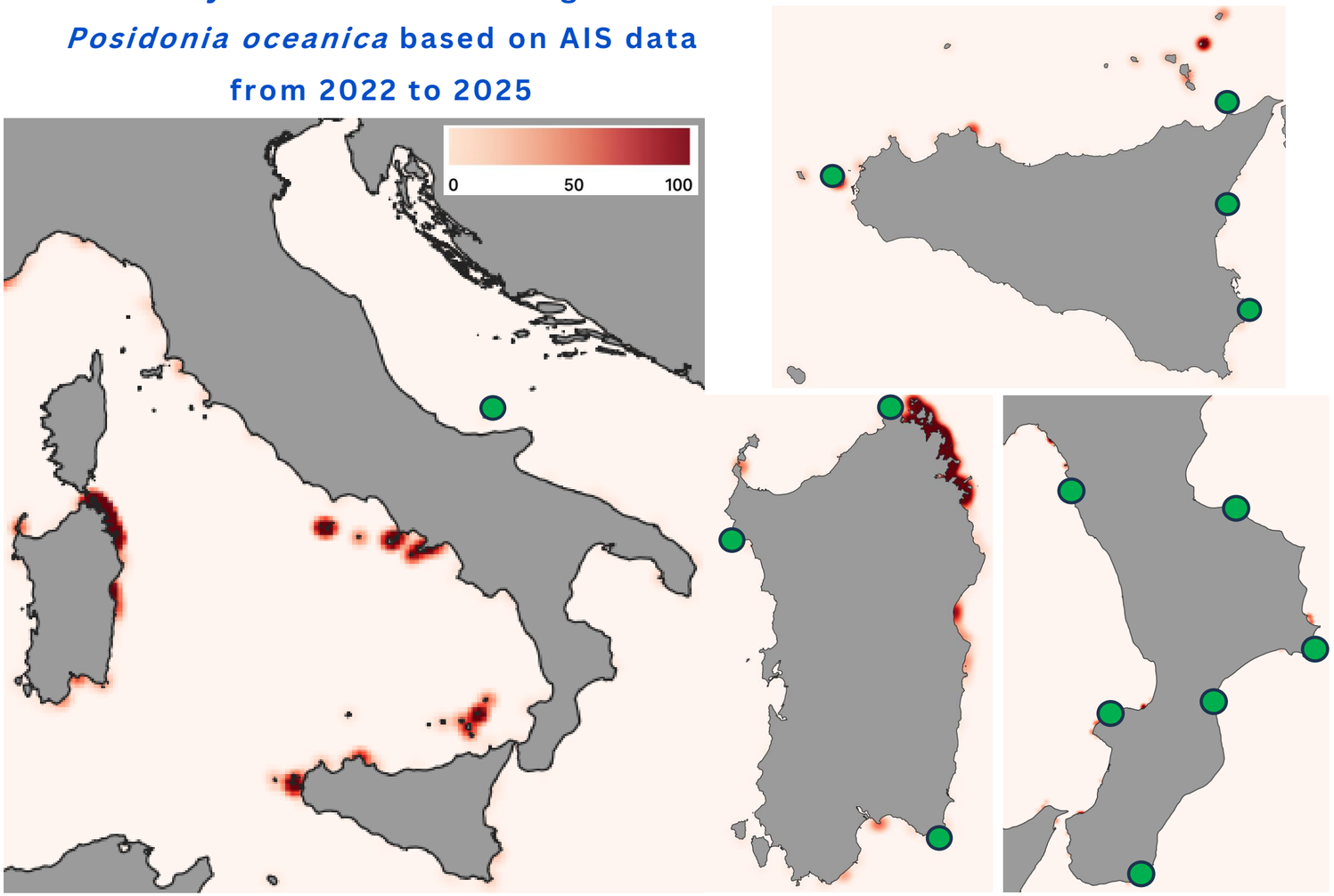
- Identificazione e quantificazione dei danni dell'ancoraggio con scientificità e robustezza dei parametri
- Soluzione replicabile per ottenere una stima realistica e completa del traffico nautico attraverso sistema integrato AIS + PlanetScope
- Replicabilità dello scenario di progetto (piani ormeggi + ormeggi sostenibili) e aderenza ai principi di addizionalità
- Approccio conservativo per il calcolo delle riduzioni di emissioni (NER)

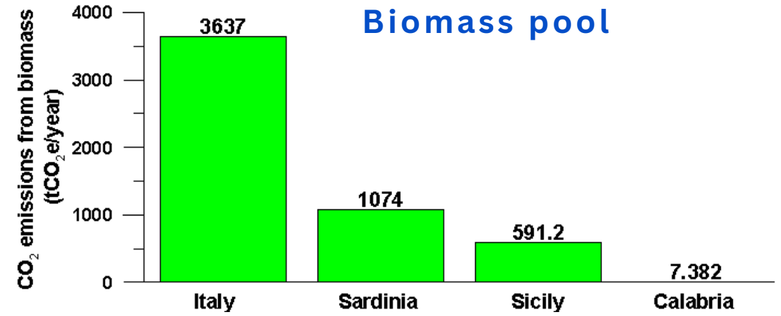
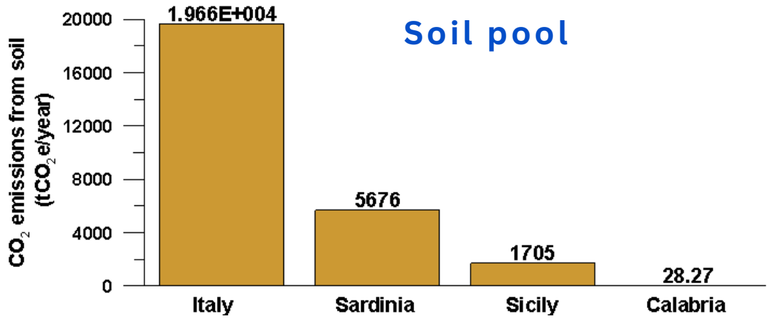
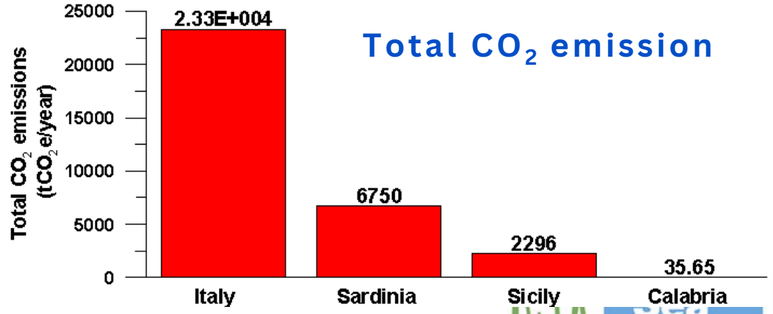
Potenziale

- Applicabile a tutte le aree mediterranee
- Allineata con priorità UE e nazionali
- Possibile generazione di crediti Blue Carbon
- Gli strumenti implementati (App, piani ormeggi, gavitelli) permettono un modello replicabile
- Contributo per la riduzione delle emissioni nel Mediterraneo

Implementation of SeaForest protocol at regional and national scale

Analysis of boat anchoring on *Posidonia oceanica* based on AIS data from 2022 to 2025



Eco-friendly mooring fields (MER Project)

CO_2 Emissions in the Baseline Scenario