Long-term fluctuation of *Cystoseira* forests along the west Istrian Coast (northern Adriatic, Croatia)

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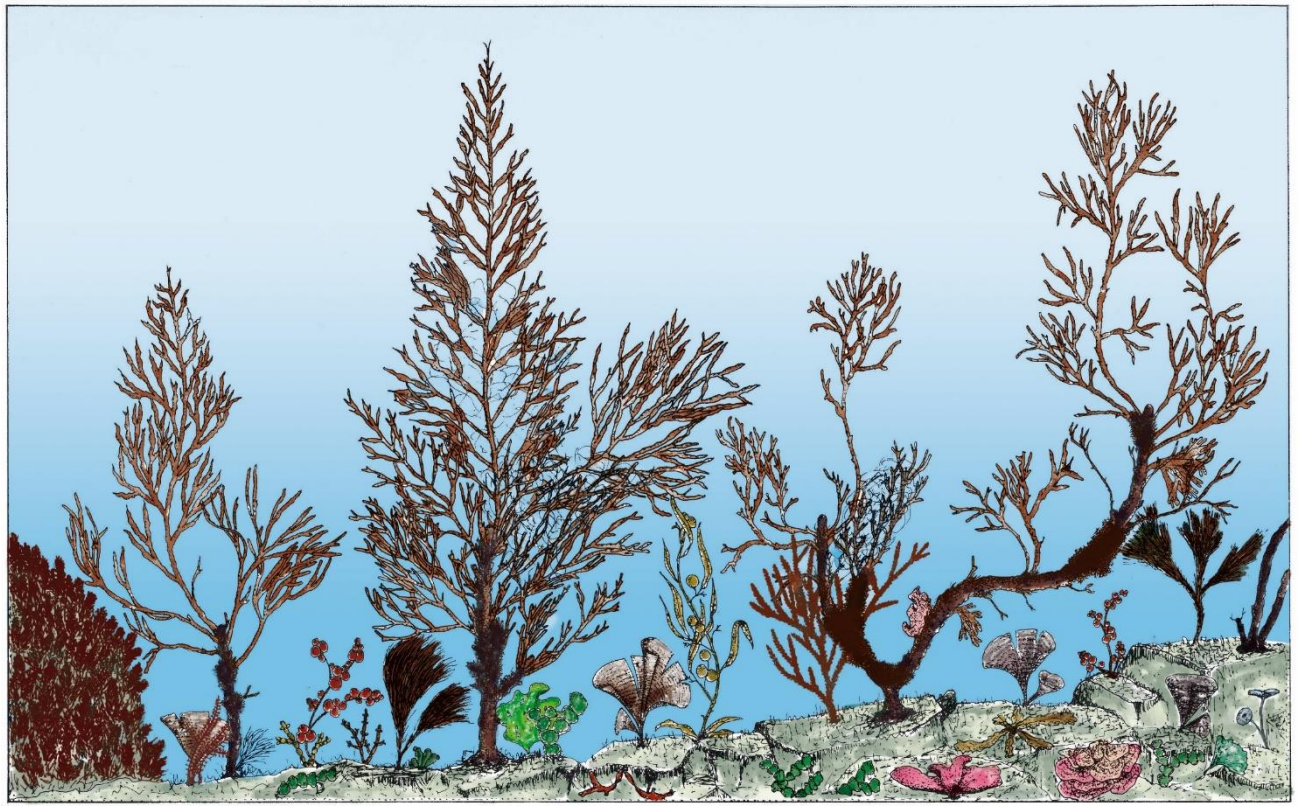
Objectives

Canopy-forming species = *Cystoseira* forests = *Cystoseira* species

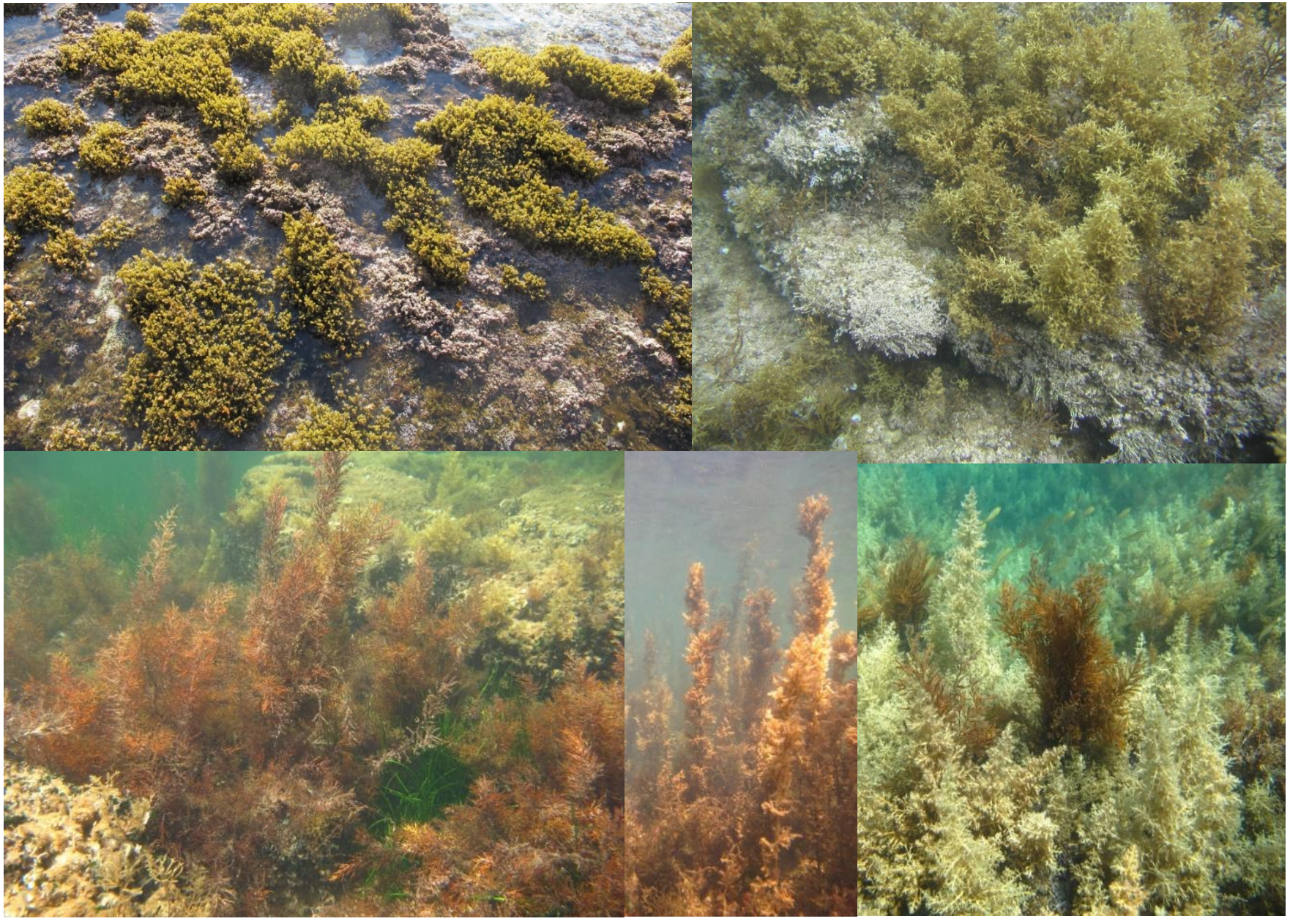


- ✓ long-term fluctuation of **canopy-forming species** in subtidal zone along the western Istria Coast

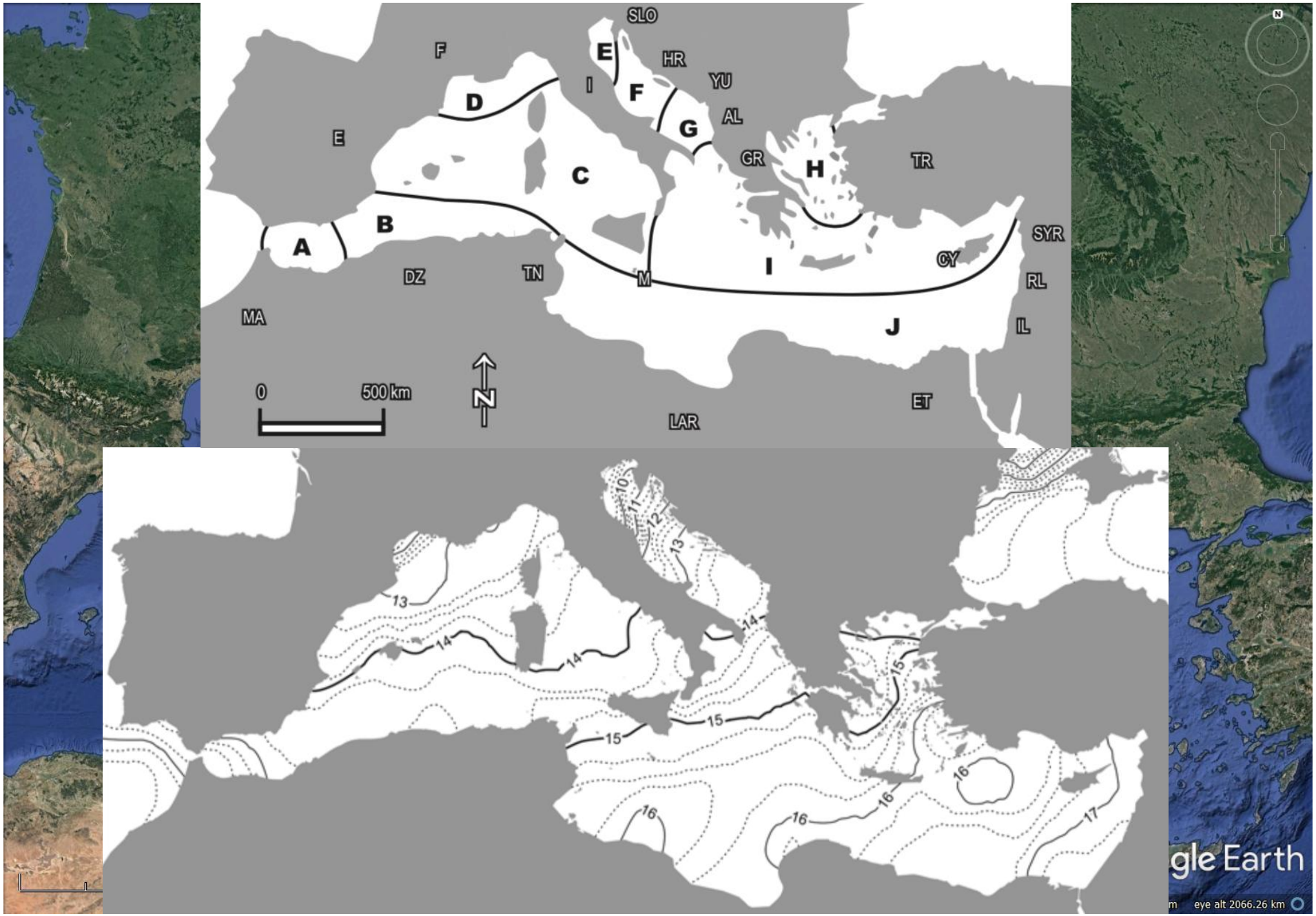
- ✓ mass mortality event of **canopy-forming species** during the period winter–spring 2016 along the western Istria Coast

✓ long-term fluctuation of **canopy-forming species** in subtidal zone along the western Istria Coast

Cystoseira forests from 2003 to 2015



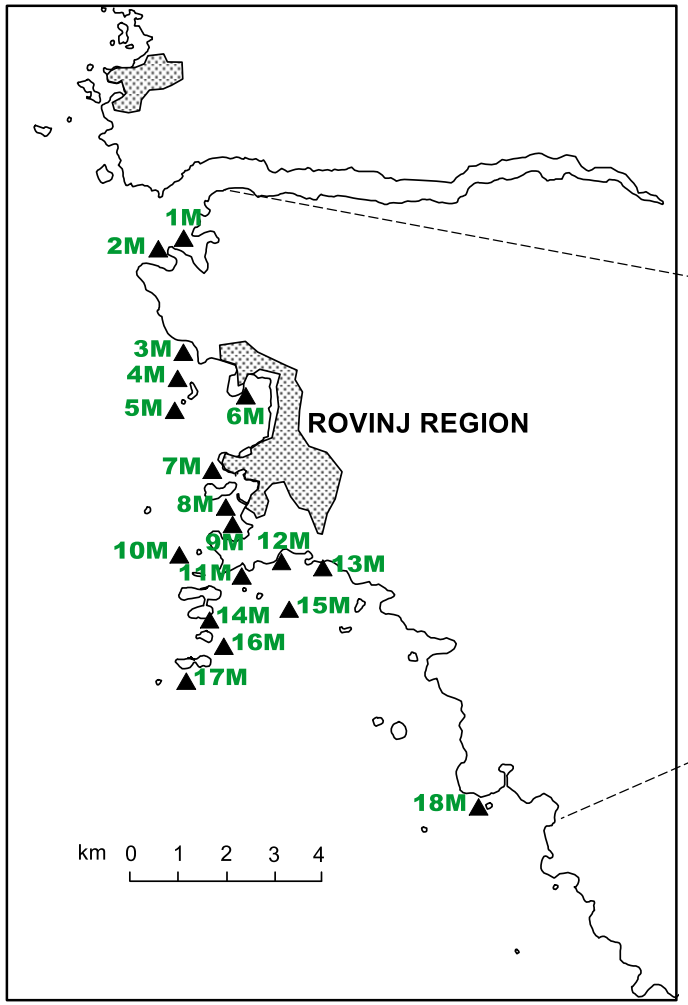
Biogeographic sectors within the Mediterranean Sea

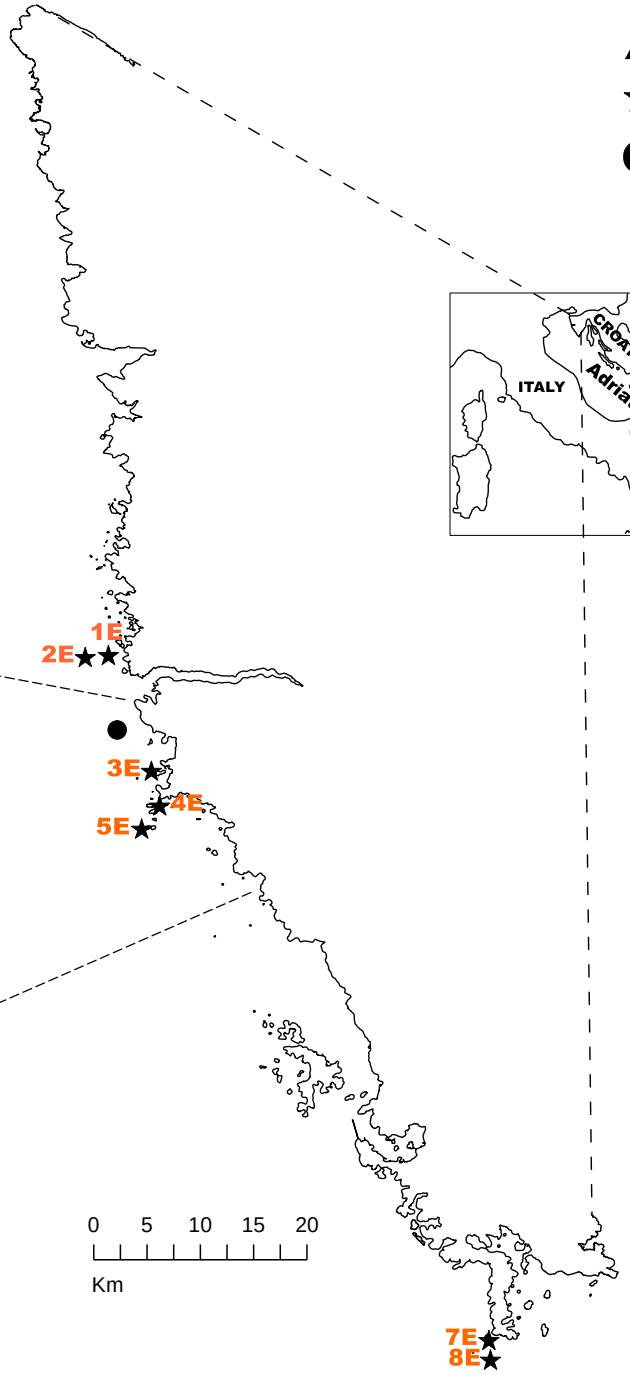


Historical data of **Cystoseira** forests

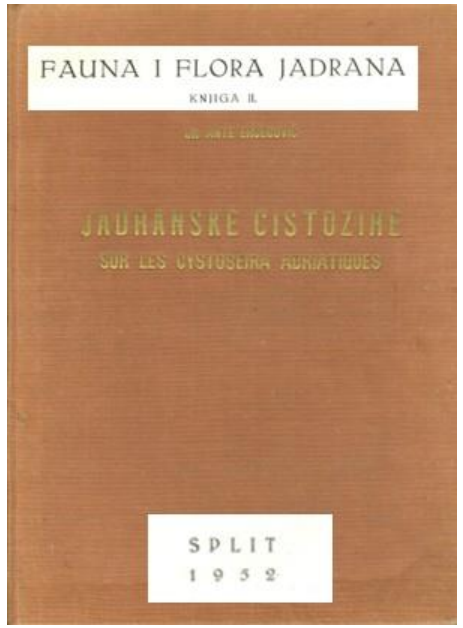
▲ Locations sampled by Munda (region of Rovinj)
★ Locations sampled by Ercegovic
● Station for oceanographic variables

1967-1970
1978-1983





1950

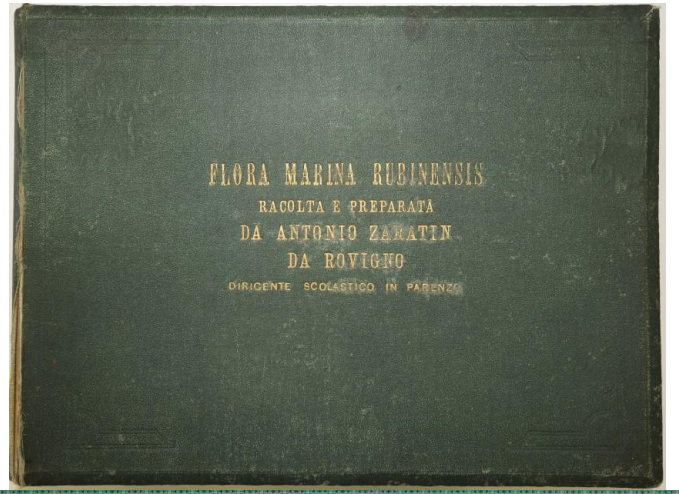


***Cystoseira* species:**
C. amantacea[1]
C. barbata
C. compressa
C. corniculata
C. crinita
C. foeniculacea
C. humilis
C. spinosa

Cystoseira taxa recorded along the west Istrian coast

Cystoseira taxa	
1) *C. amentacea* var. *spicata* (Ercegović) G. Giaccone	(E) (M) (P)
2) *C. barbata* (Stackhouse) C. Agardh	(E) (M) (P)
3) *C. compressa* (Esper) Gerloff & Nizamuddin	(E) (M) (P)
4) *C. compressa* f. *plana* (Ercegović) Cormaci, G. Furnari, Giaccone, Scammanca & D. Serio	(M) (P)
5) *C. compressa* f. *rosetta* (Ercegović) M. Cormaci, G.Furnari, G. Giaccone, B. Scammacca & D. Serio	(E) (M) (P)
6) *C. corniculata* (Turner) Zanardini	(E) (M) (P)
7) *C. crinita* Duby	(E) (M) (P)
8) *C. dubia* Valiante	(M)
9) *C. foeniculacea* (Linnaeus) Greville	(E) (M) (P)
10) *C. foeniculacea* f. *latiramosa* (Ercegović) A. Gómez Garreta, M.C. Barceló, M.A. Ribera & J. Rull Lluch	(M) (P)
11) *C. humilis* Schousboe ex Kützing	(E) (M) (P)
12) *C. spinosa* Sauvageau	(E) (M) (P)

1950 Ercegović = (E)
1967-1983 Munda = (M)
2003-2015 Our investigation = (P)

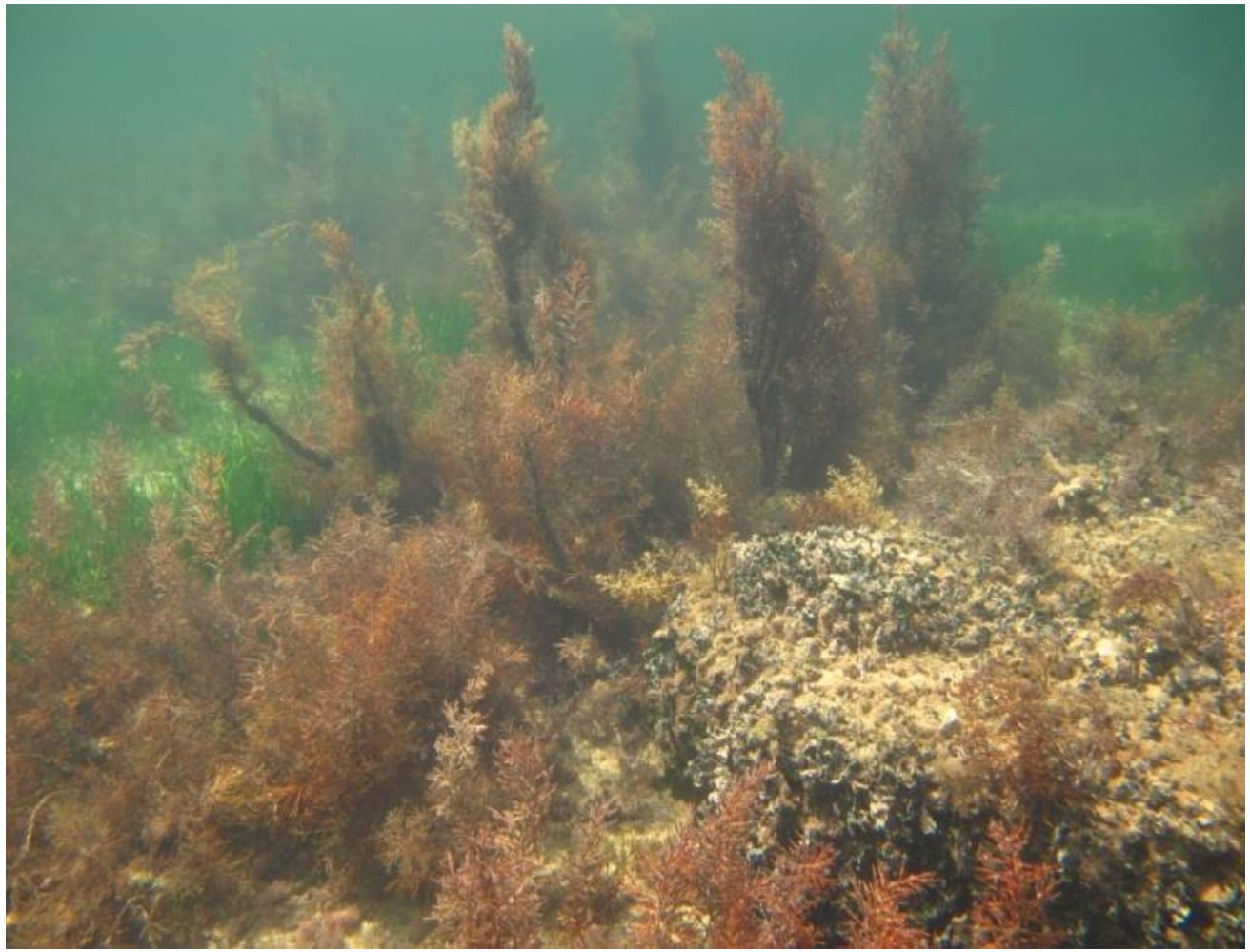


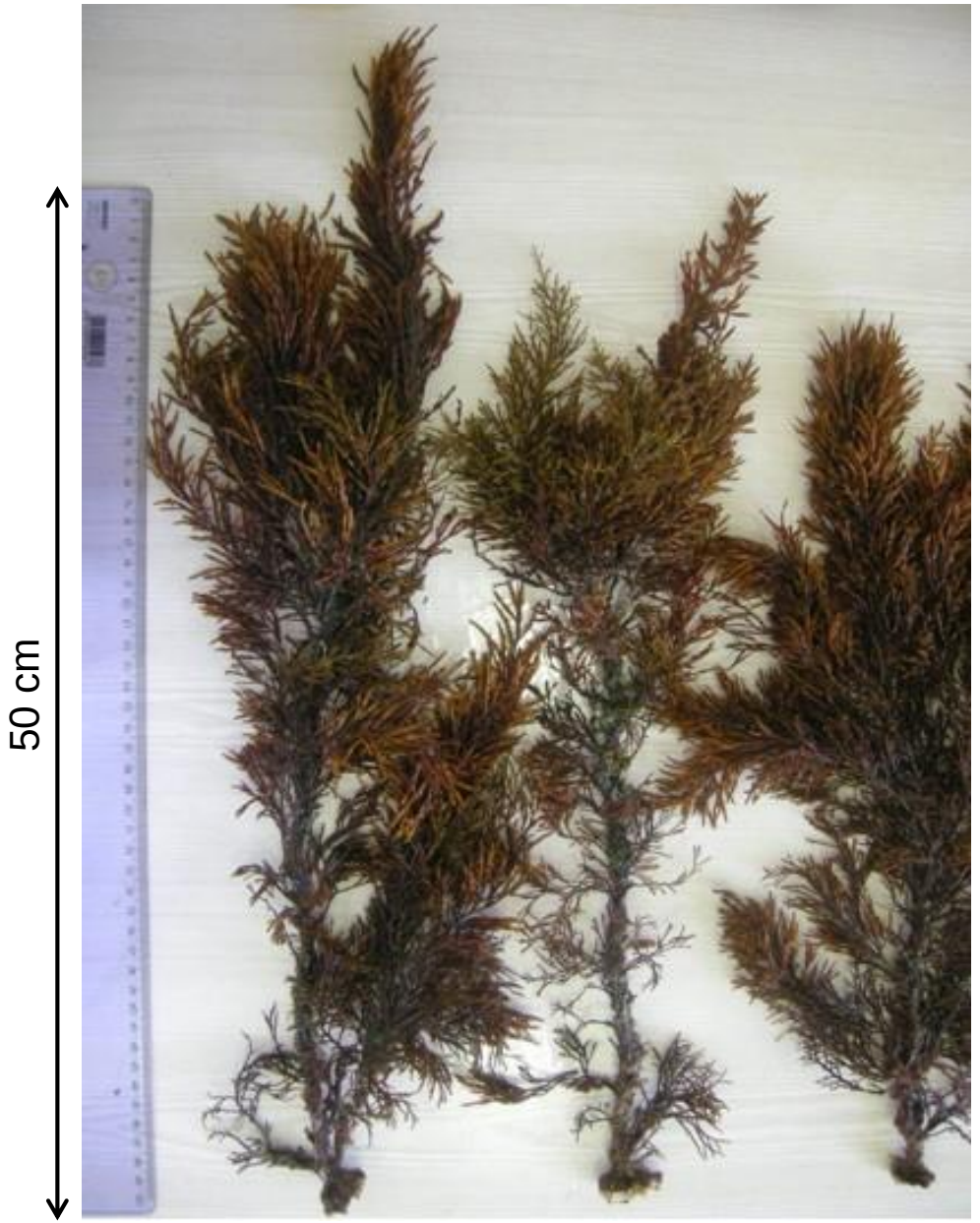
Composition of *Cystoseira* forests along the Istrian coast

Cystoseira amentacea var. *spicata* (Ercegović) G. Giaccone

- intertidal zone
- exposed placed

Cystoseira barbata (Stackhouse) C. Agardh





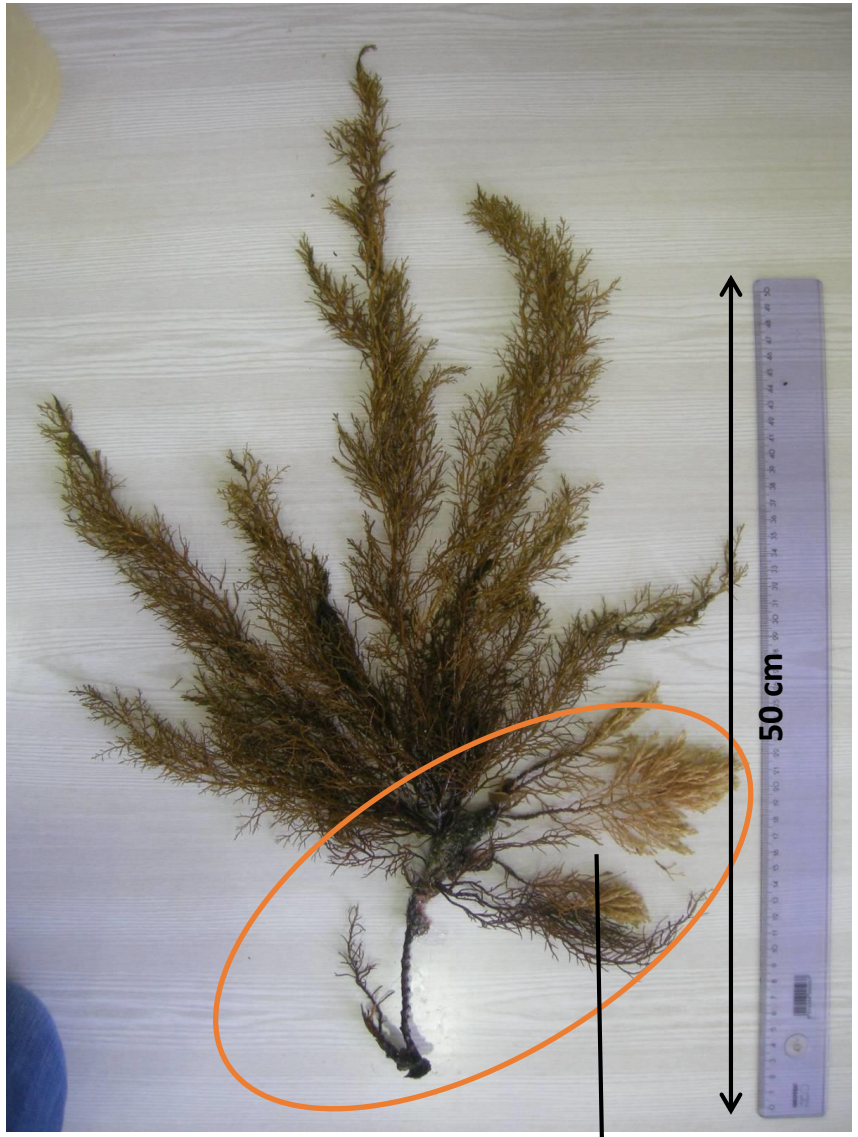
- subtidal zone
- sheltered places
- 0.5 – 40 m depth

Cystoseira compressa (Esper) Gerloff & Nizamuddin

- subtidal zone
- sheltered & exposed places
- 0 – 40 m depth

In urban areas, with some thalli more than 2 m in length.

Cystoseira humilis Schousboe ex Kützing



- intertidal & subtidal zone
- sheltered places

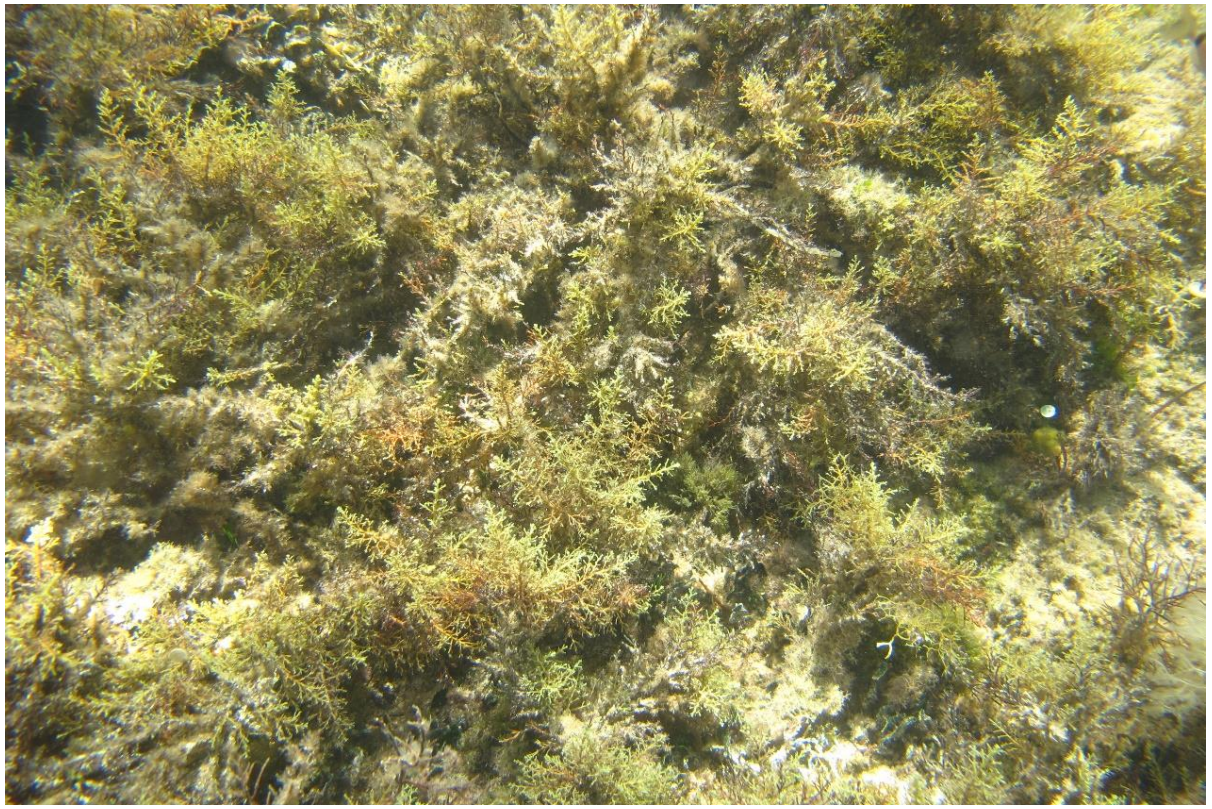
C. foeniculacea

Cystoseira corniculata (Turner) Zanardini

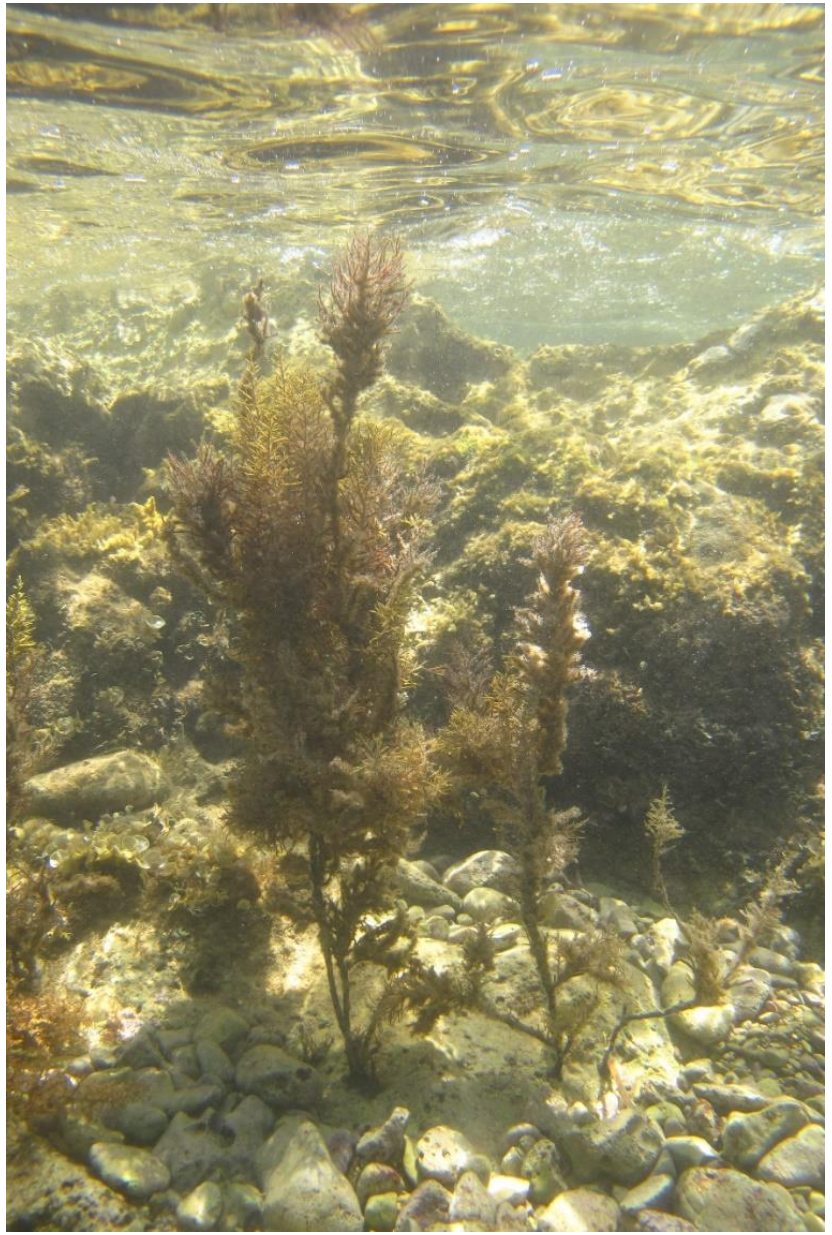
- subtidal zone
- sheltered & intermediately exposed habitats
- 0.5 – 45 m depth

Associated flora and fauna in *Cystoseira corniculata* forests

Cystoseira crinita Duby



- subtidal zone
- monospecific & mixed forests
- 0.5 – 3 m depth



Cystoseira foeniculacea (Linnaeus) Greville

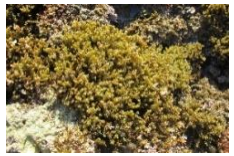
- subtidal zone
- sheltered & intermediately exposed habitats
- 0.5 – 110 m depth

Cystoseira spinosa Sauvageau

- subtidal zone
- sheltered & intermediately exposed habitats
- 0.5 – 50 m depth

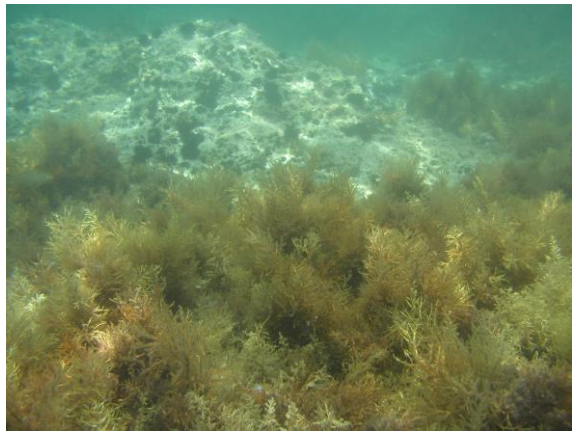
Cystoseira belts & forests

Cystoseira amentacea

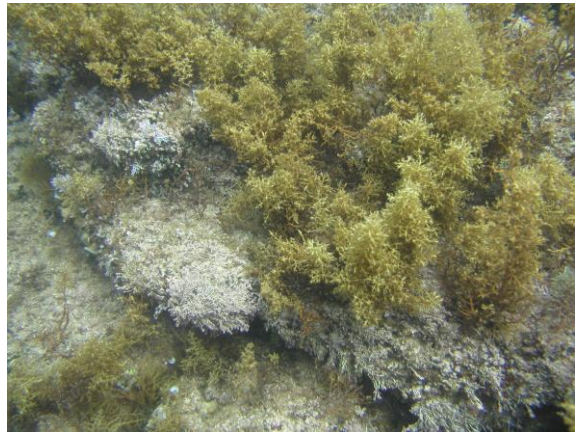


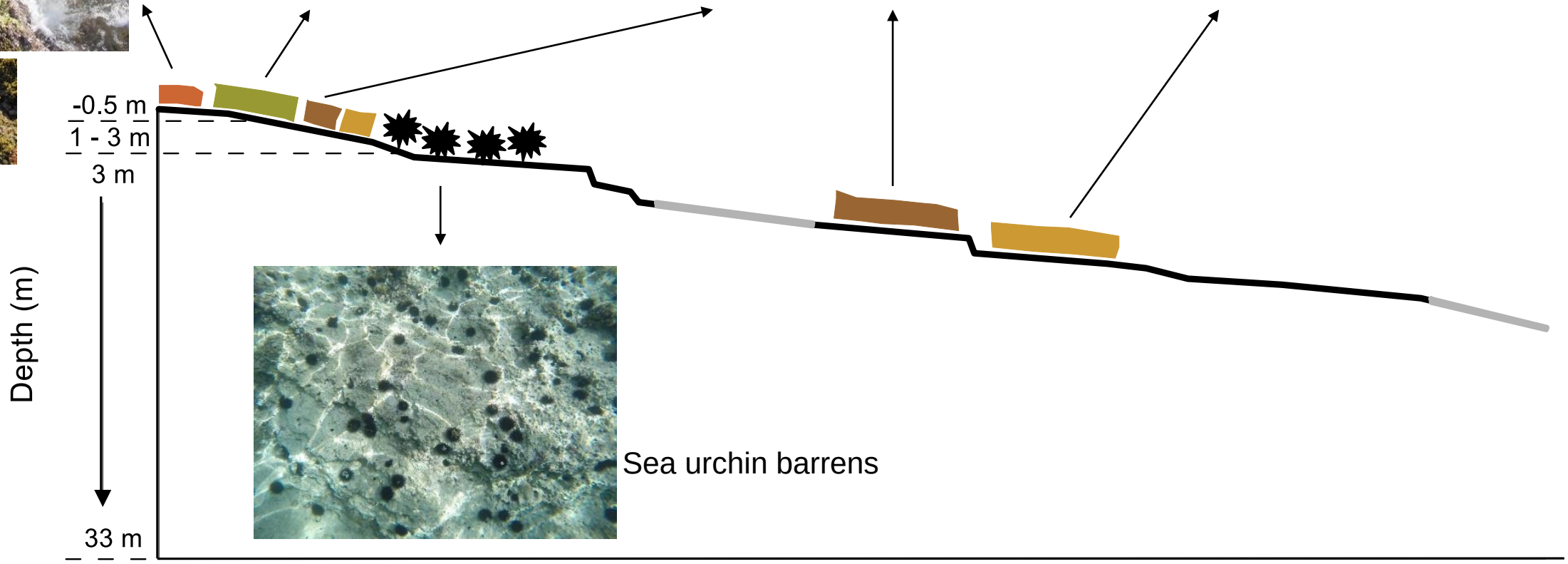
Cystoseira crinita

Cystoseira barbata



Cystoseira compressa





Sea urchin barrens

Cystoseira forests

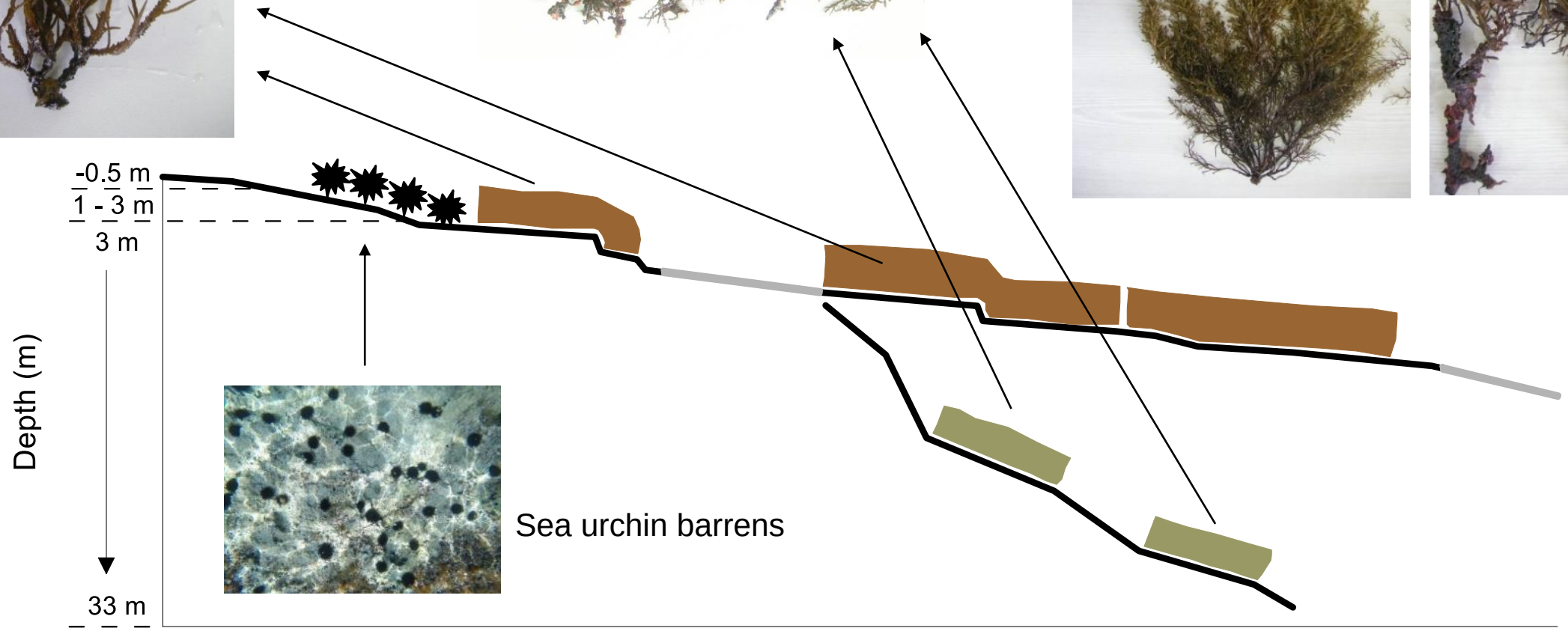
Cystoseira foeniculacea

Cystoseira corniculata

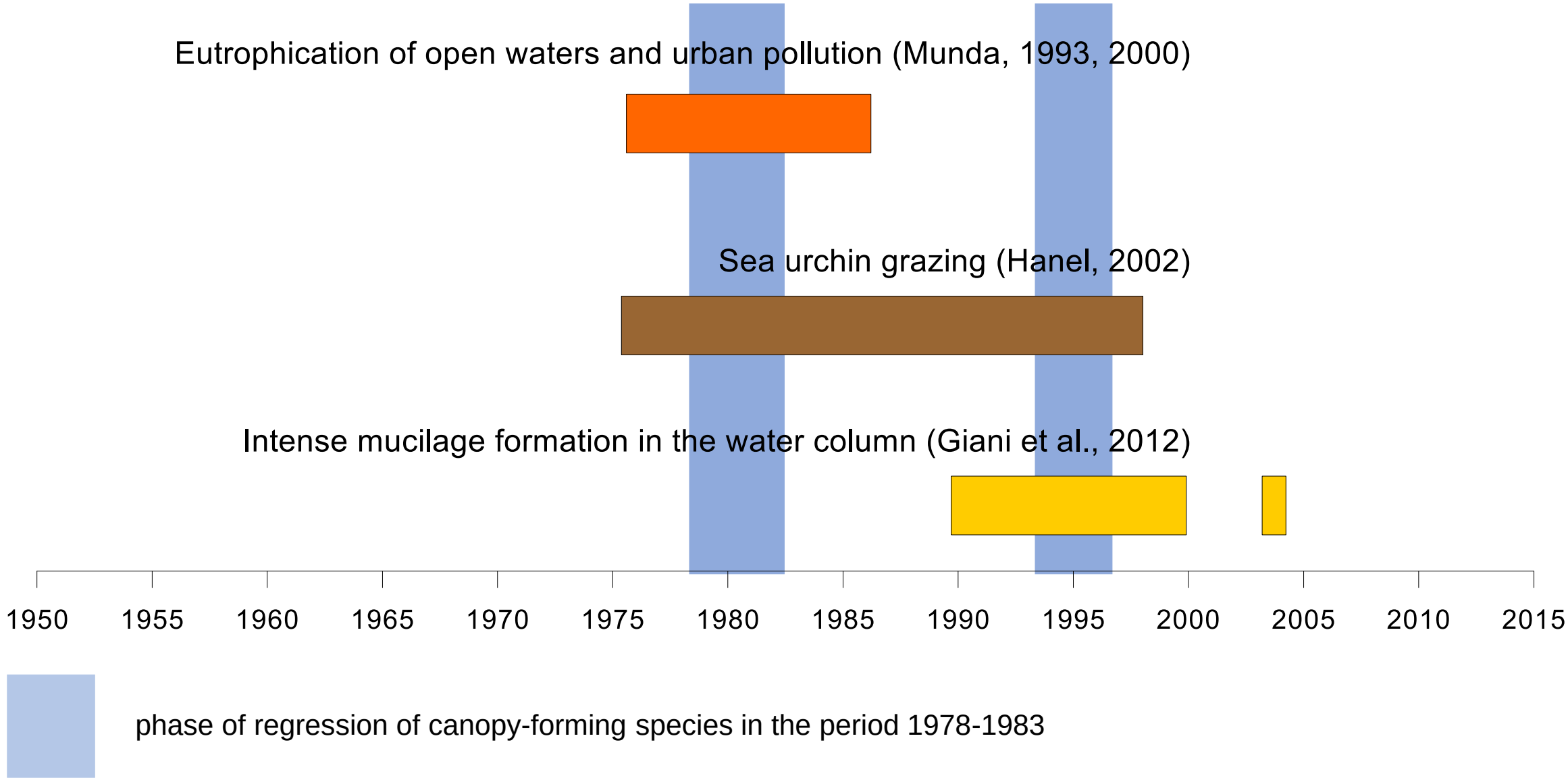
Associated species in *Cystoseira* forests

Cystoseira humilis

Cystoseira spinosa

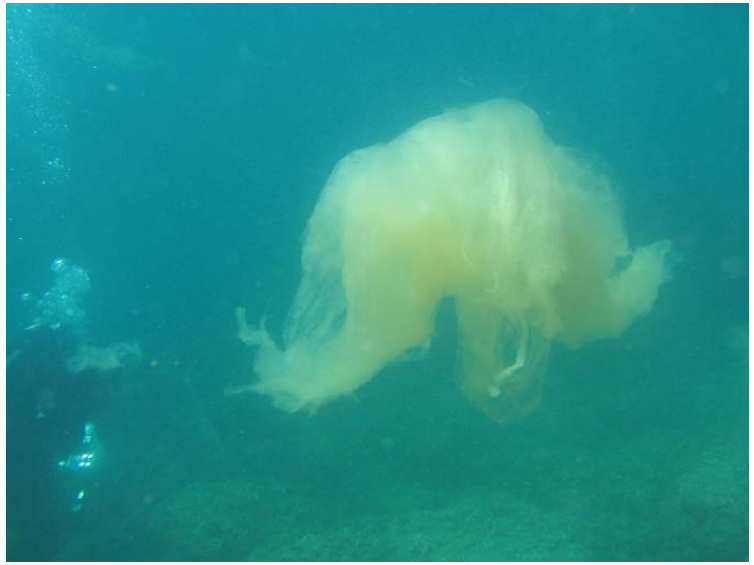


Processes affecting *Cystoseira* forest in the northern Adriatic Basin

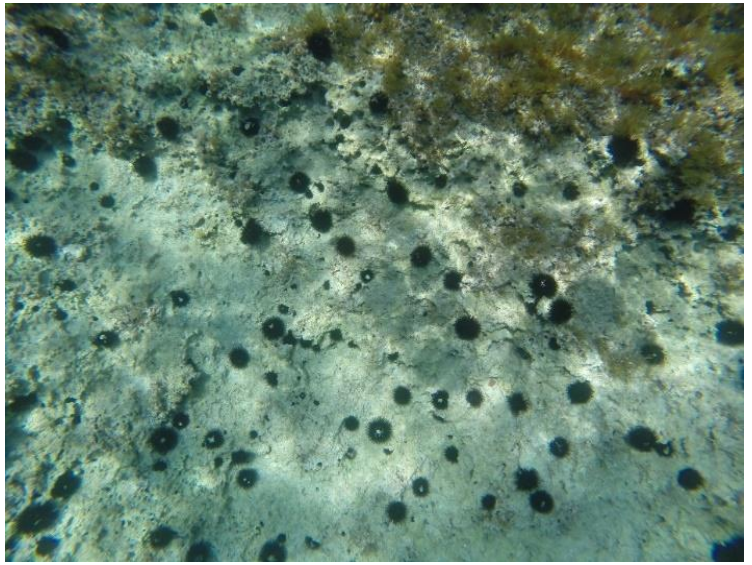


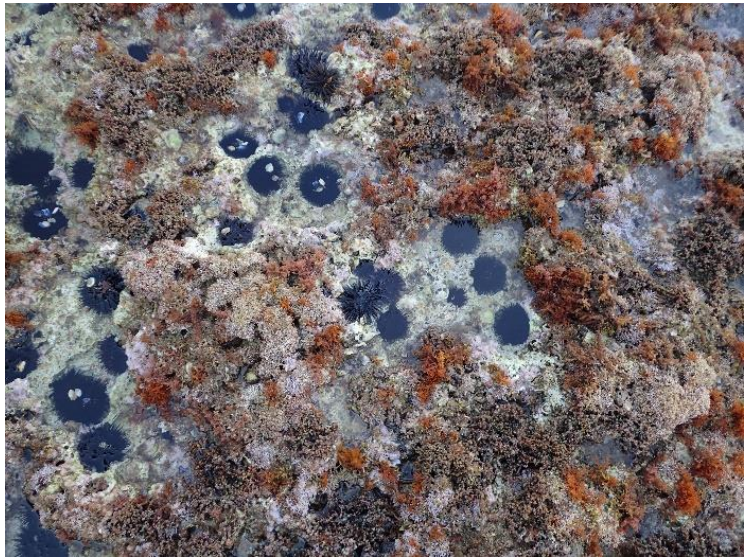
Eutrophication, mucilage phenomenon and predation

Planktonic mucilages



Sea urchins

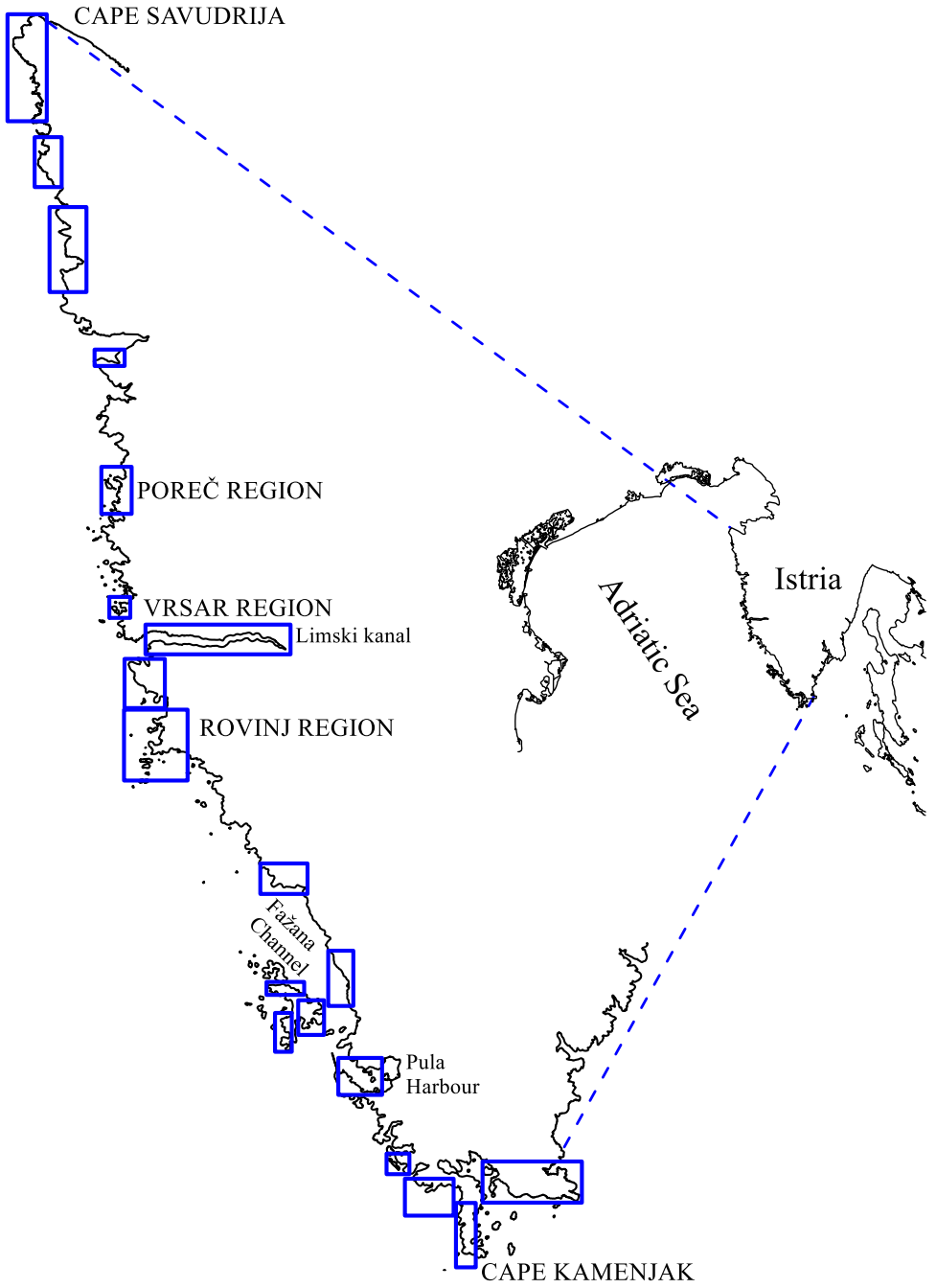




Extreme tidal range

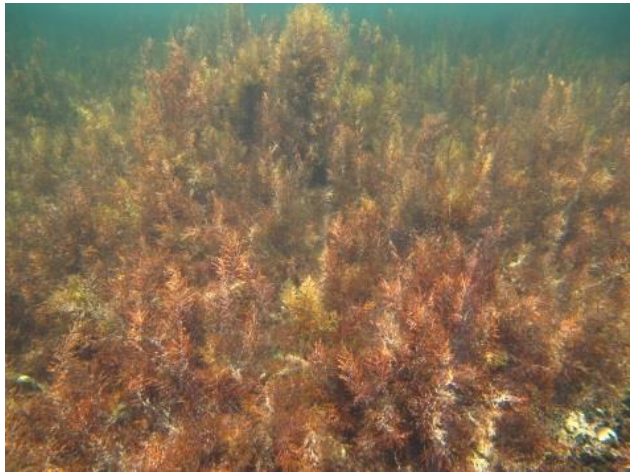
The study area (larger scale sampling)

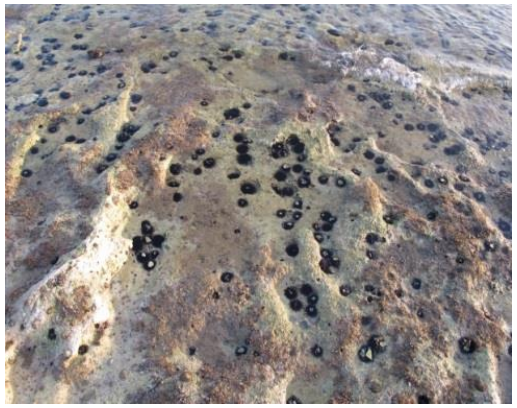
Mapping of *Cystoseira* forests

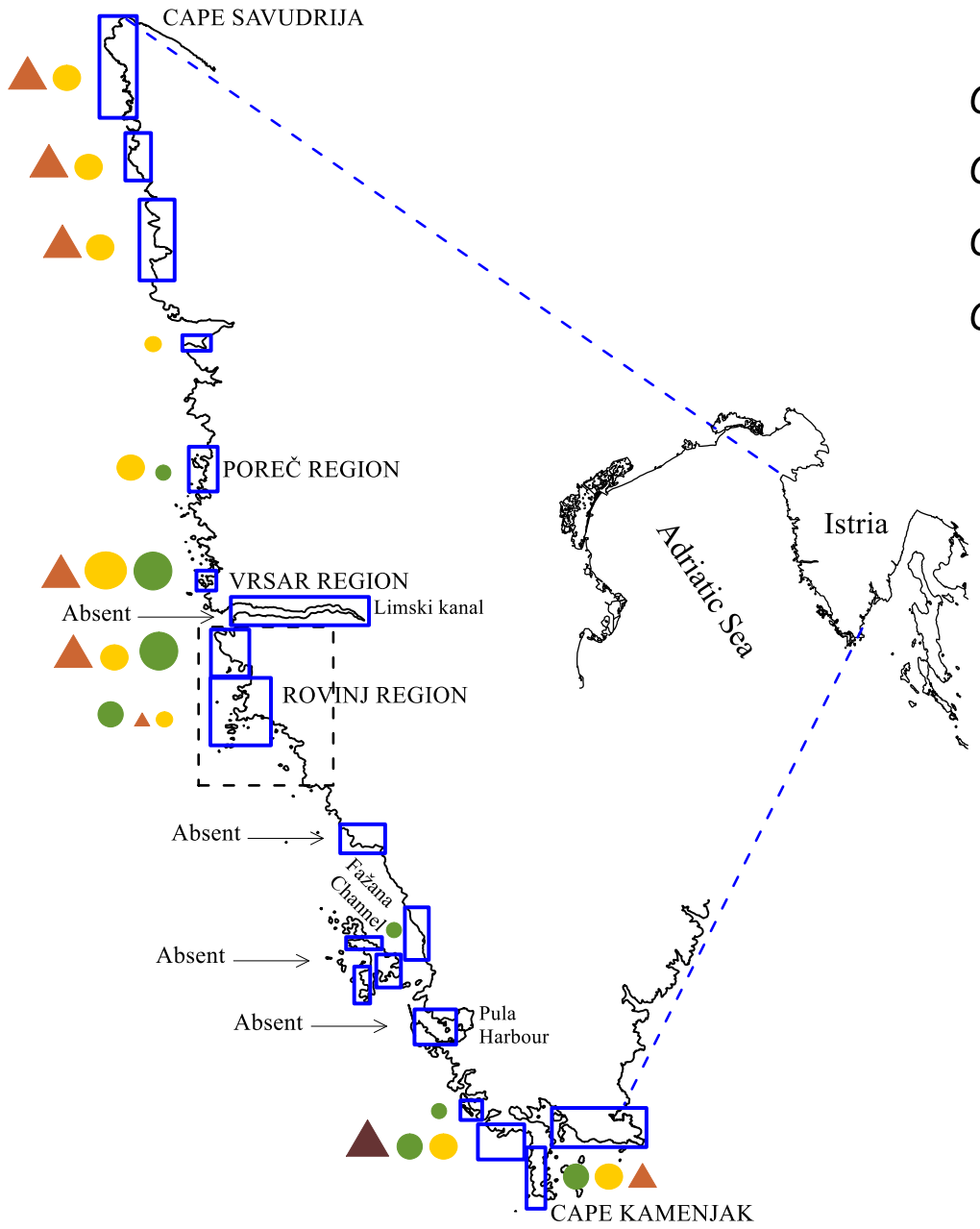


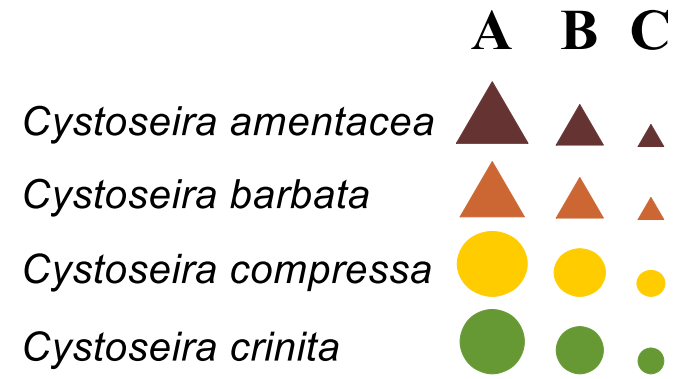
coastline mapped

Mapping of *Cystoseira* forests of the west Istria coast: 2009-2015



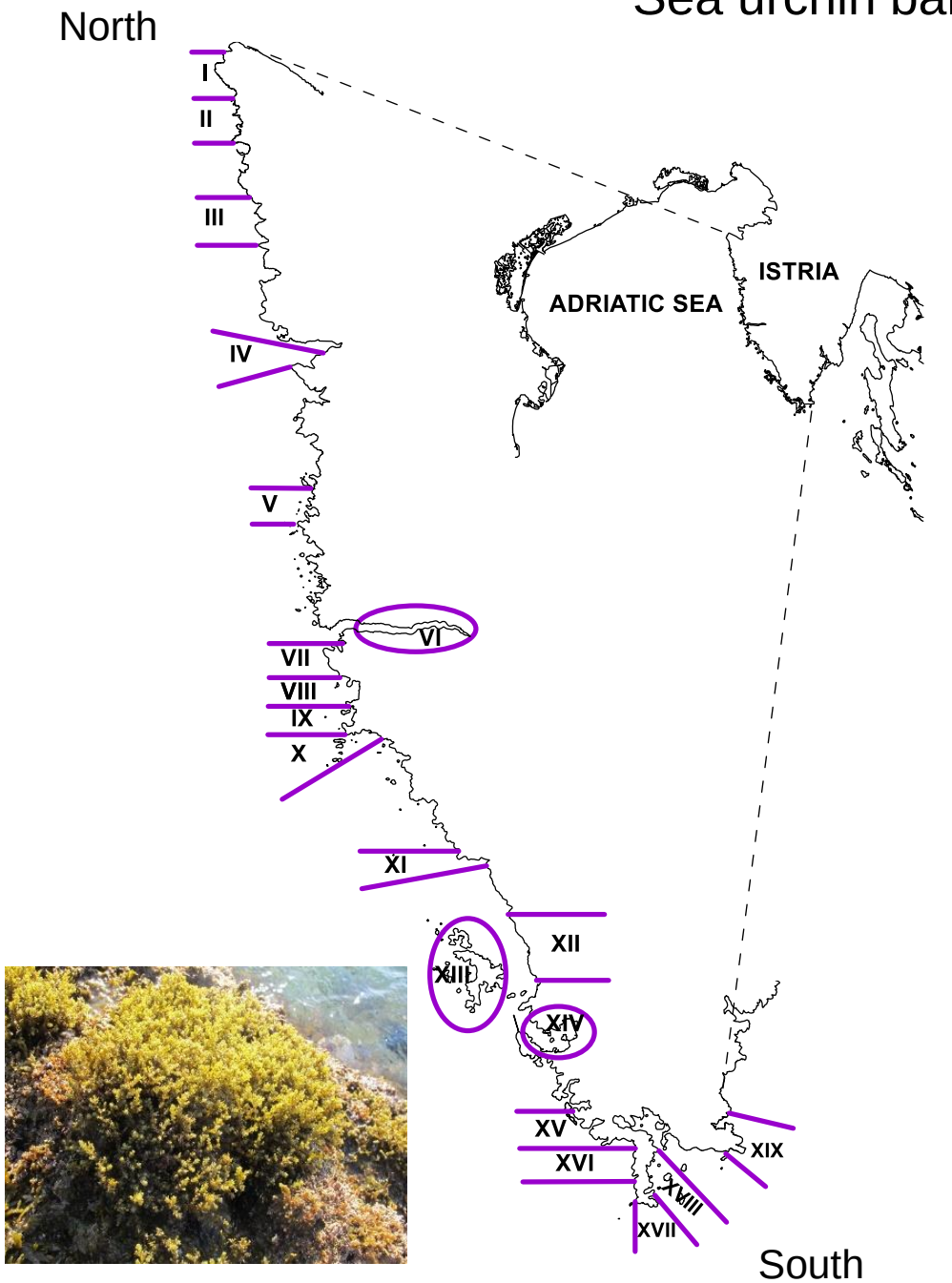


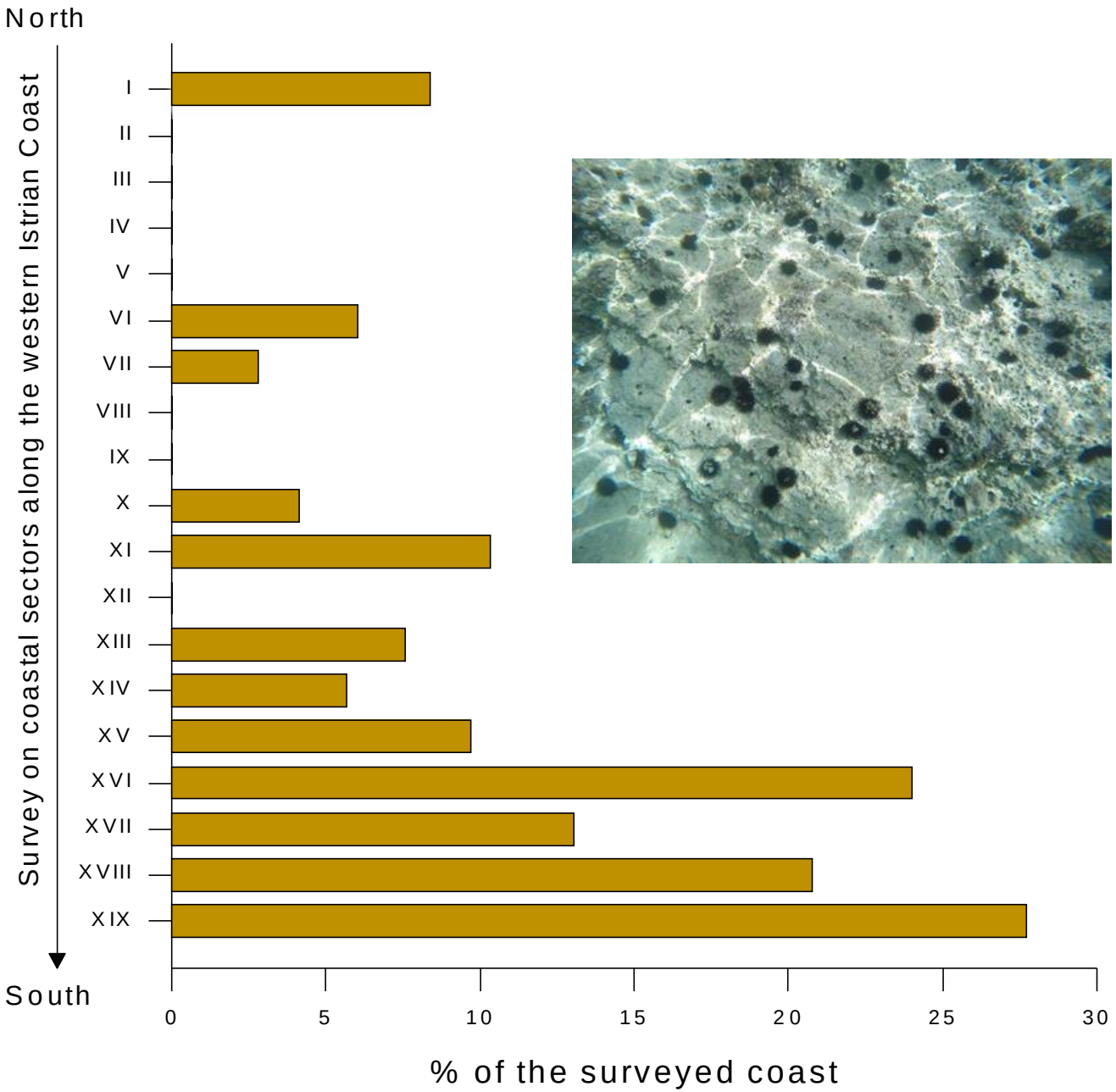




A = continuous stands
B = larger patches
C = sparse patches

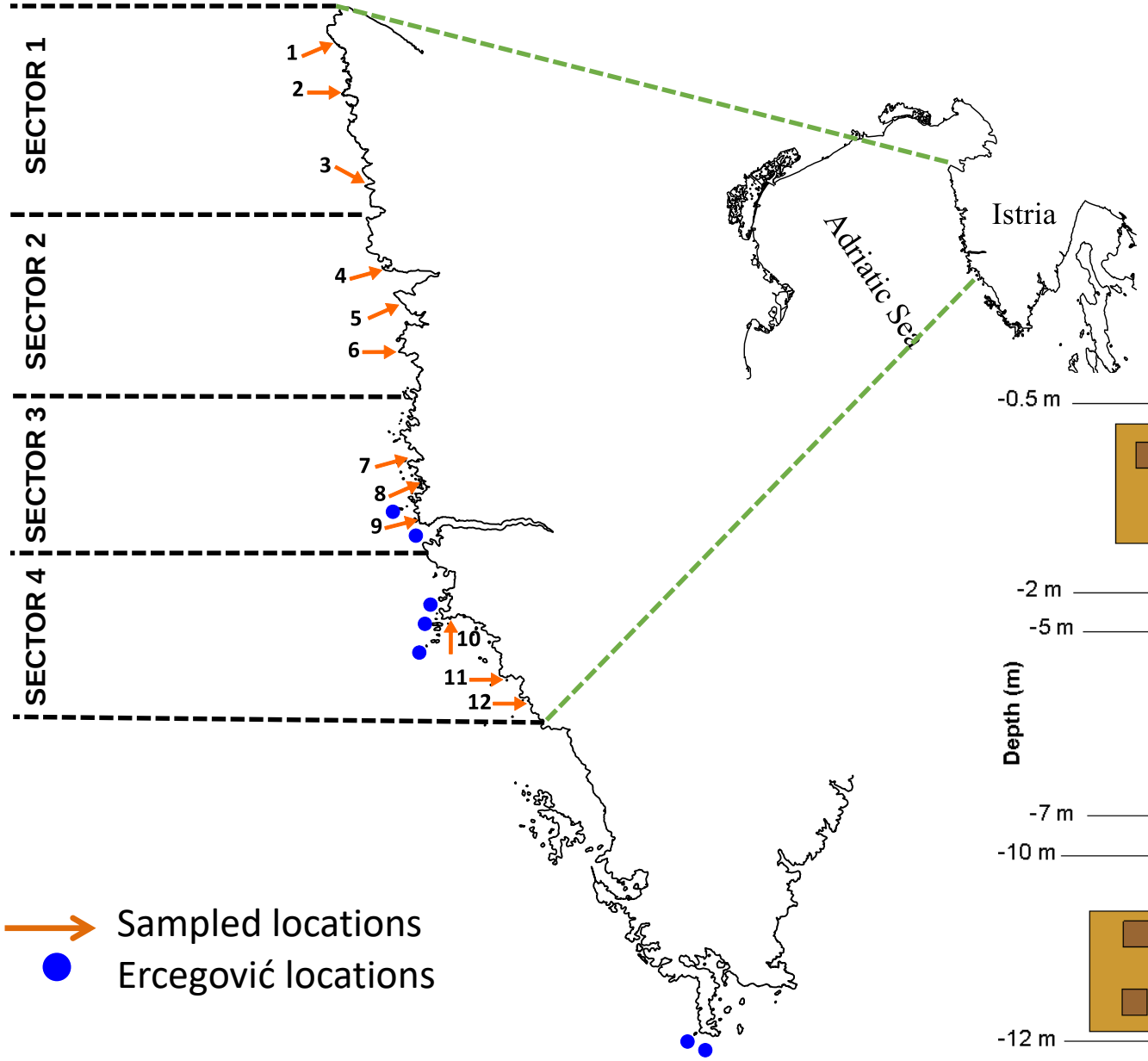
Sea urchin barrens along the Istrian coast in 2015



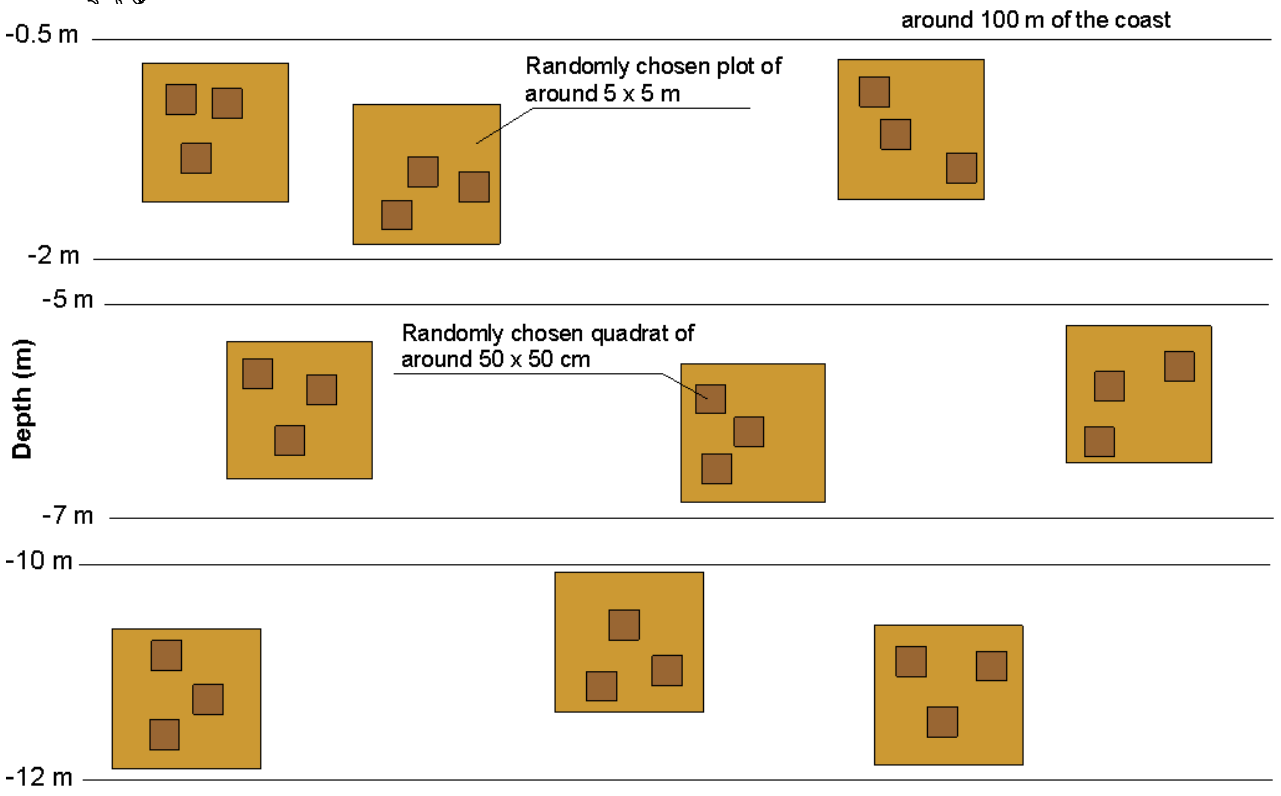


The study area (larger scale sampling)

Composition and abundance of *Cystoseira* forests



Sampling design (for each location)



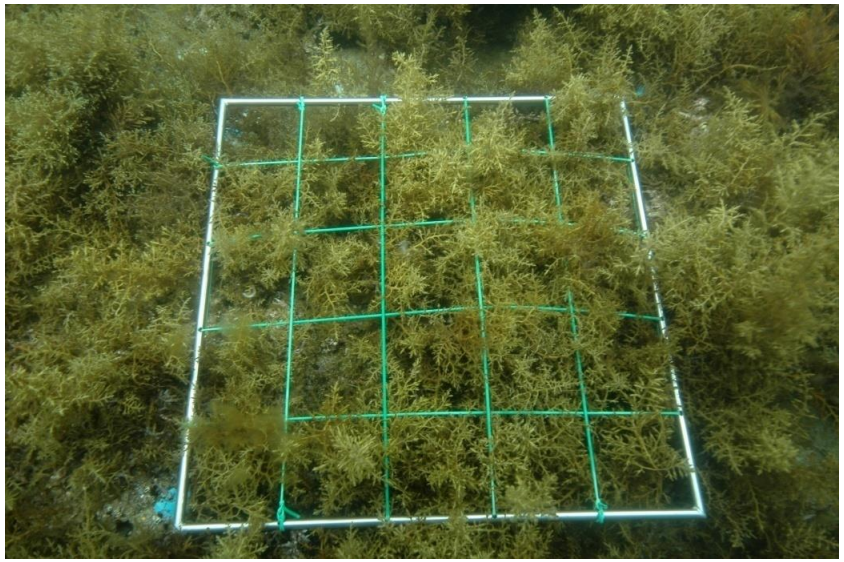
Measures of abundance for canopy-forming species

(1) **Coverage:** percentage of the total sampled area (50 x 50 cm); varies at the temporal scale.

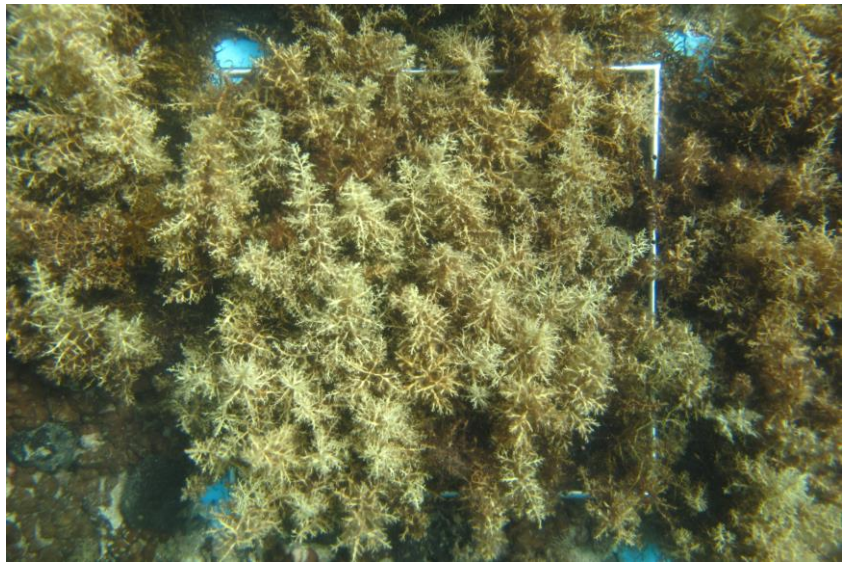
(2) **Total weight of thalli**: varies throughout time because of the **Cystoseira** vegetative cycle.

(3) **The number of thalli**: slightly vary at the temporal scale of years

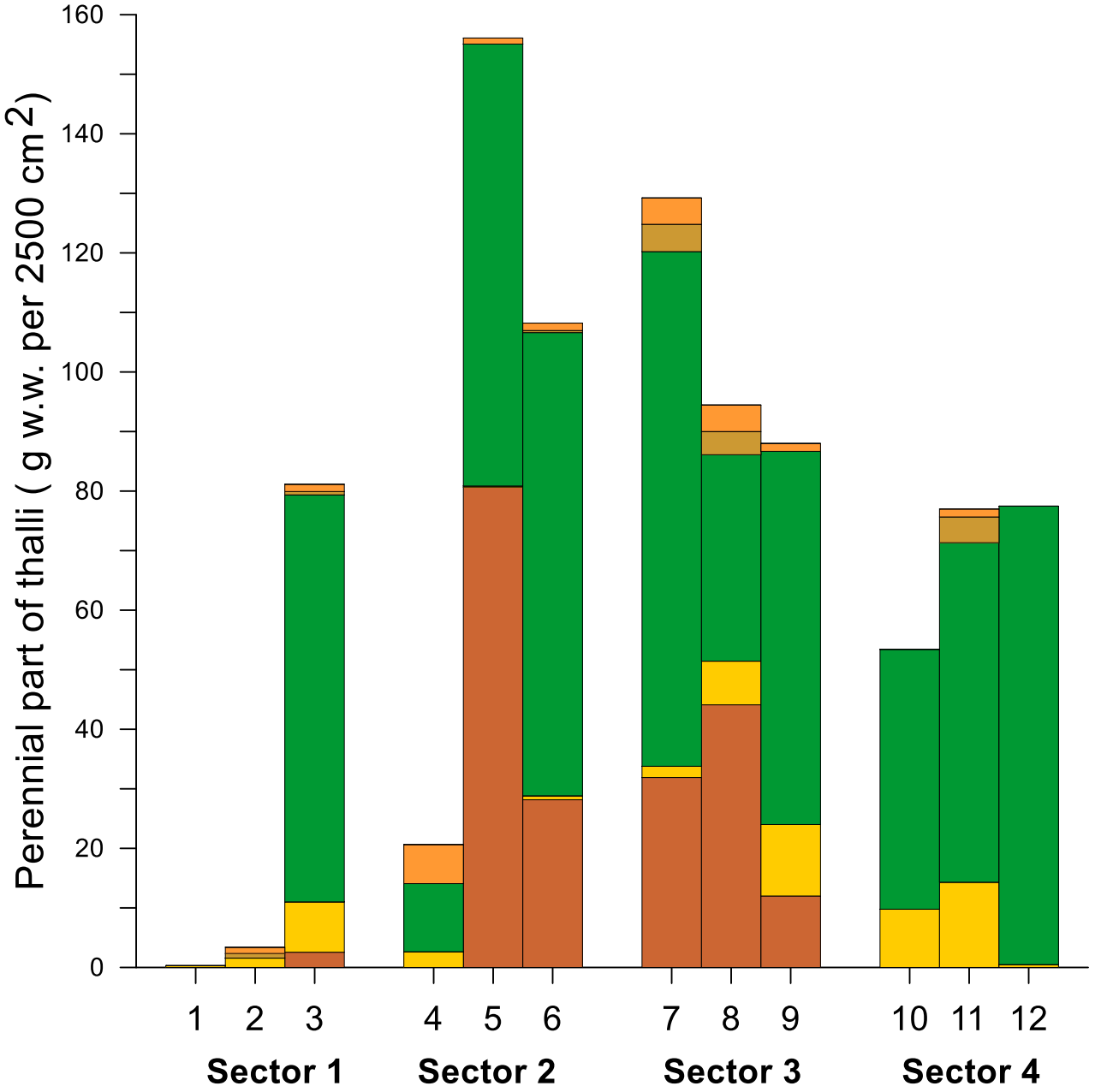
(4) **The total weight of the perennial parts of thalli** (axes + axis's branches + holdfast) may slightly vary at the temporal scale of years.

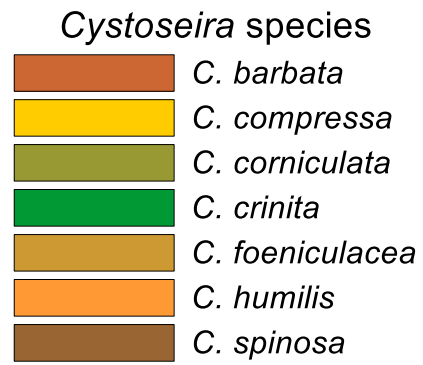


50 x 50 cm

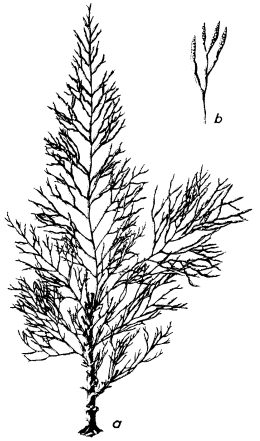


Abundance of canopy-forming species: from 0.5 to 2 m depth

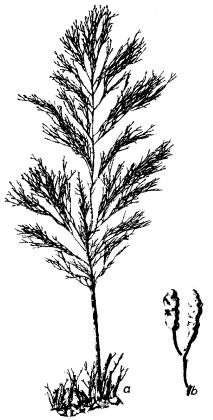




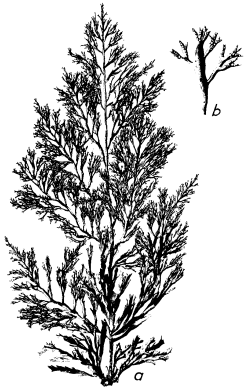
C. barbata



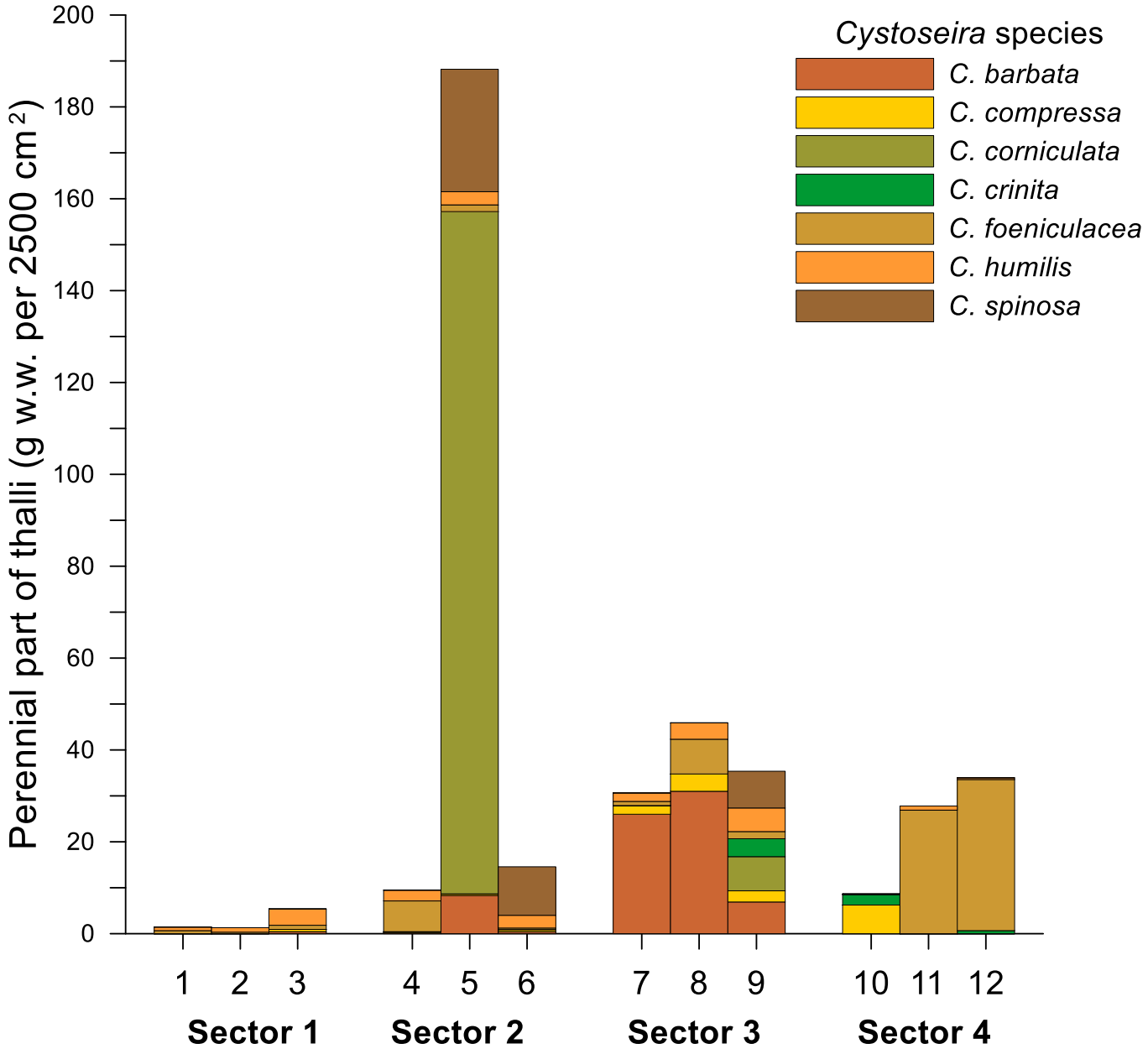
C. crinita



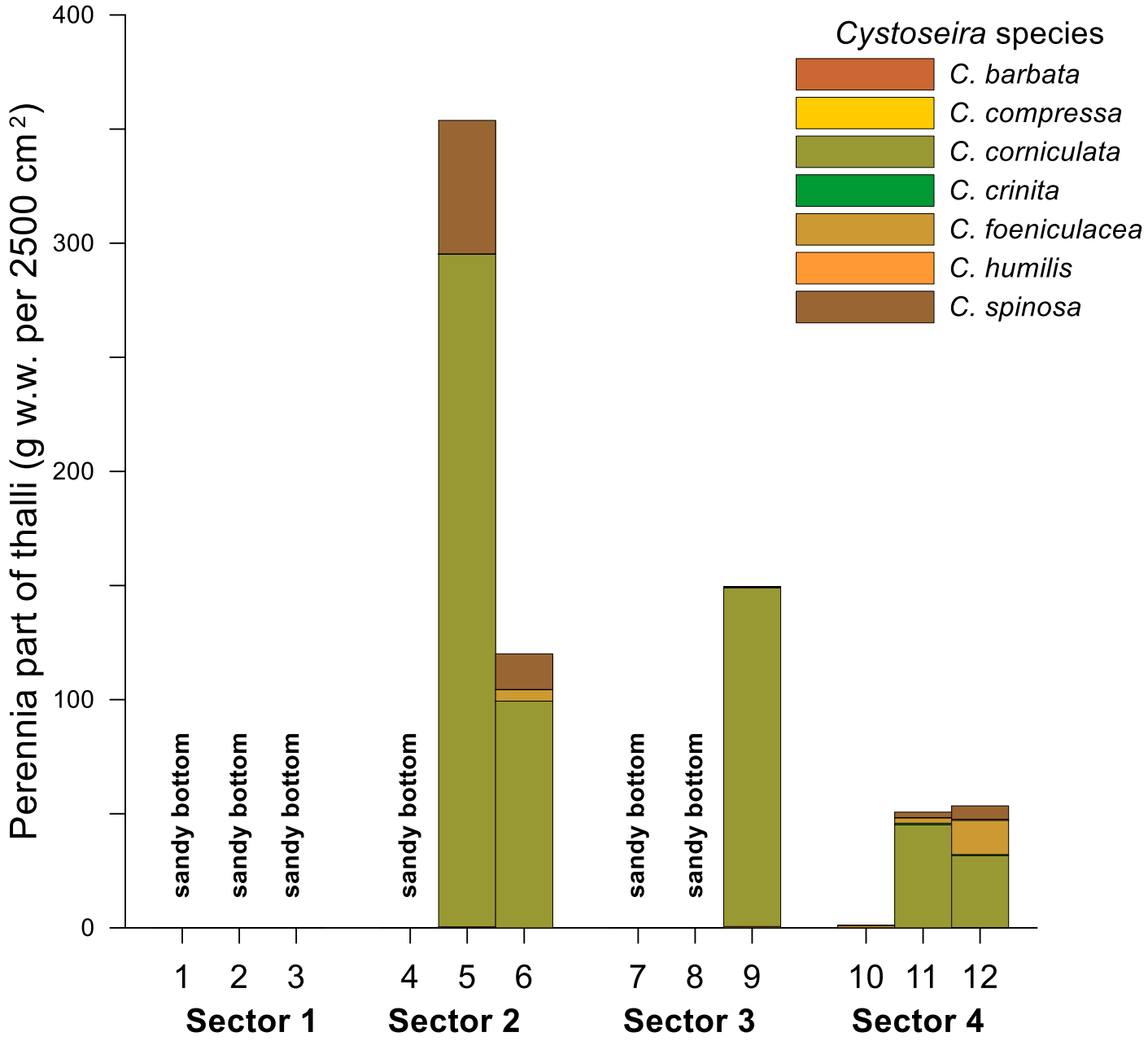
C. compressa



Abundance of canopy-forming species: from 5 to 7 m depth



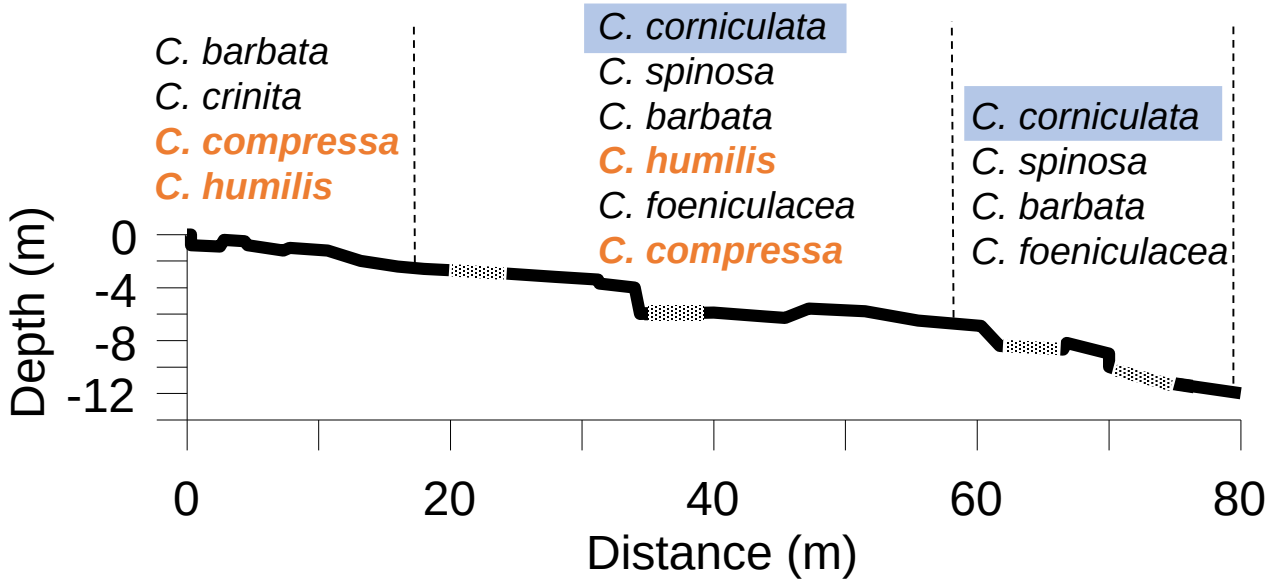
Abundance of canopy-forming species: from 10 to 12 m depth



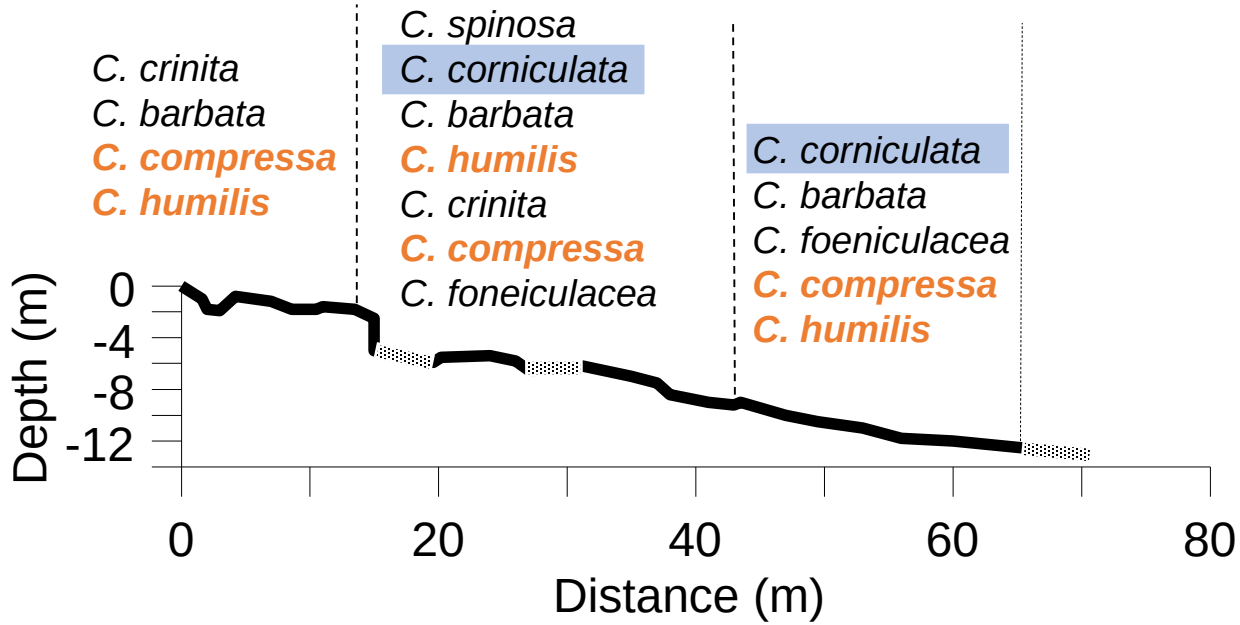
Topography of the rocky bottom

Stepped rocky bottom: slope = 8–12◦, sandy bottom fraction = 7–20% and vertical relief = 12–22%

SECTOR 2: Novigrad
Location 5



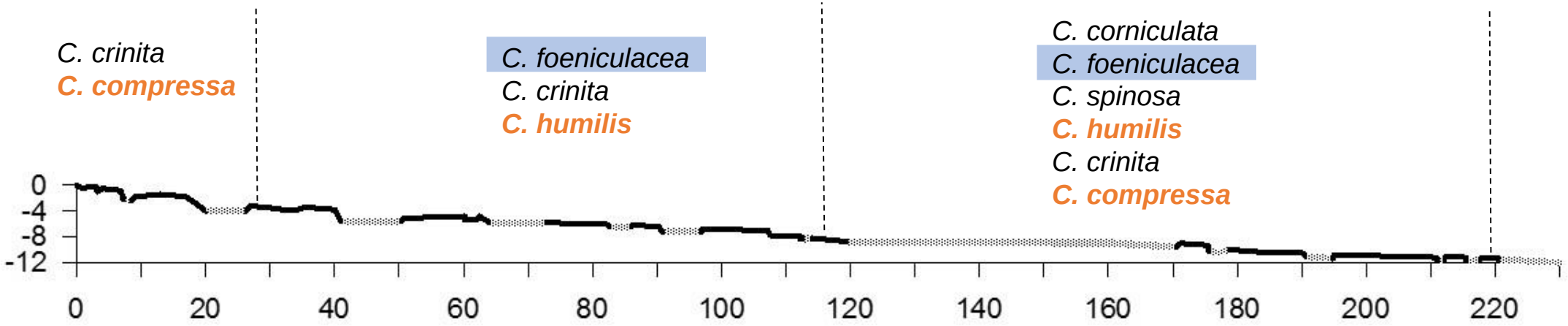
SECTOR 3: Vrsar
Location 9

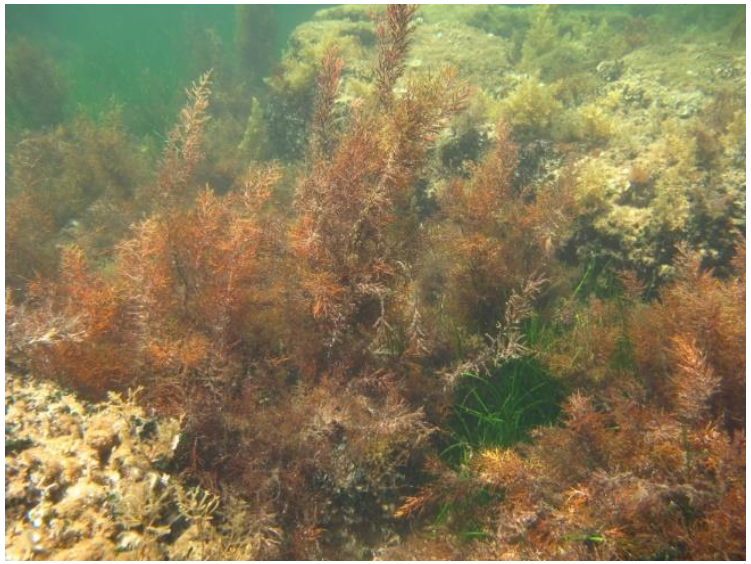


Topography of the rocky bottom

Flat rocky-sandy bottom: slope = 3–5◦, sandy bottom fraction = 47–63% and vertical relief = 2–3%

SECTOR 4: Rovinj
Location 12





Marine Pollution Bulletin 106 (2016) 162–173

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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Long-term fluctuations in *Cystoseira* populations along the west Istrian Coast (Croatia) related to eutrophication patterns in the northern Adriatic Sea

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ARTICLE INFO

Article history:
Received 23 November 2015
Received in revised form 3 March 2016
Accepted 6 March 2016
Available online 12 March 2016

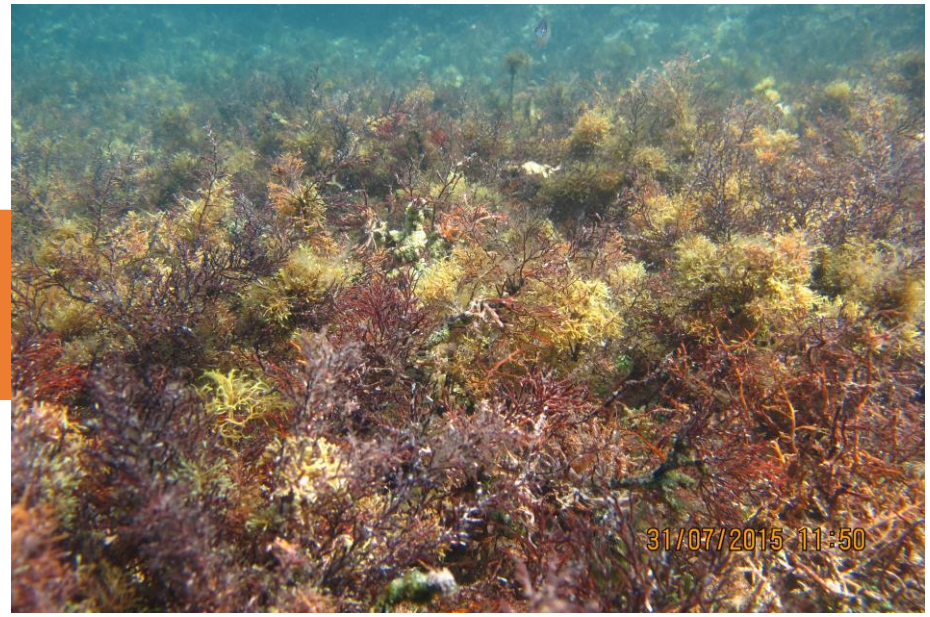
Keywords:
Cystoseira
Long-term changes
Eutrophication
Sea urchins
Pelagic mucilage
Northern Adriatic Sea

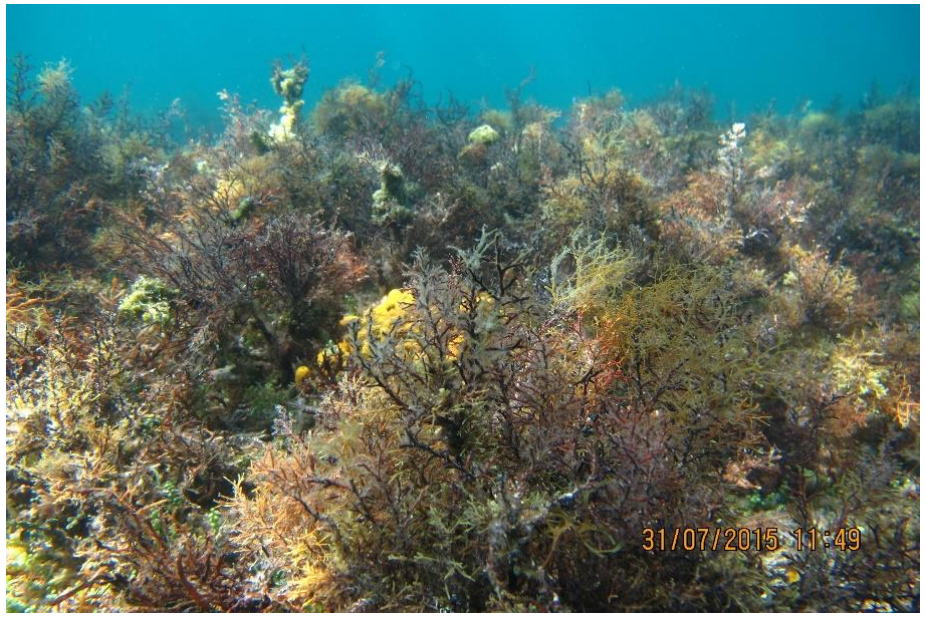
ABSTRACT

An exploration of historical data suggested that eutrophication patterns might drive long-term fluctuations in *Cystoseira* populations along the west Istrian Coast (northern Adriatic Sea, Croatia). The regimes of northern Italian rivers, which flow approximately 100 km west of the study area, mainly modulate the eutrophication levels of the northern Adriatic Sea. A regression of *Cystoseira* populations from the 1970s through the 1990s corresponded to increased levels of eutrophication in the study area. During the late 1990s, the density of sea urchins, which are efficacious macroalgal predators, decreased, likely due to an intense formation of pelagic mucilage aggregates that resulted in mass mortality episodes of macrozoobenthic species. During the 2000–2013 period, an oligotrophication of the northern Adriatic formed the basis for the recovery of *Cystoseira* taxa, whose abundances from 2009 to 2013 were similar to those characterising the most flourishing Mediterranean *Cystoseira* assemblages.

✓ mass mortality event of ***Cystoseira barbata*** during the period winter–spring 2016

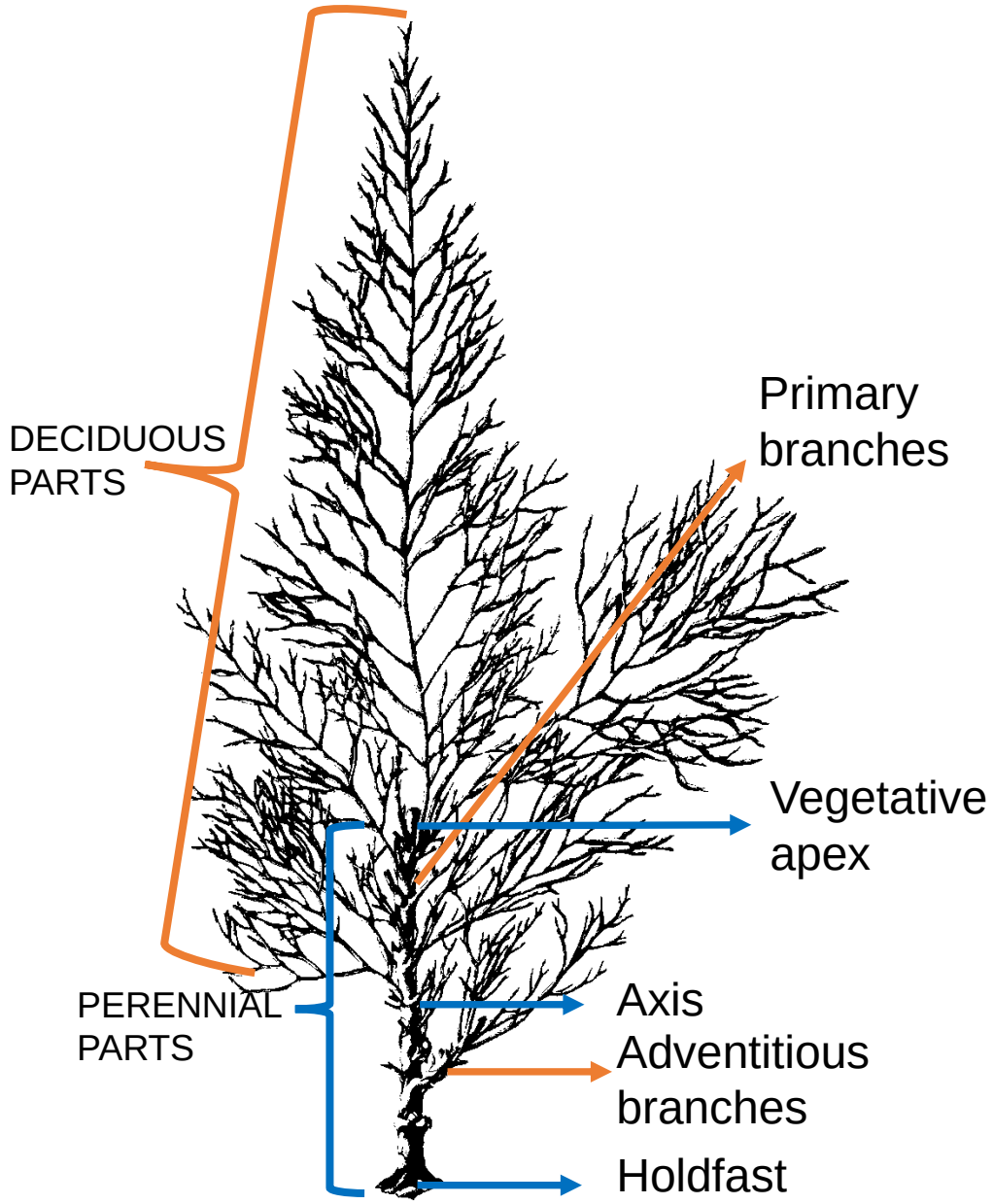
Summer 2015





Spring 2016

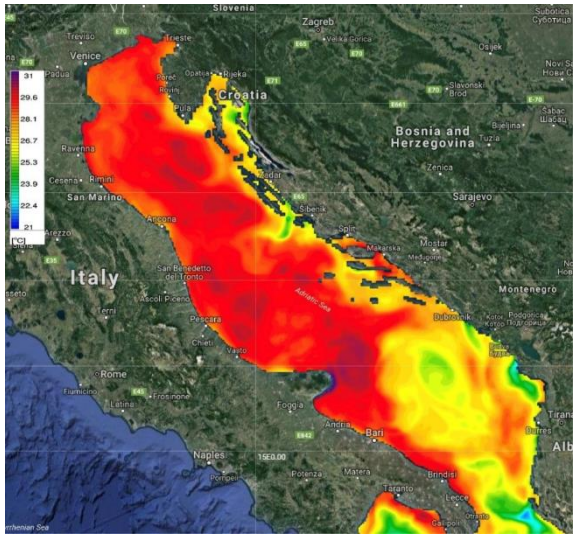
Cystoseira barbata (Stackhouse) C. Agardh

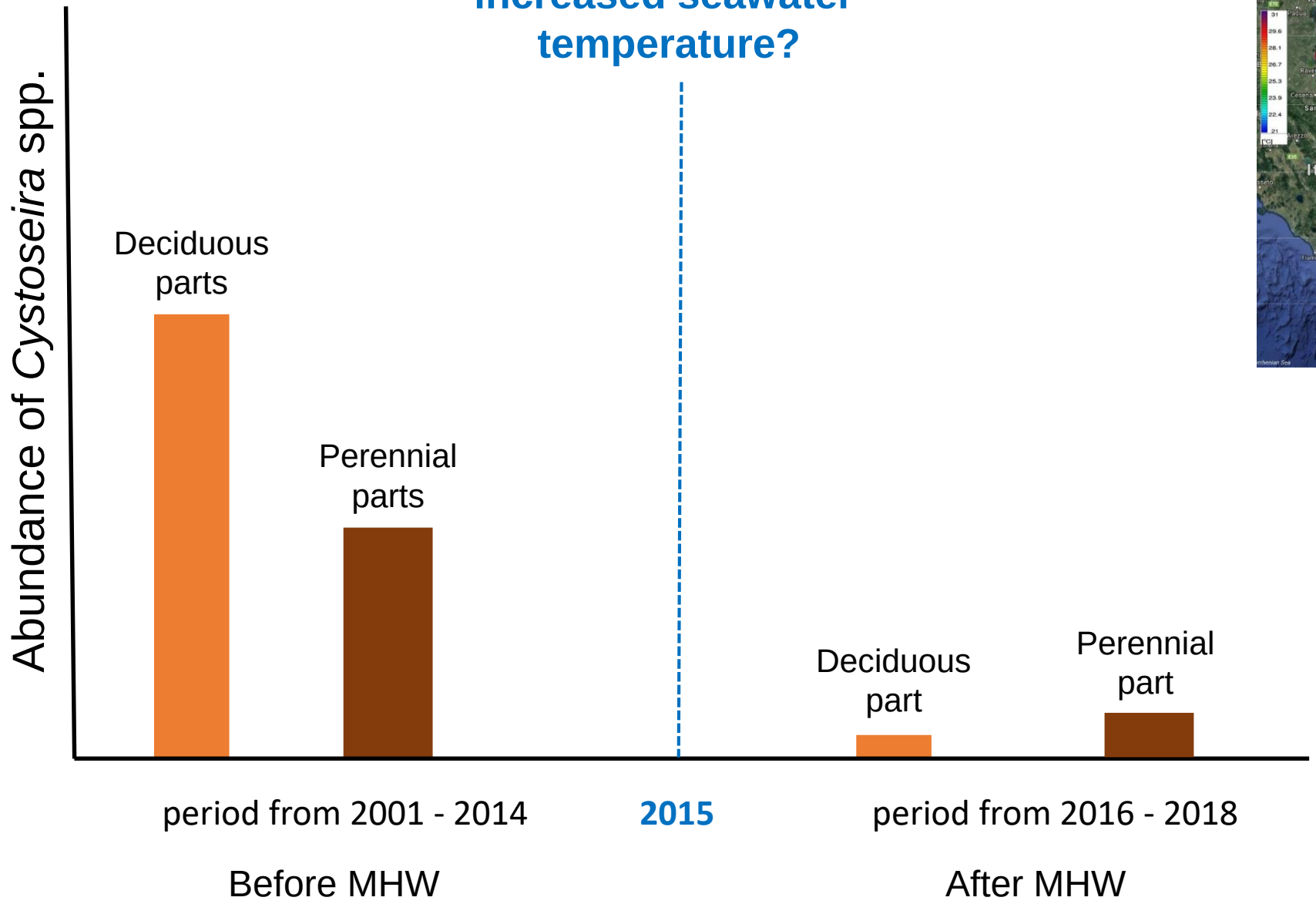


What are the mechanisms that caused *Cystoseira* regression?

1. *Cystoseira* regression and Marine heat waves (MHW)

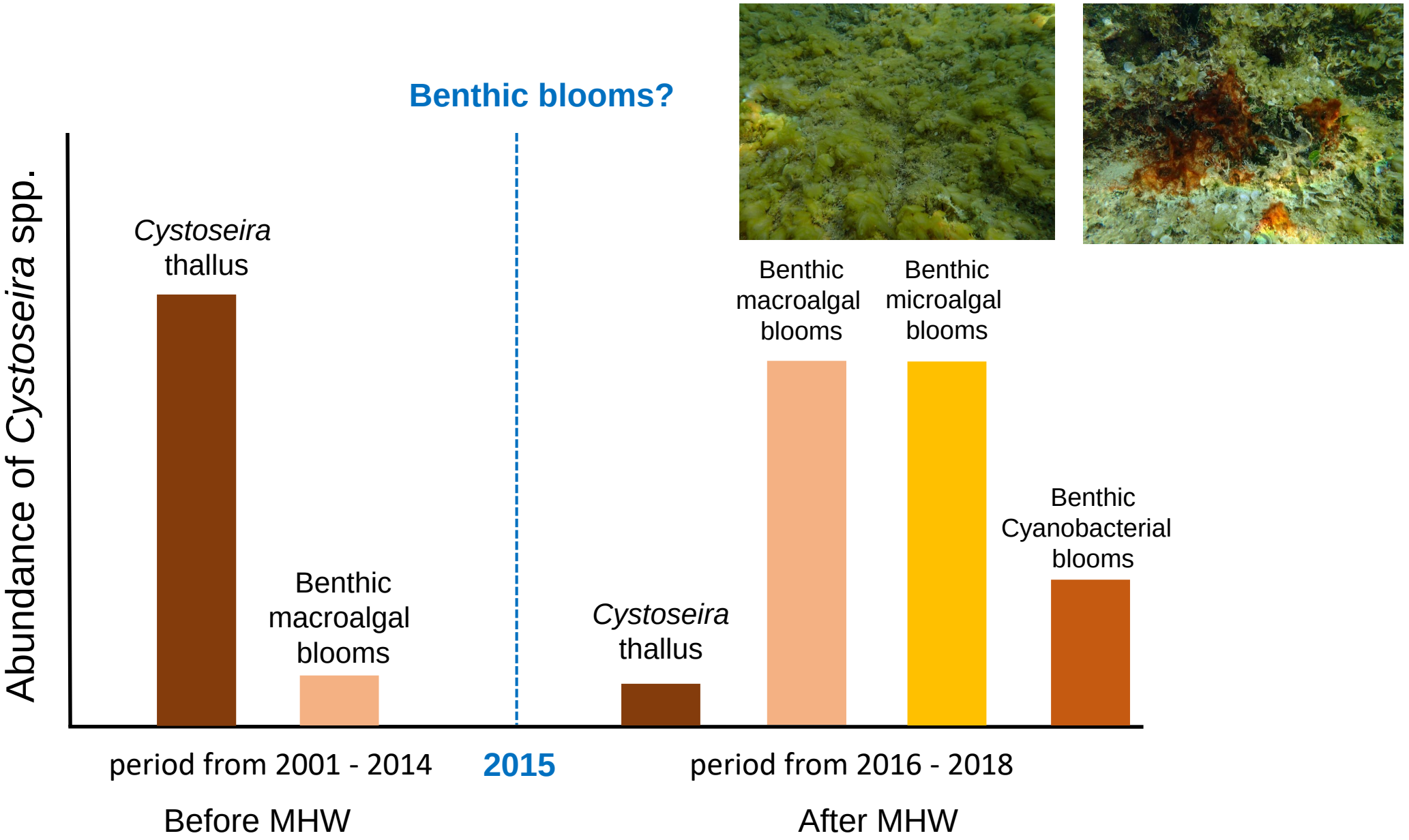
increased seawater temperature?





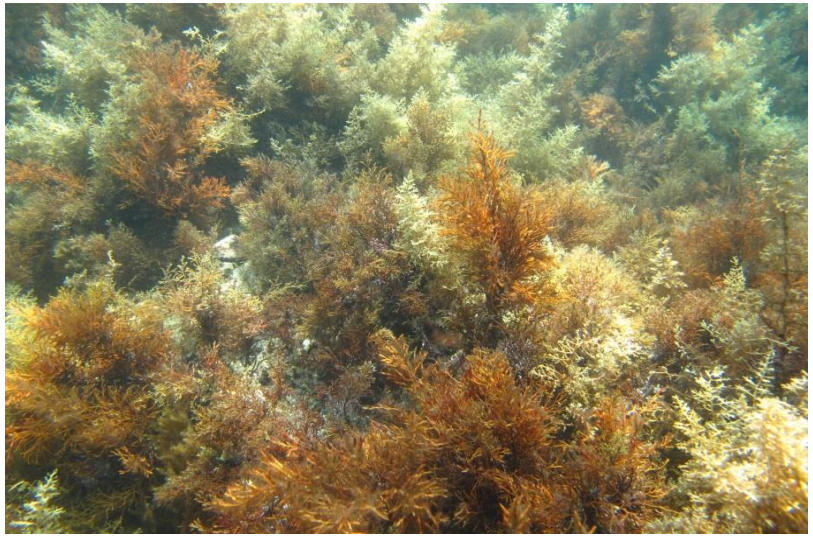
What are the mechanisms that caused *Cystoseira* regression?

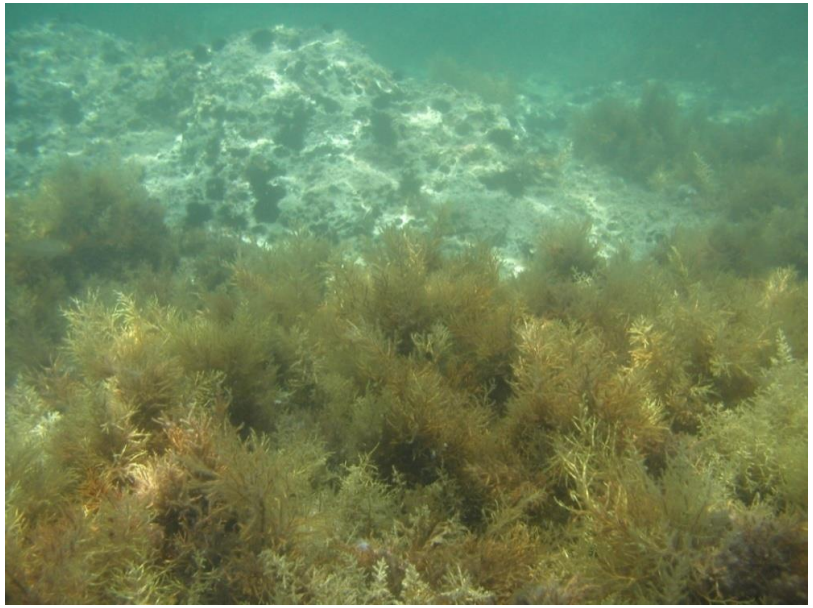
2. *Cystoseira* regression and Benthic macro- and/or micro-algal blooms

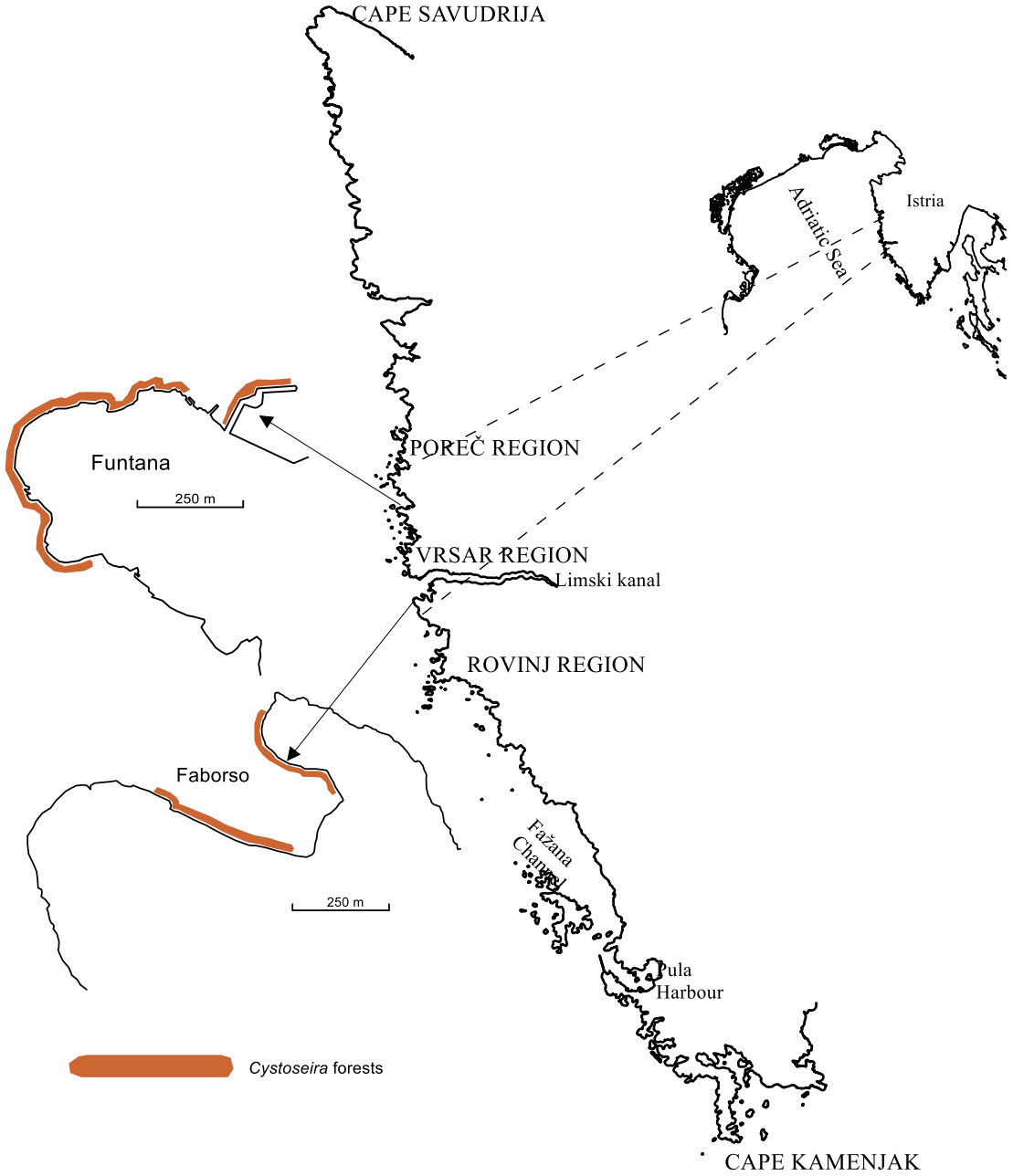


Cystoseira forests in 2 locations along the western Istria Coast from 2014 to 2018

Subtidal zone



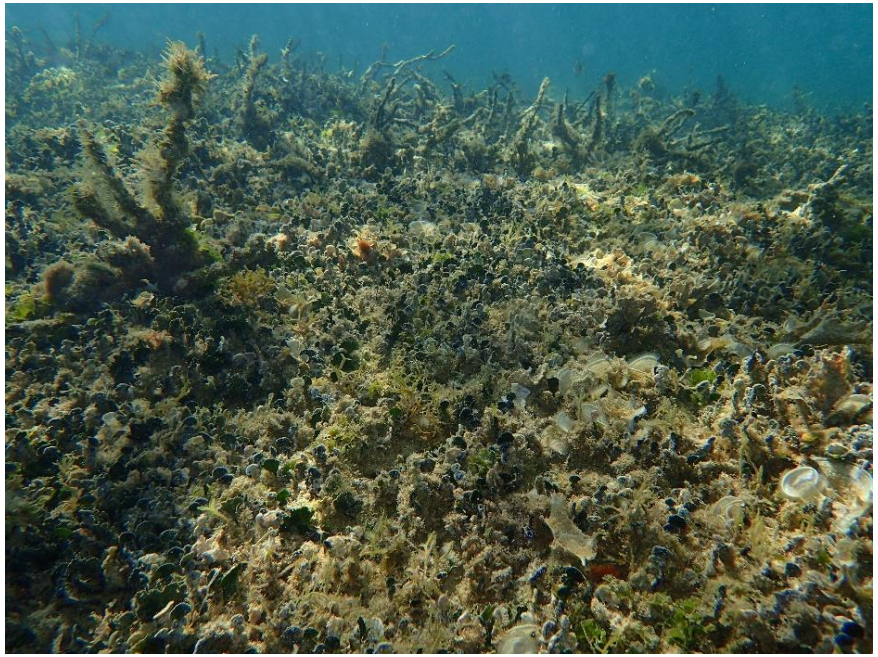




Location 1: FUNTANA

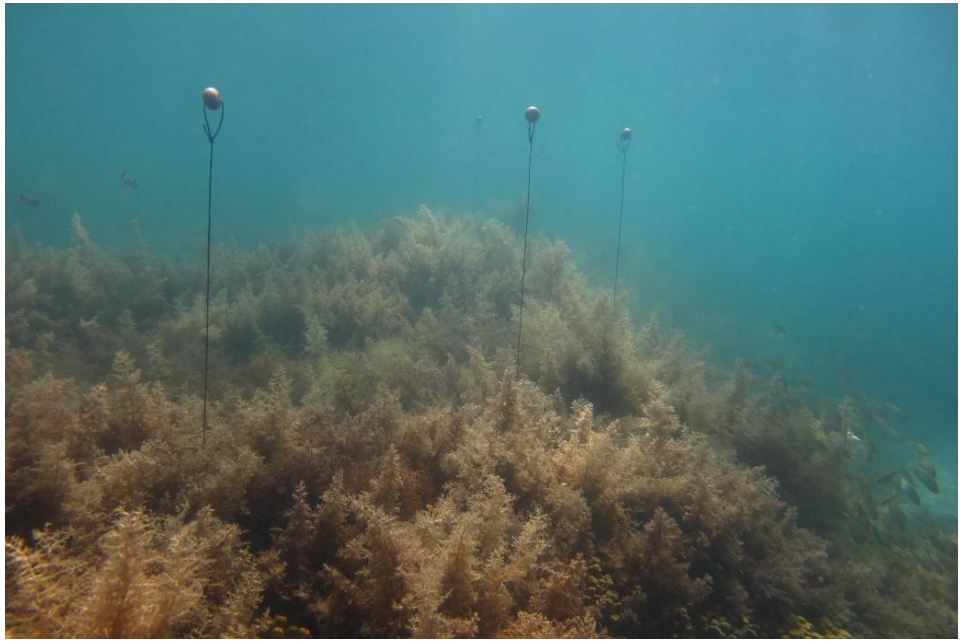
2014

2016 – 2017

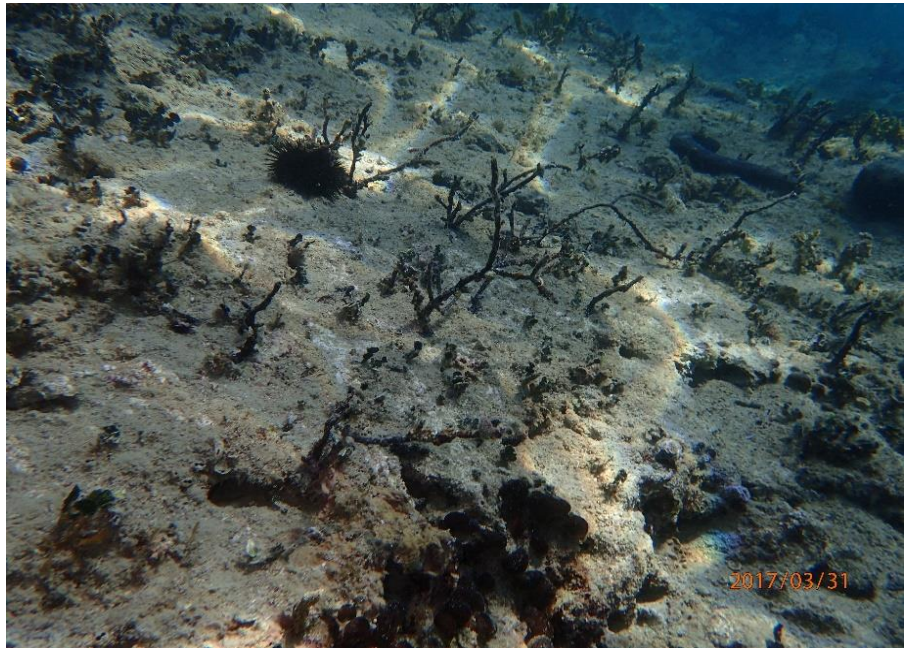


Location 2: FABORSO

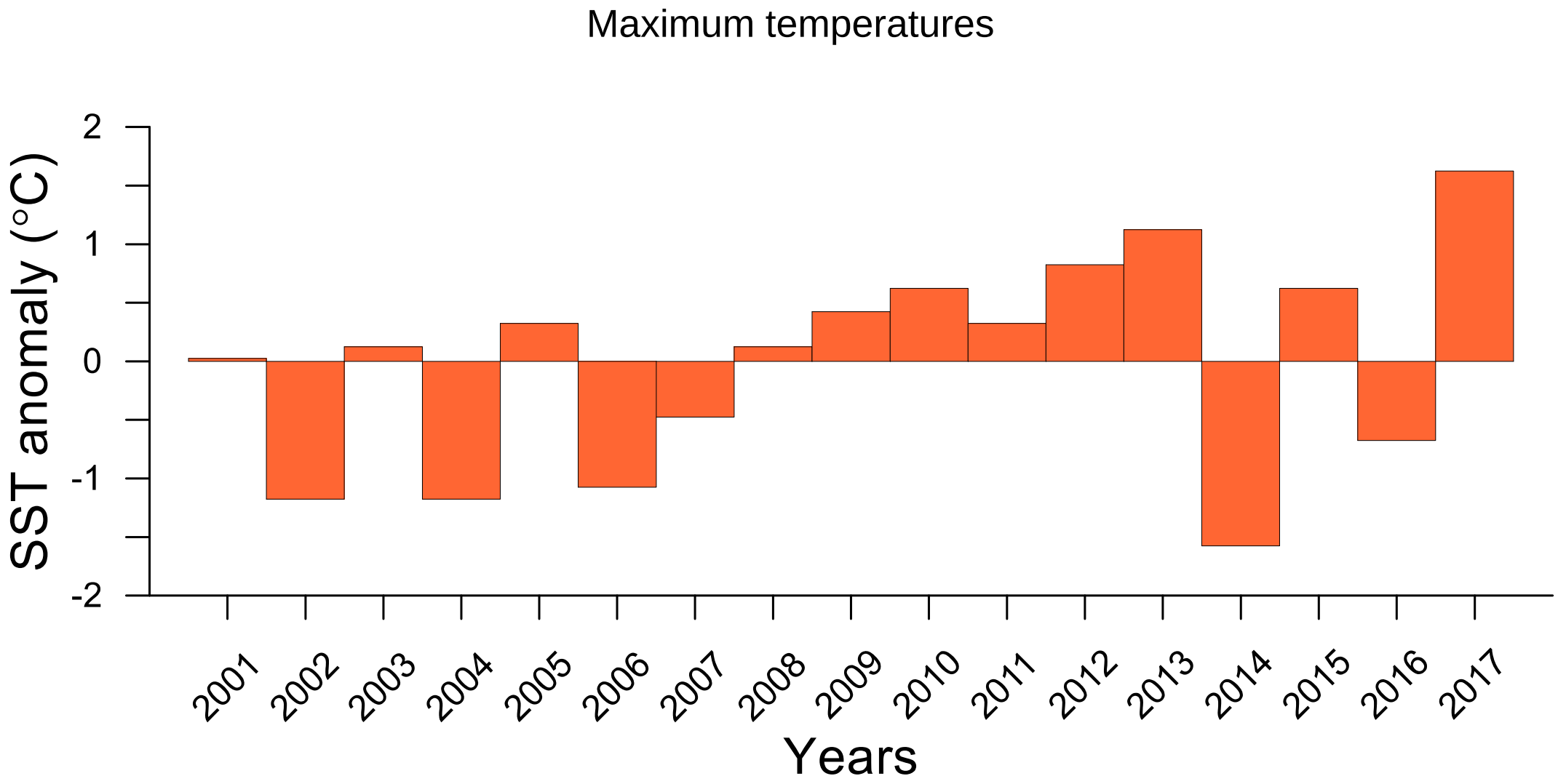
2014



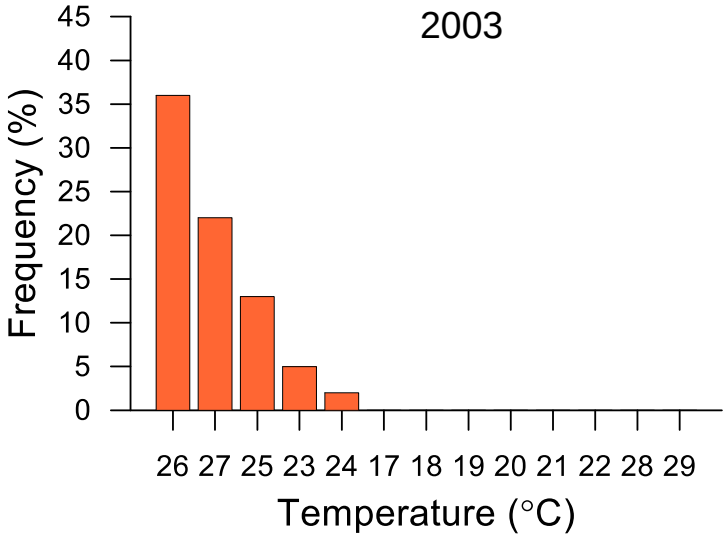
2016 – 2017

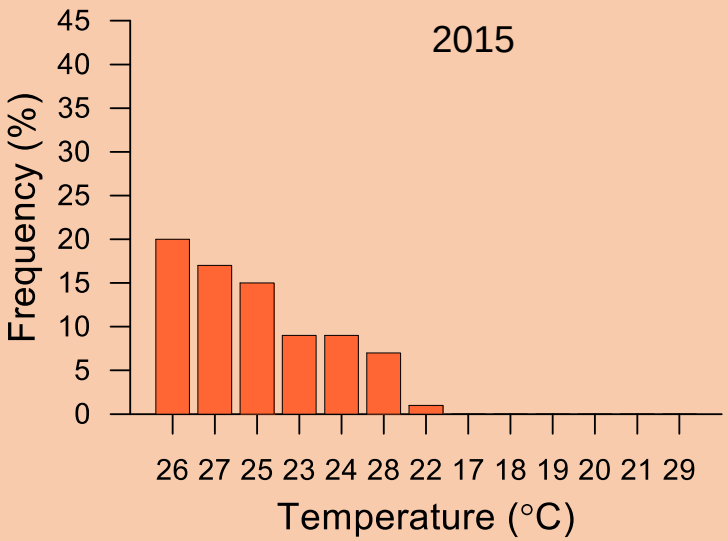


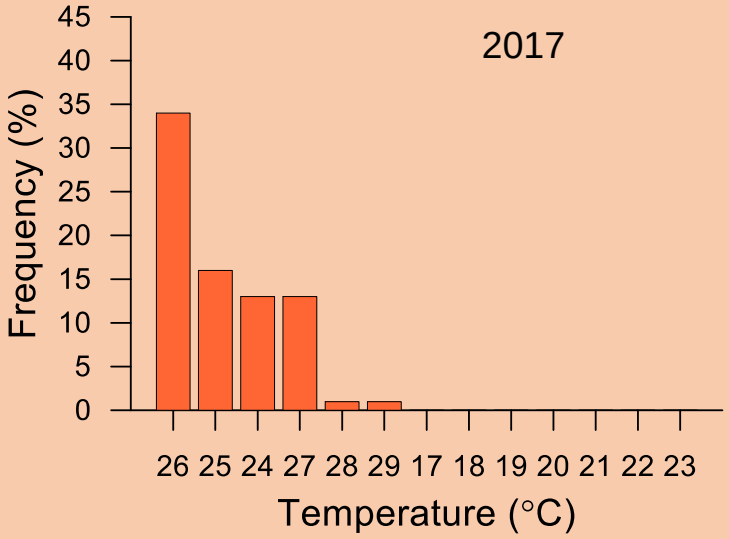
Sea surface temperature anomalies from 2001 to 2017 at the meteorological station of the Sveti Ivan Islet (Rovinj, northern Adriatic)



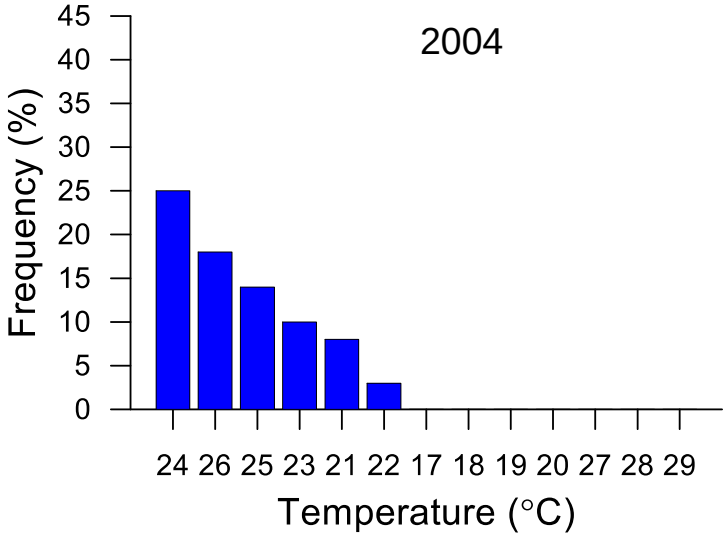
Extremely warm summer

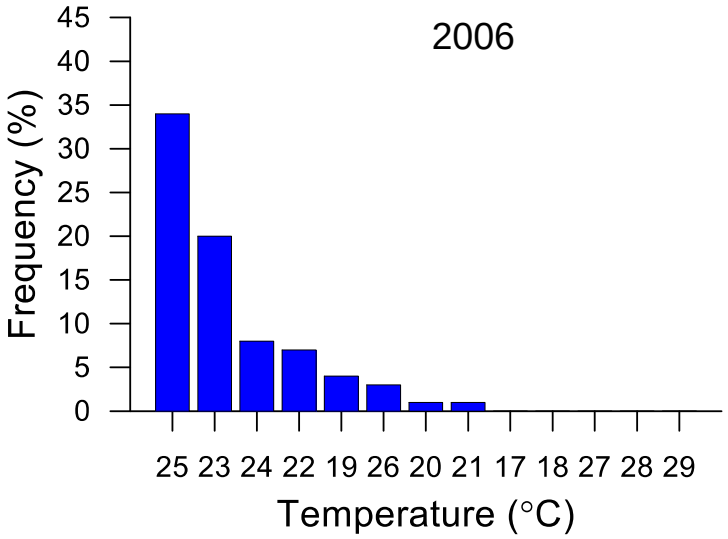


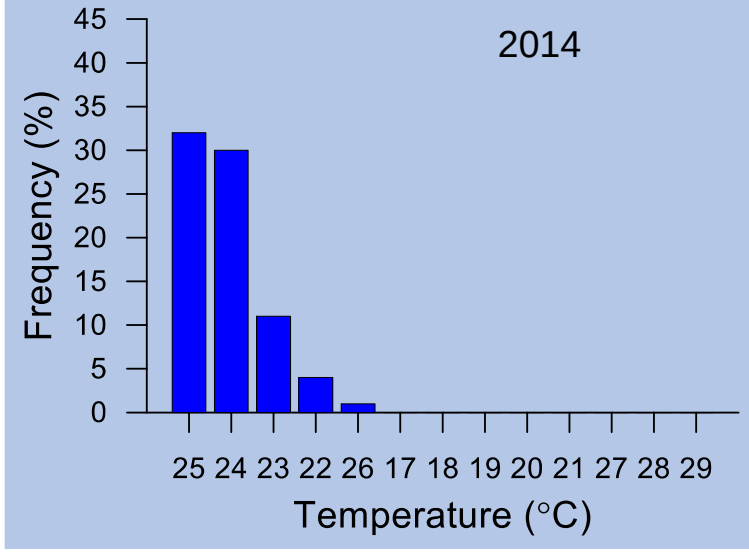




„Normal" summer

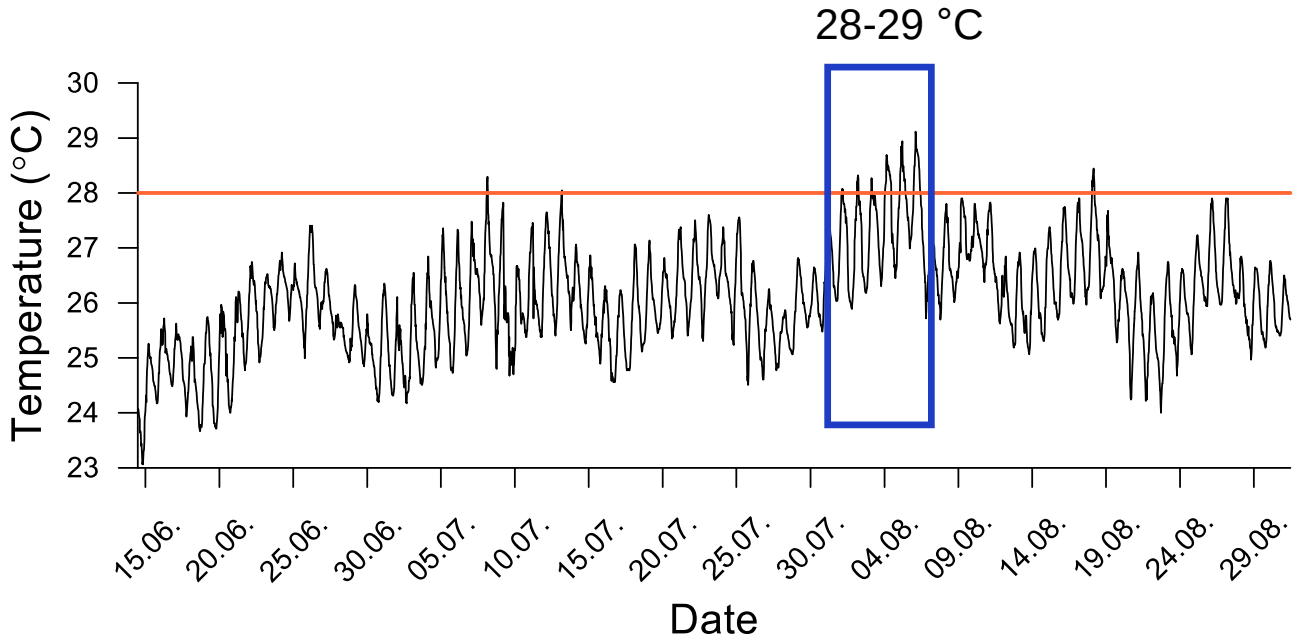




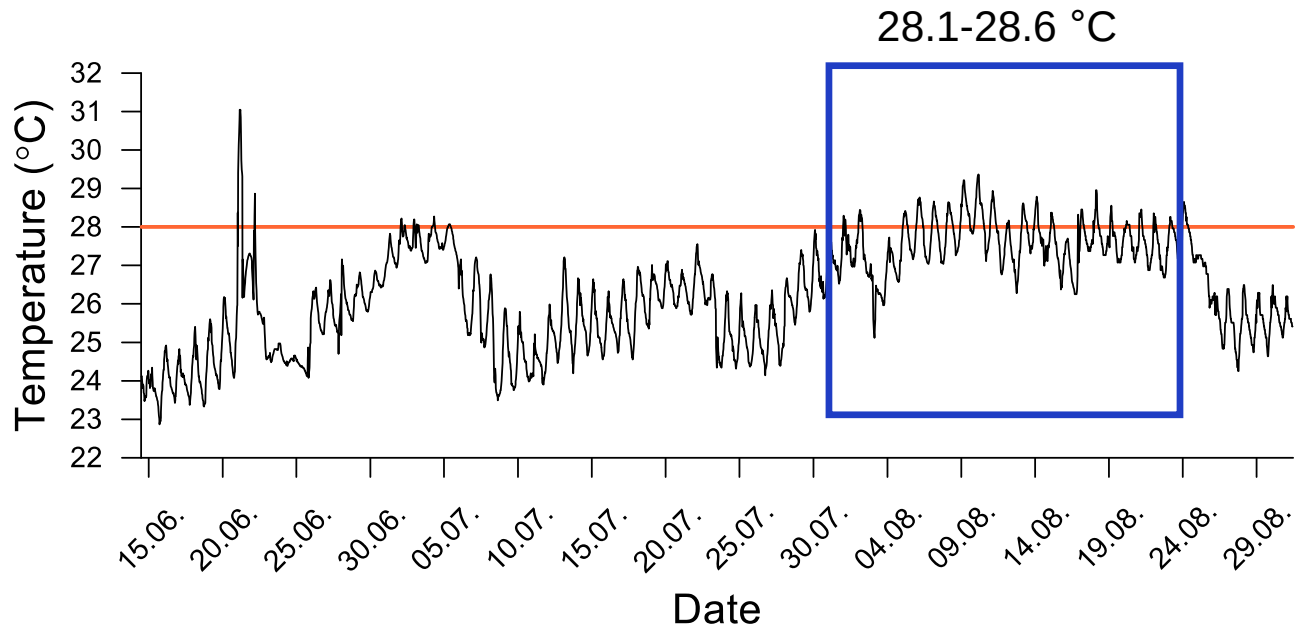


Daily seawater temperature at 2 m depth in the *Cystoseira* forests of Vrsar:
from 15/06/2017 to 30/08/2017 and from 15/06/2018 to 30/08/2018.

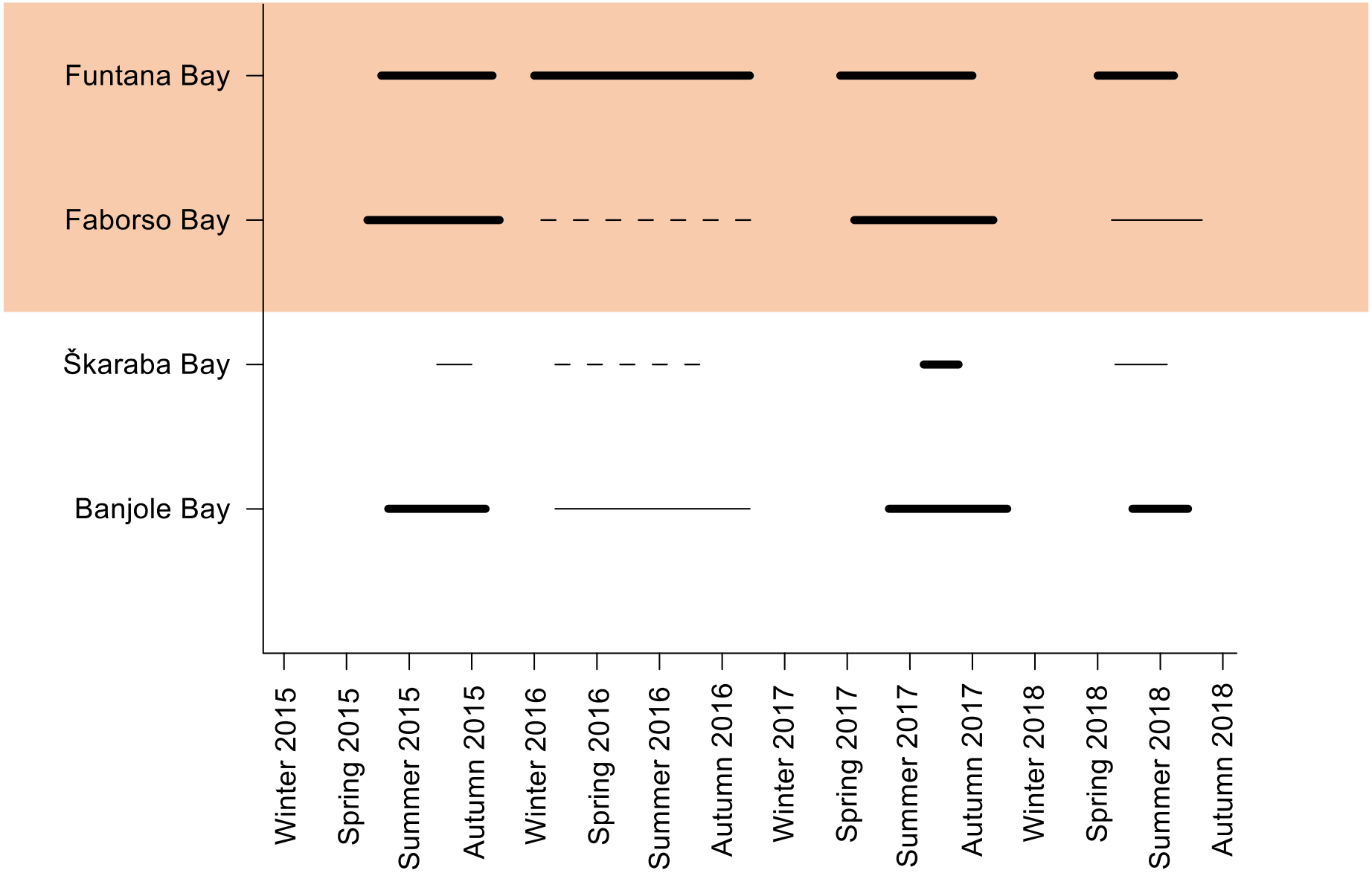
2017



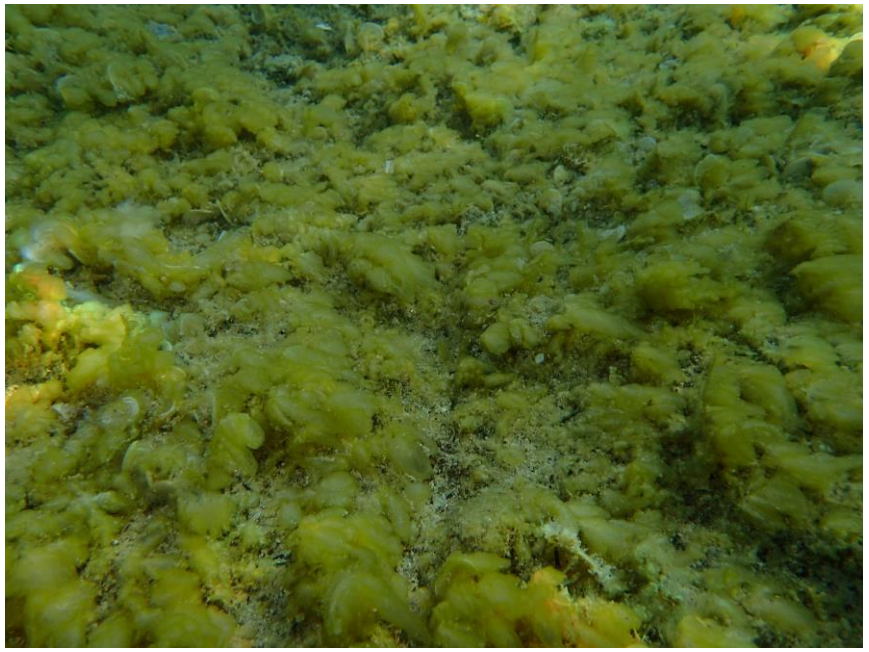
2018



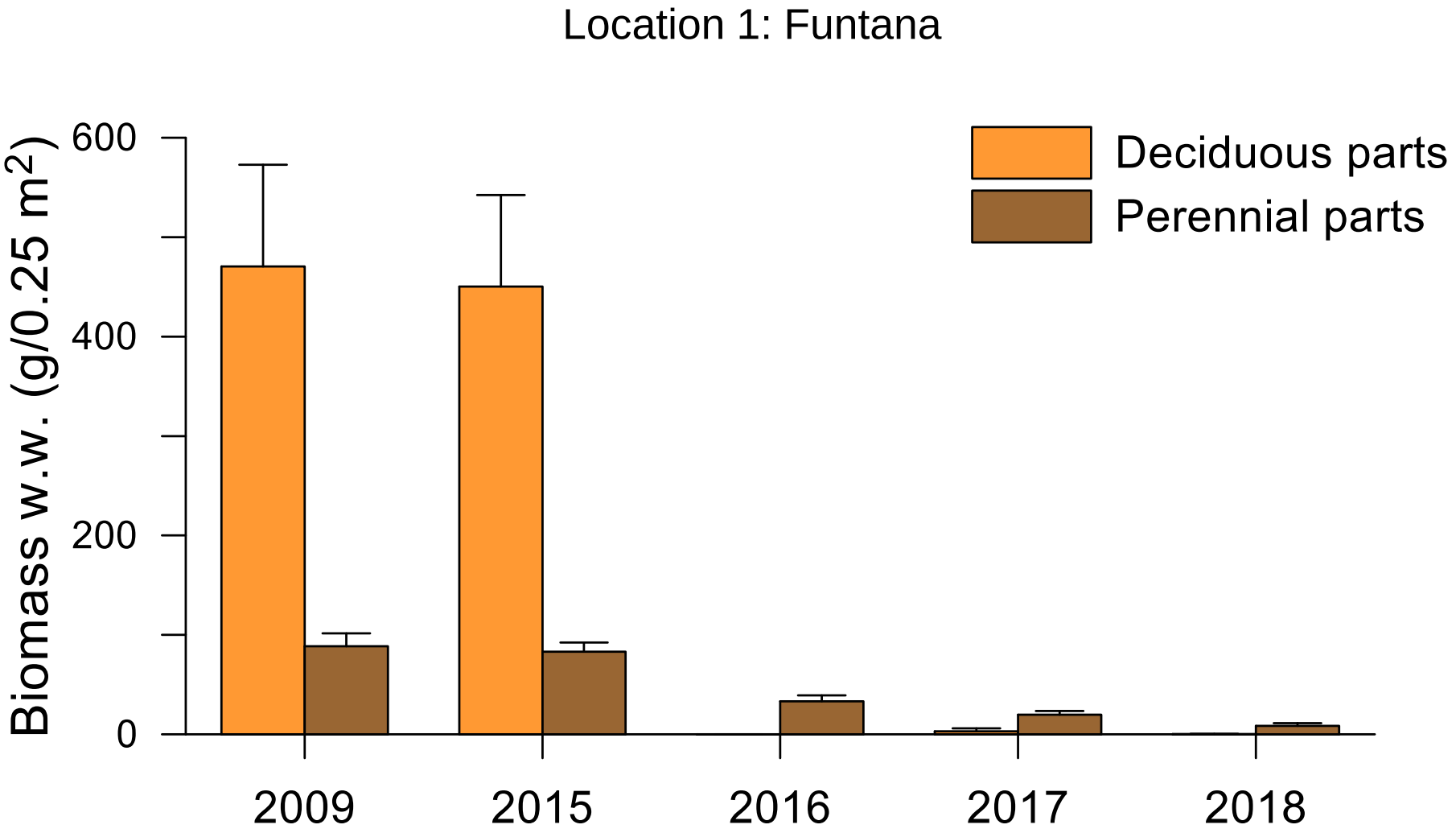
Chronology of the manifestation of the benthic mucilage phenomenon along the western Istria Coats from 2015 to 2018.



Benthic mucilage formation

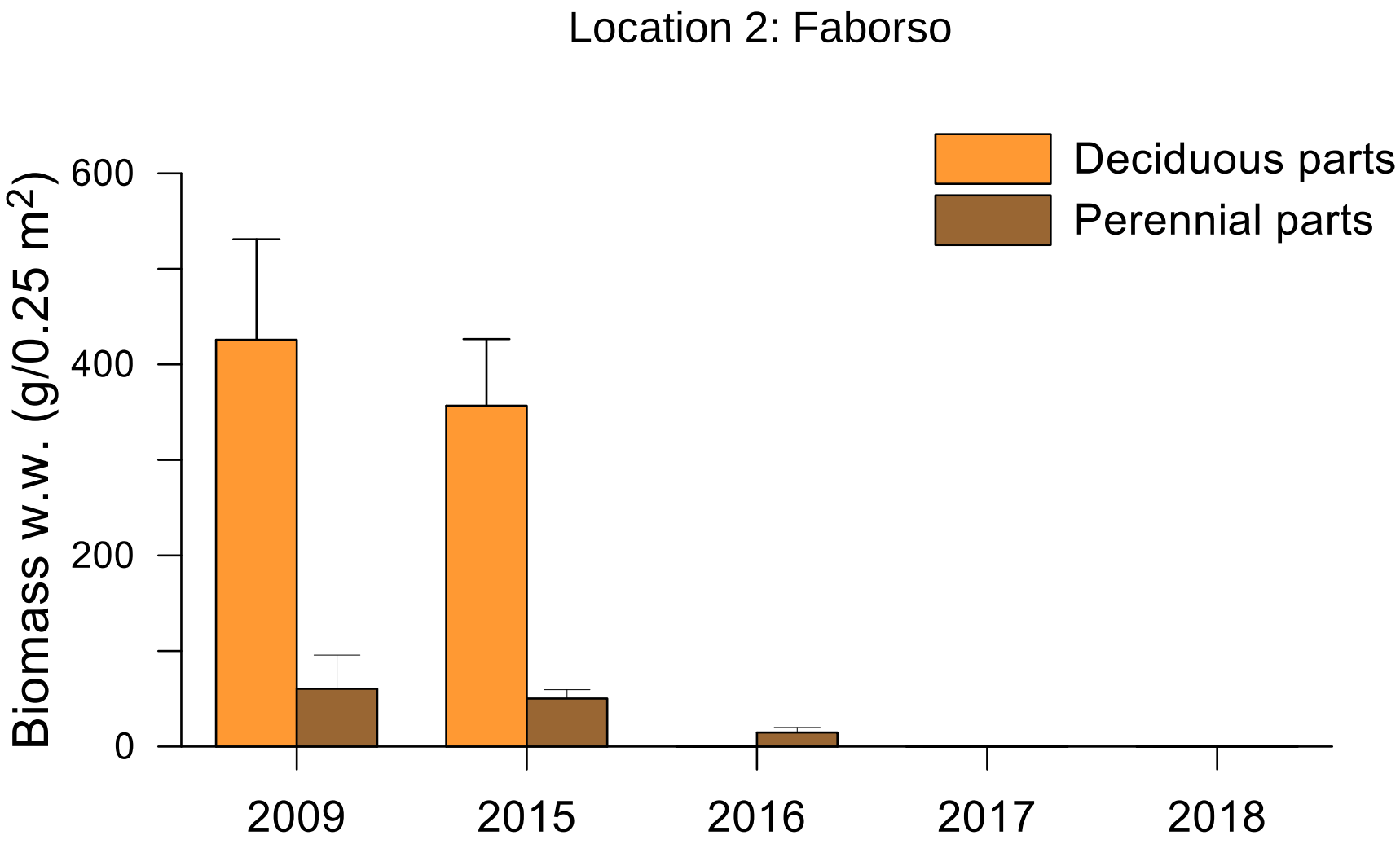


Biomass of *Cystoseira barbata* deciduous (primary and adventive branches) and perennial part (axes, axis branches and holdfast).



Perennial parts: * Year: 2018 = 2017 = 2016 < 2015 = 2009

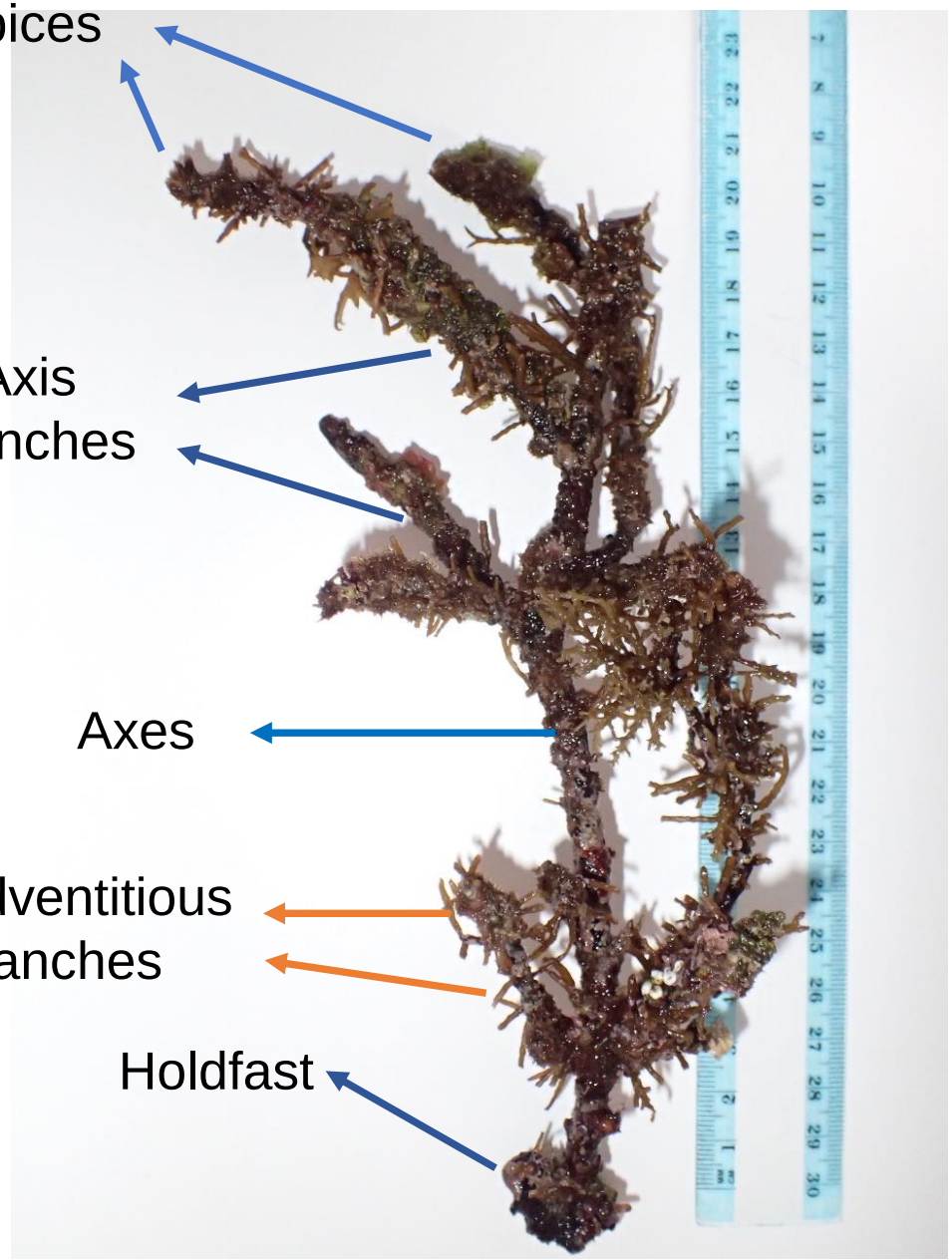
Biomass of *Cystoseira barbata* deciduous (primary and adventive branches) and perennial part (axes, axis branches and holdfast).



Perennial parts: * Year: 2016 < 2009 = 2015

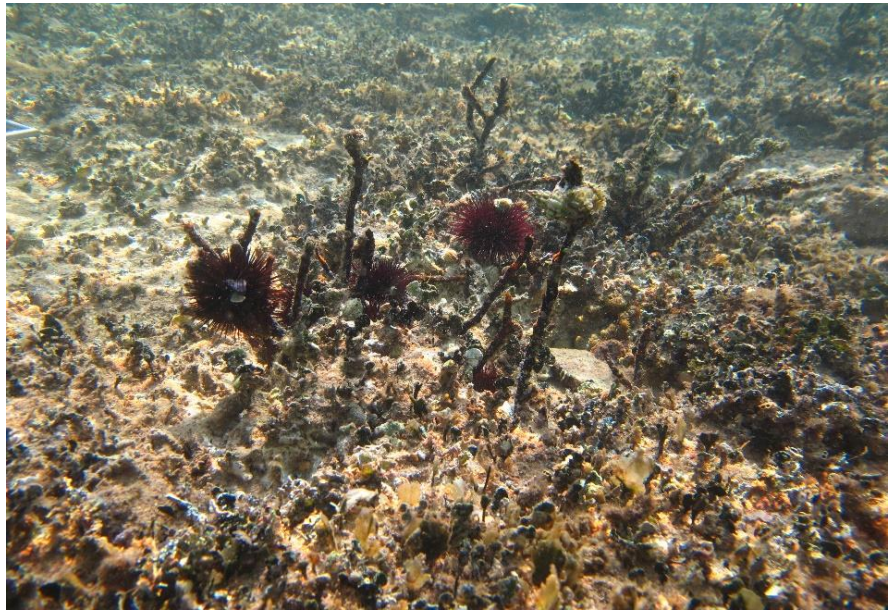
Degraded aspects of *Cystoseira barbata* (Stackhouse) C. Agardh in 2016

Thallus of *Cystoseira barbata* after separation of epiphytes



Highly ramified form of the axis which is typical for an older northern Adriatic *Cystoseira* thallus.

Aspect of the “dead *Cystoseira* forests” and sea urchins in 2017

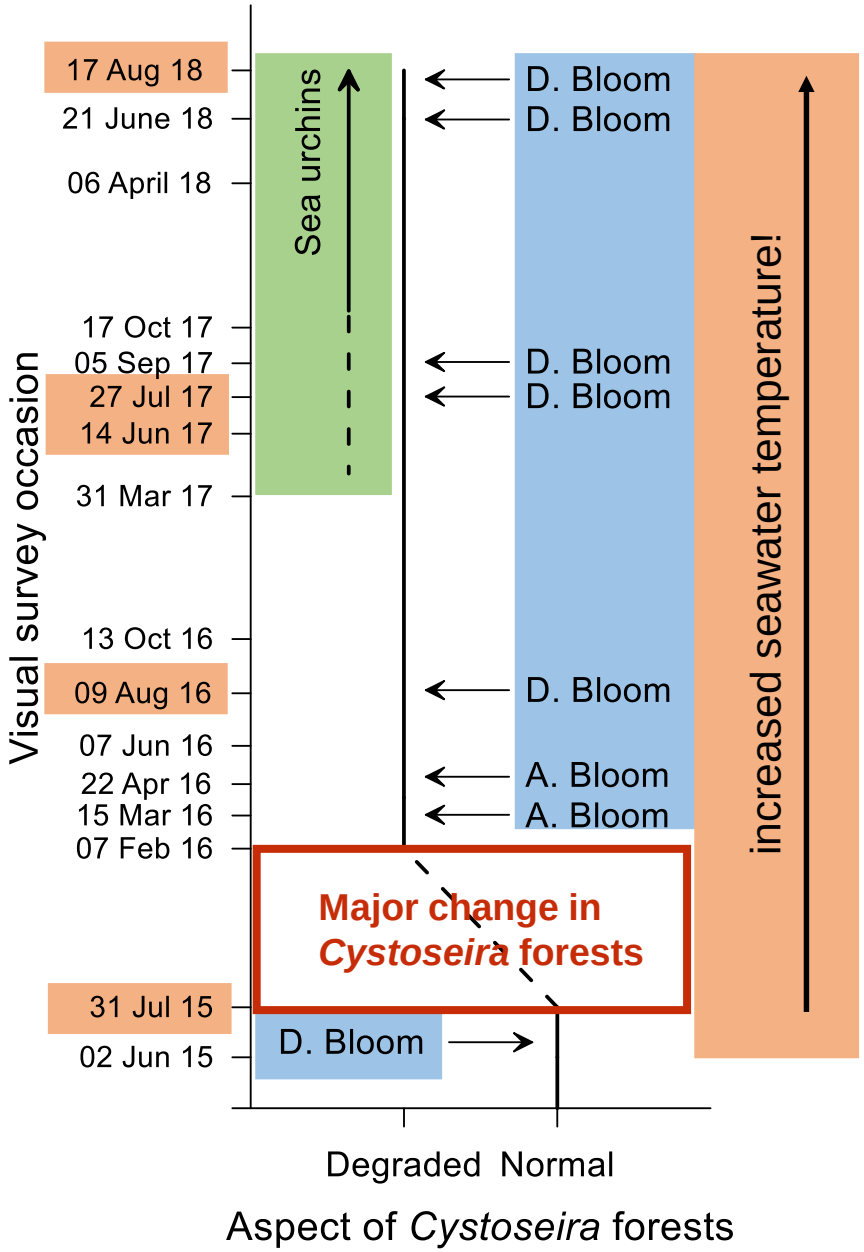


sea urchins „marks”

Degraded aspects of *Cystoseira* forests

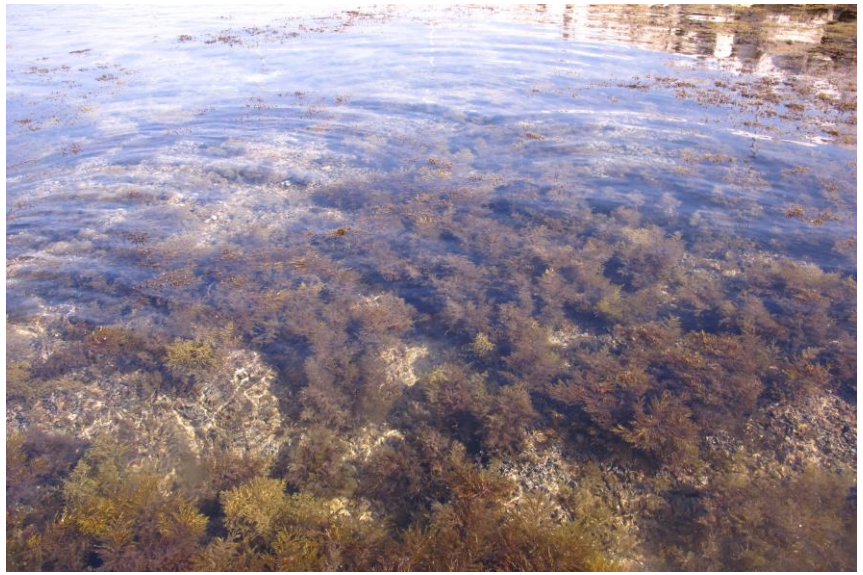
Cystoseira decline was clearly evident in spring 2016 so we can exclude the role of sea urchins predation as the process that promote this decline.

Changes within *Cystoseira* forests at Location 1 detected during 16 visual surveys

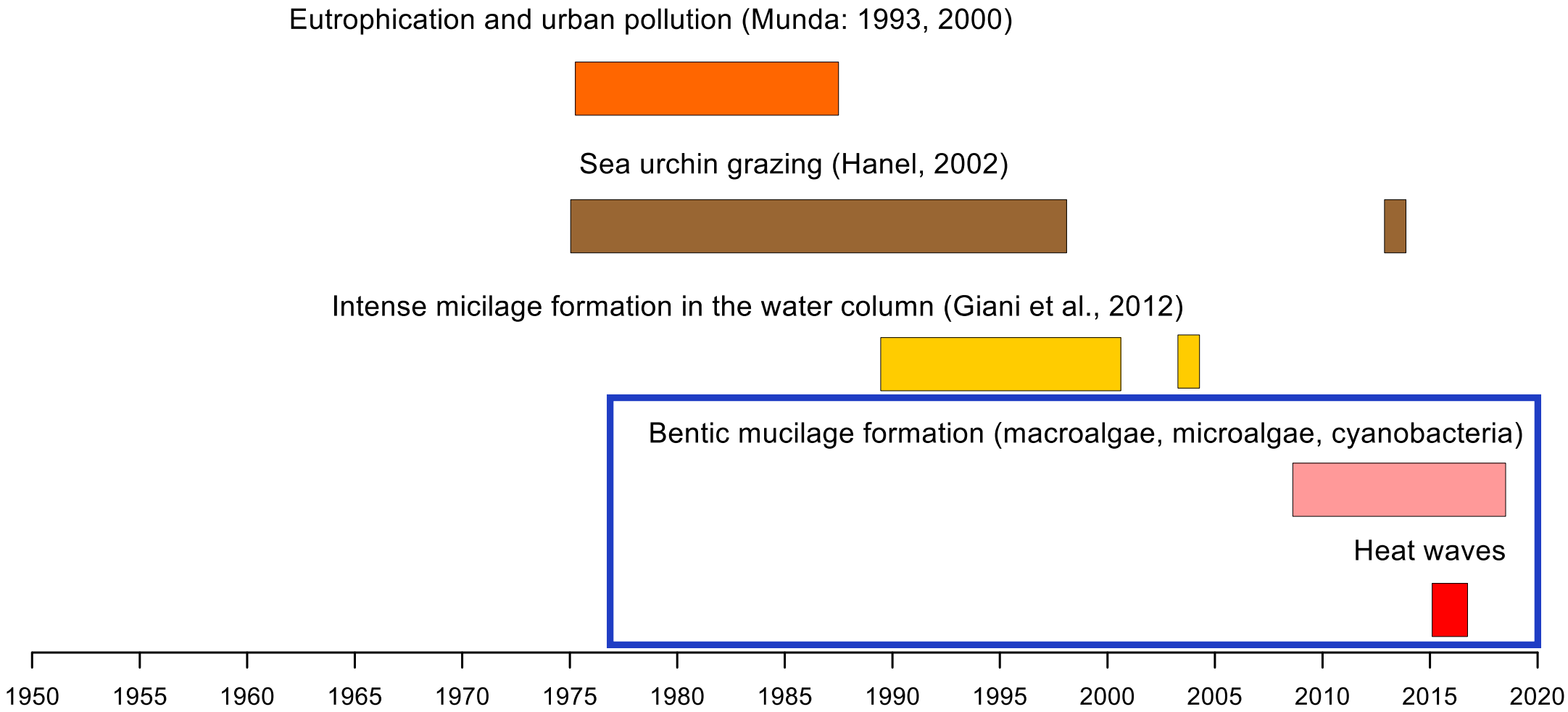


Degraded Aspect

Normal Aspect



Processes affecting *Cystoseira* forests in the northern Adriatic Basin



Extreme storms

Rovinj, 10 February 2016

Rovinj, 28 November 1965

Conclusions

✓ **Canopy-forming** forests were dominant habitats till 2016 along the Istrian coastline

✓ Distribution patterns and composition of ***Cystoseira*** species:

- similar to those observed in 1950 and in the period 1963-1970
- phase of regression in the period 1978-1983; re-colonisation during 1990s

✓ ***Cystoseira*** forests: in mixed groups & monospecific settlements

✓ Mass mortality event of ***Cystoseira*** forests occurred in winter 2016

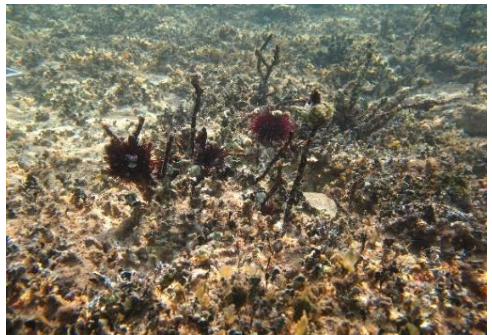
✓ ***Cystoseira*** spp. had been subjected to very warm summer seawater temperatures

✓ Benthic blooms of micro- and macroalgae from 2015 to 2018 covered ***Cystoseira*** species

✓ Local stressors can additionally drive losses and fragmentation of ***Cystoseira*** forests

✓ Affected areas could remain devoid of ***Cystoseira*** forest for many years

✓ Specific designed studies: understanding climate-driven regime shift **canopy-forming** species



But……in February 2017 in study location in the south Istria Coast

Cystoseira barbata in intertidal zone

Cystoseira barbata in subtidal zone

Cystoseira forests in Lagoon Šćuza (Pomer, sothern Istria Coast)

Cold water species *Cystoseira barbata* in 2018

Acknowledgments

Projects: Biodiversity of benthic communities in the Adriatic: natural and human impacts

WICOS Western Istria Coastal Sea

Thanks to all members of the Laboratory for Ecology and Systematics from the Center for Marine Research

Center for Marine Research
Institute Ruđer Bošković