Regional Activity Centre for Specially Protected Areas (RAC/SPA)
Boulevard du Leader Yasser Arafat | B.P. 337 - 1080 Tunis Cedex -Tunisia
phone: +216 71 206 649 / +216 71 206 485 / +216 71 206 851 / +216 71 206 765
Fax: +216 71 206 490
E-mail: car-asp@rac-spa.org

Centre d'Activités Régionales pour les Aires Spécialement Protégées (CAR/ASP)
Boulevard du Leader Yasser Arafet - B.P. 337 - 1080 - Tunis Cedex - Tunisie
Téléphone: +216 71 206 649 / +216 71 206 485 / +216 71 206 851 / +216 71 206 765
Fax: +216 71 206 490
E-mail: car-asp@rac-spa.org
web: www.rac-spa.org

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PROCEEDINGS OF THE 5th MEDITERRANEAN SYMPOSIUM ON MARINE VEGETATION

Portorož, Slovenia, 27-28 October 2014

ACTES DU 5ème SYMPOSIUM MÉDITERRANÉEN SUR LA VÉGÉTATION MARINE

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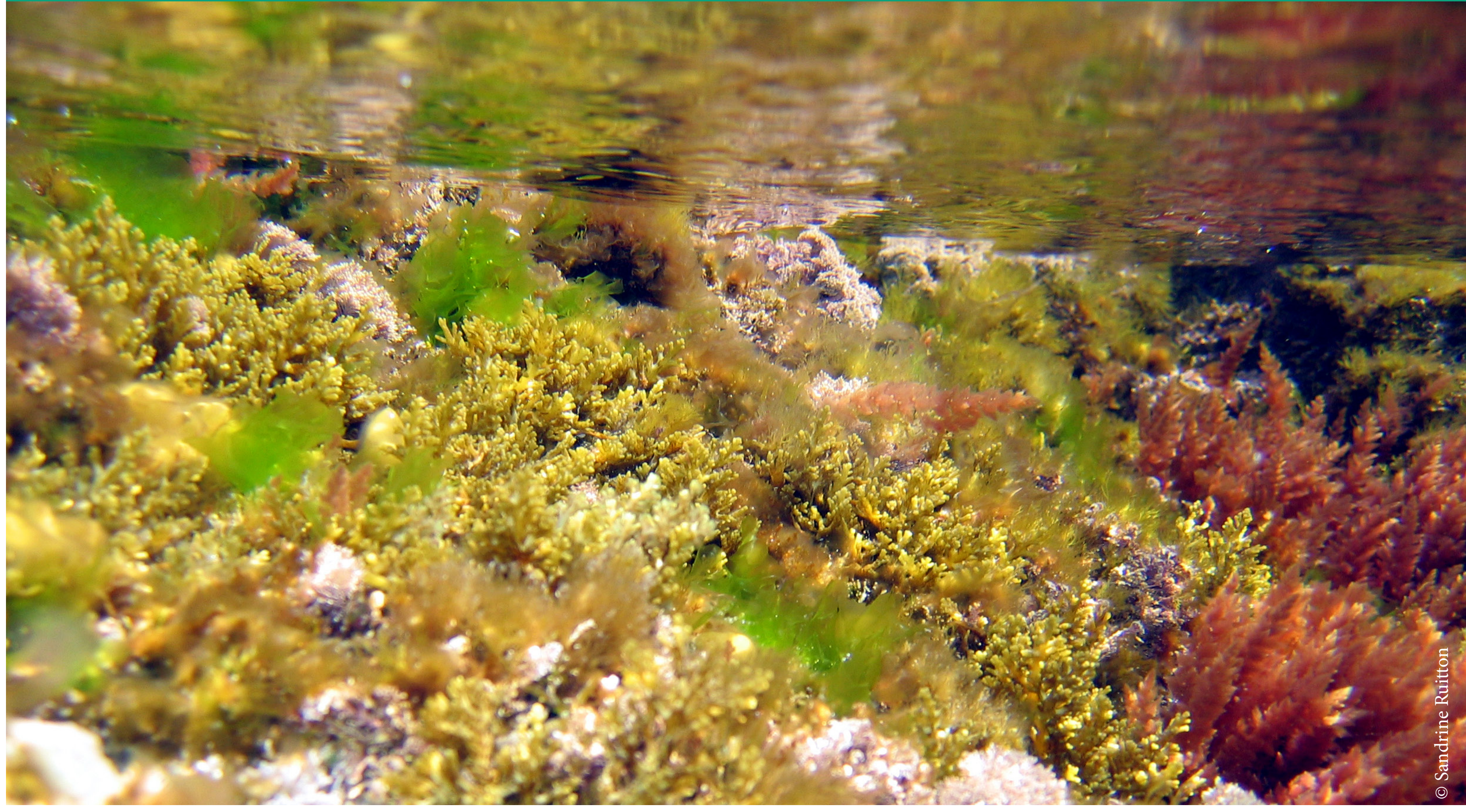

INSTITUTE OF THE REPUBLIC OF SLOVENIA FOR NATURE CONSERVATION

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Laura AIROLDI, BALLESTEROS E., BUONUOMO R., VAN BELZEN J., BOUMA T.J., CEBRIAN E., DE CLERK O., ENGELEN A.H., FERRARIO F., FRASCHETTI S., GIANNI F., GUIDETTI P., IVESA L., MANCUSO F.P., MICHELI F., PERKOL-FINKEL S., SERRAO E.A., STRAIN E.M., MANGIALAJO L.
Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, University of Bologna, Via S. Alberto 163, 48123, Ravenna Italy.
Email: laura.airoldi@unibo.it

MARINE FORESTS AT RISK: SOLUTIONS TO HALT THE LOSS AND PROMOTE THE RECOVERY OF MEDITERRANEAN CANOPY-FORMING SEAWEEDS

Abstract
Along Mediterranean coasts, canopy-forming seaweeds used to form diverse, productive and valuable "forest" habitats, but in the past decades conspicuous declines, sometimes to local extinction, have been reported in many regions. Canopies are retracting particularly close to urban areas, and are replaced by turf-forming and ephemeral algae or barrens. The persisting forests are under continued threat, and current protection measures are insufficient. We provide evidence that declines of canopy algae are dramatically extensive, and are driven by multiple local (nutrient enrichment and high sediment loads, fishing, heavy metal pollution) and global stressors (increasing temperature, high wave exposure). We also show that the combined management of local stressors (such as nutrients and sediments) would increase significantly the resilience of canopy algae to future climatic stressors, preventing their further deterioration. Finally, we discuss restoration prospects in areas where these systems have been lost. We conclude identifying the main needs to understand, guide and motivate effective conservation actions in these valuable ecosystems.

Key words: Canopy algae, habitat loss, Mediterranean Sea, multiple threats, conservation

Introduction
Along Mediterranean coasts, canopy-forming seaweeds (most frequently brown algae belonging to the order Fucales) form diverse, productive and valuable "forest" habitats. These habitats are becoming rare at local, regional and basin scales at an alarming rate (Airoldi & Beck, 2007). This is concerning because algal canopies play a key role in coastal primary production and nutrient cycling, and facilitate rich flora and fauna communities. In the past decades, algal canopies have suffered widespread and apparently irreversible loss, much of which may have gone unnoticed. Algal canopies are retracting particularly close to urban areas, and are replaced by turf-forming and ephemeral algae or sea urchin barrens, with major negative consequences for associated benthic and fish communities (Benedetti-Cecchi *et al.*, 2001). The persisting forests are under continued threat, and the benefits of current protection measures have been low.
We synthetize past research efforts aiming at quantifying the losses, and identifying what factors drive the loss or enhance the resilience of these systems. We also discuss the restoration prospects in areas where canopies have been lost and the main needs.

Materials and methods
We reviewed published primary literature and summarized it in a table. The review is organized into three sections: 1) a compilation of data on historical loss of canopies along

Mediterranean coastlines and main drivers of loss; 2) a compilation of data on known factors enhancing resilience and restoration success; 3) a discussion of gaps in the data, ecological knowledge, and protection measures for these coastal habitats and recommendations for how to address these gaps.

Results

Historical loss and main drivers

Conspicuous declines of algal canopies, sometimes to local extinction, have been reported in many regions along the coasts of Spain, France, Italy, Croatia, Albania, Greece and Turkey (Fig. 1 and Tab. 1). Along the Albères coast only 5 out of 14 species of Fucales (*Cystoseira* spp. and *Sargassum* spp.) documented as abundant in 1912 were present in 2003 (Thibaut *et al.*, 2005). Lost algal forests tend to be replaced by assemblages of lower structural complexity, such as turf-forming, filamentous or other ephemeral seaweeds, mussels or "barrens' (Mangialajo *et al.*, 2008; Connell *et al.*, 2014; Strain *et al.*, 2014). Canopy algae, turfs and barrens have been suggested to represent alternative states in shallow temperate rocky coasts under different disturbance and stress regimes (Airoldi *et al.*, 2009). There is a growing consensus and empirical evidence that these habitat shifts are driven by multiple anthropogenic stressors, including overfishing of higher trophic groups leading to outbreaks of grazers, eutrophication, excess sediment loads, coastal development, heavy metal pollution, point source pollutants such as oil spills, detergents and anti-fouling paints and invasive species (Table 1). These local anthropogenic stressors can interact negatively with environmental stressors or global climatic stressors (such as increasing temperature and CO_2) resulting in accelerated declines of canopy-algae (Perkol-Finkel & Airoldi, 2010; Asnaghi *et al.*, 2013; Olabarria *et al.*, 2013; Strain *et al.*, 2014).

Factors enhancing resilience or restoration efforts

While the proximate drivers of canopy loss are now relatively well understood, the factors that control the recovery have been more difficult to identify, and over a certain deterioration threshold, these systems may not be able to recover at all (Perkol- Finkel & Airoldi, 2010). The alternative habitat replacing lost canopies seems

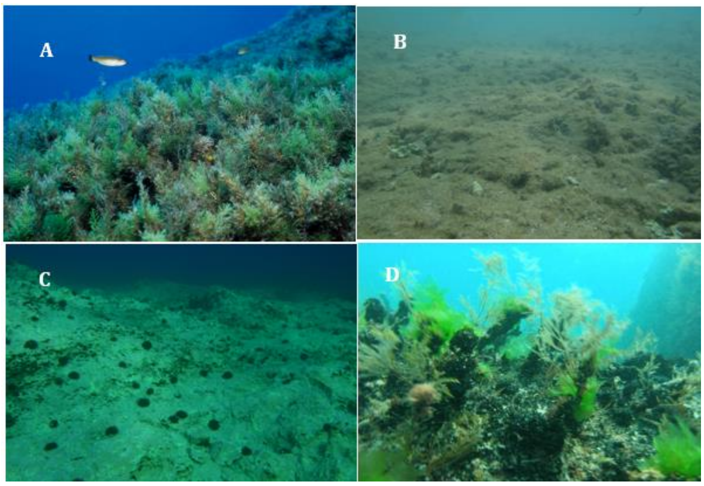

Fig. 1: Canopy algae characterise Mediterranean rocky coasts (*e.g.* A-*Cystoseira balearica* forest, Scandola, Corse), but many forests have been replaced by algal turfs (*e.g.* B- Haifa, Israel), urchin barrens (*e.g.* C- Porto Cesareo, Italy), or mussel beds (*e.g.* D - Monte Conero, Italy). Photographs by: A) E Ballesteros, B) L Airoldi, C) P Guidetti, D) L Airoldi

to play a crucial role in controlling the return to a canopy dominated state once the stressors have been removed (Airoldi *et al.*, 2009). Thus, while there are examples of recovery of canopies from outbreak of urchins when effective protection measures have been established (*e.g*. Guidetti, 2006), when algal forests become replaced by turfs, sediments, or mussels it is not yet clear what prevents the recovery of the system, other than severe recruitment failure (Perkol-Finkel & Airoldi, 2010). Recent work has shown that management of water quality and particularly sediment loads is critical for ensuring the persistence of *Cystoseira* forests (Sales *et al*. 2011, Strain *et al*. unpub.). Reduction of nutrients would provide the greatest opportunity to prevent the shift from canopy to turf algae because of the prevalence of synergistic interactions between nutrients with other local and global stressors (Strain *et al.*, 2014). If depletion of forests has already occurred over wide areas, natural recovery could be slow or even implausible (Perkol-Finkel & Airoldi, 2010). The artificial restoration of fucoids in the Mediterranean Sea has been understudied compared to kelps and fucoids in other parts of the world, but results so far suggest it could be an effective strategy (Sales *et al.*, 2011; Perkol-Finkel *et al*., 2012; Gianni *et al.*, 2013).

Discussion

Mediterranean canopy forests are affected by many threats. The greatest impacts are associated with degraded water quality, coastal development, outbreaks of herbivores and invasive species, while effects of diseases and climate changes are uncertain. Current losses are alarming and protection is insufficient. Some key needs and opportunities for conservation and management are suggested below:

1) There is no comprehensive summary of the distribution of canopy forests, particularly deep sea ones, and their management is impeded by lack of knowledge on their status. Detailed habitat mapping should be given priority. The ecosystem services that these coastal habitats provide (such as nurseries for fisheries and recreation) also need to be better assessed to illustrate the costs of their loss and provide impetus and economic incentives for their protection and restoration.

2) An adequate evolutionary framework is needed to inform decisions on local and regional species diversity and to differentiate local extinction from species extinction. The loss of genetic biodiversity as populations undergo bottlenecks is also undescribed. New molecular tools need to be applied (RAD-seq) or developed (SNPs or microsatellites) to assess genetic diversity and link it to population resilience and ecosystem functioning, assess connectivity of populations, and study parentage and recruitment at local scales.

3) Like in other ecosystems (*e.g*. lakes, coral reefs, or forests) a gradual degradation of resilience paves the loss of these algal forests to alternative habitats, so that the mere restoration of environmental conditions preceding the loss may be insufficient to restore the system (Perkol-Finkel & Airoldi, 2010). Strategies for conservation of canopy forests should focus on “early-warning signals” of approaching shifts and on effective and rapid management of local stressors to maintain resilience in face of global stressors. This knowledge is presently limited for Mediterranean canopy forests, but results so far suggest that management of water quality and sediment loads would provide some of the greatest opportunities, particularly in enclosed bays or estuaries.

Tab. 1: Selected studies reporting the loss (as either percentage area lost and/or number of species lost) of canopy-forming algae in the Mediterranean Sea, suggested drivers of loss, and signs of recovery if observed. Na= no quantitative data reported

Lost species	Geographic location	Amount of loss	Driver of loss	Alternative habitat	Signs of recovery	References
Cystoseira spp, and *Sargassum acinarium* (as *S.* linifolium)	Monte Conero (Italy, Central Adriatic Sea)	90% (6 out of 8 sp lost)	High sediment loads/poor water quality, increased substratum instability, increased storminess	Turfs or mussels	no	(Romagnoli & Solazzi, 2003; Irving *et al.*, 2009; Perkol-Finkel & Airoldi, 2010)
Cystoseira spp, and *Sargassum* spp	Albères Coast (France, NW Mediterranean)	80% (9 out of 14 sp lost)	Poor water quality, overgrazing by urchins, coastal development, human trampling	Turfs, mussels or urchin barrens	no	(Thibaut *et al.*, 2005)
Cystoseira spp.and *Fucus virsoides*	Istrian coast (Croatia, North Adriatic Sea)	11 out of 15 sp lost)	Poor water quality, overgrazing by urchins	Ephemeral algae	yes	(Munda, 1979, 2000; Zavodnik *et al.*, 2002)
Cystoseira spp	Genova (Italy, Ligurian Sea)	>50%	Coastal urbanisation	Algal turfs	no	(Mangialajo *et al.*, 2008)
Cystoseira spp	Albania	90%	Coastal development and urbanisation			(Fraschetti *et al.*, 2011)
Cystoseira spp, and *Sargassum* spp	Tremiti islands (Italy, South Adriatic Sea)	na	Poor water quality, overgrazing by urchins	Ephemeral algae or urchin barrens	yes	(Cormaci & Furnari, 1999; Fraschetti *et al.*, 2012)
Cystoseira spp	Salento Peninsula, (South Adriatic and Ionian Sea)	90%	Overgrazing by urchins	Urchin barrens	yes	(Guidetti *et al.*, 2003; Guidetti, 2006)
Cystoseira spp and *Sargassum* spp	Linosa Island (Italy, Sicily Channel)	60% (10 out of 15 sp lost)	Increased water temperature and changes in water circulation	Turfs and ephemeral algae	no	(Serio *et al.*, 2006)
Cystoseira spp	Several locations (Italy, NW Mediterranean)	90%	Coastal urbanisation, poor water quality, high sediment loads	Turfs	no	(Benedetti-Cecchi *et al.*, 2001)
Cystoseira spp	Several locations, (Greece and Turkey, Southern Aegean Sea)	>90%	Invasive fish	Urchin-less barrens	no	(Sala *et al.*, 2011; Giakoumi, 2014)
Cystoseira crinita	Cap Corse (France, NW Mediterranean)	7%	Coastal development	Turfs	no	(Sales & Ballesteros, 2010)
Cystoseira crinita, *C. barbata*	Maó harbour, Menorca, (Spain, Balearic Sea)	100%	Poor water quality, heavy metal pollution, and aquaculture	Ephemeral algae	Yes after transplant	(Sales *et al.*, 2011)
Cystoseira zosteroides	Medes Islands, (Spain, NW Mediterranean)	90%	Exceptional storm	Turfs	yes	(Navarro *et al.*, 2011)

4) Fucoids show high reproductive potential but low dispersal, which limits their natural recovery of wide lost/degraded areas. Given the extent of damage, restoration will be required in many places to meet any reasonable goals for conservation and management. Artificial restoration of *Cystoseira* forests in the Mediterranean Sea is much behind compared to other systems (i.e. seagrass beds), and much more work is needed to develop effective tools and approaches (Gianni *et al.*, 2013).

There are still opportunities for conservation of Mediterranean canopy forests. This protection should be achieved quickly because conservation is cheaper than restoration. Reducing cumulative local human impacts would represent the most effective strategy for the conservation and recovery of these systems, but, whenever this alone cannot reverse the loss, well-designed restoration projects can assist. Overall, there should be greater public, political and even scientific awareness of the extent, importance, and consequences of the loss of canopy forests, and greater commitment to motivate serious conservation and restoration actions in these highly threatened ecosystems.

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