marbef

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*Consorzio Nazionale Interuniversitario per le Scienze del Mare*

Università del Salento

# Fish diversity components and community-wide changes: an experimental case study in the Mediterranean rocky sublittoral


Paolo Guidetti

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MarFISH-workshop on Ecosystem functioning relevant to fish biodiversity and fisheries; Nantes, April 10, 2008

# Increasing interest in BEF

In the last decades there has been an increased concern about species loss (or functional loss of species) and introduction

REPORTS

SCIENCE VOL 294 26 OCTOBER 2001

**Diversity and Productivity in a Long-Term Grassland Experiment**

David Tilman,[1*] Peter B. Reich,[2] Johannes Knops,[3] David Wedin,[4] Troy Mielke,[1] Clarence Lehman[1]

Plant diversity and niche complementarity had progressively stronger effects on ecosystem functioning during a 7-year experiment, with 16-species plots

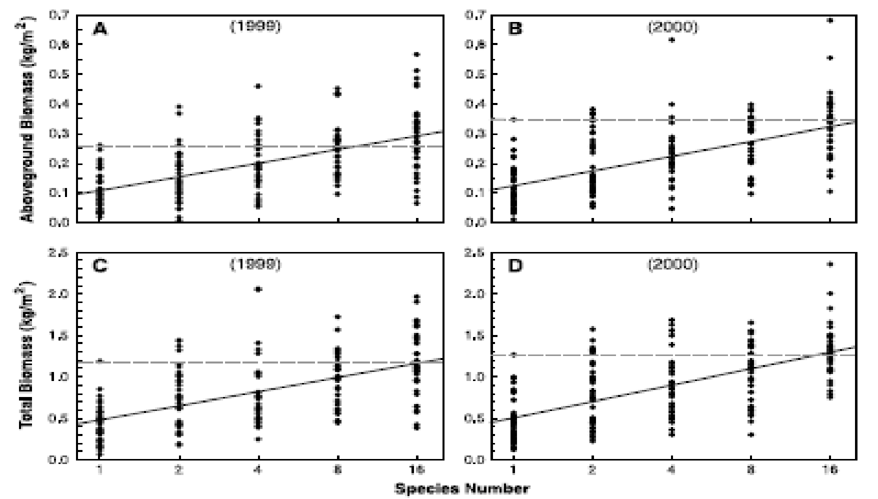



Fig. 2. The dependence of aboveground (A and B) and of total (C and D) biomass of each plot on planted species number for 1999 and 2000. The broken line shows the biomass of the top monoculture for a given year. The solid line is a regression of biomass on the logarithm of species number. Logarithm of species number was used in the figure because it gave slightly better fits, but was not used in Table 1 because it often gave slightly lower $R^2$ values than species number.

Attention was mostly devoted to changes in ecosystem properties due to changes in diversity of primary producers (or other low-level species in food webs) both in terrestrial and …

# … and aquatic ecosystems

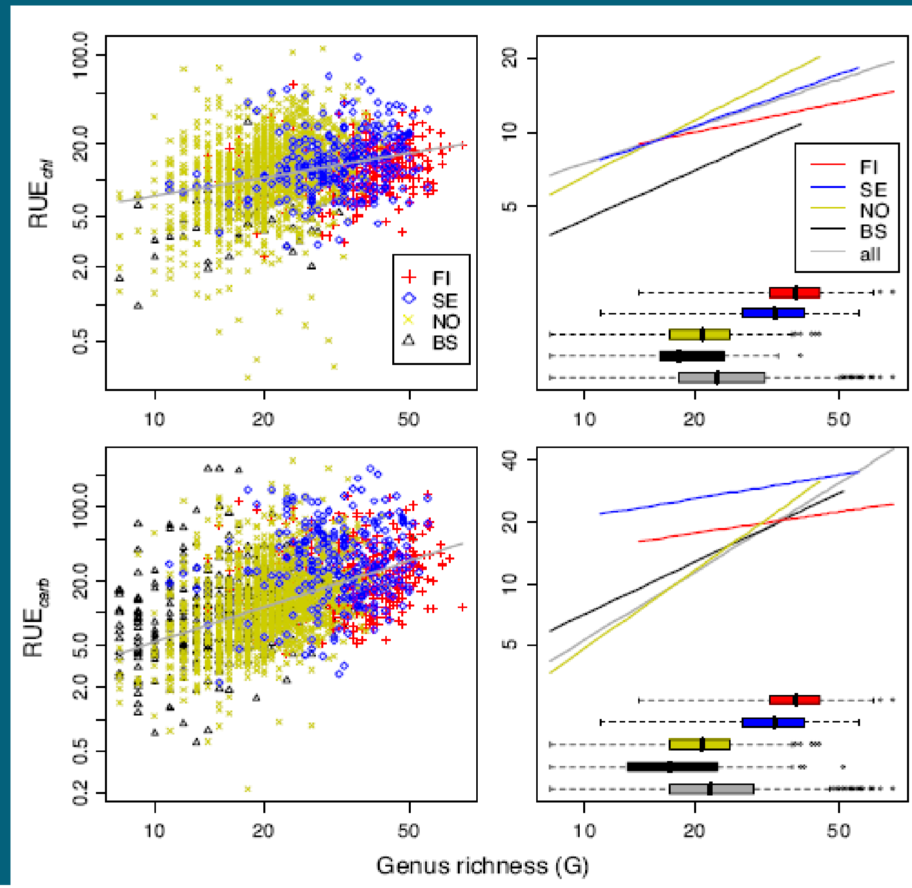
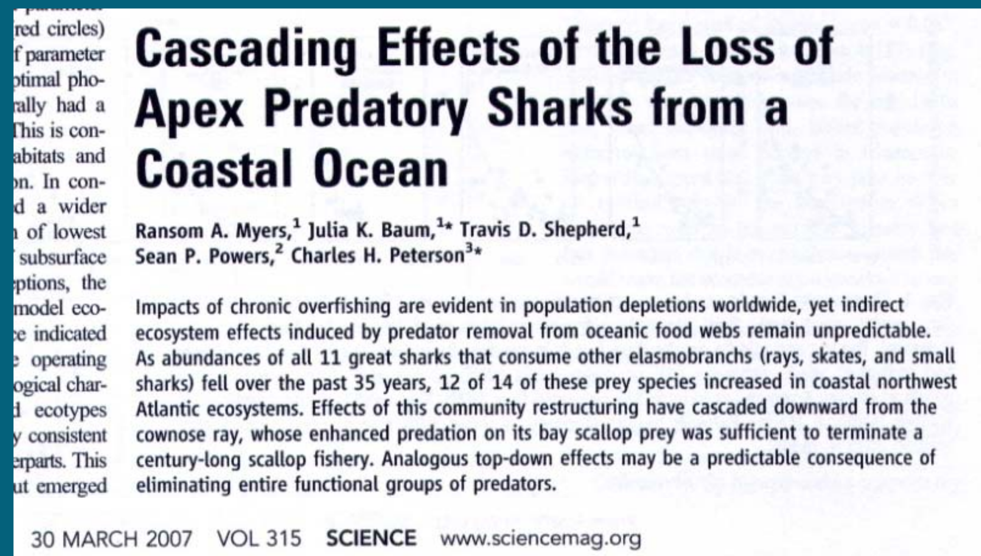



Fig. 1. Resource use efficiency (RUE) as a function of diversity [genus richness (*G*)]. (*Top*) RUE in terms of chlorophyll-a per unit phosphorus ($RUE_{Chl}$). (*Bottom*) The same for algal carbon per unit phosphorus ($RUE_{Carb}$). (*Left*) Raw data with a fit for all observations. (*Right*) Fits for the individual datasets, corresponding to coefficients given in Table 1. The horizontal box plots show the diversity distribution for each dataset. Color codes refer to the single datasets. FI, Finland; NO, Norway; SE, Sweden; BS, Baltic Sea.

In general (with a few exceptions), diversity was found to enhance productivity and stability

The number of papers published about the marine fish diversity loss has also dramatically increased in the last years



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**Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean**

Ransom A. Myers,[1] Julia K. Baum,[1*] Travis D. Shepherd,[1] Sean P. Powers,[2] Charles H. Peterson[3*]

Impacts of chronic overfishing are evident in population depletions worldwide, yet indirect ecosystem effects induced by predator removal from oceanic food webs remain unpredictable. As abundances of all 11 great sharks that consume other elasmobranchs (rays, skates, and small sharks) fell over the past 35 years, 12 of 14 of these prey species increased in coastal northwest Atlantic ecosystems. Effects of this community restructuring have cascaded downward from the cownose ray, whose enhanced predation on its bay scallop prey was sufficient to terminate a century-long scallop fishery. Analogous top-down effects may be a predictable consequence of eliminating entire functional groups of predators.

30 MARCH 2007 VOL 315 **SCIENCE** www.sciencemag.org

… with special emphasis on the impacts of human disturbances, particularly **fishing** that chiefly affects high level predatory fishes

# Fish diversity loss and ecosystem functions and stability … not only large predators are important

Update

*TRENDS in Ecology and Evolution* Vol.22 No.1

Full text provided by www.sciencedirect.com ScienceDirect

Research Focus

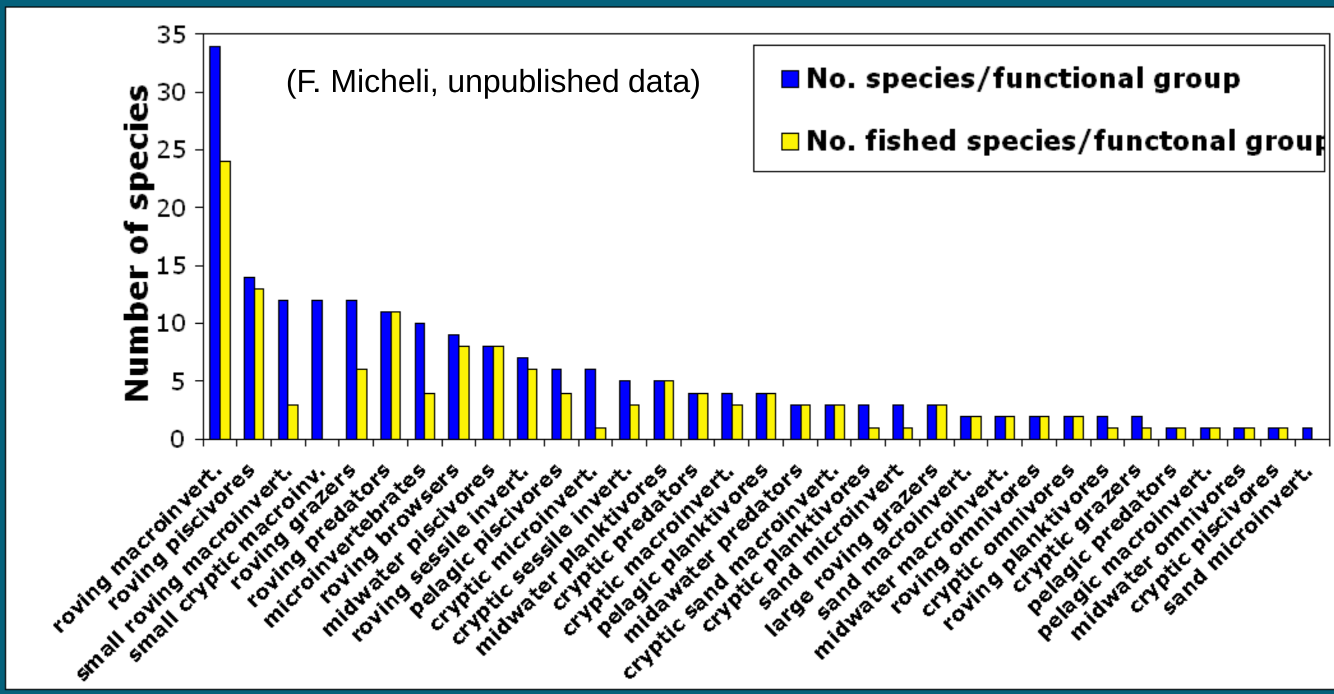
**No-take areas, herbivory and coral reef resilience**

**Terry P. Hughes[1], David R. Bellwood[1,2], Carl S. Folke[3], Laurence J. McCook[1,4] and John M. Pandolfi[5]**

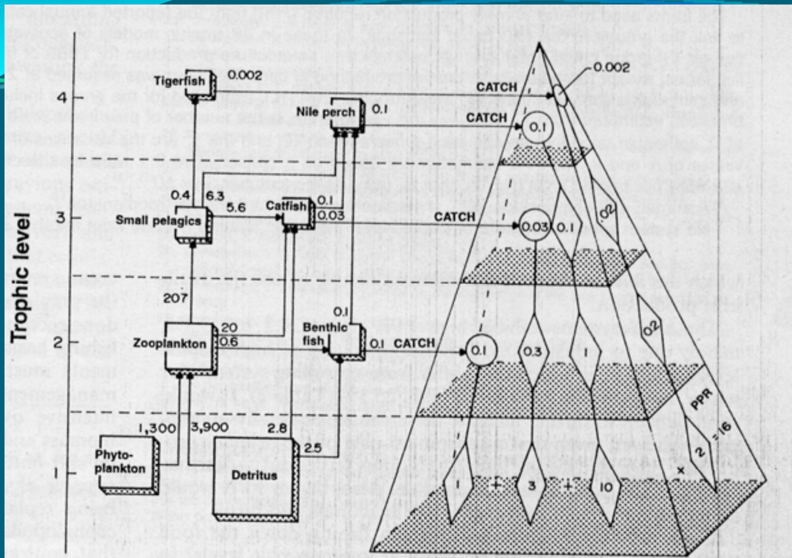
[1] ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD 4811, Australia
[2] School of Tropical & Marine Biology, James Cook University, Townsville, QLD 4811, Australia
[3] Centre for Transdisciplinary Environmental Research (CTM) and Department of Systems Ecology, Stockholm University, 10691 Stockholm, Sweden
[4] Great Barrier Reef Marine Park Authority, Townsville, QLD 4810, Australia
[5] ARC Centre for Coral Reef Studies and Centre for Marine Studies, University of Queensland, Brisbane, QLD 4072, Australia

Loss of herbivore fishes may have dramatic effects in coral reef ecosystems

# Fish assemblages from Bahamian coral reefs (159 species): limited redundancy and potential for widespread fishing impacts

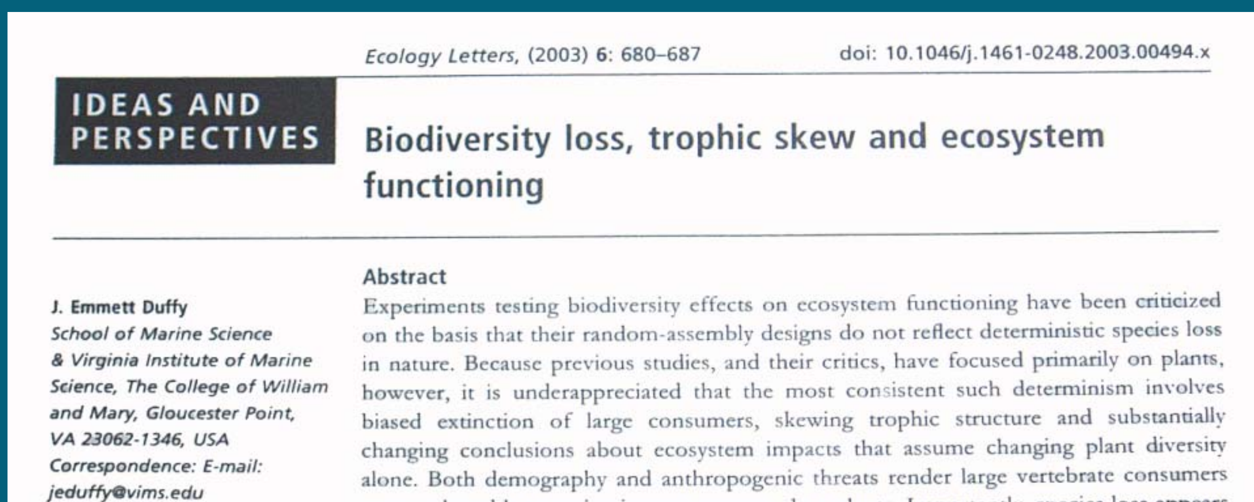



1) 1/3 of functional groups include 1-2 species
2) Fished species in all but two functional groups
3) All species are fished in 1/2 of functional groups




(Pauly & Christensen 1995. Nature)

Many fishes targeted by fishing are, however, high level predators.
Predator species loss may disrupt food webs due to usually low redundancy and typical life traits, and affect ecosystem functioning more than plant diversity loss


*Ecology Letters*, (2003) **6**: 680–687 doi: 10.1046/j.1461-0248.2003.00494.x

IDEAS AND PERSPECTIVES

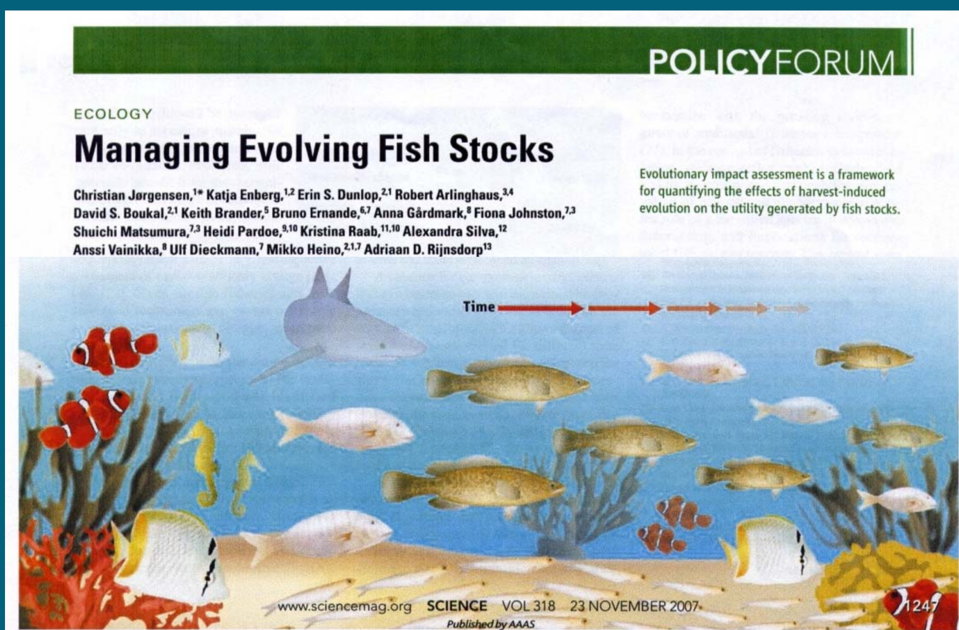
**Biodiversity loss, trophic skew and ecosystem functioning**

J. Emmett Duffy
*School of Marine Science & Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA 23062-1346, USA*
*Correspondence: E-mail: jeduffy@vims.edu*

**Abstract**
Experiments testing biodiversity effects on ecosystem functioning have been criticized on the basis that their random-assembly designs do not reflect deterministic species loss in nature. Because previous studies, and their critics, have focused primarily on plants, however, it is underappreciated that the most consistent such determinism involves biased extinction of large consumers, skewing trophic structure and substantially changing conclusions about ecosystem impacts that assume changing plant diversity alone. Both demography and anthropogenic threats render large vertebrate consumers more vulnerable to extinction, on average, than plants. Importantly, species loss appears

# Evolutionary implications

Fishing selection has been proposed to oppose natural selection for size, behavior, morphology, maturity status, with potential consequences on demography, stock biomass, economic revenues, competitive and predator-prey interactions


POLICYFORUM

ECOLOGY

**Managing Evolving Fish Stocks**

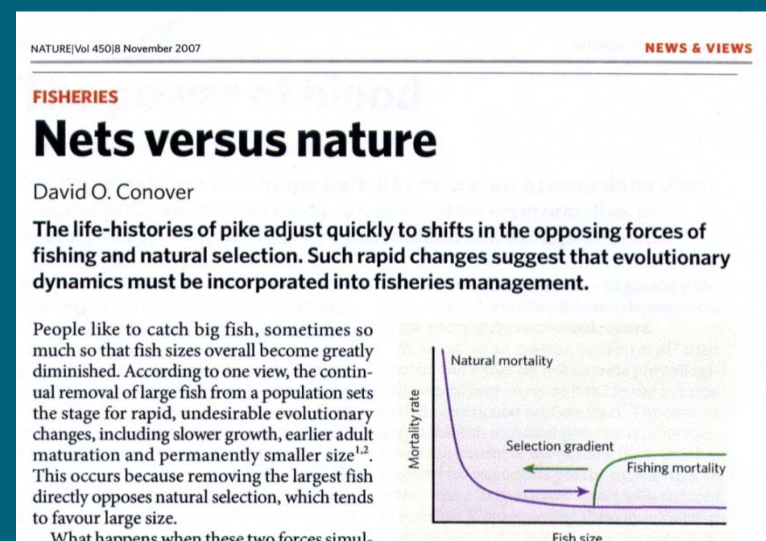
Christian Jørgensen,[1*] Katja Enberg,[1,2] Erin S. Dunlop,[2,1] Robert Arlinghaus,[3,4] David S. Boukal,[2,1] Keith Brander,[5] Bruno Ernande,[6,7] Anna Gårdmark,[8] Fiona Johnston,[7,3] Shuichi Matsumura,[7,3] Heidi Pardoe,[9,10] Kristina Raab,[11,10] Alexandra Silva,[12] Anssi Vainikka,[8] Ulf Dieckmann,[7] Mikko Heino,[2,1,7] Adriaan D. Rijnsdorp[13]

Evolutionary impact assessment is a framework for quantifying the effects of harvest-induced evolution on the utility generated by fish stocks.



www.sciencemag.org SCIENCE VOL 318 23 NOVEMBER 2007 1247

Published by AAAS


NATURE|Vol 450|8 November 2007 NEWS & VIEWS

FISHERIES

**Nets versus nature**

David O. Conover

**The life-histories of pike adjust quickly to shifts in the opposing forces of fishing and natural selection. Such rapid changes suggest that evolutionary dynamics must be incorporated into fisheries management.**

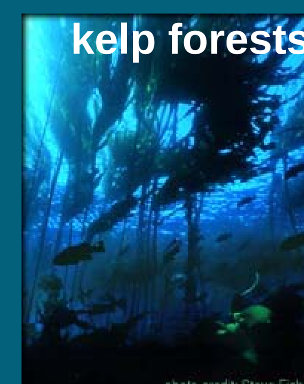
People like to catch big fish, sometimes so much so that fish sizes overall become greatly diminished. According to one view, the continual removal of large fish from a population sets the stage for rapid, undesirable evolutionary changes, including slower growth, earlier adult maturation and permanently smaller size[1,2]. This occurs because removing the largest fish directly opposes natural selection, which tends to favour large size.

What happens when these two forces simul-

# Community-wide effects

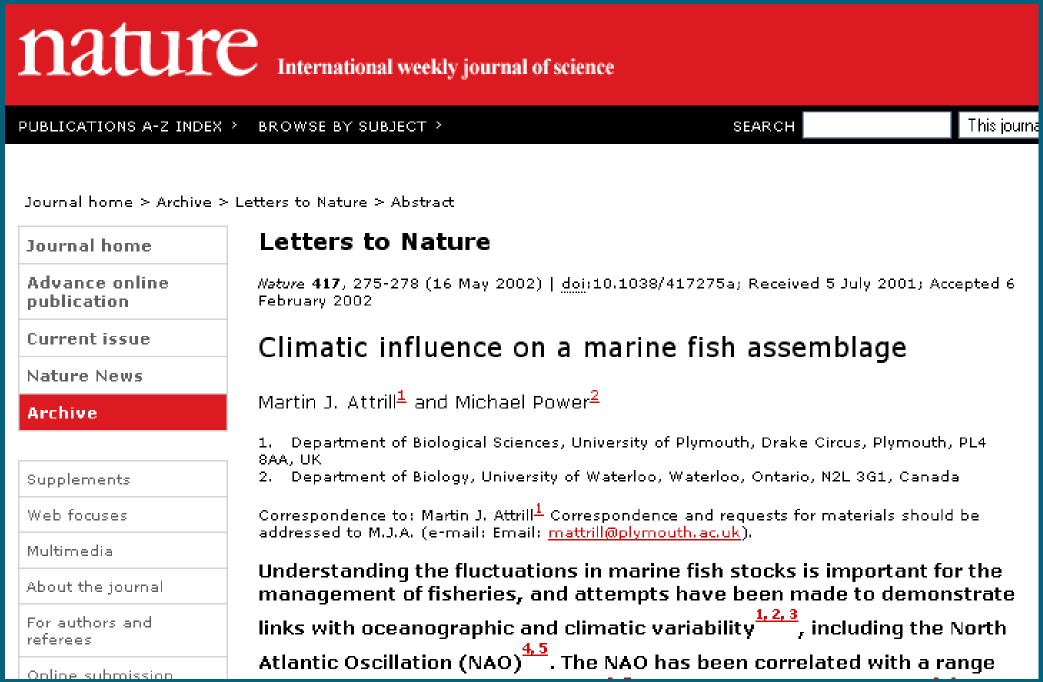
Besides direct effects on target species, fishing may affect entire communities (and ecosystem functioning) through changes in trophic interactions, e.g. the so-called trophic cascades (top-down control)


predators (of grazers)

# Not only species loss …

In many regions of the world, fish communities are changing due to climate changes (e.g. water warming) and, sometime, 'new' species appear … increasing the species richness and potentially influencing both native species and assemblages through interactions


nature International weekly journal of science

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Online submission

## Letters to Nature

*Nature* **417**, 275-278 (16 May 2002) | doi:10.1038/417275a; Received 5 July 2001; Accepted 6 February 2002

### Climatic influence on a marine fish assemblage

Martin J. Attrill[1] and Michael Power[2]

1. Department of Biological Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK
2. Department of Biology, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

Correspondence to: Martin J. Attrill[1] Correspondence and requests for materials should be addressed to M.J.A. (e-mail: Email: mattrill@plymouth.ac.uk).

**Understanding the fluctuations in marine fish stocks is important for the management of fisheries, and attempts have been made to demonstrate links with oceanographic and climatic variability[1, 2, 3], including the North Atlantic Oscillation (NAO)[4, 5]. The NAO has been correlated with a range**

# Mediterranean Sea and water warming

The basin in the last decades underwent tropicalisation (new tropical-atlantic and indopacific species appeared) and meridionalisation (southern species expanding northwards)

*Thalassoma pavo*

*Sargocentron rubrum*

*Sphoeroides marmoratus*

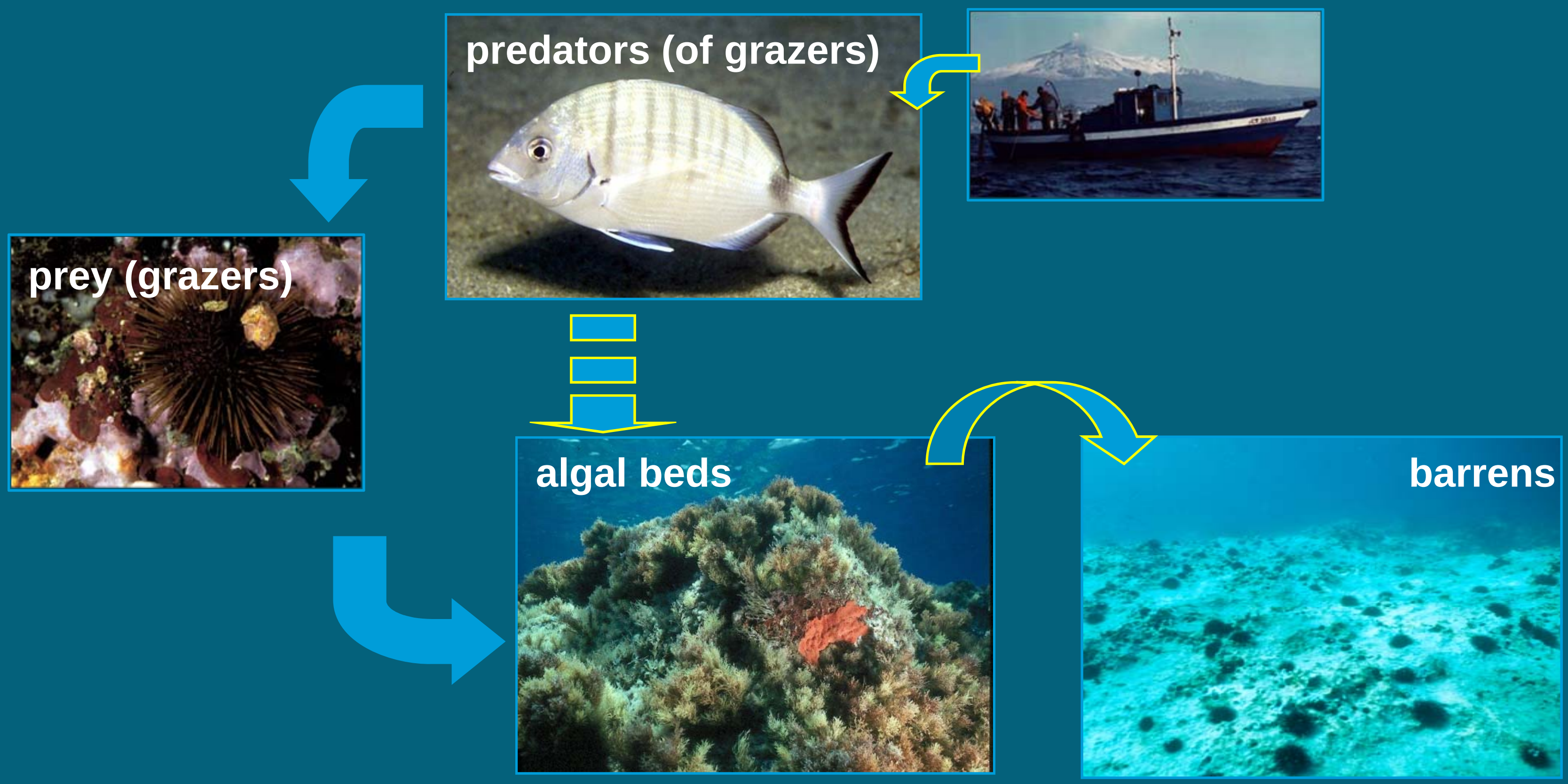
*Fistularia commersoni*

*Siganus luridus*

*Sparisoma cretense*

# The Mediterranean rocky sublittoral

There is increasing evidence that fishing (also interacting with other processes e.g. sedimentation and water warming) may have community-wide effects similar to those occurring in kelp forests



# The protagonists


**Sea urchins, through unselective grazing, may form and maintain *barrens*, especially at high density**



**Sea breams may eat small and relatively large sea urchins**



**Labrids may eat small urchins (<1 cm test size)**

**Professional and recreational-sportive fishing impact sea urchin fish predators**

# Marine reserves may help ecosystem recovery


Ecological Applications, 16(3), 2006, pp. 963 976

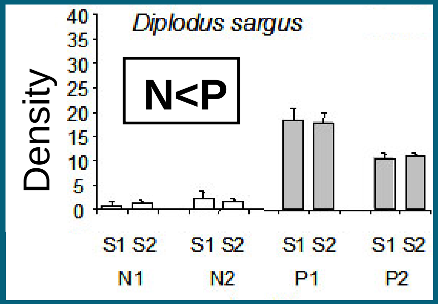

MARINE RESERVES REESTABLISH LOST PREDATORY INTERACTIONS AND CAUSE COMMUNITY CHANGES IN ROCKY REEFS

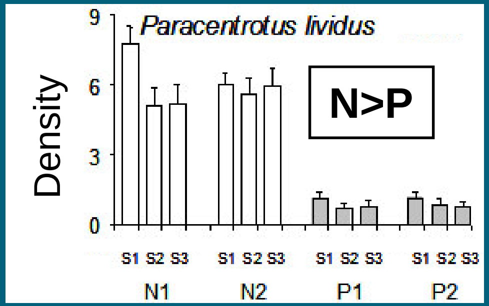
PAOLO GUIDETTI[1]

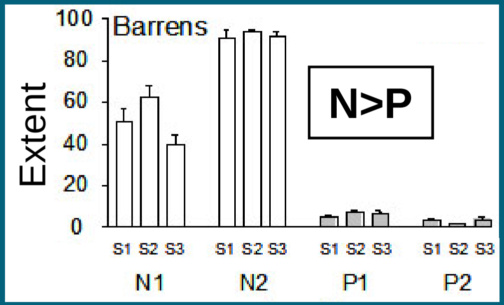
Laboratory of Zoology and Marine Biology, DiSTeBA, University of Lecce, Via Prov.le Monteroni, 73100 Lecce, Italy

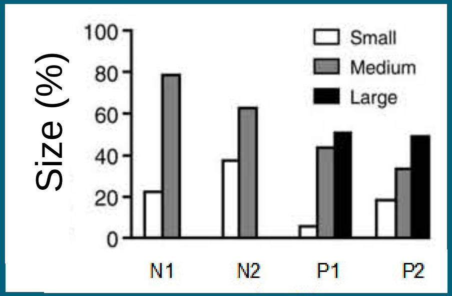
*Abstract.* In the last decades, marine reserves have dramatically increased in number worldwide. Here I examined the potential of no-take marine reserves to reestablish lost predatory interactions and, in turn, cause community-wide changes in Mediterranean rocky reefs. Protected locations supported higher density and size of the most effective fish preying

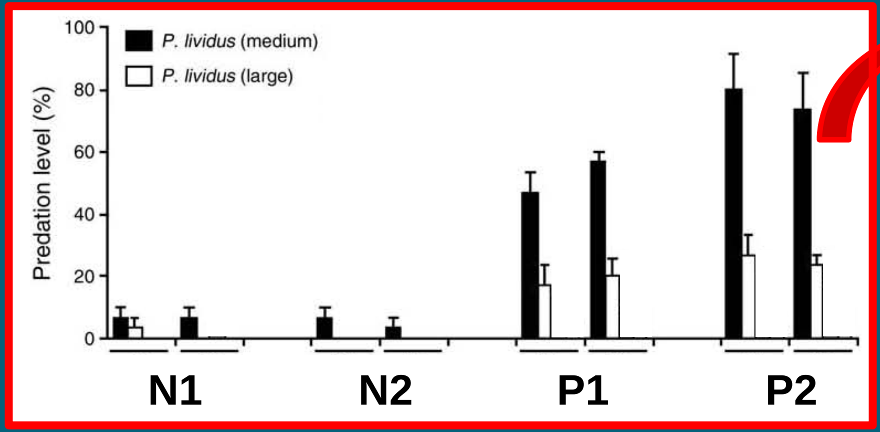
N: non protected locations
P: protected locations



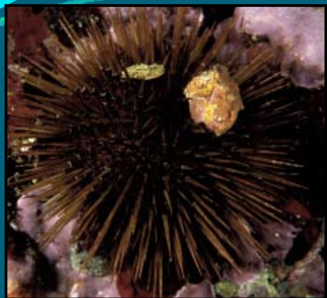



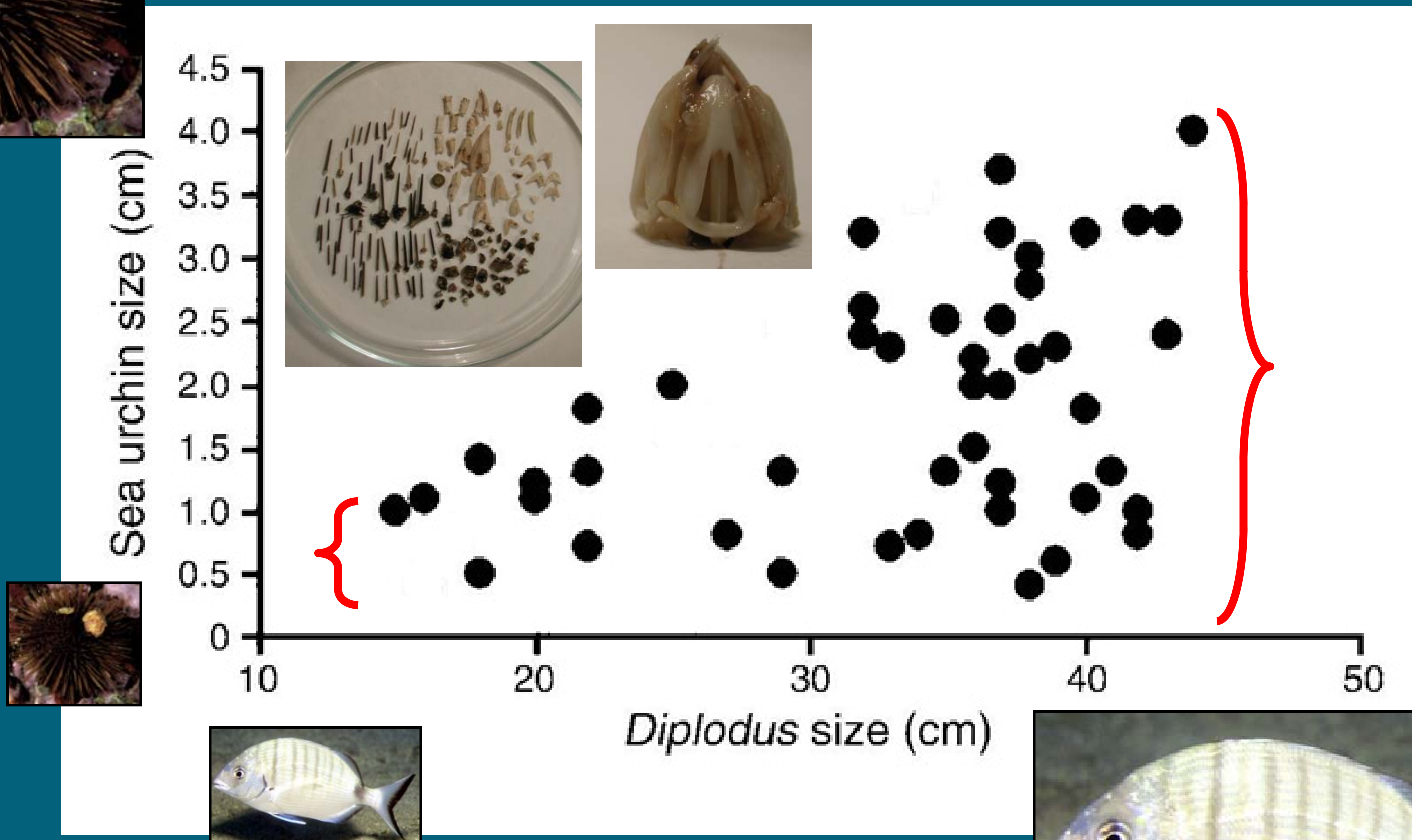




Predation levels estimated by tethering experiments

# Predator size matters!



Small predators eat only small prey, large predators may exploit a wide range of prey sizes




# Predator density and size thus rule predator-prey interactions and community structure in the Mediterranean rocky sublittoral … but what about predator diversity?

In terrestrial systems, multiple predators may have linear or non-linear ecosystem-wide effects.

Such experimental studies, however, are not that common in marine systems.

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## Predator diversity dampens trophic cascades

**Deborah L. Finke & Robert F. Denno**

*Department of Entomology, University of Maryland, College Park, Maryland 20742, USA*

**Food web complexity is thought to weaken the strength of terrestrial trophic cascades[1–3] in which strong impacts of natural enemies on herbivores cascade to influence primary production**

NATURE | VOL 429 | 27 MAY 2004 | www.nature.com/nature



*Ecology Letters*, (2002) 5: 168–172

LETTER

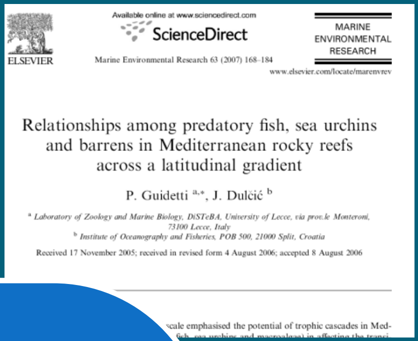
## Linearity in the aggregate effects of multiple predators in a food web

Oswald J. Schmitz* and
Lauge Sokol-Hessner
*School of Forestry and Environmental Studies, Yale University,*

**Abstract**

Theory in community ecology often assumes that predator species have similar indirect effects and thus can be treated mathematically as a single functional unit (e.g. guild or trophic level). This assumption is questionable biologically because predator species typically differ in their effects, creating the potential for nonlinearities when they coexist. We evaluated the nature of indirect effects caused by three species of hunting spider

# Assemblages of fish predators change in space, e.g. along latitudinal gradients



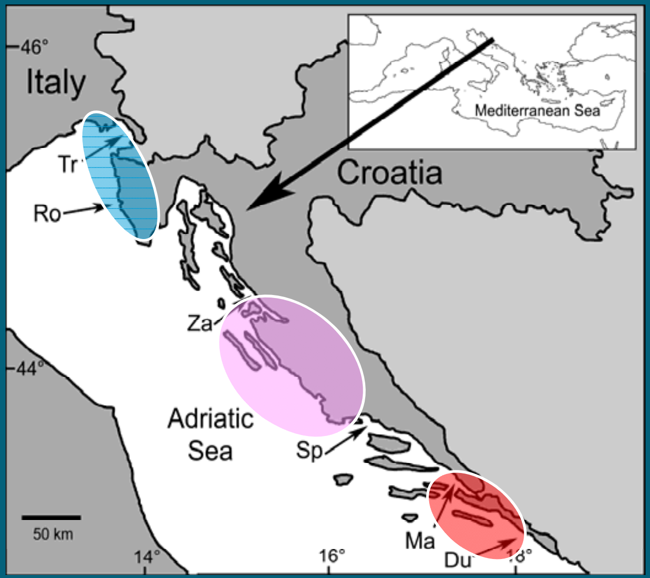

Relationships among predatory fish, sea urchins and barrens in Mediterranean rocky reefs across a latitudinal gradient

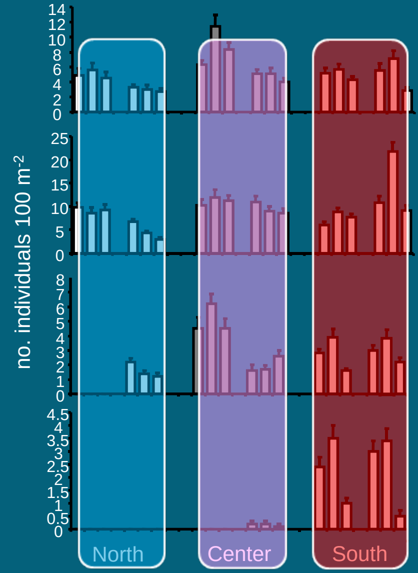
P. Guidetti [a,*], J. Dulčić [b]

[a] Laboratory of Zoology and Marine Biology, DiSTeBA, University of Lecce, via prov.le Monteroni, 73100 Lecce, Italy
[b] Institute of Oceanography and Fisheries, POB 500, 21000 Split, Croatia

Received 17 November 2005; received in revised form 4 August 2006; accepted 8 August 2006

...scale emphasised the potential of trophic cascades in Med-



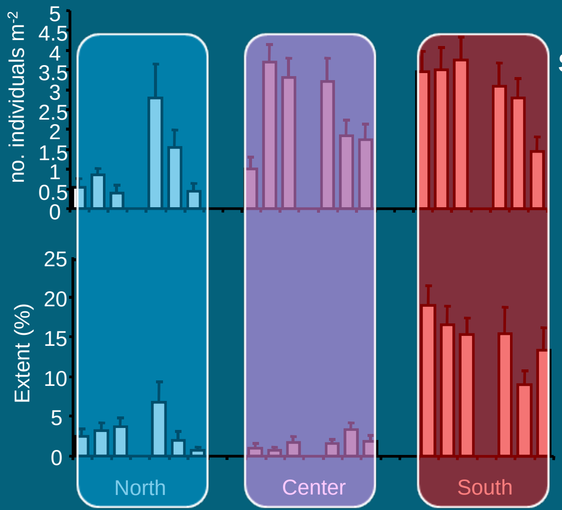

*Diplodus sargus*

*Diplodus vulgaris*

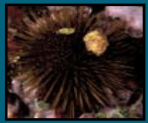
*Coris julis*

*Thalassoma pavo*

Correlative observations suggest the higher predator diversity the higher grazer density and barren extent … but here possible ‘diversity effects’ are *confounded* with climatic conditions changing with latitude




**Sea urchins**



**Barren**

# Diversity components and experiments

insight review articles

NATURE | VOL 405 | 11 MAY 2000 | www.nature.com

## Consequences of changing biodiversity

F. Stuart Chapin III*, Erika S. Zavaleta†, Valerie T. Eviner§, Rosamond L. Naylor‡, Peter M. Vitousek†, Heather L. Reynolds||, David U. Hooper¶, Sandra Lavorel#, Osvaldo E. Sala☆, Sarah E. Hobbie**, Michelle C. Mack* & Sandra Díaz††

*Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska 99775, USA (e-mail: fschapin@lter.uaf.edu)
†Department of Biological Sciences and ‡Institute for International Studies, Stanford University, Stanford, California 94305, USA
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||Department of Biology, Kalamazoo College, Kalamazoo, Michigan 49006, USA
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☆Cátedra de Ecología and Instituto de Fisiología y Ecología Vinculadas a la Agricultura, Faculty of Agronomy, University of Buenos Aires, Ave San Martín 4453, Buenos Aires C1417DSE, Argentina
**Department of Ecology, Evolution, and Behavior, University of Minnesota, St Paul, Minnesota 55108, USA
††Instituto Multidisciplinario de Biología Vegetal, Universidad Nacional de Córdoba, FCEFyN, Casilla de Correo 495, 5000 Córdoba, Argentina

**Human alteration of the global environment has triggered the sixth major extinction event in the history of life and caused widespread changes in the global distribution of organisms. These changes in biodiversity alter ecosystem processes and change the resilience of ecosystems to environmental change. This has profound consequences for services that humans derive from ecosystems. The large ecological and societal consequences of changing biodiversity should be minimized to preserve options for future solutions to global environmental problems.**

1) Number of species present (species richness)

2) Relative abundances (impacts more often affect evenness than presence/absence)

3) Species identity: particular species can have strong–idiosyncratic effects on community and/or processes

How to cope with all this?

## Increasing accuracy of causal inference in experimental analyses of biodiversity

*Functional Ecology* 2004
**18**, 761–768

L. BENEDETTI-CECCHI

*University of Pisa, Dipartimento di Scienze dell'Uomo e dell'Ambiente, Via A. Volta 6, I-56126 Pisa, Italy*

**Summary**

**1.** Manipulative experiments are often used to identify causal linkages between biodiversity and productivity in terrestrial and aquatic habitats.

**2.** Most studies have identified an effect of biodiversity, but their interpretation has stimulated considerable debate. The main difficulties lie in separating the effect of species richness from those due to changes in identity and relative density of species.

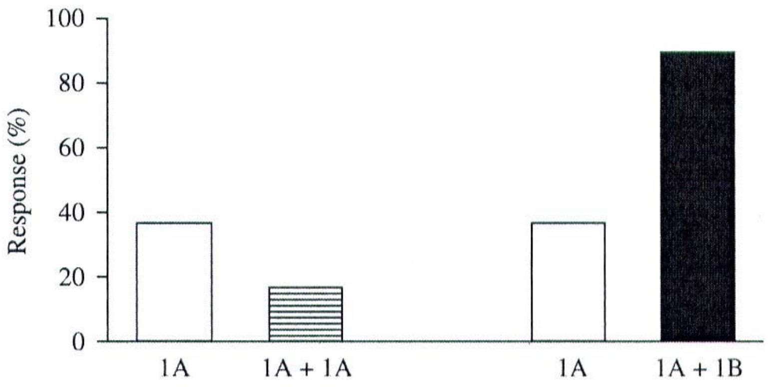
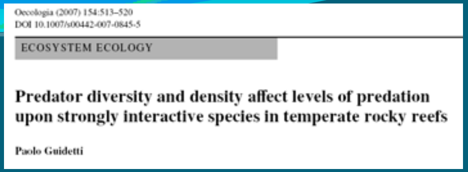



**Fig. 2.** Illustration of a possible alternative to the null hypothesis of no effect of SR in the presence of negative density-dependent effects. The effect of adding one unit of B to one unit of A differs in magnitude and direction from the effect of adding one unit of A. This would be detected by a significant interaction between SR and density.

# Manipulative experiment using caging

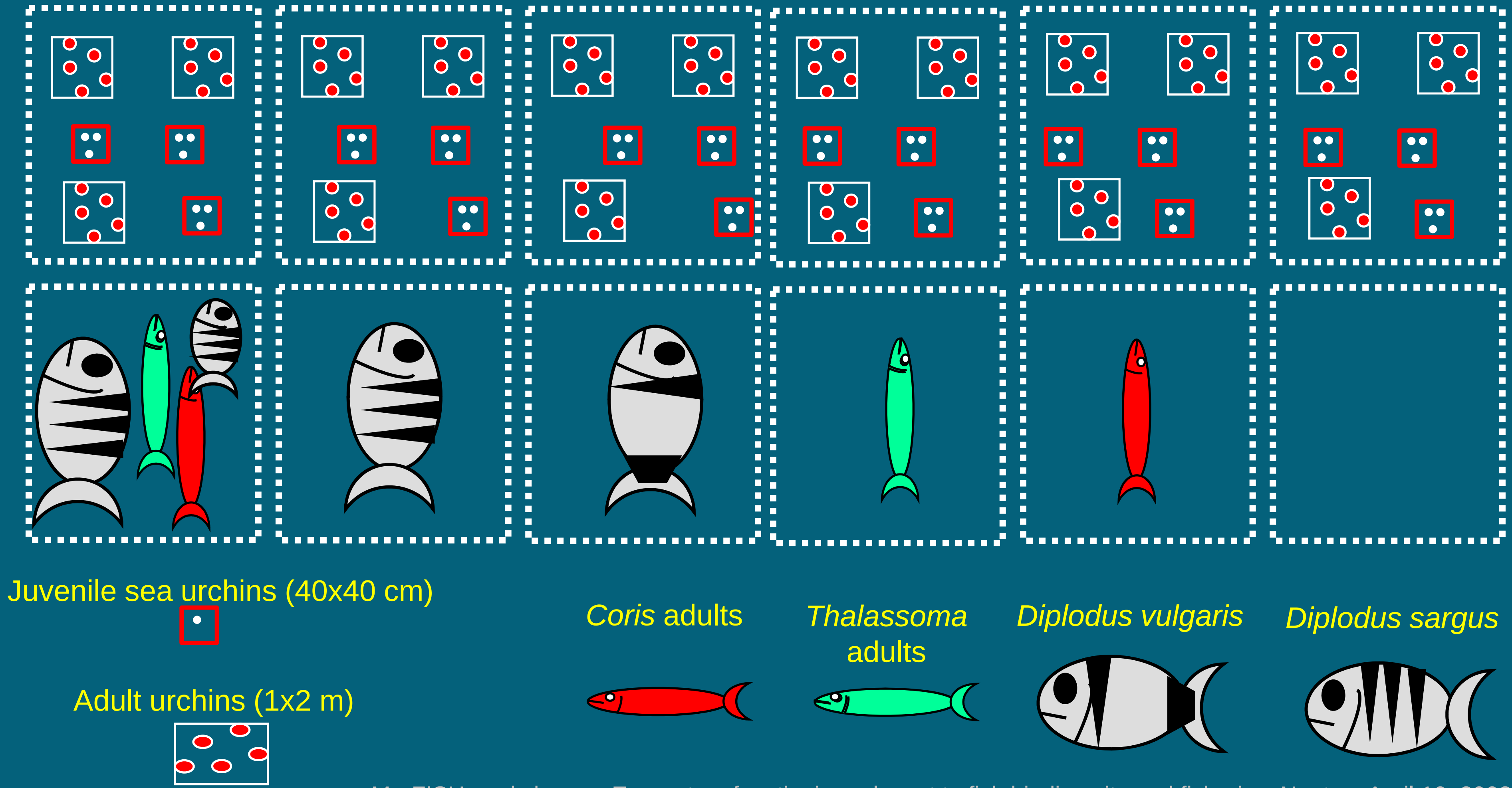

Oecologia (2007) 154:513–520
DOI 10.1007/s00442-007-0845-5

ECOSYSTEM ECOLOGY

**Predator diversity and density affect levels of predation upon strongly interactive species in temperate rocky reefs**

**Paolo Guidetti**

1) What can we predict in the case of species loss or addition?
2) Do the four predator species interact?
3) Does capacity of controlling sea urchin density change relative to predator diversity and/or density (additive *vs* interactive effects)?



# Rationale

Caging experiments were repeated in two bays (spatial replication)

In each bay, EUs 5x5 m were prepared according to 6 treatments: (1) no predators (control), (2) *C. julis*, (3) *T. pavo*, (4) *D. vulgaris*, (5) *D. sargus*, and (6) the complete assemblage of the four predators

Experiment 1: additive design, with density of each predator species equivalent to the values measured in the field (INTRA-specific interactions constant)

Experiment 2: substitutive design, with overall predator density kept constant

N=3 replicates for each treatment in each bay for both design type

Response variable: PREDATION RATE ON SEA URCHINS

Data treated with ANOVA: 1) ‘treatment’, fixed; 2) ‘bay’, random orthogonal

# Emerging impacts of multiple predators

To solve the additive problem in summing the relative impacts of multiple predators on prey, I used the *multiplicative risk model* (Sih et al. 1998)

350 Copyright © 1998, Elsevier Science Ltd. All rights reserved. 0169-5347/98/$19.00 PII: S0169-5347(98)01437-2 *TREE vol. 13, no. 9 September 1998*

REVIEWS

**Emergent impacts of multiple predators on prey**

**Andrew Sih, Goran Englund and David Wooster**

Predation is one of the key factors governing patterns in natural systems. Experi-

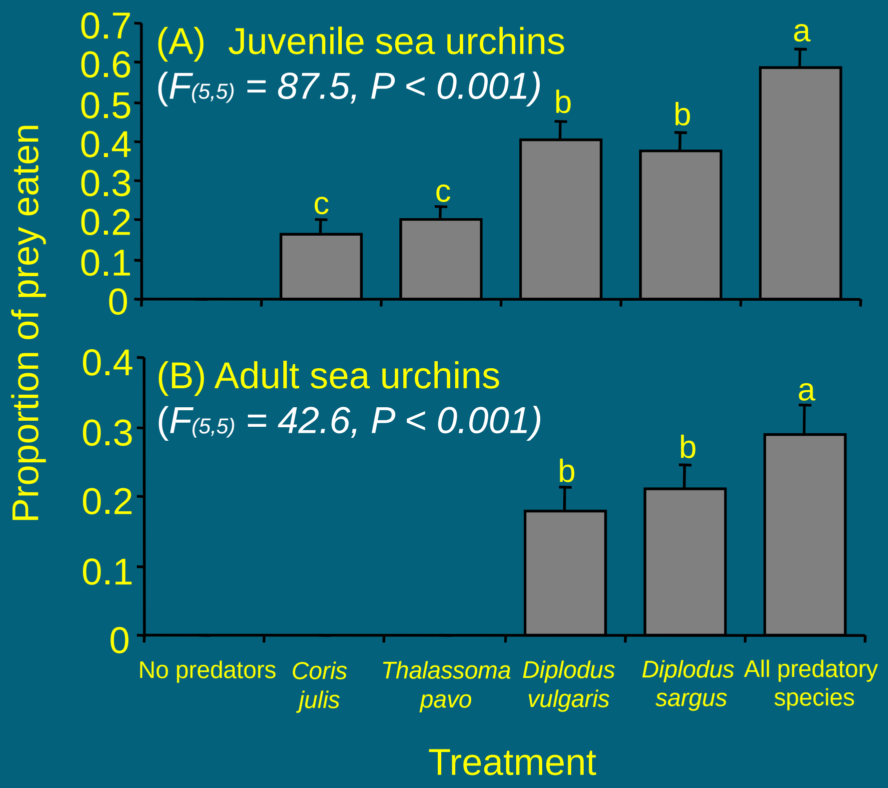
**Although almost all prey live with many types of predator, most experimental studies of predation have examined the**

*capita* effect of one species on the proportional change in the population size of a target species. The

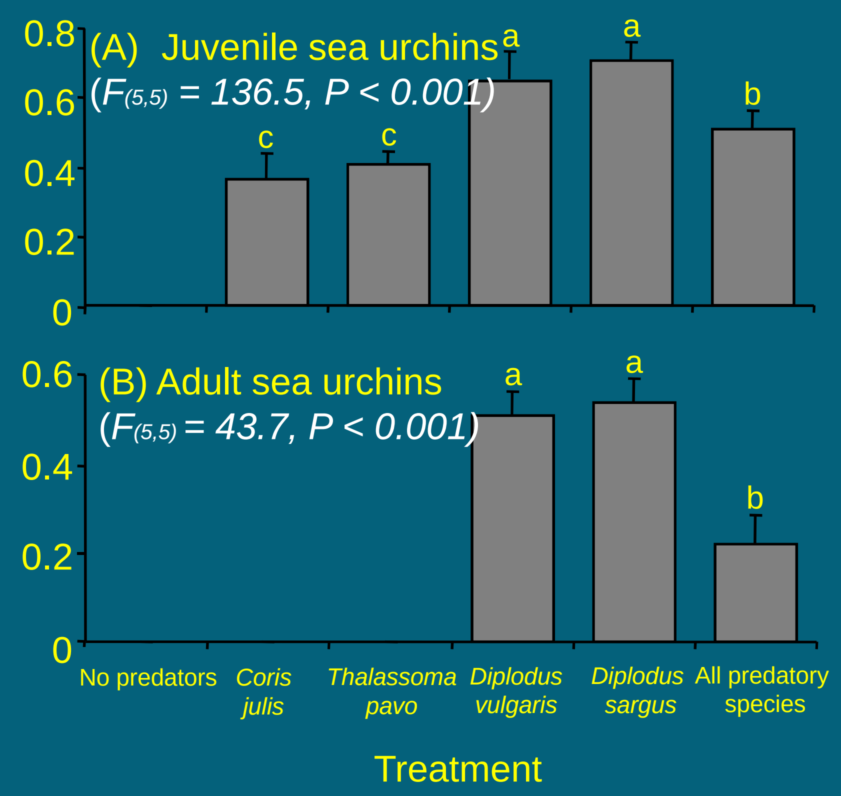
Additive or emergent effects of multiple predator guilds (i.e. wrasses and sea breams) on sea urchins were tested by comparing the observed predation risk to the predicted values generated by a null model, i.e. the *MRM*, using a two-way ANOVA : “treatment” (three levels: wrasses, sea breams, wrasses + sea breams) and the categories “observed *vs* expected” (two levels) were treated as fixed and orthogonal factors

# Patterns were coherent between the two bays

Experiment 1 (ADDITIVE)




Experiment 2 (SUBSTITUTIVE)

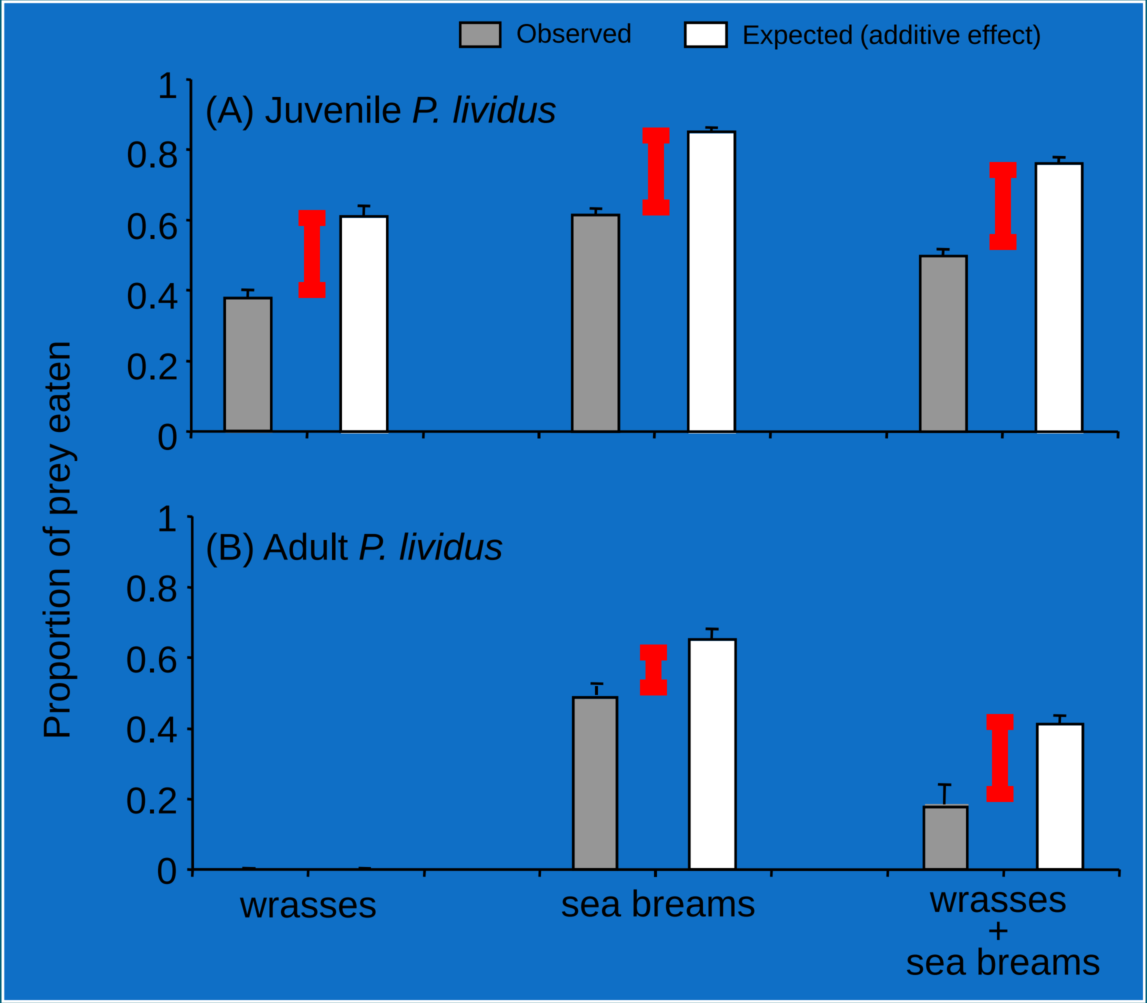



In treatments with ‘all predators’ there is the max species richness, but also max density

Total density constant, but predator assemblage composition changes

The two labrid fishes, and the two sparids have the same effects … they can be treated as two guilds

# An emerging impact (negative) of multiple predators has been observed only for adult sea urchins




**Tr:** ***F*=25.20; *P* < 0.01**

**O*vs*E:** ***F*=71.10; *P* < 0.001**

**Tr x O*vs*E:** ***F*=0.13; *P* = 0.88**

- Non-additivity *intraguild* (density-dependence) and non-additivity *interguild* are **<u>similar</u>**

**1 or 2 guilds have the same effects on predation rates**

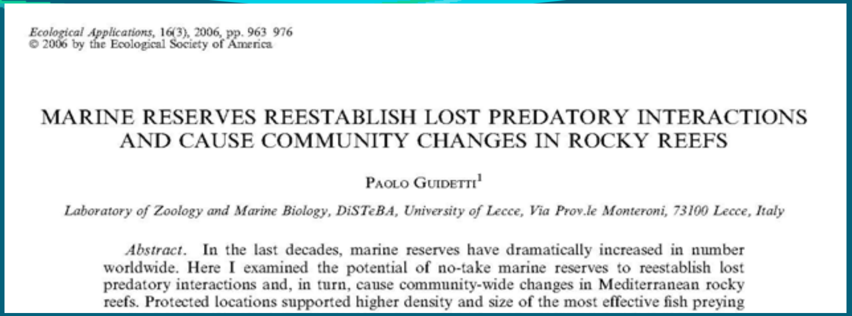
**Tr x O*vs*E:** ***F*=7.01; *P* < 0.01**

- Non-additivity *intraguild* and non-additivity *interguild* are **<u>NOT similar</u>**

**2 guilds cause a decrease in predation rates**

# Final remarks

Cascading effects of fish predator removal on entire communities (observed worldwide) suggest that decreasing predator density may disrupt natural communities



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MARINE RESERVES REESTABLISH LOST PREDATORY INTERACTIONS AND CAUSE COMMUNITY CHANGES IN ROCKY REEFS

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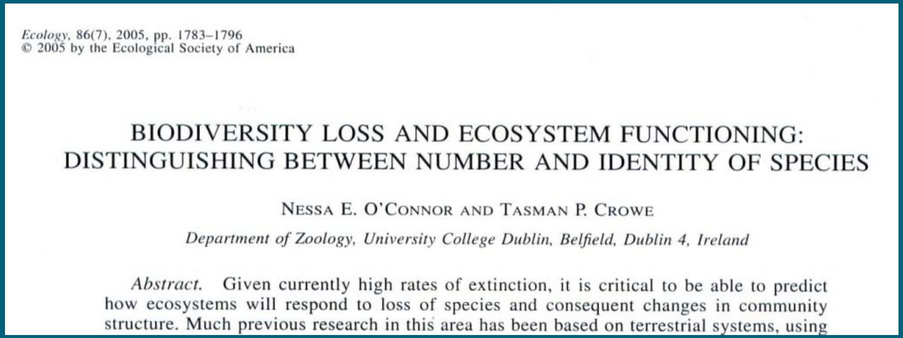
*Abstract.* In the last decades, marine reserves have dramatically increased in number worldwide. Here I examined the potential of no-take marine reserves to reestablish lost predatory interactions and, in turn, cause community-wide changes in Mediterranean rocky reefs. Protected locations supported higher density and size of the most effective fish preying



*Ecology*, 86(7), 2005, pp. 1783–1796
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BIODIVERSITY LOSS AND ECOSYSTEM FUNCTIONING: DISTINGUISHING BETWEEN NUMBER AND IDENTITY OF SPECIES

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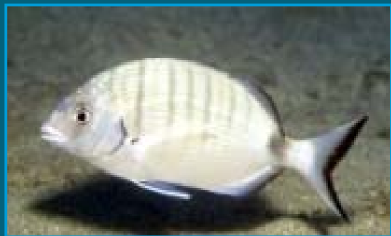
*Abstract.* Given currently high rates of extinction, it is critical to be able to predict how ecosystems will respond to loss of species and consequent changes in community structure. Much previous research in this area has been based on terrestrial systems, using

There is increasing evidence, however, that the is no linear relationship between functioning and species richness, but that different species may have idiosyncratic effects

This study experimentally stressed:

1) the major contribution from sea breams to predation upon sea urchins in rocky reefs compared to that from wrasses (species identity *vs* species richness);

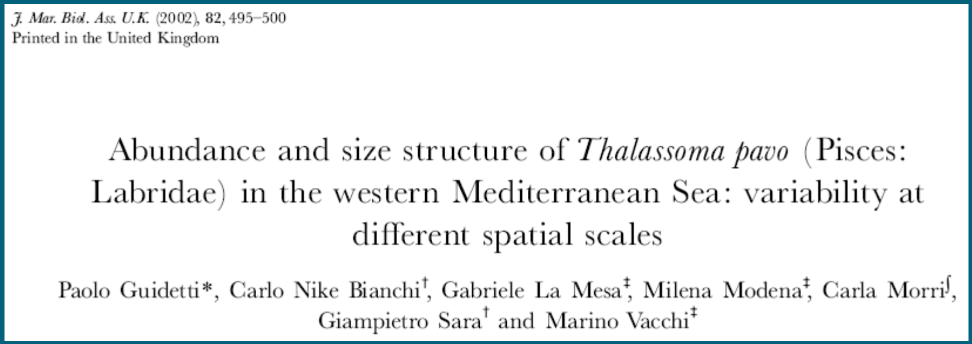
# 2) the foraging efficiency of sea breams decreases in the presence of wrasses (interference competition)



Null, positive or negative effects of multi-predator assemblages on prey and communities depend on the relationships among predators (interference, intra-guild predation, facilitation)

From this perspective, the finding that increasing wrasse density may decrease the capacity of the fish predator assemblage to control sea urchin populations and, consequently, formation of barrens is of some concern

*T. pavo* is increasing in the Med. Water warming could thus affect species interactions and enhance desertification of rocky reefs in the Mediterranean Sea



*J. Mar. Biol. Ass. U.K.* (2002), 82, 495–500
Printed in the United Kingdom

Abundance and size structure of *Thalassoma pavo* (Pisces: Labridae) in the western Mediterranean Sea: variability at different spatial scales

Paolo Guidetti*, Carlo Nike Bianchi†, Gabriele La Mesa‡, Milena Modena‡, Carla Morri∫, Giampietro Sara† and Marino Vacchi‡

LETTERS

## Chaos in a long-term experiment with a plankton community

Elisa Benincà[1,2]*, Jef Huisman[1]*, Reinhard Heerkloss[3], Klaus D. Jöhnk[1]†, Pedro Branco[1], Egbert H. Van Nes[2], Marten Scheffer[2] & Stephen P. Ellner[4]

Mathematical models predict that species interactions such as competition and predation can generate chaos[1–4]. However, experimental demonstrations of chaos in ecology are scarce, and have been limited to simple laboratory systems with a short dura-

Here, we analyse a time series of a plankton community isolated from the Baltic Sea. The plankton community was cultured in a laboratory mesocosm under constant external conditions for more than eight years[16]. In total, two nutrients (nitrogen and phosphorus),

Manipulative experiments can help provide guidelines to interpret effects of biodiversity loss or elucidate species roles and the effects of diversity components on processes, but they are possible only in limited cases and for limited temporal scales

Although with weaker inference, historical ecology is a valid tool to understand the effects of diversity loss in multispecies systems where predictive approaches are not unanimously accepted

## Ecological hypotheses for a historical reconstruction of upper trophic level biomass in the Baltic Sea and Skagerrak

Brian R. MacKenzie, Jürgen Alheit, Daniel J. Conley, Poul Holm, and Carl Christian Kinze

Can. J. Fish. Aquat. Sci. 59: 173–190 (2002)

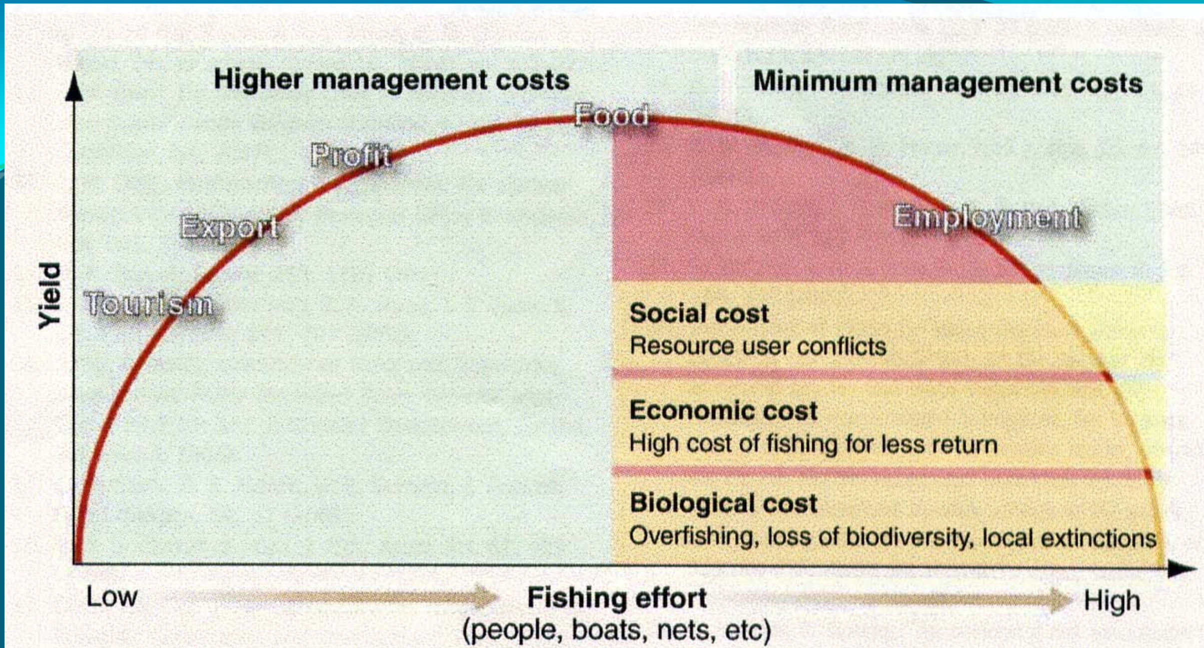
www.sciencemag.org SCIENCE VOL 293 27 JULY 2001

## Historical Overfishing and the Recent Collapse of Coastal Ecosystems

Jeremy B. C. Jackson,[1,2]* Michael X. Kirby,[3] Wolfgang H. Berger,[1] Karen A. Bjorndal,[4] Louis W. Botsford,[5] Bruce J. Bourque,[6] Roger H. Bradbury,[7] Richard Cooke,[2] Jon Erlandson,[8] James A. Estes,[9] Terence P. Hughes,[10] Susan Kidwell,[11] Carina B. Lange,[1] Hunter S. Lenihan,[12] John M. Pandolfi,[13] Charles H. Peterson,[12] Robert S. Steneck,[14] Mia J. Tegner,[1]† Robert R. Warner[15]

Ecological extinction caused by overfishing precedes all other pervasive human disturbance to coastal ecosystems, including pollution, degradation of water quality, and anthropogenic climate change. Historical abundances of large consumer species were fantastically large in comparison with recent observations. Paleoecological, archaeological, and historical

longer term cycles or shifts in oceanographic regimes and productivity (15–17). To help address this problem, we describe ecosystem structure predating modern ecological studies using well-dated time series based on biological




Whatever the focus of any study (e.g. fishing management, conservation), understanding the effects of changes or losses in marine biodiversity and the related causal processes (e.g. fishing or climate changes) represents the most exciting challenge for any marine ecologist in these days

## Thank you for your attention