



Growth responses of *Macrocystis pyrifera* (Laminariales), Southern Chile, juvenile sporophytes to nutrient limitation

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INTRODUCTION

Kelp forests represent some of the most conspicuous coastal habitats and today we recognize only one giant kelp species (*Macrocystis pyrifera*) distributed globally [1, 2]. *M. pyrifera* is recognized as a perennial kelp species with a low capacity of energy storage, whereas its high productivity is associated the availability of nitrogen from the water column [3]. The relation between *M. pyrifera* growth and biomass production results from a plastic response of the sporophytes to temporal and spatial variability in nitrogen availability [4, 5]. However, the low storage capacity of giant kelp [6, 7] is clearly disadvantageous during periods of suboptimal environmental conditions; as those that occur seasonally in California and the inland waters of southern Chile. Due to an increased demand for kelp biomass in Chile for the world alginate industry and abalone farming in Chile [8, 9] there is an increased demand of raw material and interest for developing kelp aquaculture technologies [10].

The present study evaluates the effect of different nitrogen availability on the growth and regeneration of juvenile fronds of *M. pyrifera* sporophytes from southern Chile and explore its consequences for the development of seeding strategies of kelp farming in southern Chile.

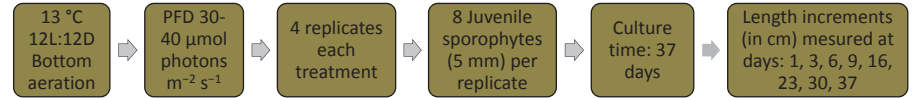
MATERIAL & METHODS

M. pyrifera juvenile sporophytes (5 mm) were obtained under controlled environmental conditions from sporophylls collected in Metri in southern Chile (41°48'S). Two experiments were conducted to determine the ability of regeneration of juvenile fronds of *M. pyrifera* sporophytes:

Experiments (E)	Conditions
E1. Acclimation in natural seawater with Provasoli medium effects	• 9 days acclimation with AMN +N* • 3 treatments (AMA -N, AMA +N, AMN +N)*
E2. Acclimation in artificial seawater with Provasoli medium without nitrogen source effects	• 17 days acclimation with AMA -N* • 4 treatments (AMA -N, AMA +N, AMN -N, AMN +N)*

*AMA -N, artificial sea water [11] plus Provasoli's Enrichment Solution (PES) [12] without nitrogen | AMA +N, artificial sea water plus PES | AMN -N, natural sea water plus PES without nitrogen | AMN +N, natural sea water plus PES.

The experimental conditions for both experiments were:



Calculations

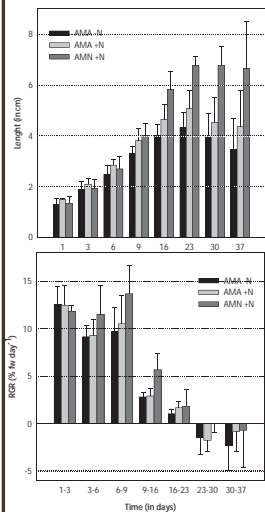
Relative Growth Rates (RGR) and Yield were calculated according to [13].

Data analysis

Mean and standard deviation (SD) | one-way ANOVA: ≠ among treatments | Student Newman Keuls: multiple posthoc comparisons among means | H0 rejected 5% significance level | Software GMAV v5

RESULTS

E1. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in natural sea water with PES



- Kelp fronds that grew in natural seawater with PES had the best response after 30 days reaching a size of 6.78 ± 0.73 cm (Fig. 1A and Fig 2d).
- Best RGR (13.68 ± 2.98 , $P < 0.05$) with AMN +N between days 6-9 (Fig. 1B).
- RGR decreased from days 9-16 towards the end of the experiment at all conditions (Fig. 1B).

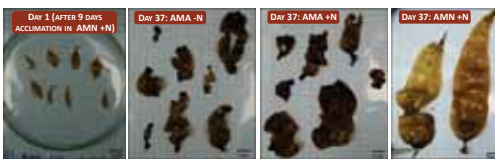
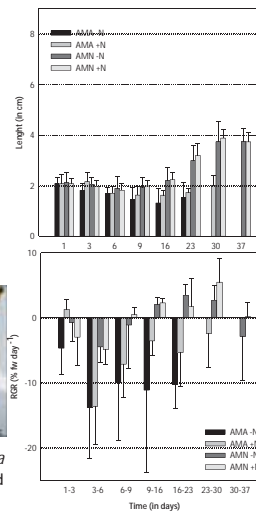


Fig. 2. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in natural sea water with PES. Kelp fronds at day 1 (A) and at day 37 (B, C, D).

Fig. 1. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in natural seawater with PES. (A) Length (in cm). (B) growth rates (% fw day⁻¹) (mean±SD, n=4).

E2. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in artificial seawater with PES without nitrogen source



- Juvenile fronds that grew in natural seawater with full PES and without nitrogen were able to recover and reach after 37 days a size of 3.73 ± 0.37 and 3.74 ± 0.51 cm, respectively (Fig. 2A and Fig. 3C-D).
- Juvenile fronds that were maintained in artificial seawater plus PES (with and without nitrogen) were unable to recover after 30 days (Fig. 4A and Fig. 3B)
- Best RGR (5.50 ± 3.71 , $P < 0.05$) with AMN +N between days 23-30 (Fig. 3B).



Fig. 4. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in artificial seawater with PES without nitrogen source. Kelp fronds at day 1 (A) and at day 37 (B, C, D)..

Fig. 3. Effect of ≠ nitrogen availability on the growth of *M. pyrifera* acclimated in artificial seawater with PES without nitrogen source. (A) length (in cm). (B) growth rates (% fw day⁻¹) (mean±SD, n=4).

Discussion & Conclusions

- *M. pyrifera* juvenile sporophytes can regenerate only to some extent after a period of nutrient' deprivation and therefore have storage capabilities.
- Information on the factors that enhance nutrient uptake, tissue storage and productivity of kelps is crucial to increase the efficiency of their aquaculture and biomitigation capacity.
- Understanding the storage capacity of this kelp population is essential for further studies on aquaculture approaches [10] in southern Chile for biomass production.

References

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Book of Abstracts

Mares Conference

Marine Ecosystems Health and Conservation

Olhão, Portugal

17 – 21 November 2014

An initiative from The MARES Joint Doctoral Programme on Marine Ecosystem Health & Conservation - www.mares-eu.org

Organized by The Mares Conference Coordination Office
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Organizers

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The first international MARES Conference is an initiative from the MARES Joint Doctoral Programme (www.mares-eu.org).

This joint international thematic doctoral programme, funded through Erasmus Mundus and coordinated by Ghent University, was initiated in 2010. Since then, over 30 young scientists are actively conducting research focused on the impacts of human activities on marine ecosystems.

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Themes

The Mares Conference aims to address the main issues of marine ecosystems health and conservation. Six thematic subjects will be developed, these six themes are the ones developed by the MARES doctoral candidates :

1. Future Oceans : temperature changes - hypoxia - acidification

Temperature rise, ocean acidification and expanding hypoxic zones, related to anthropogenic release of carbon dioxide and climate changes, impact significantly marine ecosystems health. Marine organisms responses towards climate change can be various and drastic (e.g. changes in distribution range, regime shifts, etc.), and could propagate through the entire marine food chain.

2. Understanding biodiversity effects on the functioning of marine ecosystems

The current biodiversity decline, primarily caused by human activities, has serious consequences on the goods and services provided by the marine ecosystems. There is a real need to understand the mechanisms that underlie the observed relationships between biodiversity and ecosystem functioning.

3. Biological invasions

Due to globalization, intentional or non-intentional introductions of marine species have contributed to the outbreak of invasive alien species having adverse effects on the receiving ecosystems. A new systematic approach is required to assess the key descriptors of biological invasions and to identify effective management actions.

4. Natural Resources : overexploitation, fisheries and aquaculture

The steady increase of world fish catches leads to the overexploitation of the majority of marine stocks and affects drastically marine ecosystem resilience. To meet the growing demand for marine commercial products, aquaculture practices have intensified and often cause destructive effects on the surrounding marine environment. In order to implement efficient management measures, a good understanding of fisheries and aquaculture interactions with the environment is needed.

5. Ocean noise pollution

Due to expansion of underwater human activities, anthropogenic sources of noise are increasing. Noise pollution can induce chronic and acute impacts on marine organisms. Bioacoustics methods appear to be valuable tools in impact assessment and conservation management.

6. Habitat loss, urban development, coastal infrastructures and Marine Spatial Planning

Coastal seas are altered and shoreline habitats are converted for urban development as a result of pressure from growing human populations. Even if urban ecology has not been as much a focus of marine science and management, there is now a rising interest in Marine Spatial Planning as a tool to manage the uses of marine systems.

Programme

Monday 17th November 2014

- 14.00-17.00 Registration at the Real Marina Hotel reception desk
- 17.30-18.00 Welcome and introduction
- 18.00-19.00 **Opening Lecture: Hans Pörtner**
"Climate change impacts on the world's oceans: A sectorial analysis by IPCC AR5"
- 19.00-20.00 Welcome drink at Real Marina Hotel

Tuesday 18th November 2014

Session 1: Future Oceans: temperature changes - hypoxia – acidification

Chair: Carl van Colen

- 9.00-9.45 **Keynote speaker : Frank Melzner**
"Will there be calcifying invertebrate communities in warmer, more acidic and hypoxic coastal oceans of the future?"
- 9.45-10.30 Marina Carreiro-Silva
"OceanA-Lab: an ocean acidification laboratory in the NE Atlantic (Faial Island, Azores)"
- Joy Smith
"Ocean acidification causes abundance loss and community shifts in residential zooplankton living within coral reefs – A case study"
- Jan Vanaverbeke
"Near future ocean acidification can reduce nitrification processes in coastal sediments"
- 10.30-11.00 Coffee Break
- 11.00-12.30 Susana Almeida
"Past signatures of habitat shifts shape present genetic diversity and evolutionary potential in a warming ocean"
- Laura Miralles
"Pilot whales under an incipient despeciation process"
- Joao Neiva
"Severe loss of genetic diversity in the intertidal seaweed Bifurcaria bifurcata predicted for future scenarios of climate warming"

Joana Boavida-Portugal

"Climate change impacts on global patterns of lobster diversity"

Miguel Baptista

"Developmental and ecophysiological challenges of shark early life stages in a changing tropical ocean"

Laura Airoidi

"Identifying effective management scenarios for multiple human stressors: an example with Mediterranean canopy-forming seaweeds"

12.30-14.00 Lunch break

Session 2: Natural Resources: overexploitation, fisheries and aquaculture

Chair: Catherine Boyen

14.00-14.45 **Keynote speaker: Rainer Froese**
"Can the Oceans Feed Humanity?"

14.45-15.30 Pedro Moreira
"Metadatabases of fisheries-history and fish life-history traits"

Roxanne Duncan
"Investigation of the population and sub-population structure of Albacore tuna in the Northeast Atlantic and Mediterranean"

Gregory Neils Puncher
"Misidentification of fish larvae: A call for caution and taxonomic reform"

15.30-16.00 Coffee break

16.00-17.00 Jaap van der Meer
"Inference on energetics of deep-sea fish that cannot be aged: The case of the hagfish"

Teresa Cruz
*"The status of the fishery, management and conservation of the stalked barnacle *Pollicipes pollicipes* in Portugal"*

Rui Coelho
"Habitat use of pelagic sharks in the eastern Atlantic Ocean based on satellite electronic tagging"

Bárbara Horta e Costa
"How to characterize and classify the large variability of marine partially protected areas – the BUFFER project case study"

17.15-19.00 Digital object and Poster session 1: Future Oceans & Natural Resources

Wednesday 19th November 2014

Session 3: Understanding biodiversity effects on the functioning of marine ecosystems

Chair: Jan Vanaverbeke

- 9.00-9.45 **Keynote speaker: Lisa Levin**
 "Oxygenation and Marine Biodiversity Challenges in the 21st Century"
- 9.45-10.30 Doriane Stagnol
 "Macrobenthic structural and functional diversity response to macroalgal canopy harvesting"
- Jorge Assis
 "European kelp forests and future climate change: shifting genes and ecosystems"
- Marina Zure
 "Physiological differences between Rhodopirellula species"
- 10.30-11.00 Coffee break
- 11.00-12.30 Bart De Smet
 "Life through isotope-colored glasses: revealing the Lanice conchilega food web"
- Carla Monteiro
 "Temporal windows of reproductive opportunity in marine broadcast spawners: speciation versus hybridization"
- Jan Reubens
 "An Acoustic receiver network to monitor fish movements and migrations"
- Sara Teixeira
 "Synonymous species and connectivity between fragmented ecosystems"
- Sandrine Fanfard
 "Predation, a fundamental process in macrofauna community assembling"
- David Thieltges
 "Parasite biodiversity and the functioning of marine ecosystems"
- 12.30-14.00 Lunch break

Session 4: Biological Invasions

Chair: Wiebe Kooistra

- 14.00-14.45 **Keynote speaker : Gregory M. Ruiz**
"Invasion history and vector dynamics in coastal marine ecosystems: A North American perspective"
- 14.45-15.30 Nadescha Zwerschke
"Competition between native (Ostrea edulis) and non-native (Crassostrea gigas) oysters and implications for native oyster beds"
- Elena Varela-Álvarez
"Ploidy levels vs. life history traits in native and invasive Mediterranean Caulerpa species"
- Aschwin Engelen
"Temperate gorgonians & invasive seaweed proliferation"
- 15.30-16.00 Coffee Break
- 16.00-17.00 Lies Vansteenbrugge
"Gelatinous zooplankton in the Belgian part of the North Sea and the adjacent Schelde estuary: a real problem?"
- Eva Garcia-Vazquez
"Invasion alert: North Sea native mud snail Hydrobia ulvae resists tropical conditions in ballast water"
- Anastasija Zaiko
"Metabarcoding approach in biodiversity and biosecurity surveys: a pilot study from the Baltic Sea"
- Alba Ardura
"Molecular tools to early detection of invasive mollusk species in the Baltic Sea"
- 17.15-19.00 **Digital object and Poster session 2: Biodiversity Effects, Biological Invasions, Ocean Noise & Habitat Loss**
- 19.00 Conference Dinner at the Real Marina Hotel

Thursday 20th November 2014

Chair: Laura Airoidi

Session 5: Ocean Noise Pollution

- 9.00-9.45 **Keynote speaker : Peter L. Tyack**
 “Effects of Anthropogenic Sound on Marine Mammals”
- 9.45-10.15 Elisabeth Debusschere
 “Startled but not traumatized: the effects of pile-driving on fish behavior”

Session 6: Habitat loss, urban development, coastal infrastructures and Marine Spatial Planning

- David Abecasis
 “The use of acoustic telemetry studies in marine spatial planning”
- 10.15-10.45 Coffee Break
- 10.45-11.30 **Keynote speaker: Michael Beck**
 “Building Coastal Resilience for Climate Adaptation and Risk Reduction”
- 11.30-12.30 Nuno Sales Henriques
 “MPA design using Marxan with Zones and an Ecosystem Based Management approach”
- Pierre-Alain Mannoni
 “Discriminating pressure sources responsible for local mediolittoral ecosystems degradation”
- Janne Wong
 “Different susceptibility of saltmarsh vegetation and soils to sea level rise and eutrophication”
- Federica Costantini
 “Marine connectivity in temperate biogenic reefs and implication for their conservation: a Mediterranean meta-analysis”
- 12.30-14.00 Lunch break
- 14.00- 17.00 **Round Tables: Conservation Issues**
- 17.00-18.30 Closing event at Real Marina Hotel

Friday 21th November 2014

- 9.00-13.00 Social activity: Optional Excursion

Natural Resources

Growth responses of *Macrocystis pyrifera* (Laminariales), Southern Chile, juvenile sporophytes to nutrient limitation

Patarra, RF¹ González-Carvajal, L² Hernández-González, MC² Neto, AI¹ Buschmann, AH²¹CIRN, Dep Biología, Universidade dos Açores & CIIMAR-AIR, Porto²Centro i-mar, Universidad de Los Lagos, Puerto Montt, Chile

Kelp forests represent some of the most conspicuous coastal habitats and today we recognize only one giant kelp species (*Macrocystis pyrifera*) distributed globally. The relation between *M. pyrifera* growth and biomass production results from a plastic response of the sporophytes to temporal and spatial variability in nitrogen availability. But, the low storage capability of giant kelp is clearly disadvantageous during periods of suboptimal environmental conditions. This study provides experimental evidence on the ability of regeneration of juvenile fronds of *M. pyrifera* juvenile sporophytes (5 mm) obtained under controlled environmental conditions from sporophylls collected in Metri in southern Chile (41°48'S). Under controlled conditions, the experimental design considered 4 treatments (with 4 replicates) with different nitrogen availability. After 9 days of acclimatization in a nitrogen rich medium the kelp fronds that grew on natural seawater with full Provasoli medium had the best response after 30 days reaching a size of 6.78 ± 0.73 cm. A second experiment tested the ability *M. pyrifera* to recover from a 17 days acclimation on artificial seawater with Provasoli medium without nitrogen. Juvenile fronds that were maintain on artificial seawater (with and without nitrogen) were unable to recover after 30 days. Juvenile fronds that grew on natural seawater with full Provasoli medium and without nitrogen were able to recover and reach after 37 days a size of 3.73 ± 0.37 and 3.74 ± 0.51 cm, respectively. We can conclude that *M. pyrifera* juvenile sporophytes can in only in some extent regenerate after a period of nutrients deprivation and therefore have some storage capabilities.

Keywords: Giant kelp, *Macrocystis*, Physiological adaptations, Sporophyte growth.



Ghent, 26 November 2014

Name: **Rita F. Patarra**

Mares Conference : Certificate of Poster Presentation

The Coordination Office of the Mares Conference confirms that **Rita F. Patarra**' poster entitled:

"Growth responses of *Macrocystis pyrifera* (Laminariales), Southern Chile, juvenile sporophytes to nutrient limitation"

Patarra, RF, González-Carvajal, L, Hernández-González, MC, Neto, AI, Buschmann, AH

Has been presented during the first Mares Conference on Marine Ecosystems Health and Conservation that took place in Olhão (Portugal) from 17 to 21 November 2014.

Yours Sincerely

A handwritten signature in black ink, appearing to read "Tim Deprez", written over a light blue horizontal line.

Dr. Tim Deprez, on behalf of the organizing Committee

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