Cold corals biology: focus on reproduction aspects

Covadonga Orejas

European TRACES Workshop, Faro March 2008

TRACES will examine key gaps in our understanding of cold-water coral ecosystems and focus on questions such as:

- Can we develop clear models of larval dispersal potential throughout the North Atlantic Ocean?
- What physical and biological factors are important in controlling cold-water coral occurrence?
- Can we develop predictive models of coral occurrence at local, regional and eventually global scales?

TRACES - *Trans-Atlantic Coral Ecosystem Study*

TRACES is a scientific programme to investigate cold-water coral communities found along the continental shelf break and slope, and in association with canyons and seamounts in the North Atlantic Ocean. The success of TRACES relies on scientific cooperation between Canada, the European Union, and the United States.

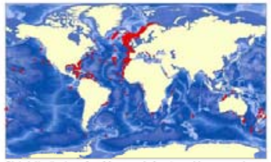
The deep-sea is the last frontier on Earth. Scientific surveys in the deep have revealed new species and even entire ecosystems that were unknown to previous generations. In the last two decades improvements in deep-sea mapping technology and research submersibles have shown that coral ecosystems are not restricted to tropical coral reefs but are found in the deep oceans of the world.

The best developed and most studied cold-water coral ecosystems are in the North Atlantic but they have never been studied and compared across the ocean basin.

TRACES will develop the first coherent plan to study cold-water coral ecosystems across an ocean basin and lay the foundations for an international research programme beginning 2010.

Why Now?

- Intense research activity over the last ten years has discovered and mapped many Atlantic cold-water coral ecosystems.
- We can now study the links between cold-water coral ecosystems using new genetic approaches.
- We can now study past ocean climate using new high resolution analyses of coral skeletons.
- These ecosystems are threatened by deep-water trawling and ocean acidification.
- Strategies based on sound science are needed now to conserve these fragile and diverse ecosystems.



Global distribution of reef framework-forming cold-water corals showing concentration of records in the North Atlantic Ocean. From: Roberts et al. (2006) *Science* 312: 543

A large Atlantic black coral. Recent work shows that these black corals may live over 2000 years. Photo: AWI & Ifremer (2003)

How will TRACES work?

- Early 2008 cold-water coral researchers meet to outline the TRACES Science Plan at North American (Wilmington, N.C., U.S.A.) and European (Faro, Portugal) workshops.
- Science Plan completed by end 2008.
- Discussions with Canadian, European and U.S. marine science funding agencies to support an integrated research programme.
- First TRACES projects apply for research funds in 2009.
- Potential preliminary TRACES cruise time summer 2009.
- Research begins 2010 onwards.

Benefits

- Better understanding of North Atlantic climate history and ecology using cold-water coral records.
- Better understanding genetic and 'biodiversity' links among Atlantic coral ecosystems used to develop sound long-term conservation management policies.
- Develop expertise and international partnerships between Canada, E.C. and U.S.
- Raise public understanding and awareness of these hidden coral worlds.

TRACES programme development is supported by the Royal Society of Edinburgh and a Marie Curie international fellowship grant from the European Commission. For more information see www.lophelia.org/traces

Contact Dr J. Murray Roberts (robertsjm@uncw.edu, Tel. +1-910-799-7926)

Brief summary on the history of deep coral studies

XVIII – XIX Centuries

- Earliest known records of deep-sea corals in the Atlantic region of Canada from 1800s.

- Earliest documentation of deep-sea corals in European waters (from Norway) by Pontoppidan (1755)

- Growth of fishing in the late 18th and 19th centuries → more information on *Lophelia pertusa* and in general in cold corals

- End 18th – Start 19th Century first ideas about distribution, mainly from the fishers

Brief summary on the history of deep coral studies

XX Century

- First in the 50th until the 70th increasing in publications on deep corals. Studies on distribution and colonization strategies. Most information based on *Lophelia pertusa*

- Technological advances → increase on the explored areas: Florida, Rockall Bank, Porcupine Bank, Porcupine Sea bight, Gulf of Lions…

- End of nineteen's increase of studies on ecology, physiology, genetic variability of deep corals ….

- Oil prospections → brougth lot of infos on distribution, abundances, growth, sizes…comparison with other areas. Valuation of fish impact

Brief summary on the history of deep coral studies

Last 8 years of cold coral biology studies

2000 European Union ACES (Atlantic Coral Ecosystem Study) → reproductive strategies, growth rates, framework-constructing potential, longevity of deep water coral ecosystems, biodiversity, coral behaviour, sensitivity to stress. Factors affecting benthic boundary layer particle dynamics, conservation issues , appraisal of destructive effects…

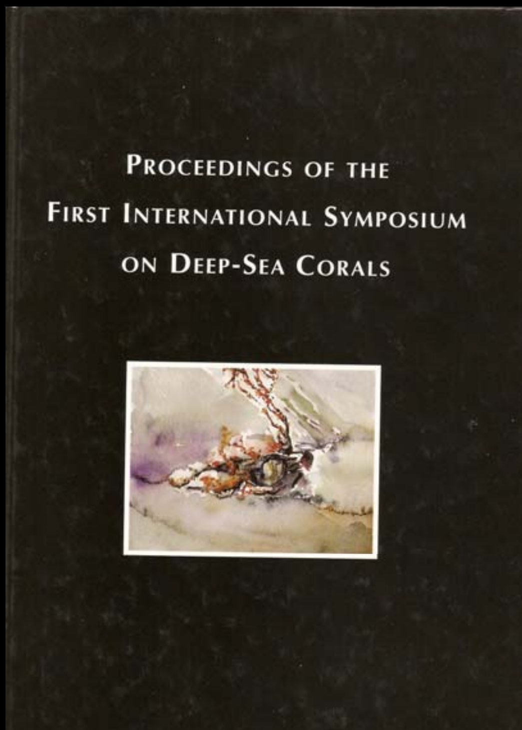
First International Symposium on Deep Sea Corals in Halifax (Canada)

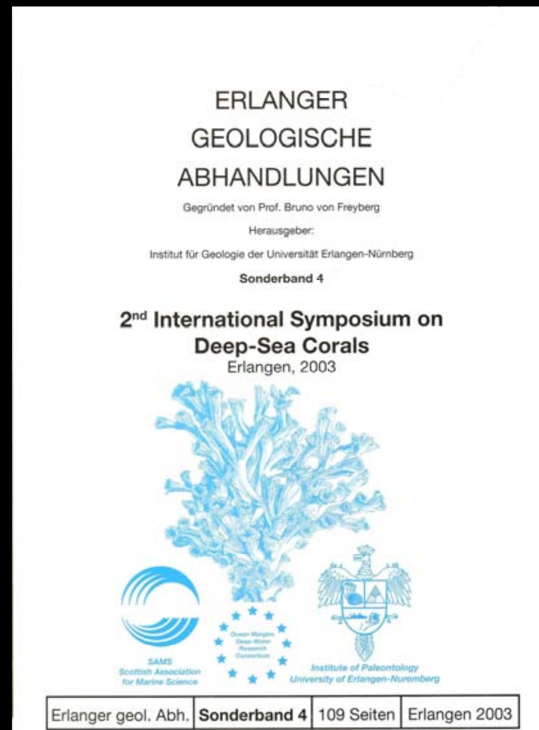
2003 Second International Symposium on Deep Sea Corals in Erlangen (Germany)

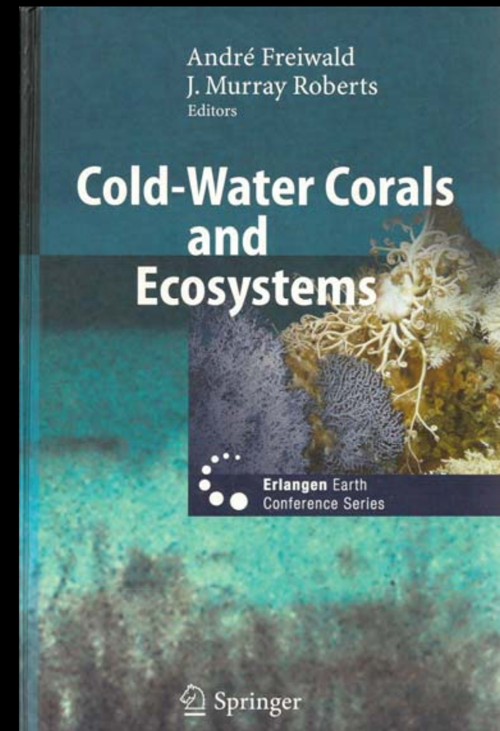
2005 Third International Symposium on Deep Sea Corals in Florida (USA)

HERMES start

What we know on Deep coral biology?

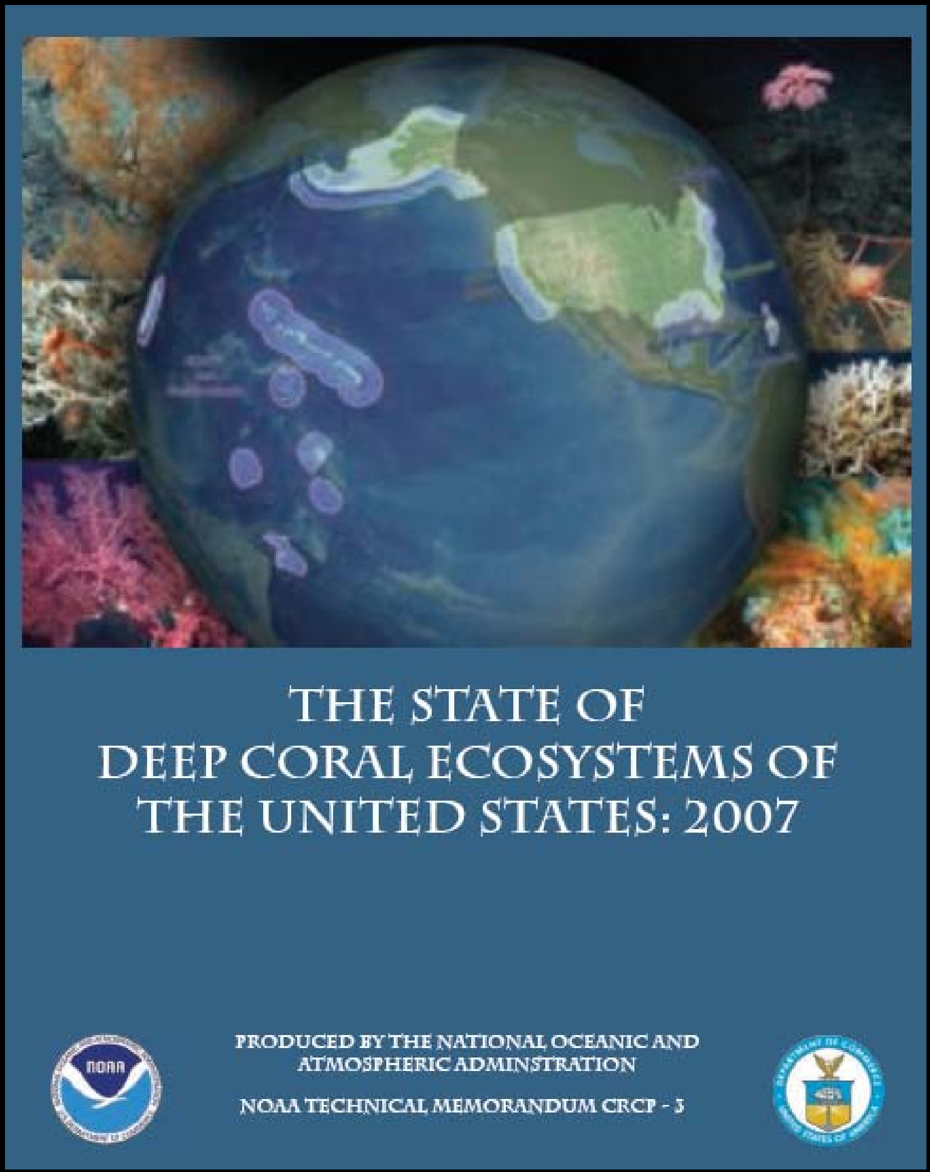






Increase in biological work, specially genetics, molecular biology, some reproduction studies and some in feeding and ecophysiology

What we know about Deep coral biology from the other side of the Atlantic ?



- More recent update on deep coral ecosystems of the USA
- Gaps on:
  - ecophysiology
  - reproduction - life history
  - processes (abiotic - biotic)
  - feeding biology
  - genetics

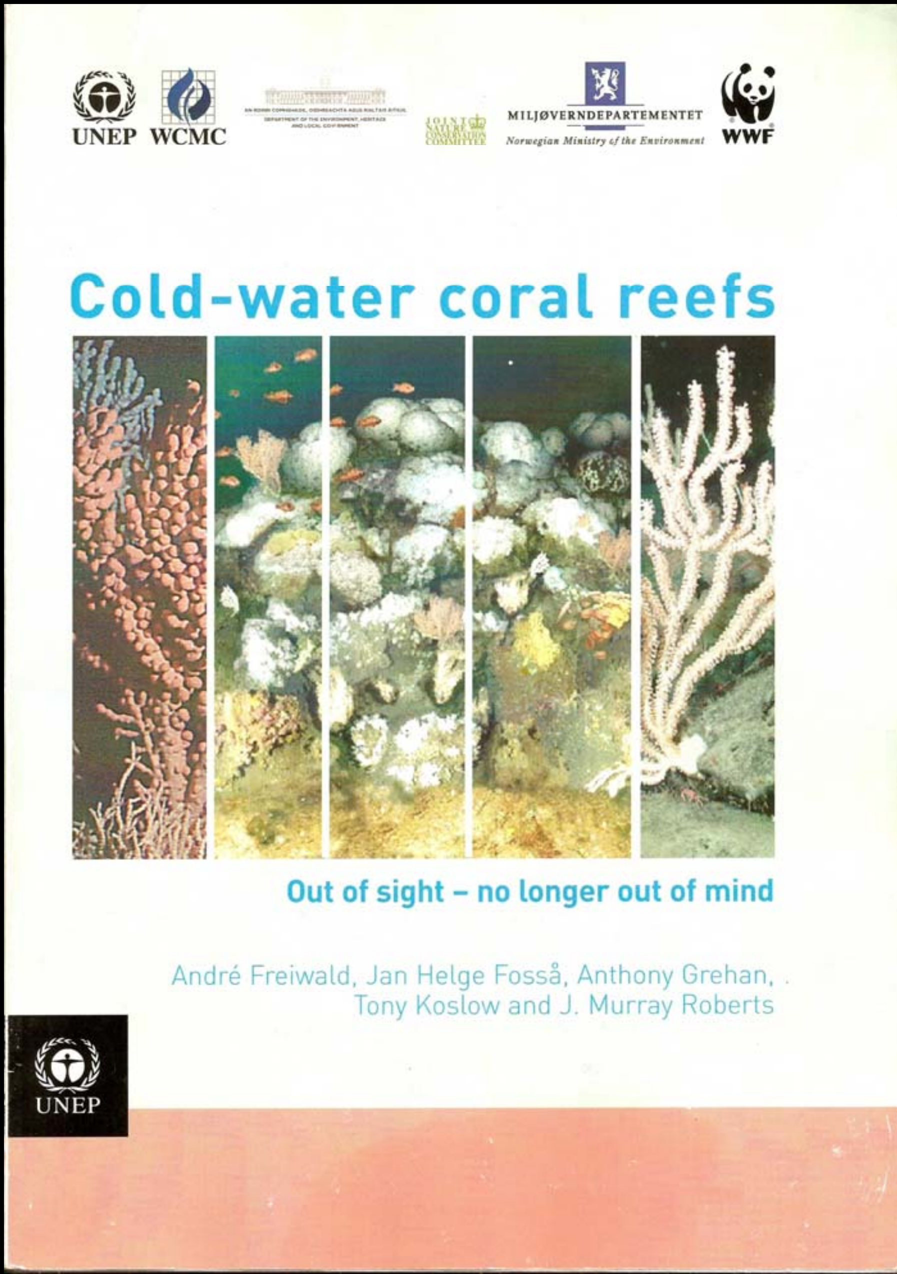
  …

What we do not know on Deep coral biology?

▪ **Biology and Physiology**: collection and analysis of specimens to better understand coral species and their genetics, to better characterise symbiotic relation ships, and to understand **more about their life history**

Reproduction studies

Growth studies



Importance of increasing knowledge on reproduction

Survival in the environment

Population dynamics

Capacity of recovering after anthropogenic impact

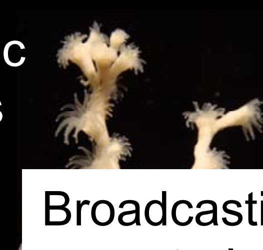
Sexual reproduction of deep corals: summary on the "basics"

- From 15 deep water Scleractinian species description of reproduction

3 observed hermaphroditic species:
Caryophyllia

Gonochorism maybe more primitive adaptation than hermaphroditism (Goffredo et al. 2000) **but** ensure genetic diversity (Szmant 1986)

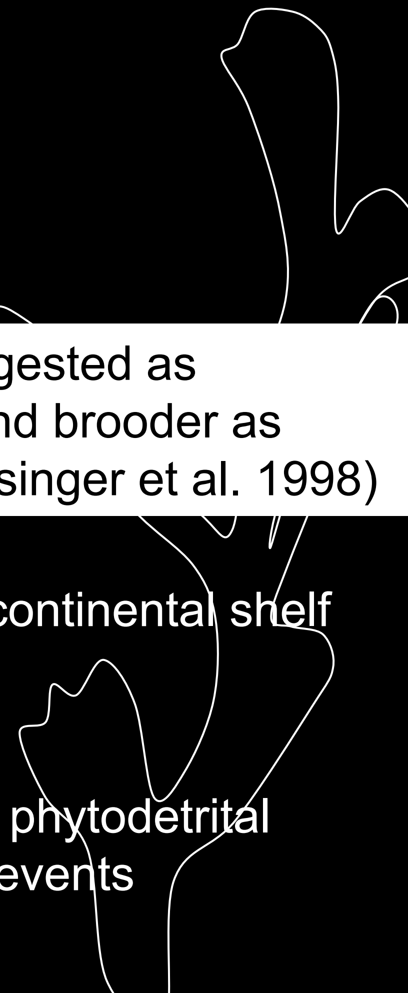
12 gonochoric (♂♀) species



Broadcasting suggested as ancestral mode and brooder as derived trait (Shlesinger et al. 1998)

- Most broadcaster
- Three records of brooders (3 *Flabellum* sps.) from the Antarctic continental shelf
- Gametogenesis: continuous, periodic, seasonal

More related to phytodetrital fall or episodic events (cascading??)



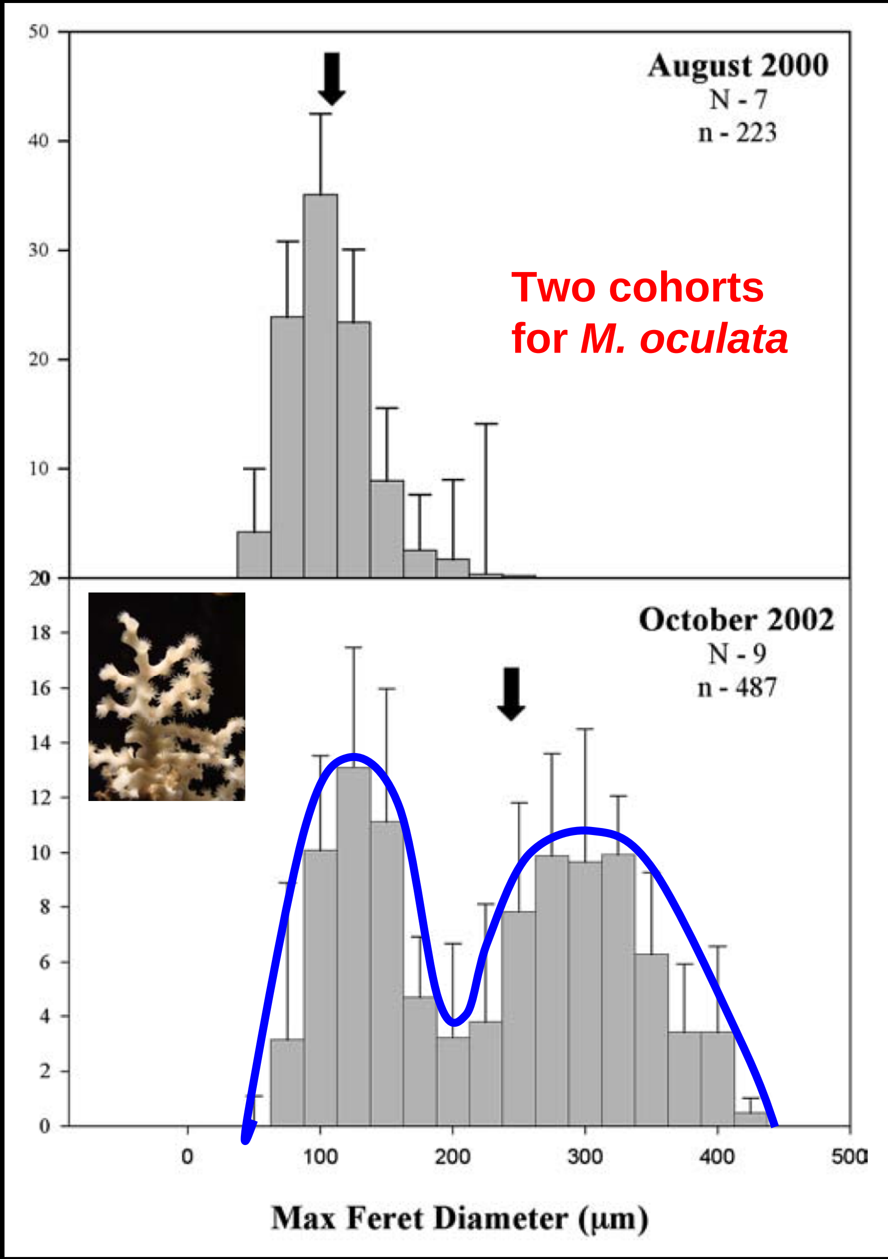
(Waller 2003, 2005, NOAA 2007)

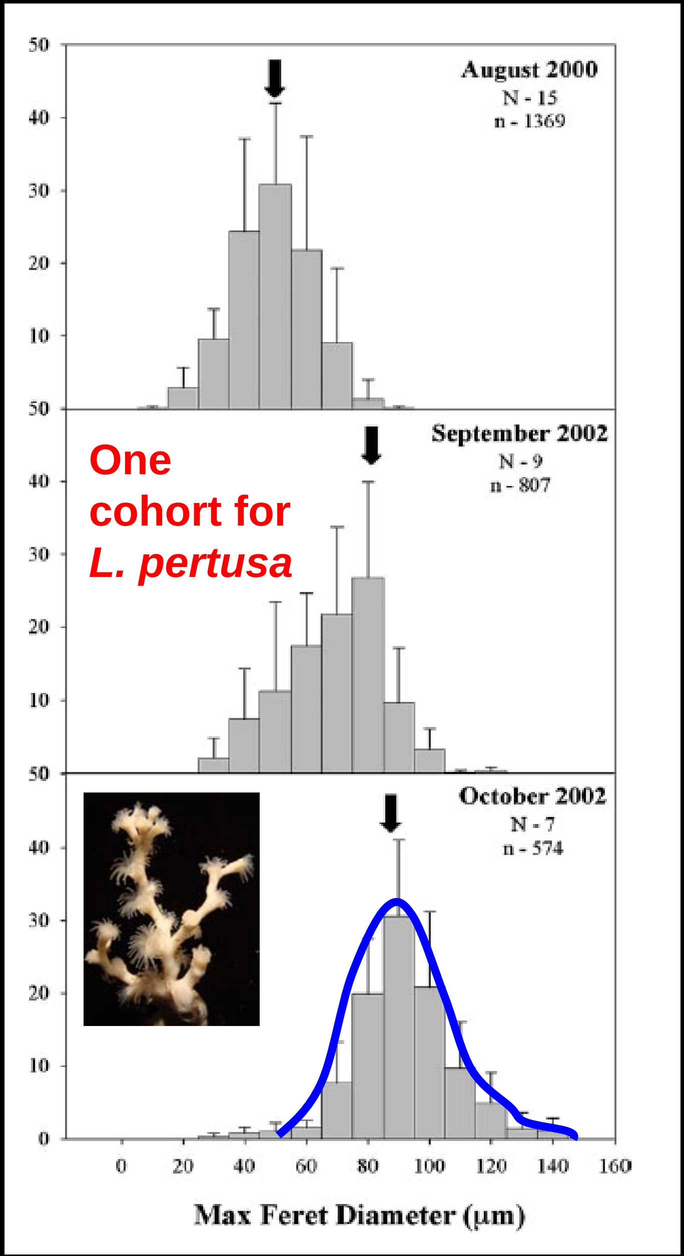
Reproduction of deep corals (15 species of scleractinias)

Species	Oocyte size (μ)	Nr Oocyte/Polyp	Incubation mode (reproductive strategy)
Lophelia pertusa	60-140	3000	♀♂, anual broadcaster spawner
Enallopsammia rostrata	400	144	♀♂, broadcast spawner
Madrepora oculata	350	40-60	♀♂, broadcaster spawner
Oculina varicosa	100		♀♂, broadcast spawner, 22 d. planula
Goniocorella dumosa	135	480	♀♂ sup., broadcast spawner
Solenosmilia variabilis	165	290	♀♂, broadcast spawner
Caryophyllia ambrosia	700	200-2750	⚥ broadcast spawner
Caryophyllia sequenzae	430	52-940	⚥ broadcast spawner
Caryophyllia cornuformis	350	-	⚥ broadcast spawner
Fungiacyathus marenzelleri	750	1290-2900	♀♂, broadcast spawner
Flabellum alabastrum	1010	550	♀♂, broadcast spawner
Flabellum angulare	814	2800	♀♂, broadcast spawner
*Flabellum thouarsii**	4800	2412	♀♂, brooder
*Flabellum curvatum**	5120	1618	♀♂, brooder
*Flabellum impensum**	5167	1270	♀♂, brooder

(Brooke 2002, Waller et al. 2002, Flint 2003, Waller & Tyler 2005, Waller 2005, Waller et al. 2005, Burguess & Babcock 2005, NOAA 2007, Waller & Baco 2007)

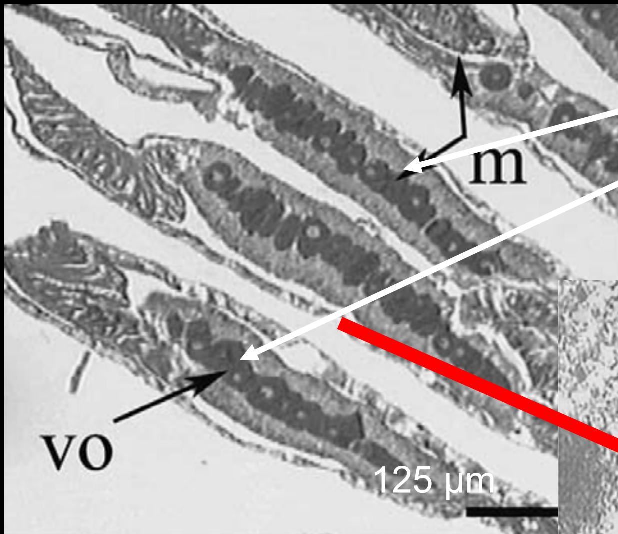
Seasonal patterns of *M.oculata* and *L.pertusa* in NE Atlantic

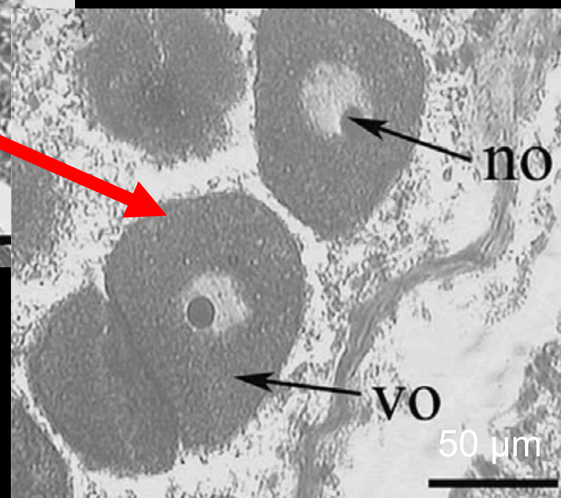


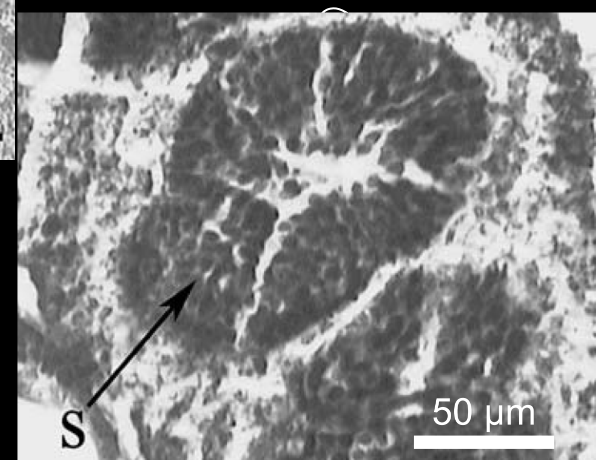


(Waller & Tyler 2005)

Reproduction of deep corals: gametogenesis in *L. pertusa*





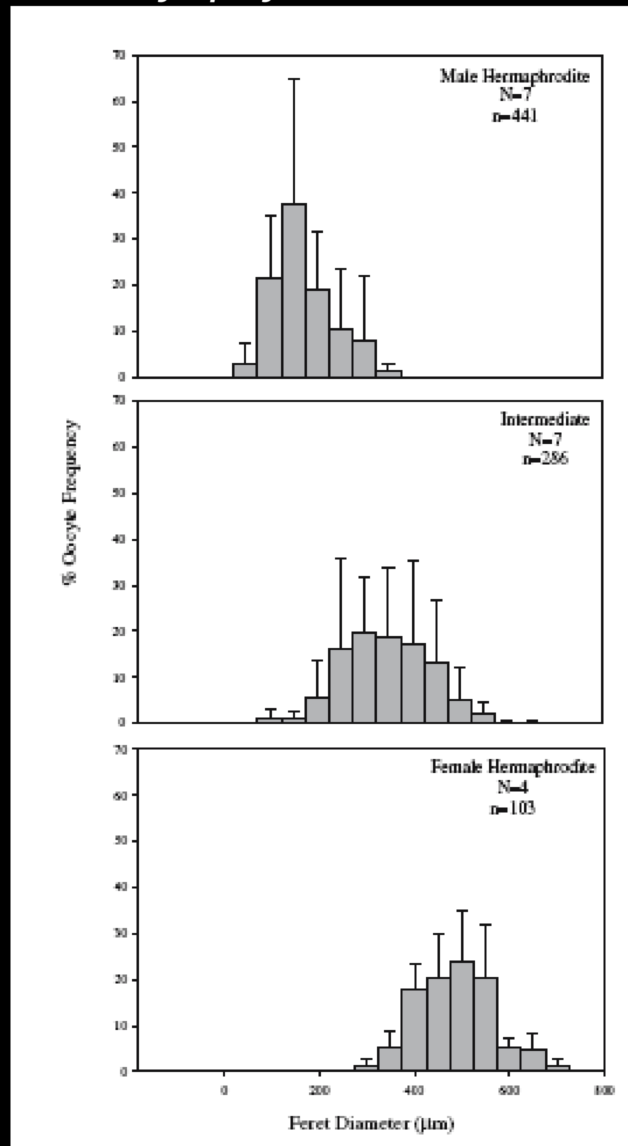


Spermatic cyst

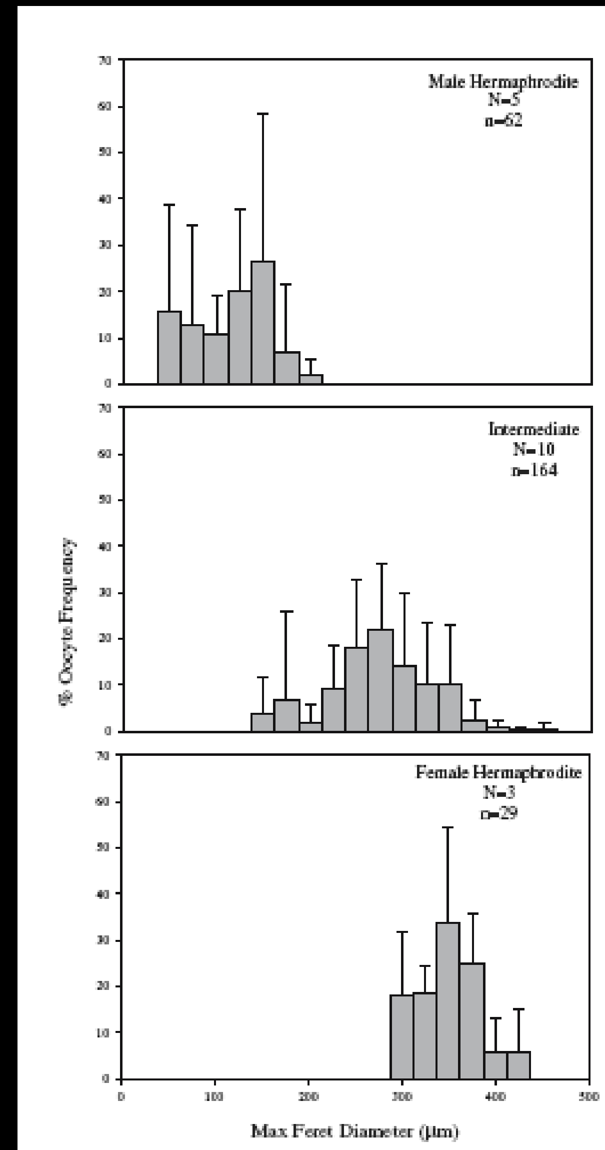
(Waller & Tyler 2005)

Reproduction of deep corals

Caryophyllia ambrosia



Caryophyllia seguenzae



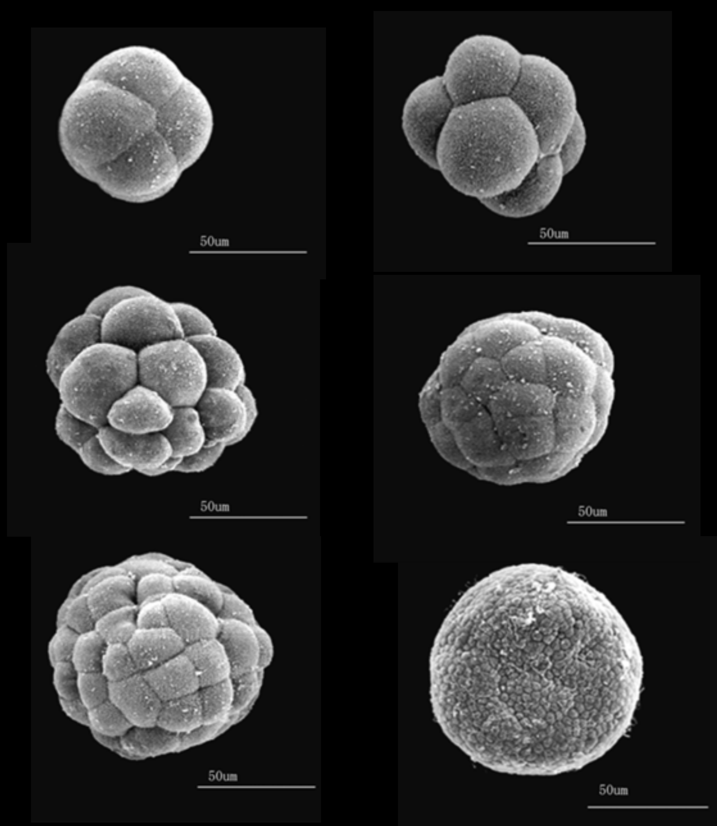
Asynchrony among individuals

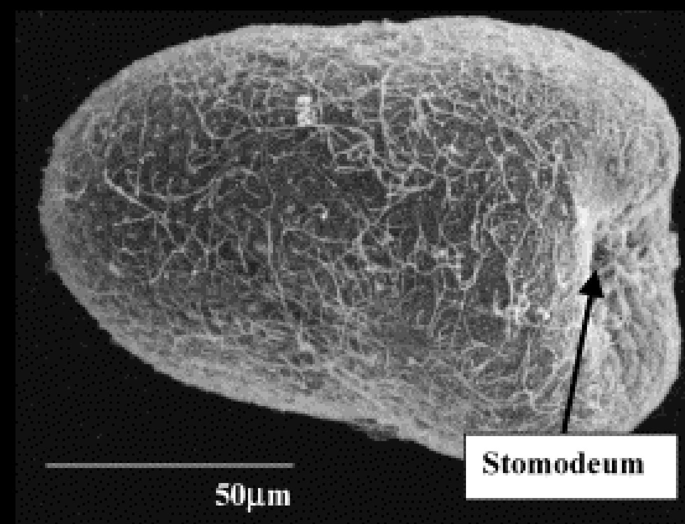
Synchrony within individuals

(Waller et al. 2005)

Larvae: we know almost nothing!

- No success with trials made with *M. oculata* and *L. pertusa* in aquaria
- No larvae have been seen but oocyte size → probably lecitotrophic larvae for most of species → high degree of local recruitment
- Larval ecology known just from *Oculina varicosa* → Long free life (until 22 days)





Scanning electron micrograph (×200) of an *O. varicosa* planula (age 24 h)

(Brooke & Young 2003, 2005, Waller 2005, Le Goff-Vitry & Rogers 2005, NOAA 2007)

Reproduction of some Antarctic octocorals

- Similarities Deep-sea - Antarctica observed in several invertebrates (Arntz et al. 1994)
- Possible migration from Antarctic shelf to deep sea in the times of maximal glacial extension (Brey et al. 1996)
    - Isolation
    - Most of Antarctic also “deep”
    - Low temperatures → few scleractinians
    - Lack of light (ahermatypic)

- Abiotic factors controlling processes:

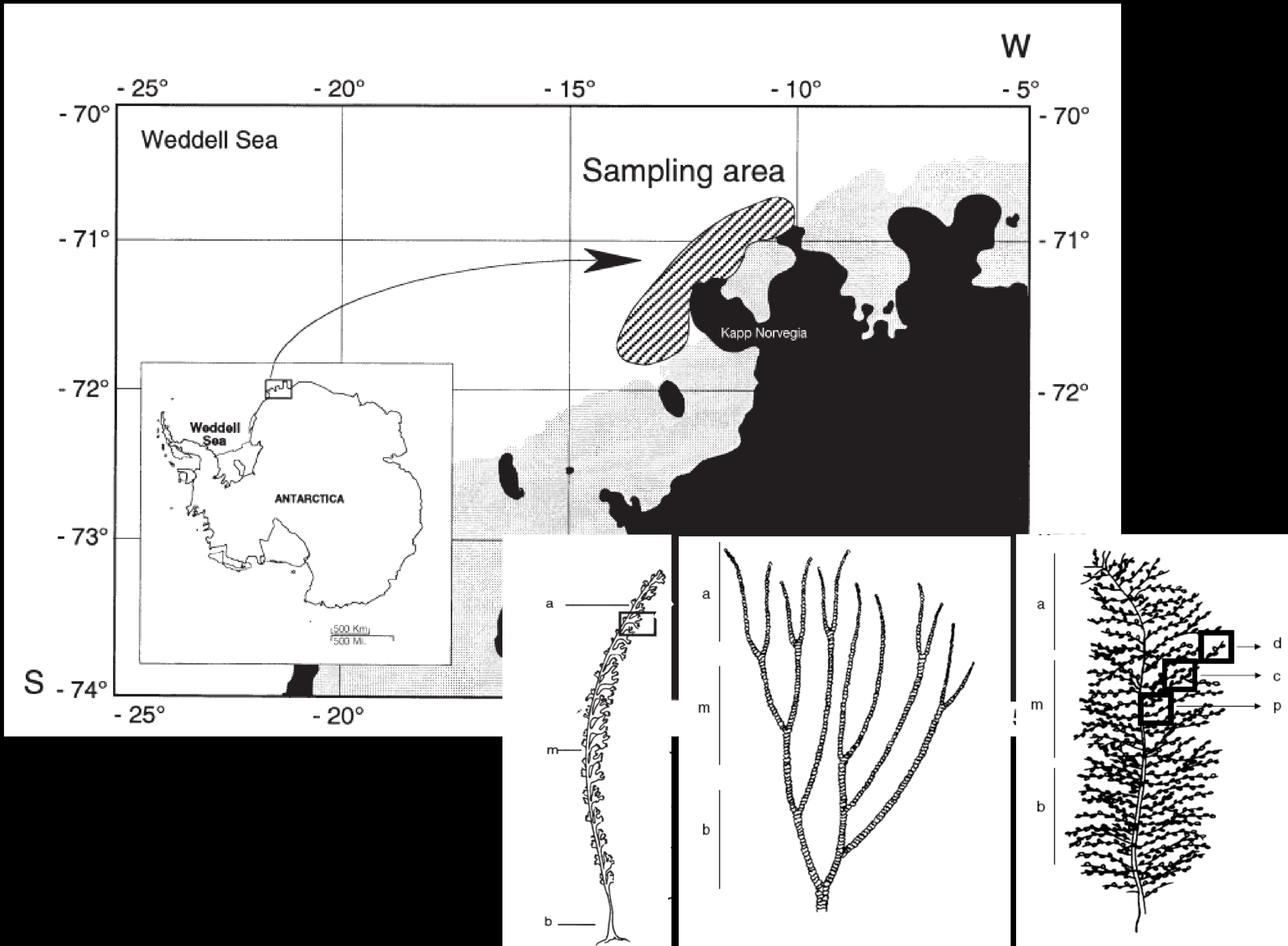
Deep Sea
- Phytodetritus fall
- Sedimentation
- Currents

…

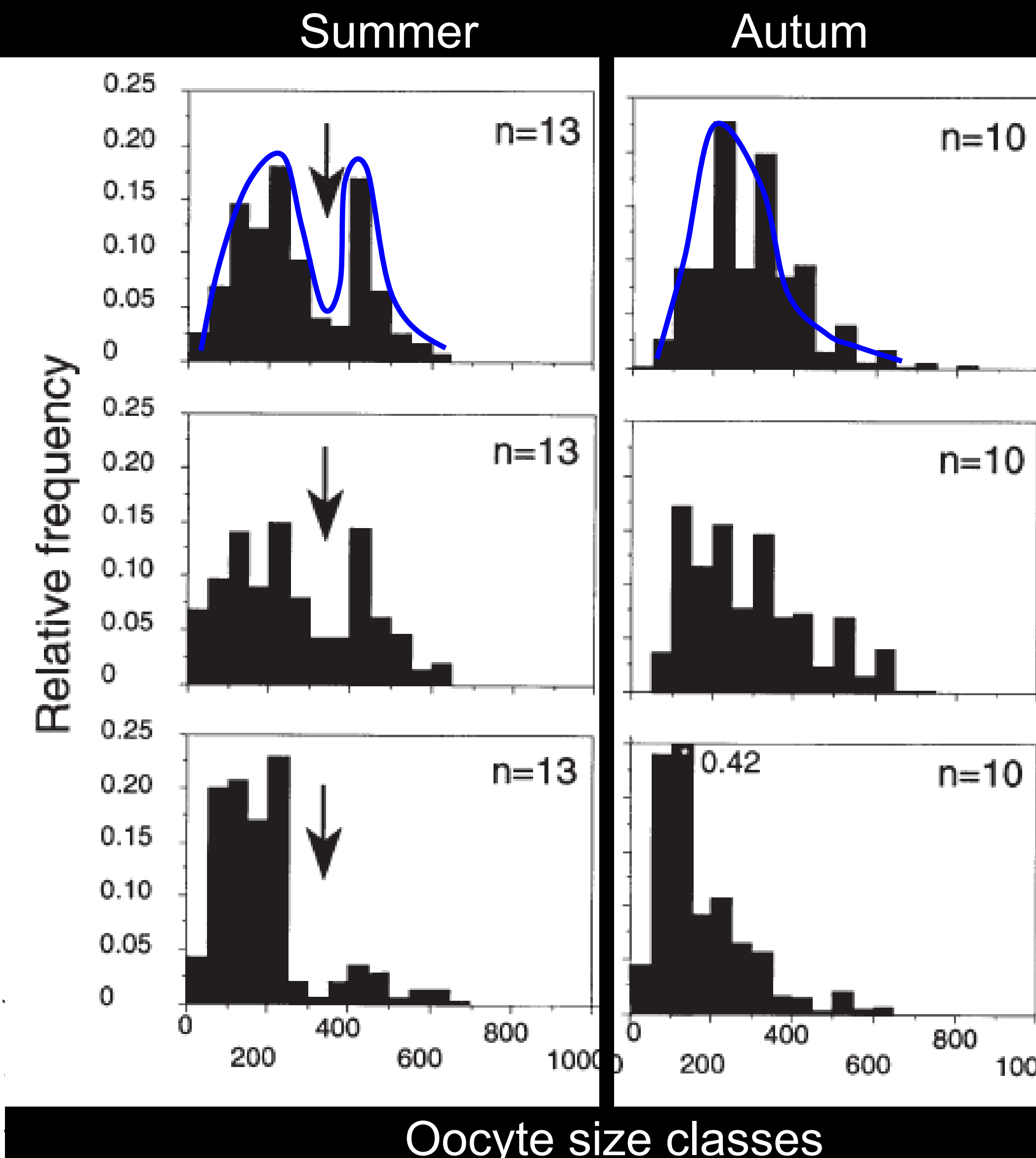
Antarctica
- Phytodetritus fall (ice – no ice)
- Currents
- Seasonality

…

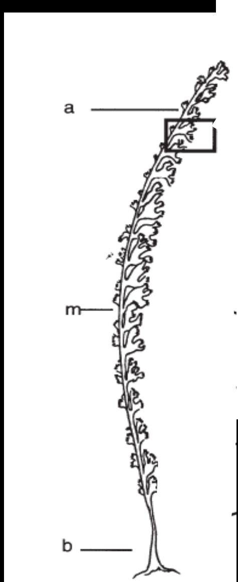
Reproduction of some Antarctic octocorals



Reproduction of some Antarctic octocorals



- -Two cohorts
- -Two years rep. cycle?
- - No larvae observed
- - Spawning late summer-autum
- - Big oocytes → lecit. (?)

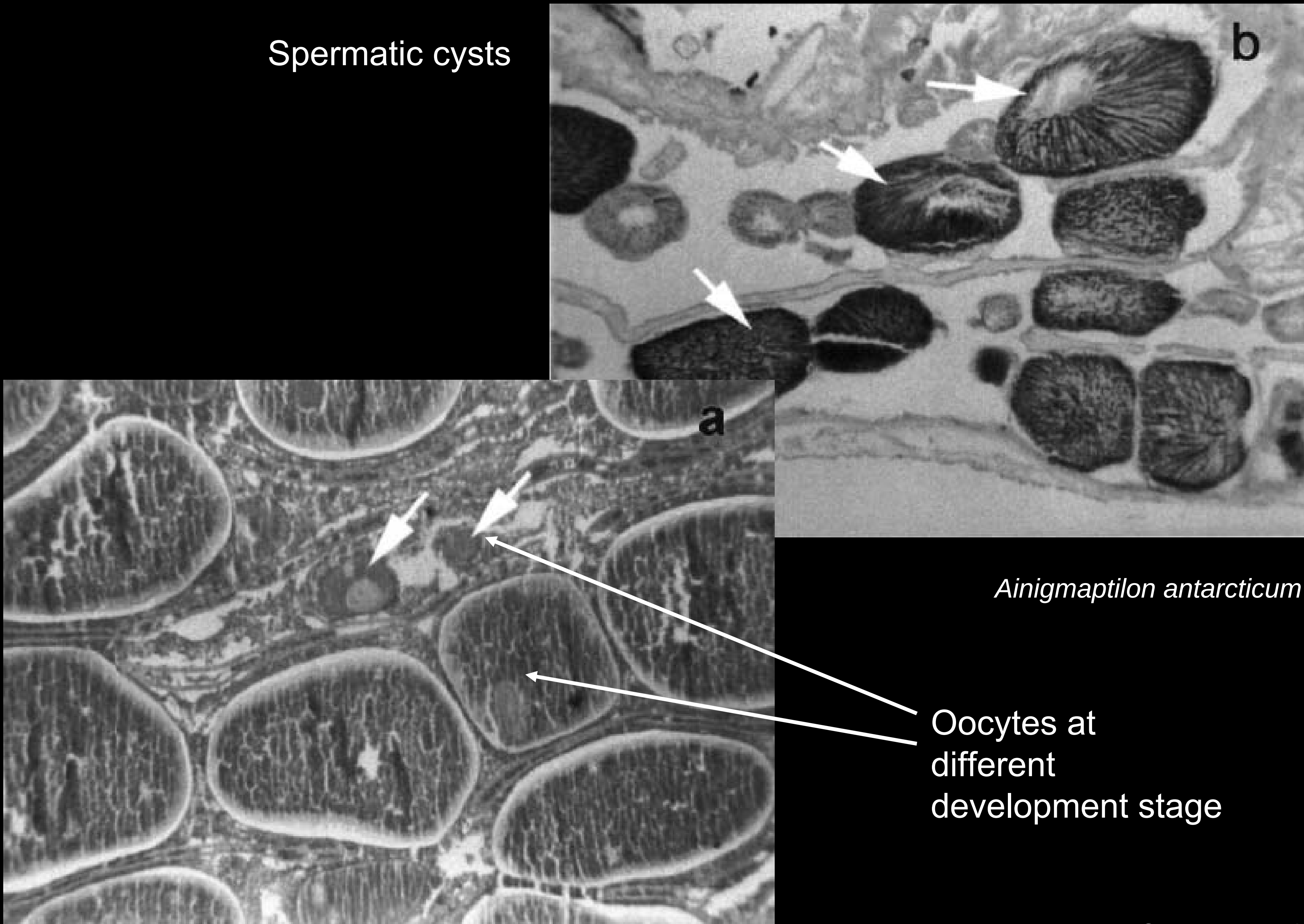


Ainigmaptilon antarcticum

Orejas et al. 2002

Reproduction of some Antarctic octocorals

Spermatic cysts



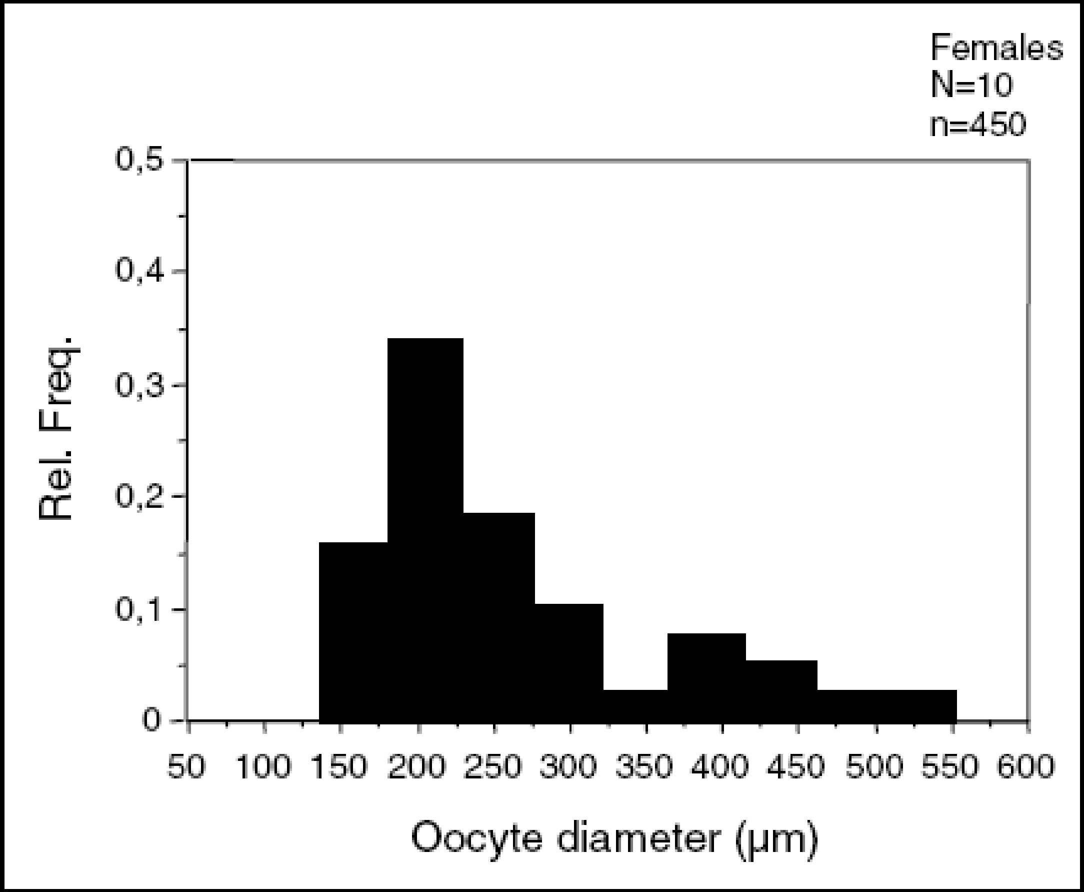
Ainigmaptilon antarcticum

Oocytes at different development stage

Orejas et al. 2002

Reproduction of some Antarctic octocorals

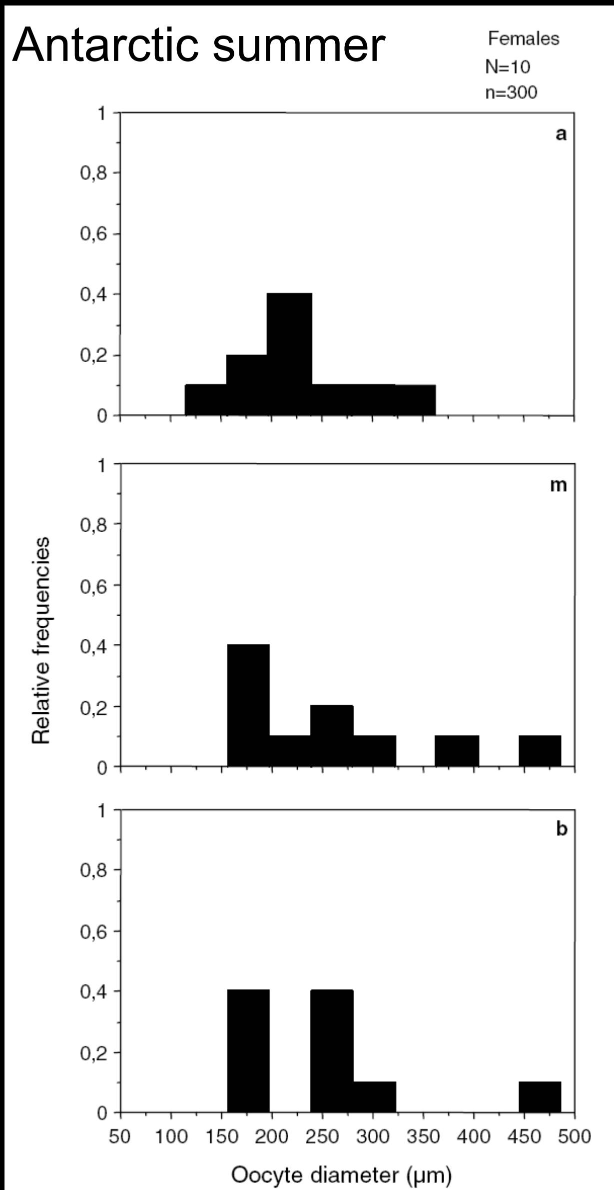
- Two cohorts
- Two years rep. cycle
- Brooder
- Larvae release in summer



Thouarella sp.

Orejas et al. 2007

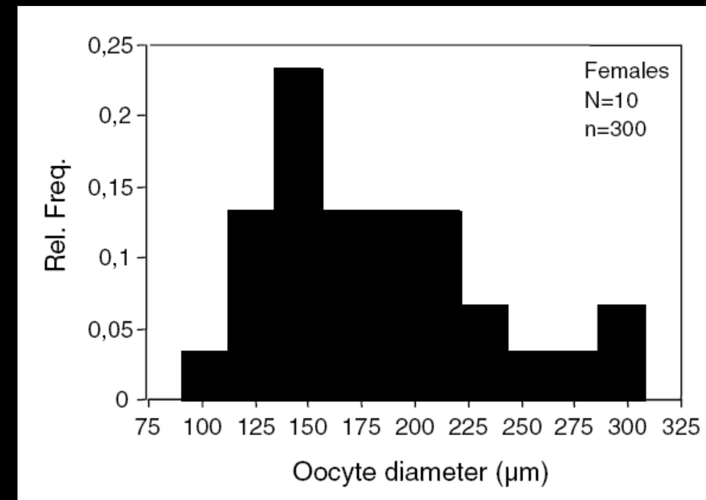
Reproduction of some Antarctic octocorals



Fannyella rosii

- One cohort
- One year rep. cycle
- Brooder
- Larva release in summer

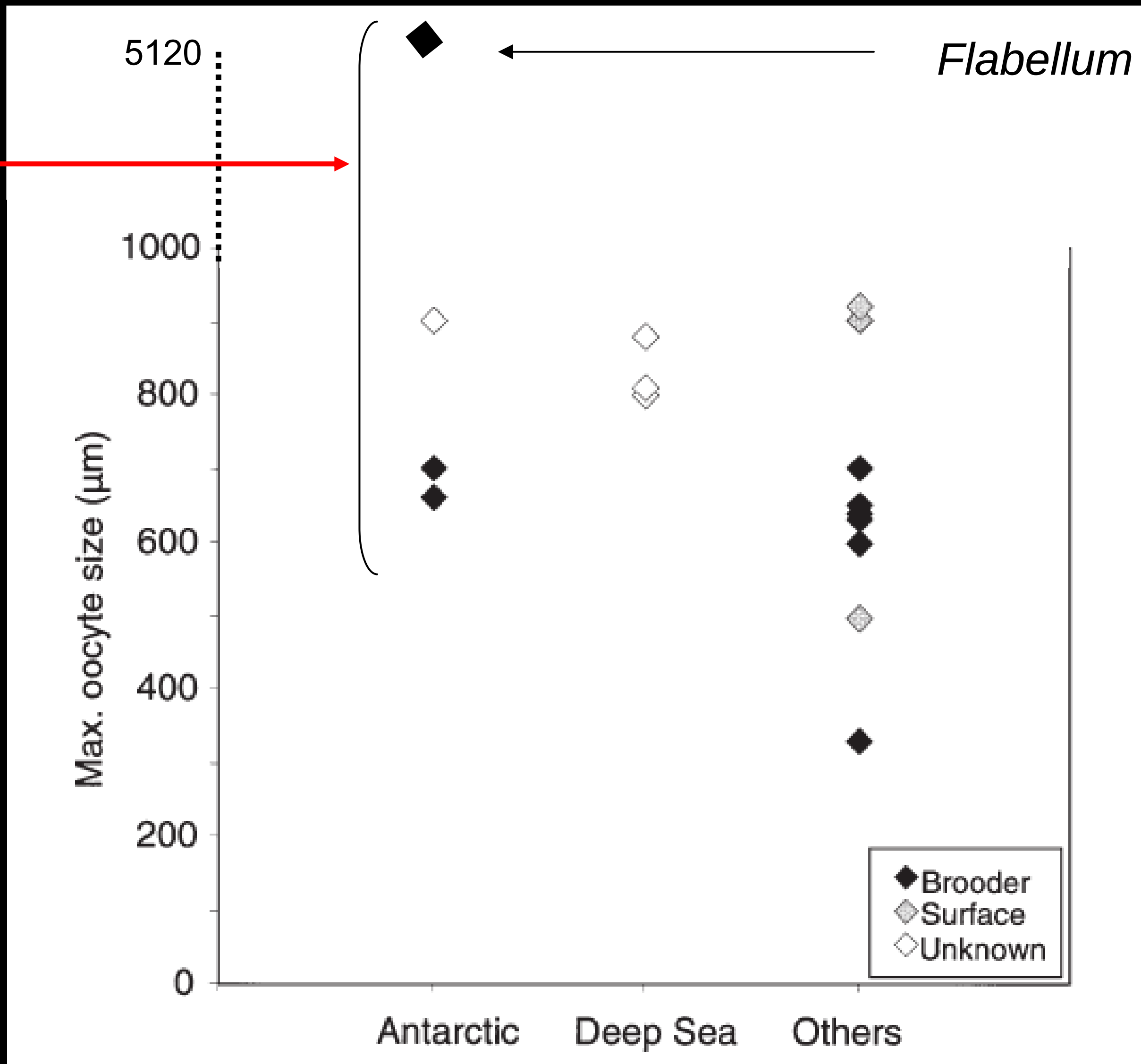
Antarctic summer



Fannyella spinosa

Orejas et al. 2007

Shallow (oct.) vs. “Deep scleractinian” vs. Antarctic (oct.)



Always big!

Orejas et al. 2001

So…what?

- Antarctic octocorals present reproduction features and patterns which seem no to be different from octocorals at other latitudes in:

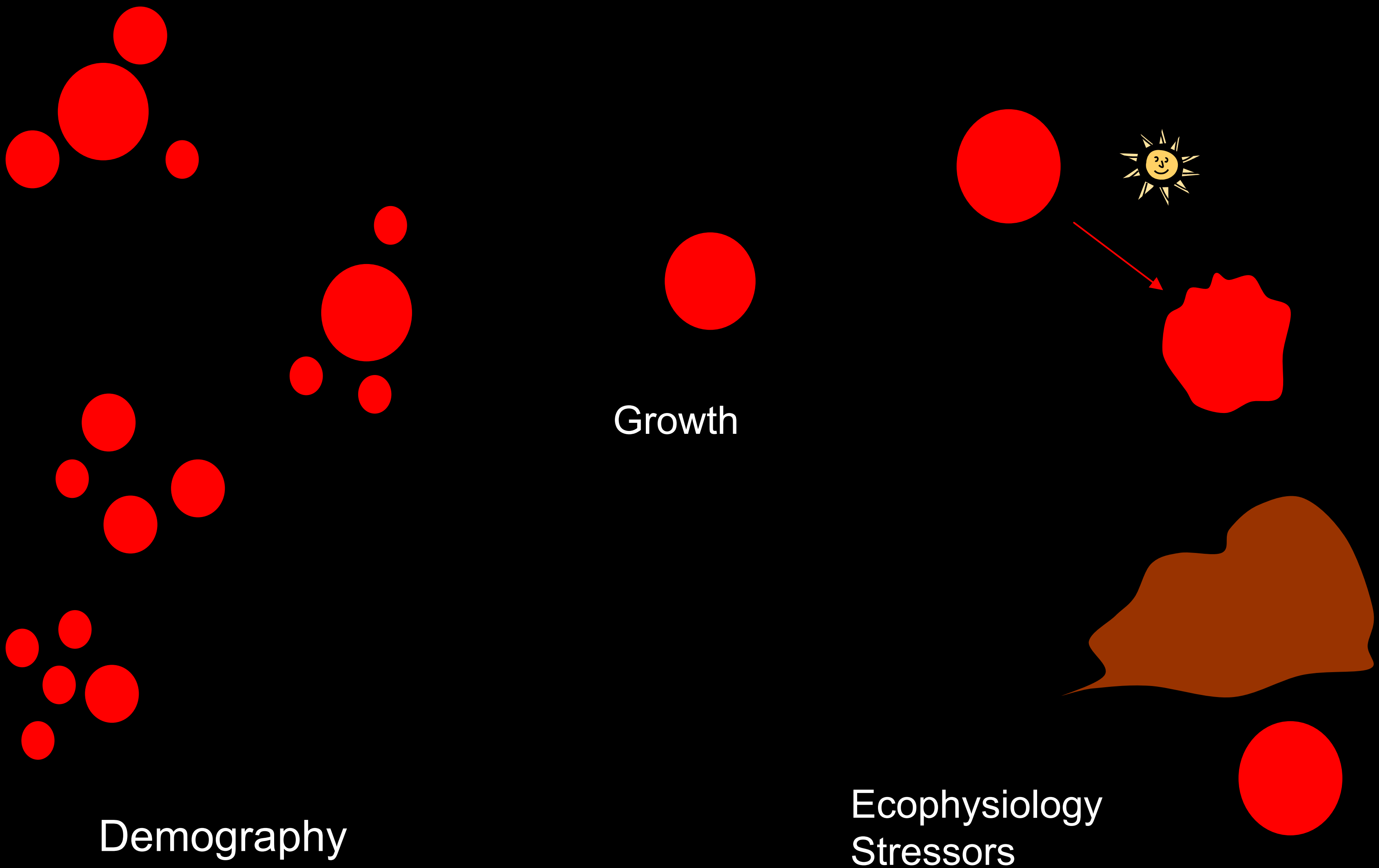
- Oocyte number and size
- Duration of gametogenic cycles
- Presence of one or more oocyte size classes
- Architectural parameters, factor to take into account for reproduction studies

Shallow *vs.* Deep *vs.* Antarctic

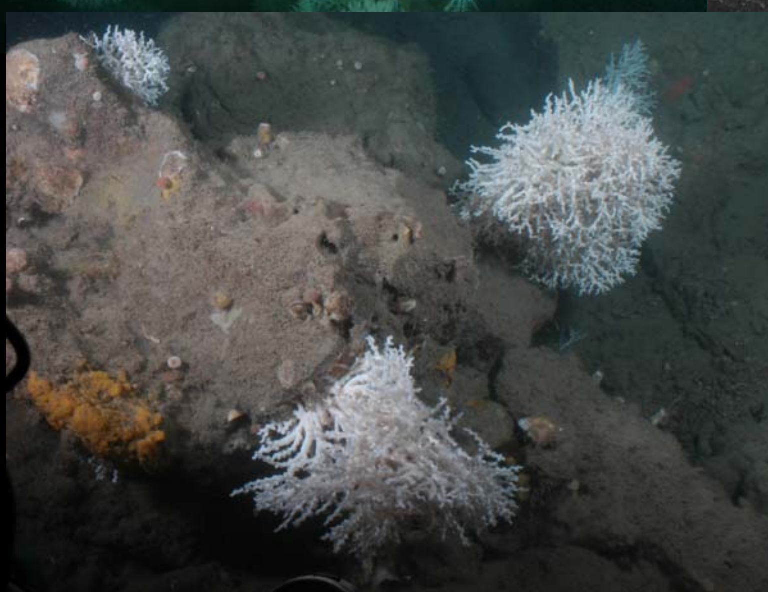
Shallow	Deep	Antarctic (octocorals)
Prepond. Hermaphr.	Most gonochoric, but also hermaph.	Most gonochoric
Prep. continuous brooding	Broadcast & brooders	Broadcast & brooders
Lecitotr. and not lecitotr. larvae	No planulae most cases (?). Lecitotrophic larvae (?)	Lecitotrophic larvae
Seasonal, monthly, continuous, moon cycle, tides, synchrony…	Seasonal, continuous, synchrony, asynchrony….	Seasonal, continuous…

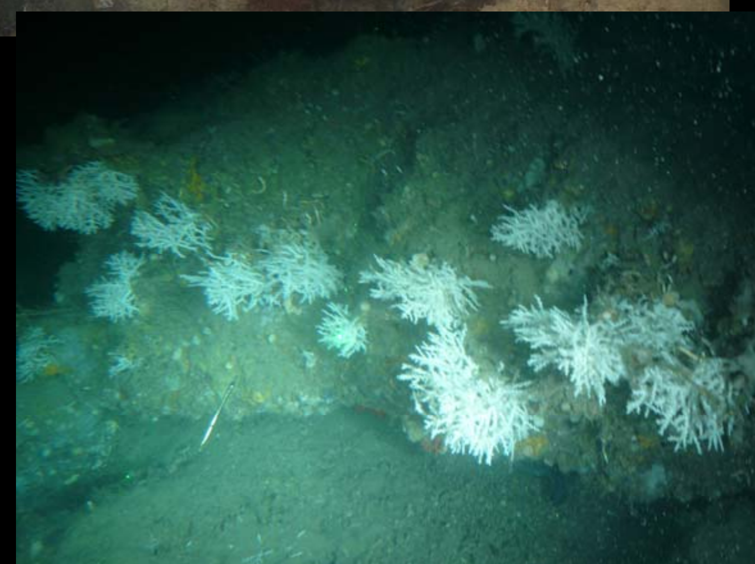
(Sources: Fadlallah 1983, Orejas et al.2002, 2007, Brooke & Young 2003, Waller 2005, Le Goff-Vitry & Rogers 2005, NOAA 2007)

Three main topics…



Demography of deep coral populations





Growth rates of deep corals

Species	Growth linear (mm. y^{-1})
Lophelia pertusa	5-34
Primnoa resediformis	1.5-17
Enallopsammia rostrata	5
Madrepora oculata	3-18
Corallium secundum	9.0
Gerardia sp.	66.0
Anthipathes sp.	61.2-64.2

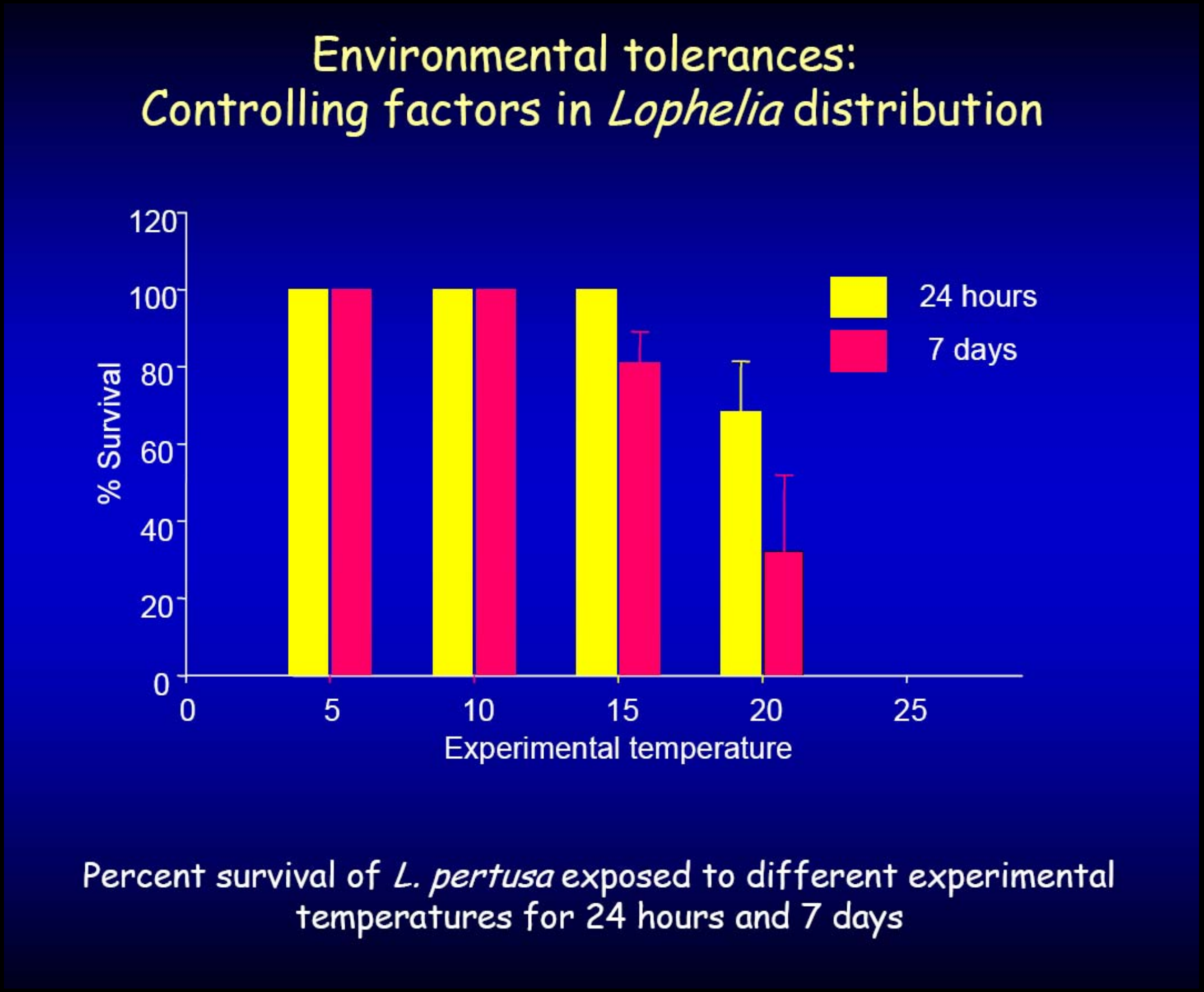
Species	Annual growth (mm/y)	SD	Number of colonies
P. damicornis	16.1	6.37	7
Acropora yongei	49.4	7.01	10
Porites heronensis	10.5	0.98	6
Cyphastrea serailea	3.4		1
C. serailea (from X-ray)	2.6		1
Montastrea curta	2.5	0.32	3
M. curta (from X-ray)	2.7	0.44	3
Favia pallida	3.3	0.01	2
F. pallida (from X-ray)	4.6		1
Goniastrea australensis	2.8		1
G. australensis (from X-ray)	2.9		1
Seriatopora hystrix	16.7		1

"Causal links between latitude, growth rates of coral colonies, and the potential for reef accretion remain unclear" (Harriot 1999)

Dec. 06 | March 07 | May 07 | Nov. 07 | Febr. 08

(From Sandra Brooke's Talk TRACES USA workshop, Harriot 1999, Orejas et al. 2007)

Ecophysiology of deep corals and response to stressors

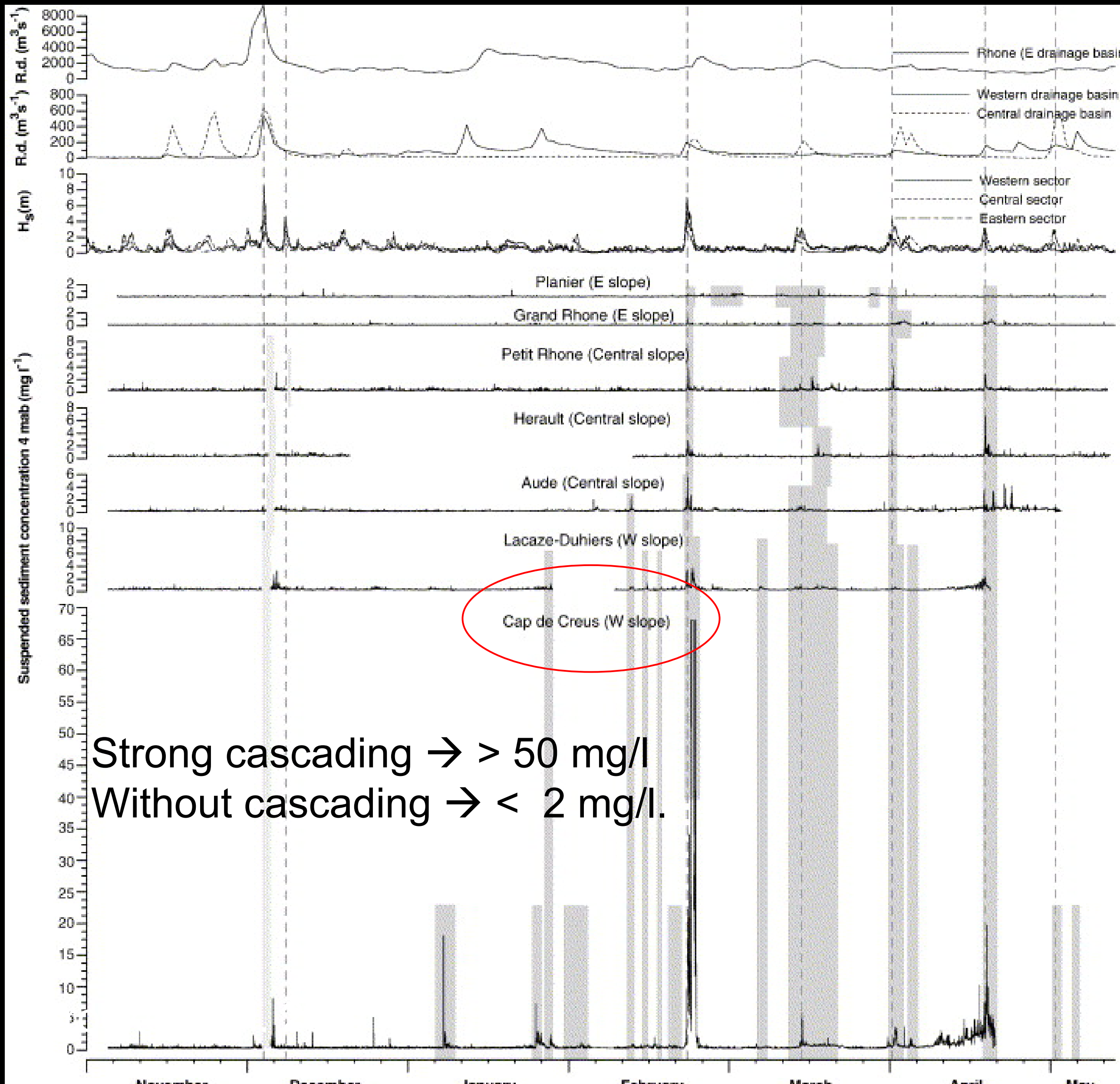


What about different locations?

Different species?

(Brooke et al. 2007)

Ecophysiology of deep corals and response to stressors



(Palanques et al. 2006)

We have to go ahead with…

Reproduction:	More species (including octocorals) More regions (no reproduction studies in the Med!) Seasonality Asexual vs. sexual reproduction
Demography:	Population structure Size classes
Growth:	Aquaria as good possibility (controlled conditions, different temperatures…)
Ecophysiology:	Temperature limits Respiration rates Response to stressors
Feeding ecology:	Role in the ecosystems. Interaction plankton-benthos

Thanks to…

Sandra Brooke and Rhian Waller for their input for this talk

Murray for organise TRACES

and you for your attention!