Biomass production by seaweed:

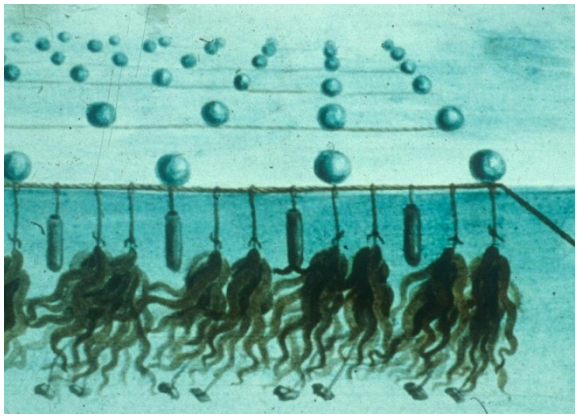
cultivation technology, potentials and challenges

Klaus Lüning, Sylter Algenfarm GmbH & Co.KG, Germany

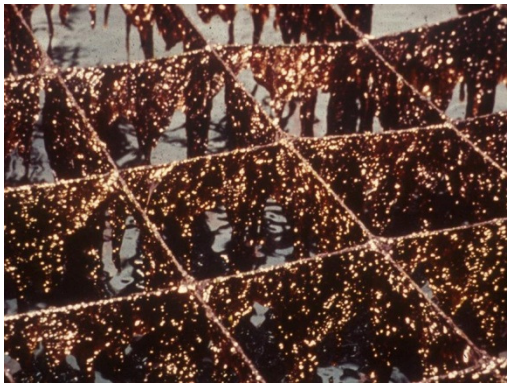
World harvest of marine macoalgae:

appr. 10 mio. t fresh weight per year,

mainly for food and appr. 90% from aquaculture



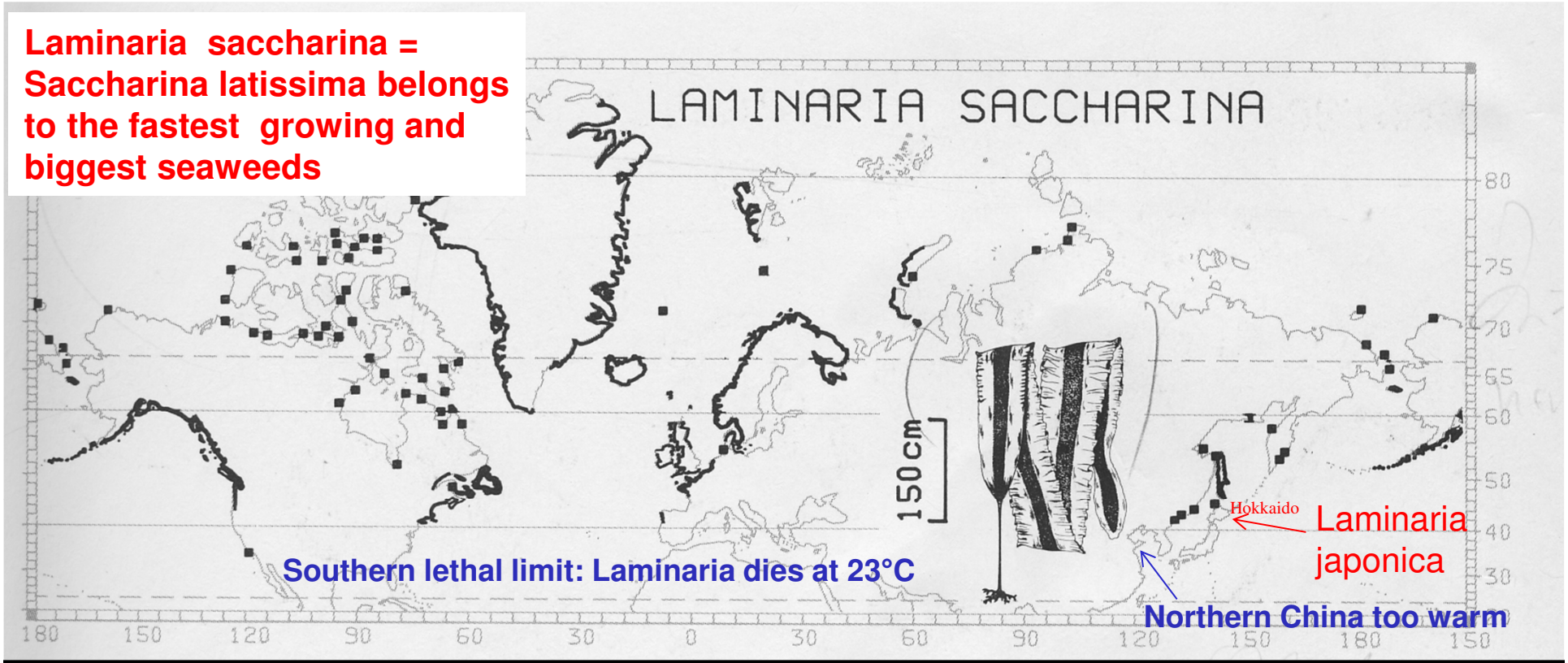
Laminaria (Kombu): 4,5 mio. t
Undaria (Wakame): 2,5 mio. t



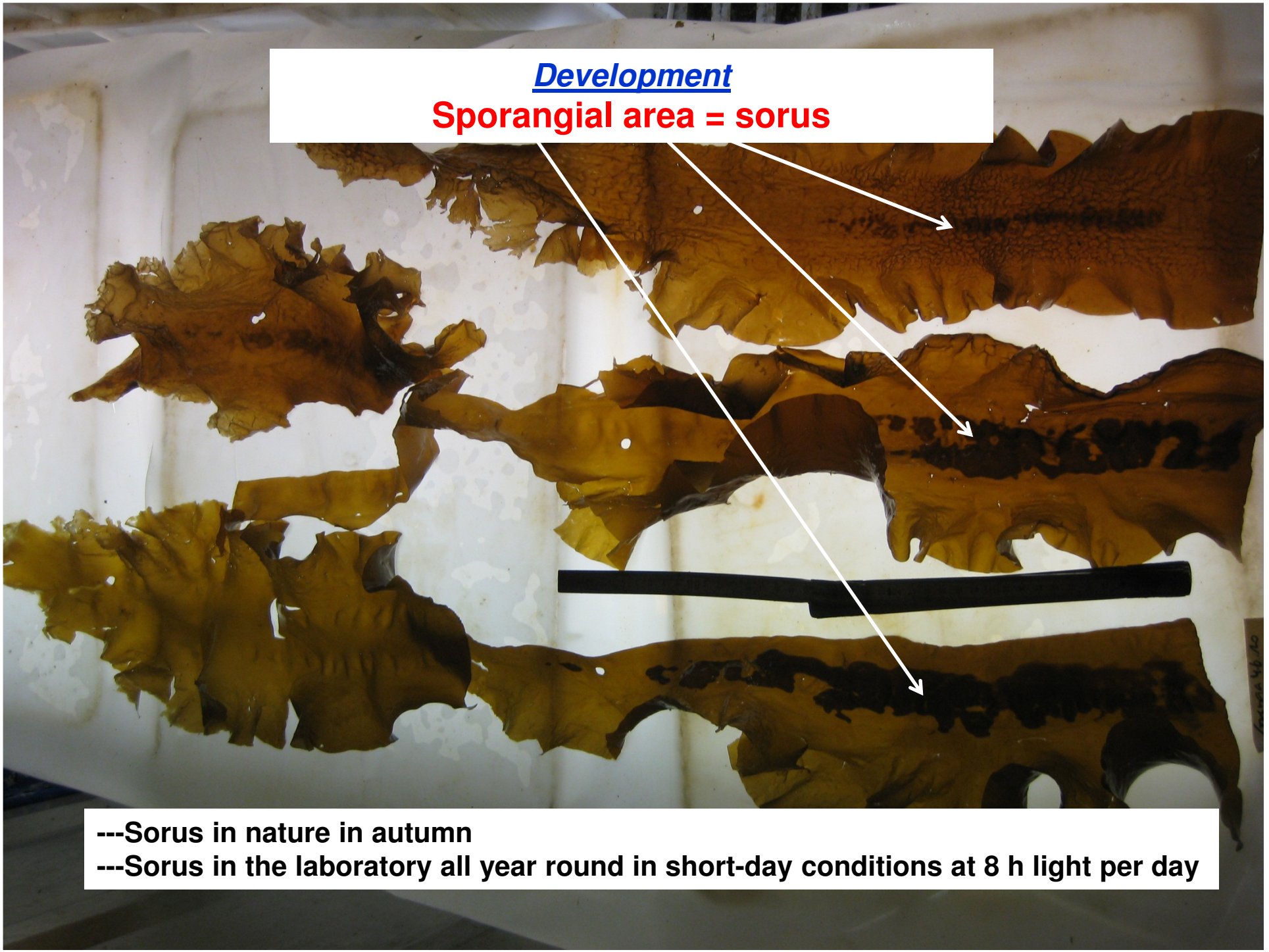
Porphyra (Nori): 1,4 mio t

Kappaphycus/Eucheuma: 1,3 mio. t

Laminaria saccharina = Saccharina latissima belongs to the fastest growing and biggest seaweeds



How to cultivate ?


Development
Sporangial area = sorus
---Sorus in nature in autumn
---Sorus in the laboratory all year round in short-day conditions at 8 h light per day

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Development of *Saccharina latissima* (Phaeophyceae) kelp hatcheries with year-round production of zoospores and juvenile sporophytes on culture ropes for kelp aquaculture

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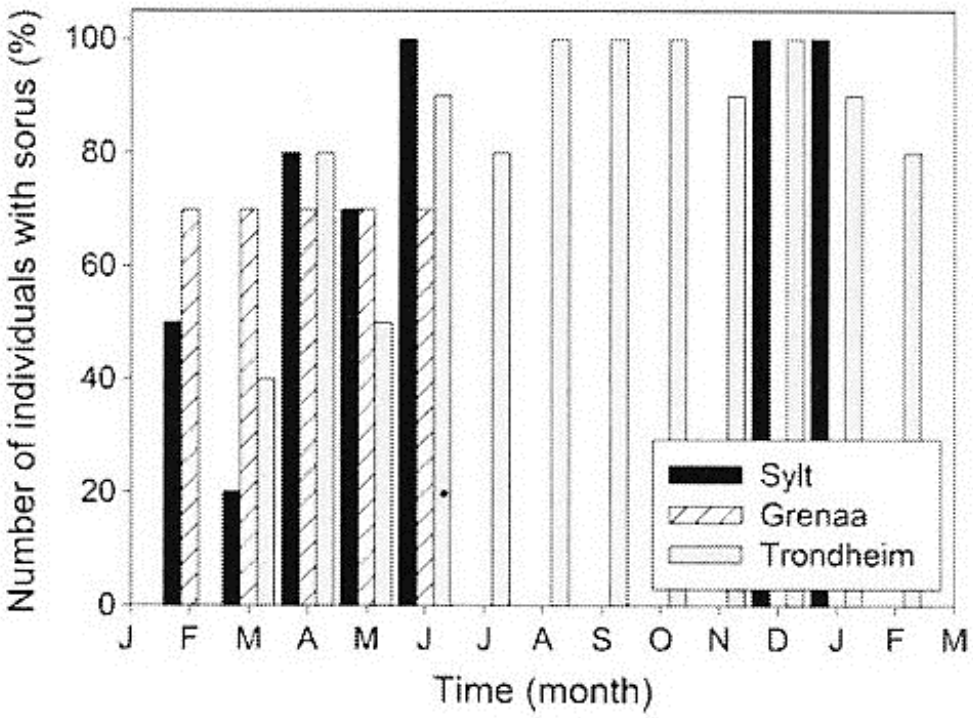
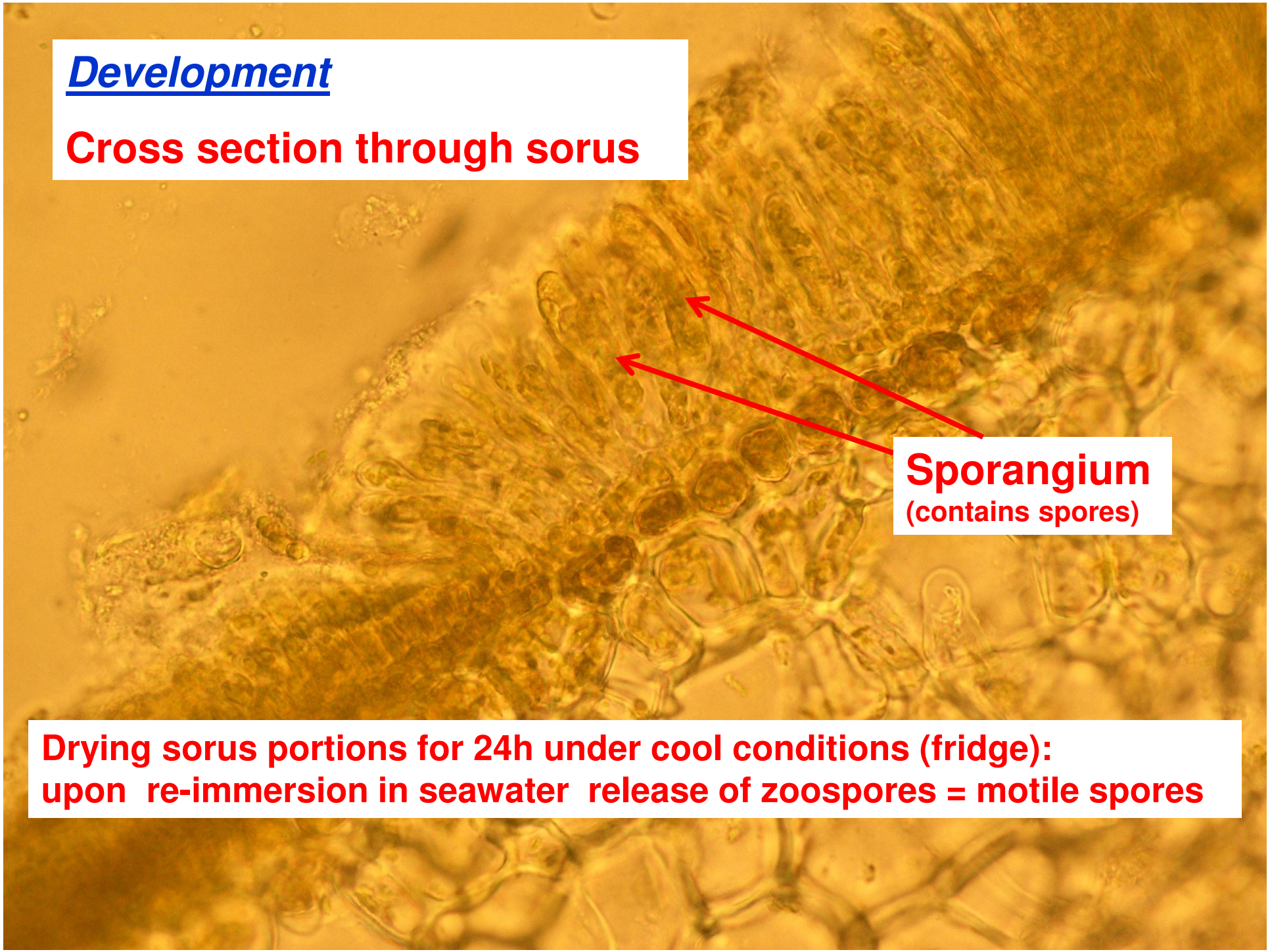


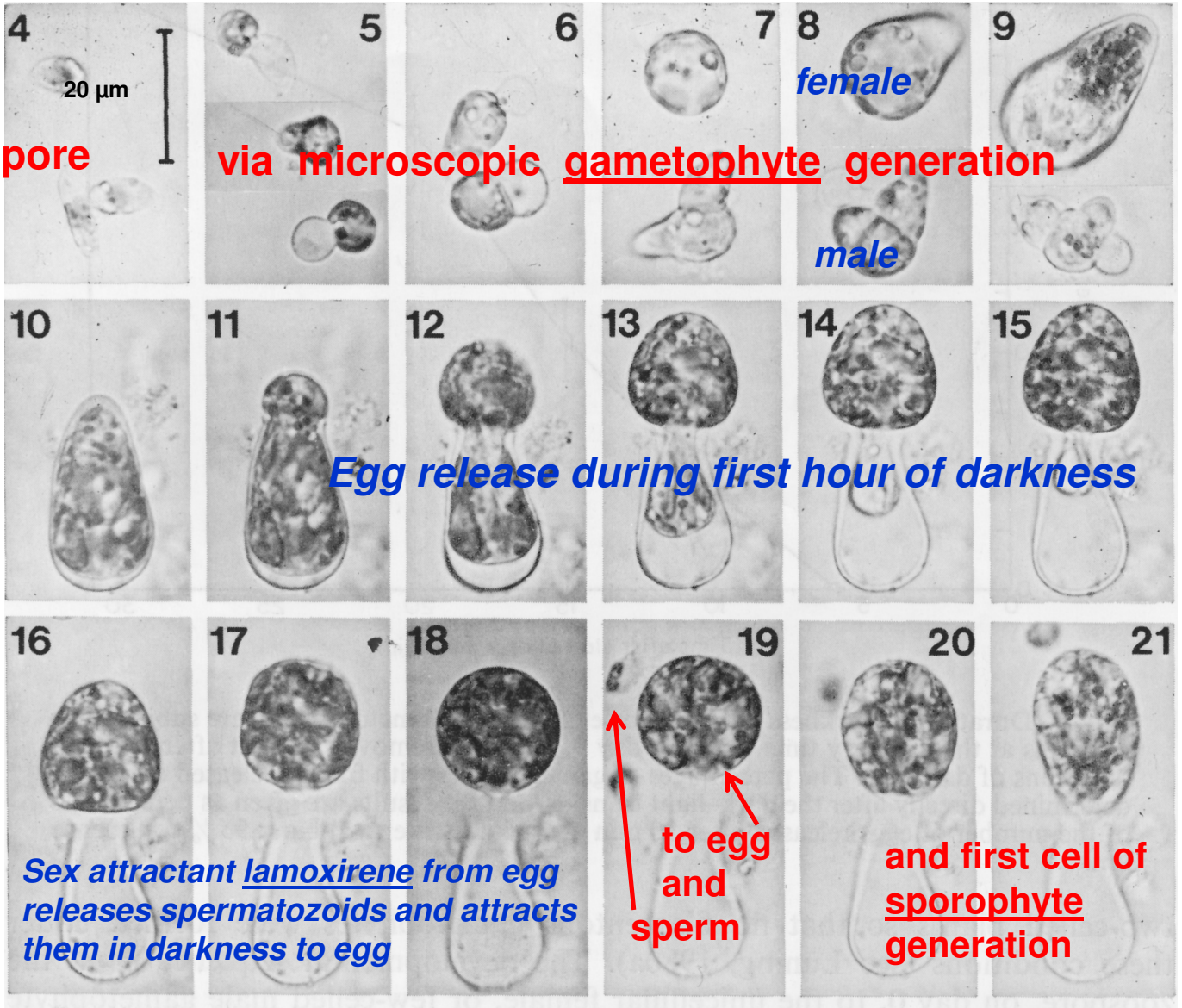
Fig. 4 Seasonal course of sorus formation as a percentage of treated individuals (n=10) with visible sorus at the end of experimental series performed at Grenaa, Sylt, and Trondheim. Experiments were ended at Sylt and Grenaa after 6 weeks and in Trondheim after 12 weeks (except for April, June, and September: after 11, 7, or 10 weeks, respectively)

Hormonal control: Sorus inhibitor (auxin?) travels from growing base in distal direction and prevents sorus formation, when alga is actively growing

The fast-growing alga actively prevents sorus formation and allocates in this way 100% of photosynthate into new tissue st the base of the blade.


Development
Cross section through sorus
Sporangium
(contains spores)
Drying sorus portions for 24h under cool conditions (fridge):
upon re-immersion in seawater release of zoospores = motile spores

Development



from zoospore

via microscopic gametophyte generation

female

male

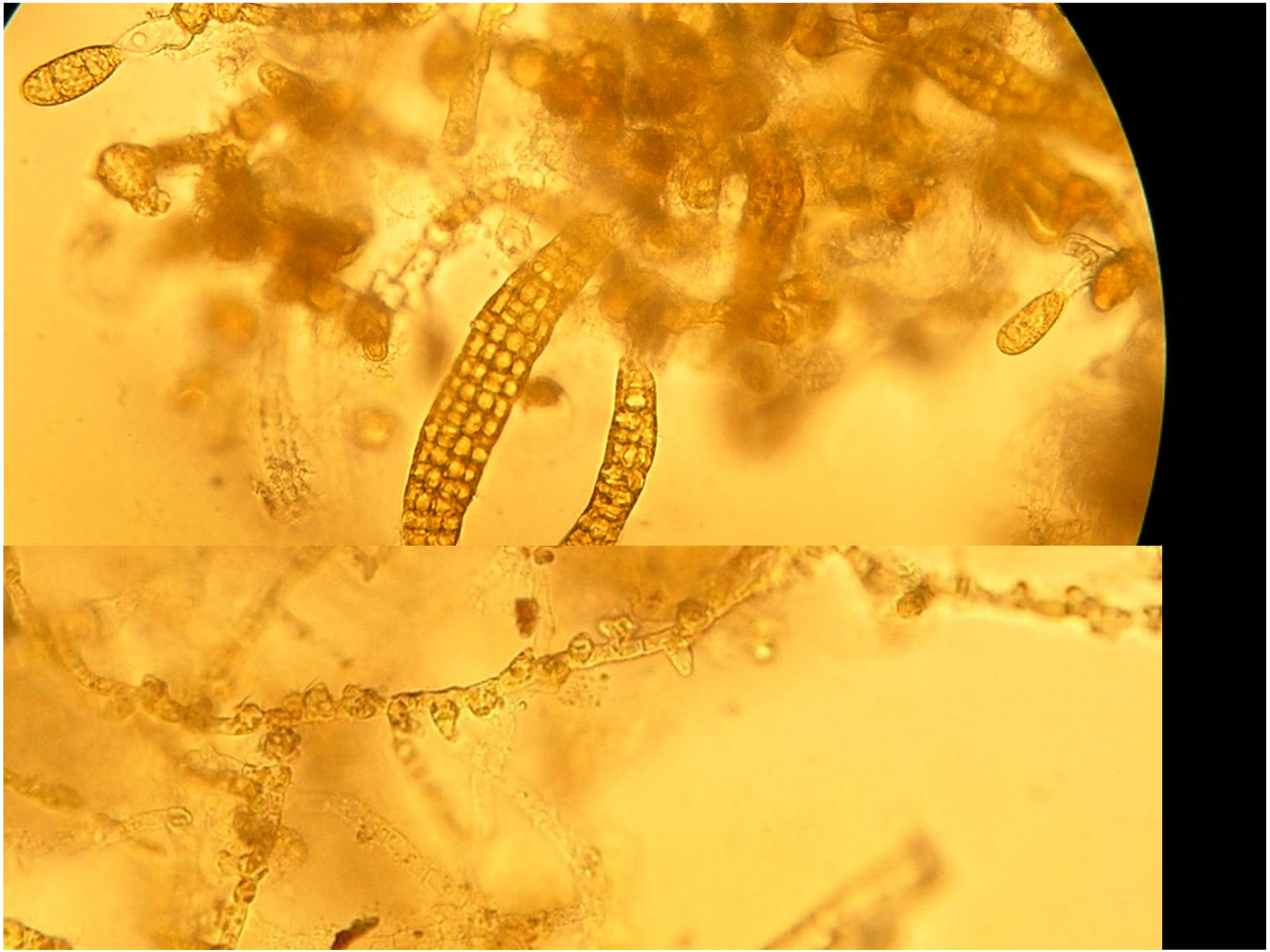
Egg release during first hour of darkness

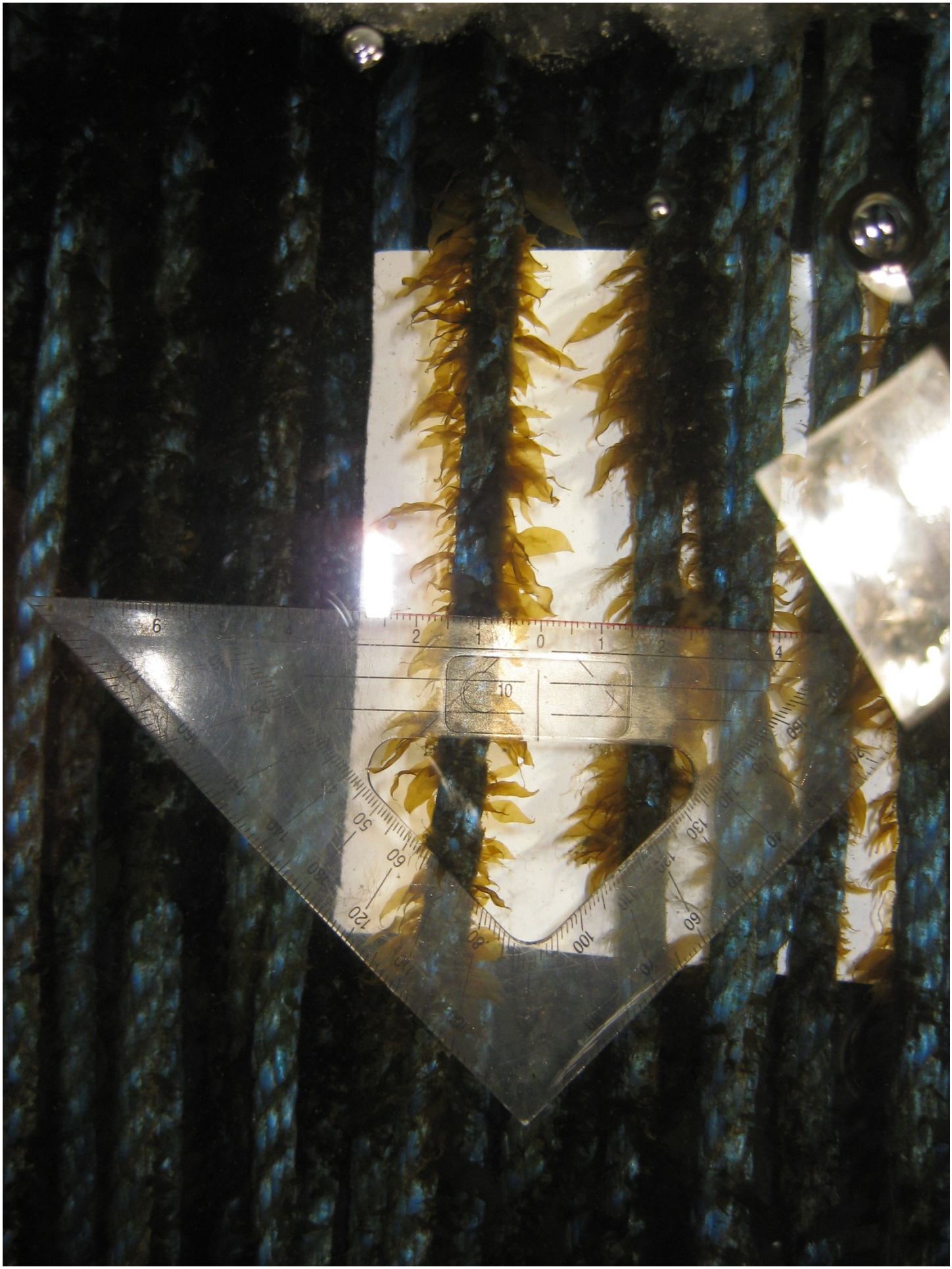
Sex attractant lamoxirene from egg releases spermatozoids and attracts them in darkness to egg

to egg and sperm

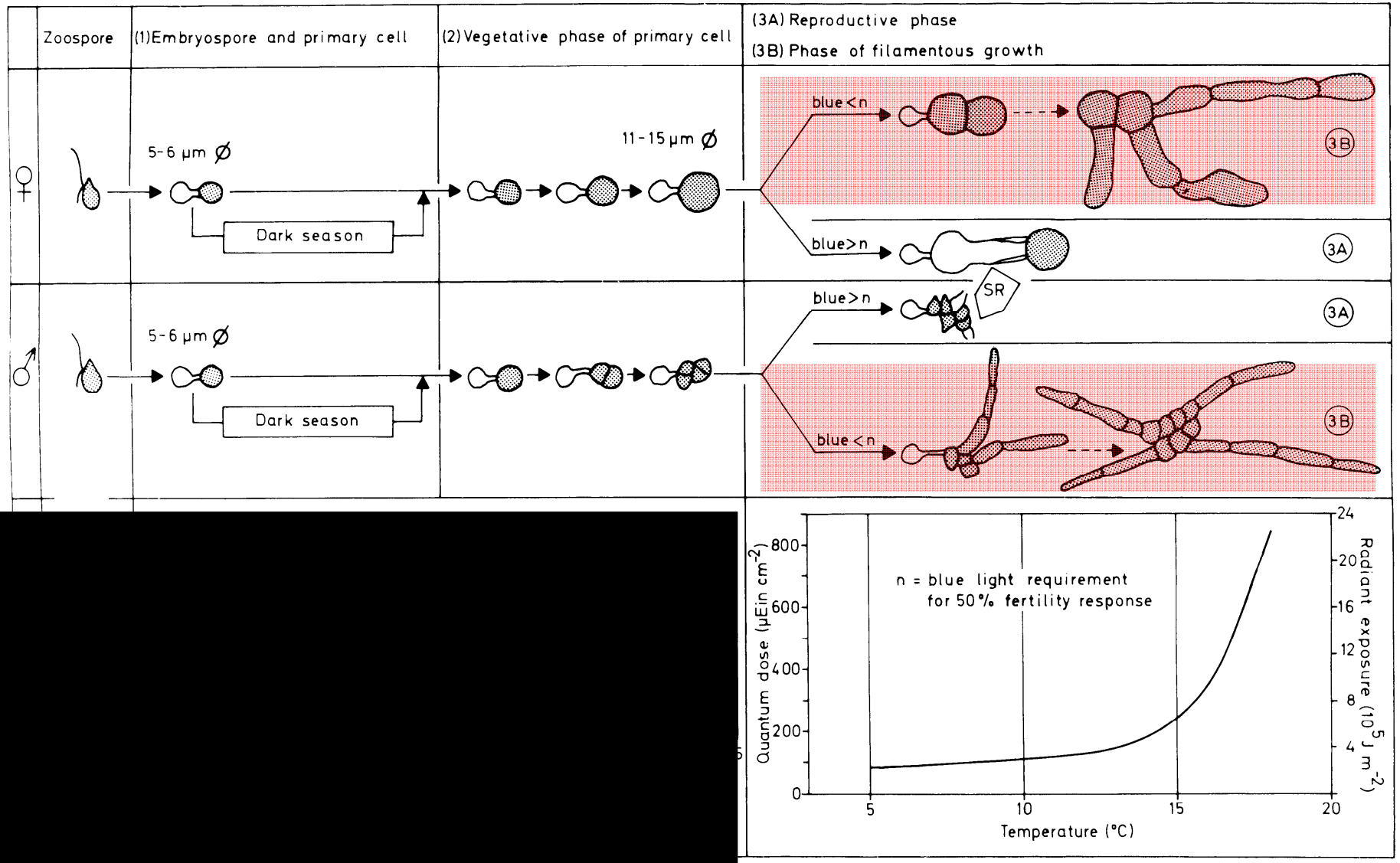
and first cell of sporophyte generation

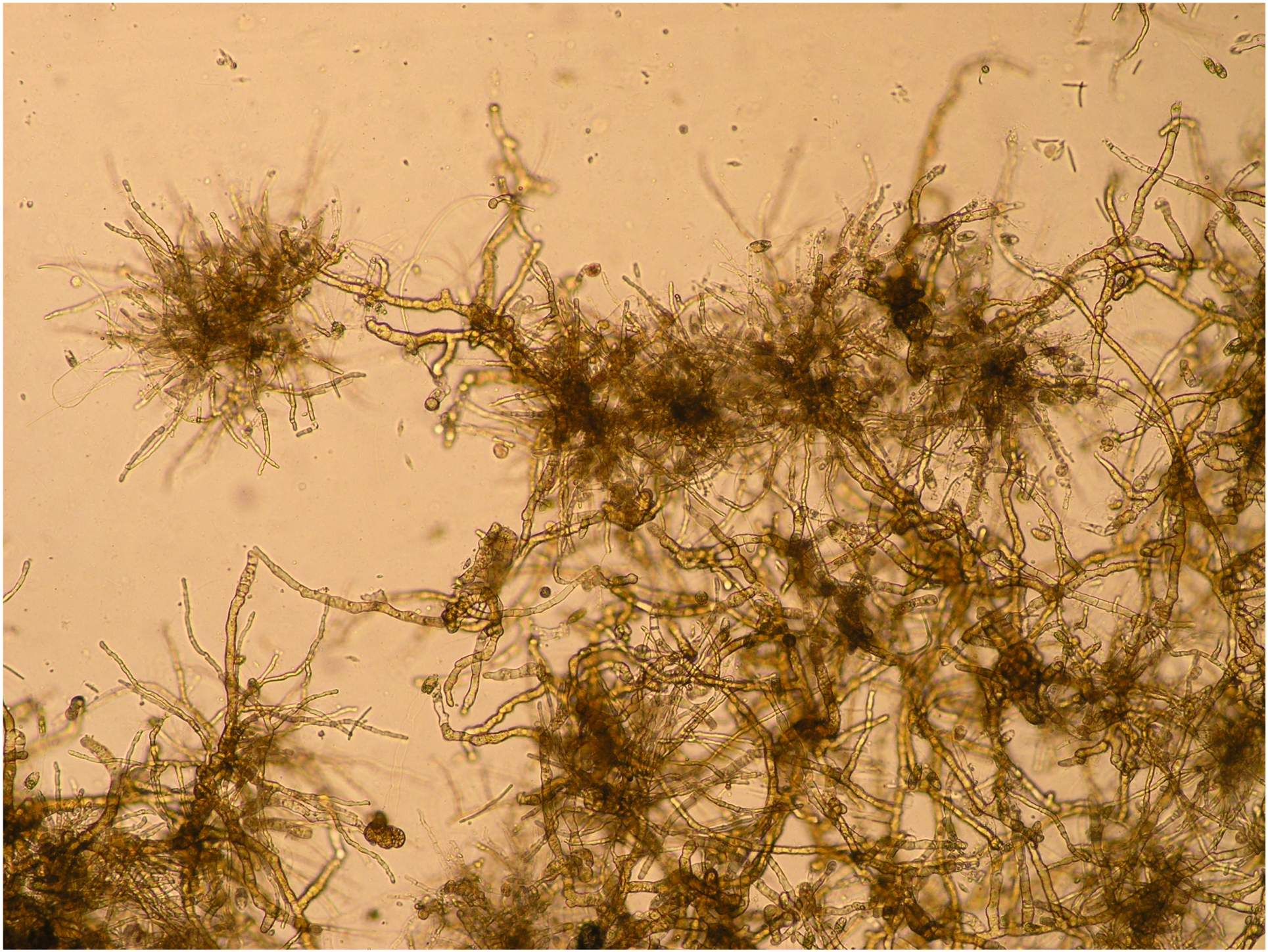
Lüning, K.(1981): Egg release in gametophytes of Laminaria saccharina induced by darkness and inhibition by blue light and. U.V. (Br. phycol. J. 16, 379-393)





Vegetative (=perennial) gametophytes, if blue light lacks or temperature higher





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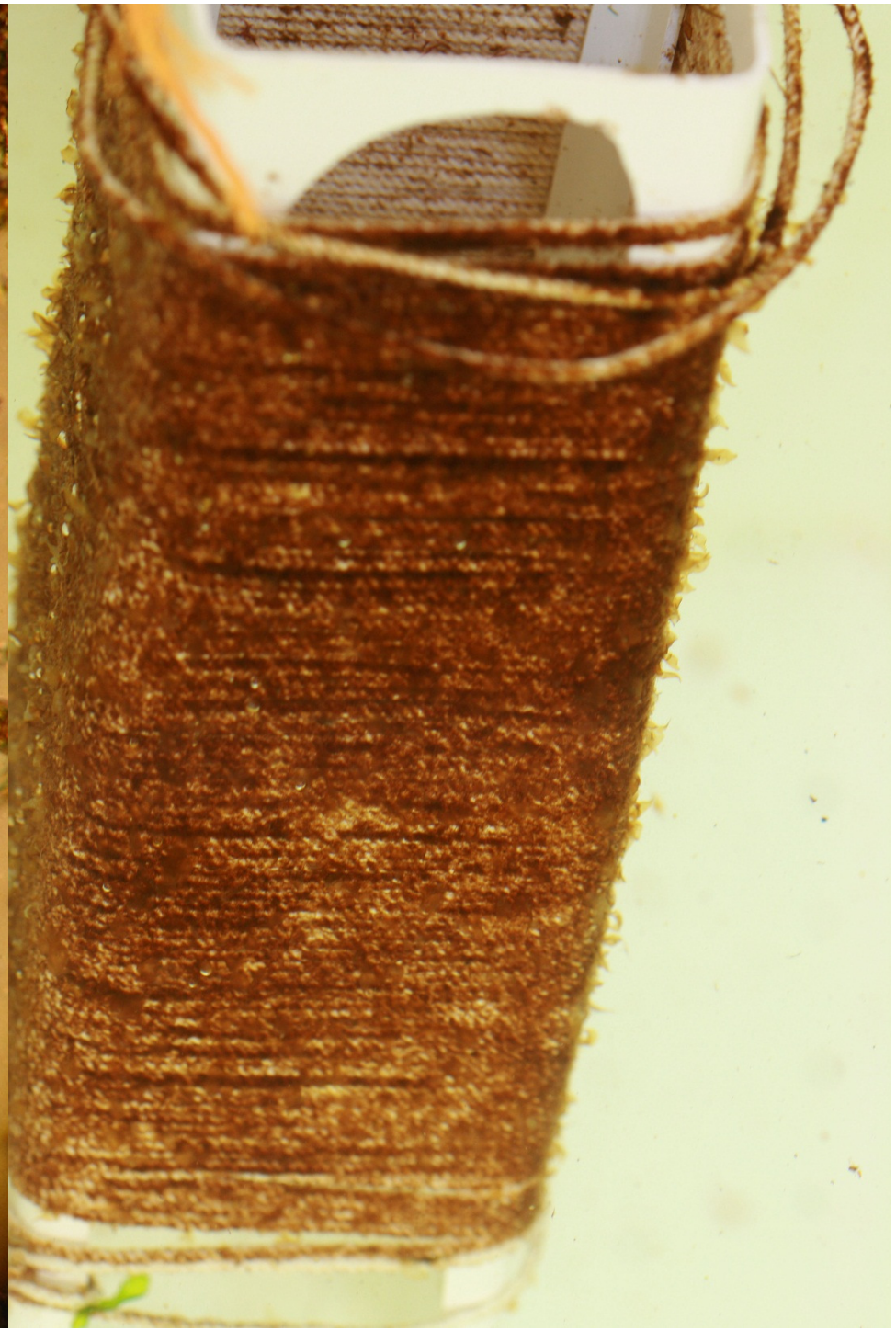
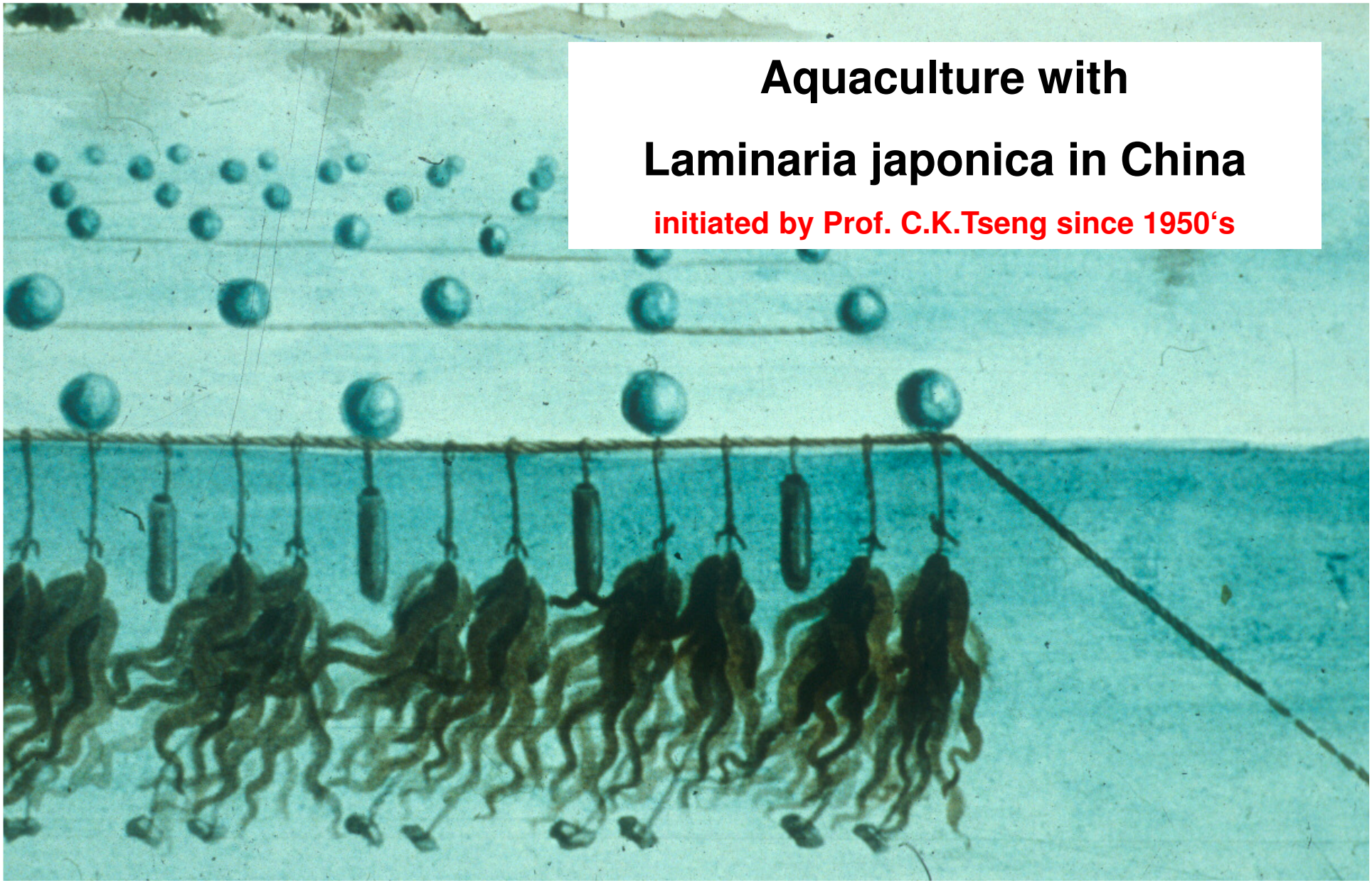
High throughput culture and gametogenesis induction of *Laminaria japonica* gametophyte clones

Quan Sheng Zhang · Shan Cun Qu · Yi Zhou Cong ·
Shi Ju Luo · Xue Xi Tang

Fig. 5 Mass gametophyte clones cultured in 20-L bottle with aeration





Aquaculture with

Laminaria japonica in China

initiated by Prof. C.K.Tseng since 1950‘s

China: Completey new and „artificial“, since sea water temperature in northern China reaches 27 °C – no survival of Laminaria in summer

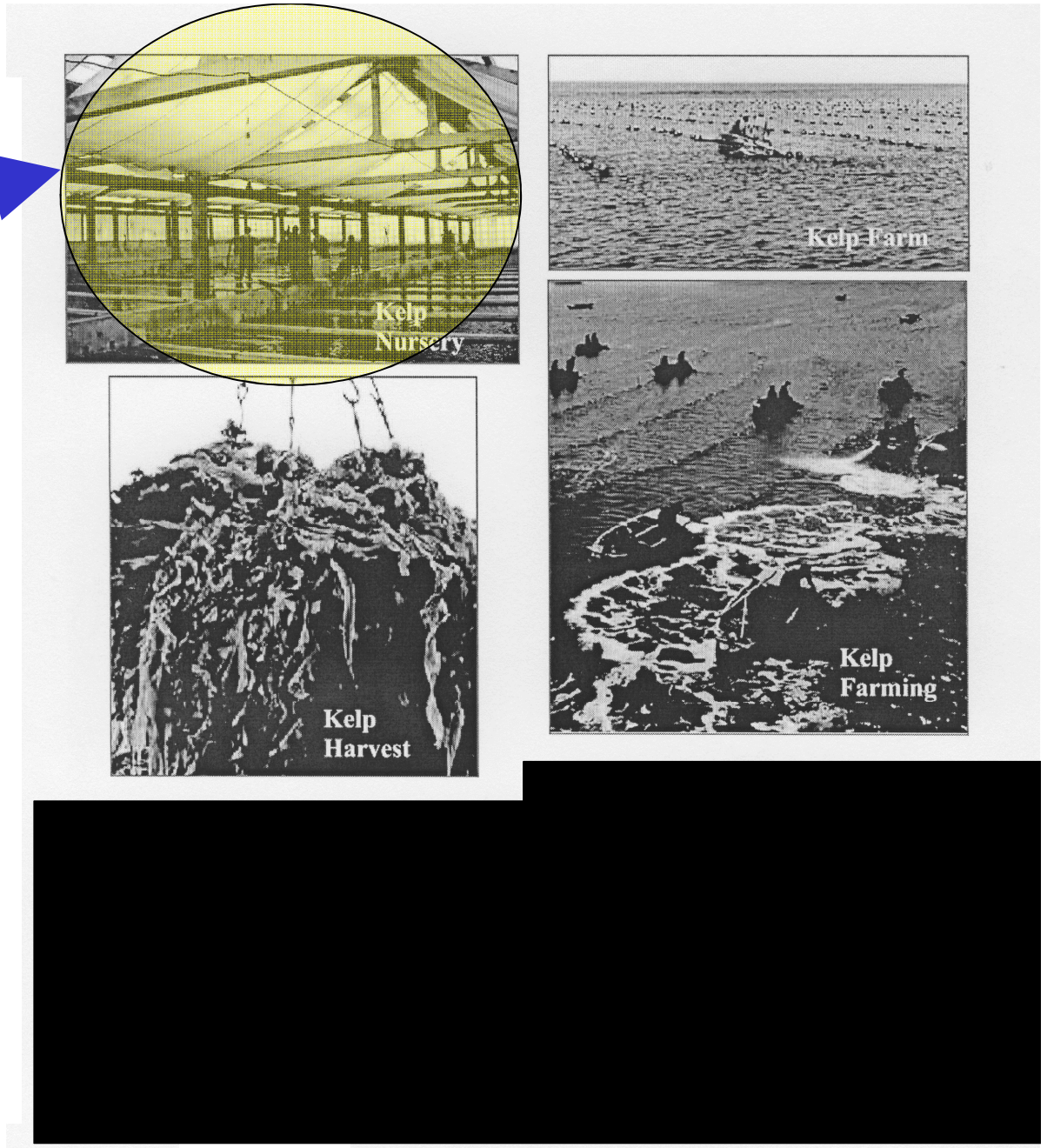
China:

Kelp nursery:

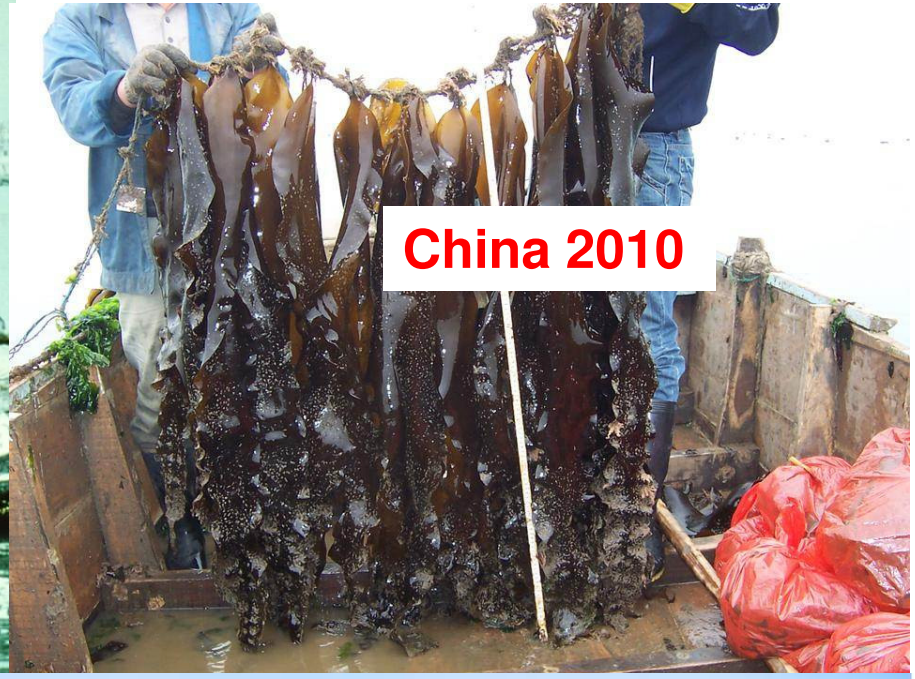
---Cooled seawater in summer (8-10℃), while 27℃ in the sea

---Cultivation of gametophytes from zoospores (partially also from vegetative gametophytes) and resulting Laminaria summer sporelings up to a length of 5-10 cm

--- immersion in the sea in September at temperatures <17℃



Seaweed farming in China (Chen, 2006).



So we learned…

but...

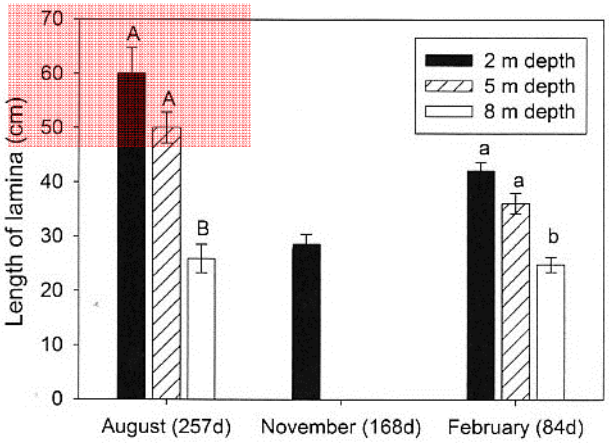


Fig. 6 Length of sporophytes that were transferred to the sea at Bjugn, Norway in August (n=45) and November (n=15) 2010 and February (n=45) 2011 and cultivated for 257, 168, and 84 days, respectively (means ± SE)

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And how to escape from this dilemma?

(We also want to have big Laminaria!)

Here comes the solution:

植 物 学 報
第4卷 第3期 1955年9月

海帶的幼苗低溫渡夏养殖試驗報告* **

曾呈奎 孫國玉 吳超元

(中國科学院海洋生物研究室)

海帶雖然是在我國民間相当普遍採用的食品，但它却不是我國固有的產物；它是日本、朝鮮和苏联遠东區沿海發源於白令海及鄂霍茨克海的寒流流域的原產植物。海帶移种於我國雖然已經有了二十多年的歷史，然而由於养殖上尚存在着許多科学的和技術的困难，以前一直停留在小規模的試驗階段中[1]。解放以後，由於党和人民政府的重視，迅速地恢復了旅大水產养殖場並建立了山东水產养殖場進行海帶养殖工作；在短短的幾年內，海帶的养殖已由小型試驗轉入企業生產，一個新興事業的基礎已經鞏固地奠定起來了。

但是，不可否認，海帶养殖業还很幼稚，存在着的、尚待解决的問題还很多[2]。由於这些問題未能得到及時的解决，这項事業的進展是受了一定程度的限制的。在这些問題中，關於幼苗發生期間所受到附着物的威脅是比較嚴重的，因此，1953年春季，我們就開展了一些試驗工作，致力於这個問題的解决。

一．問題的發生

在青島地區的海帶养殖，每年10月底到11月初旬海面水温下降到20°C以下時，就進行採孢子工作；在实踐上，这項工作具有与農業的播种同樣重要的意義；該年度(至翌年夏季)海帶的生產首先要取决於採孢子的操作。一般說來，採孢子工作是沒有多大困难的；养殖工作者已經有了一套有效的科学方法，刺激具有成熟孢子囊的海帶，强迫它在一定的小範圍內大量放散孢子，並供給人工的生長基層，如棕繩、竹片等，讓放散出來的孢子有附着的机会[1,2]。問題的發生主要是在採了孢子後，將苗繩(附着了孢子的棕繩)放养在海面的这一段期間。

孢子附着在繩子上面，不久就萌發成爲微小的配子体，但在優良的環境條件下，

* 1955年7月9日收到

** 中國科学院海洋生物研究室植物組的任國忠，費修綆，曹文達和孫福增諸同志各參加这項研究中的一部分關於海面培养、收穫、測量等工作。

ON THE CULTIVATION OF HAITAI (*LAMINARIA JAPONICA* ARESCH.) BY SUMMERING YOUNG SPOROPHYTES AT LOW TEMPERATURE

C. K. Tseng, K. Y. Sun and C. Y. Wu

Marine Biological Laboratory, Academia Sinica

1955

(Summary)

Commercial cultivation of haitai (*Laminaria japonica* Aresch.) has been carried on at Tsingtao since 1952. Although production has been stepped up quickly in the last few years, the industry has not been advancing as rapidly as it is desired. This is due to the existence of several problems inhibiting the progress of the industry. One of these concerns with the detrimental effect of various algal growths, particularly *Ectocarpus*, *Ulva* and colonial diatoms such as *Licmorphora*, on the growth of the *Laminaria* gametophytes and the development of its sporophytes.

In the haitai cultivation at Tsingtao, spore collection is effected in late October through November when surface sea water temperature has already dropped down to below 20°C. It takes from two to three weeks under good conditions, and much more time under less appropriate conditions for the completion of the growth and developmental processes from spores to sporophytes. During this period, *Laminaria* has the least ability of competition against algal weeds, and it is in the same period when *Ectocarpus* and various other algal weeds are most vigorous in their multiplication. Therefore, soon after the setting of the collectors with the *Laminaria* spores in the sea, spores of these weeds quickly adhere to these artificially set substrata, and before formation of the *Laminaria* sporophytes has been effected, these weeds have already grown to such sizes as to choke the microscopic gametophytes, prohibiting them from receiving sufficient light to satisfy their growth and developmental requirements. Thus, formation of haitai sporophytes is greatly delayed or even totally inhibited, resulting in greatly decreased production or in extreme cases, total failure of the crop.

Solution of the problem has therefore become one of the keys to the further development of the haitai cultivation industry. A means to solving this problem

China:

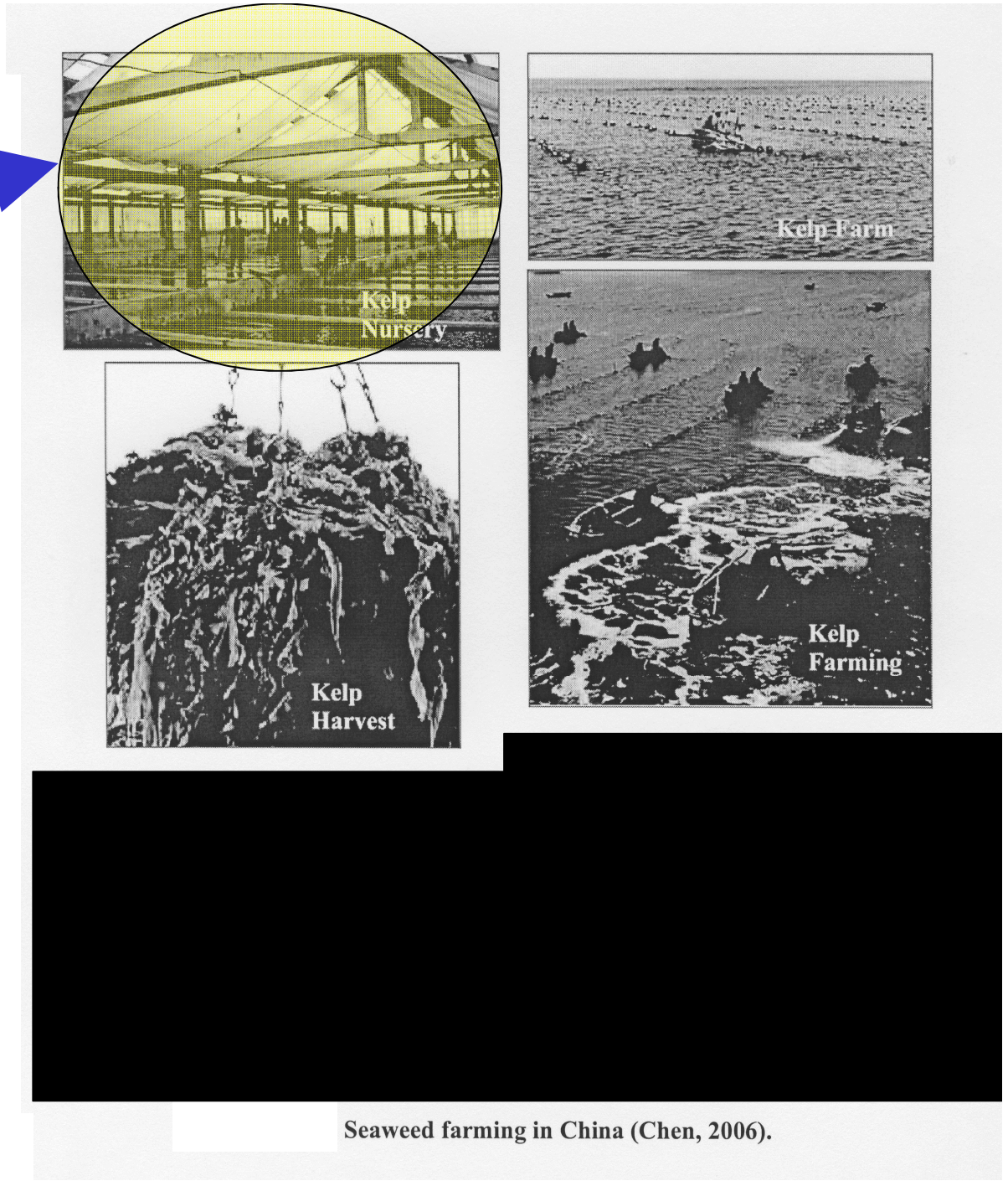
Kelp nursery:

---Cooled seawater in summer (8-10℃), while 27℃ in the sea

---Cultivation of gametophytes from zoospores (partially also from vegetative gametophytes) and resulting Laminaria summer sporelings up to

a length of 5-10 cm

--- immersion in the sea in September at temperatures <17℃



Seaweed farming in China (Chen, 2006).

Forced cultivation

Tseng et al. (1957, 1962), Hasegawa (1971)

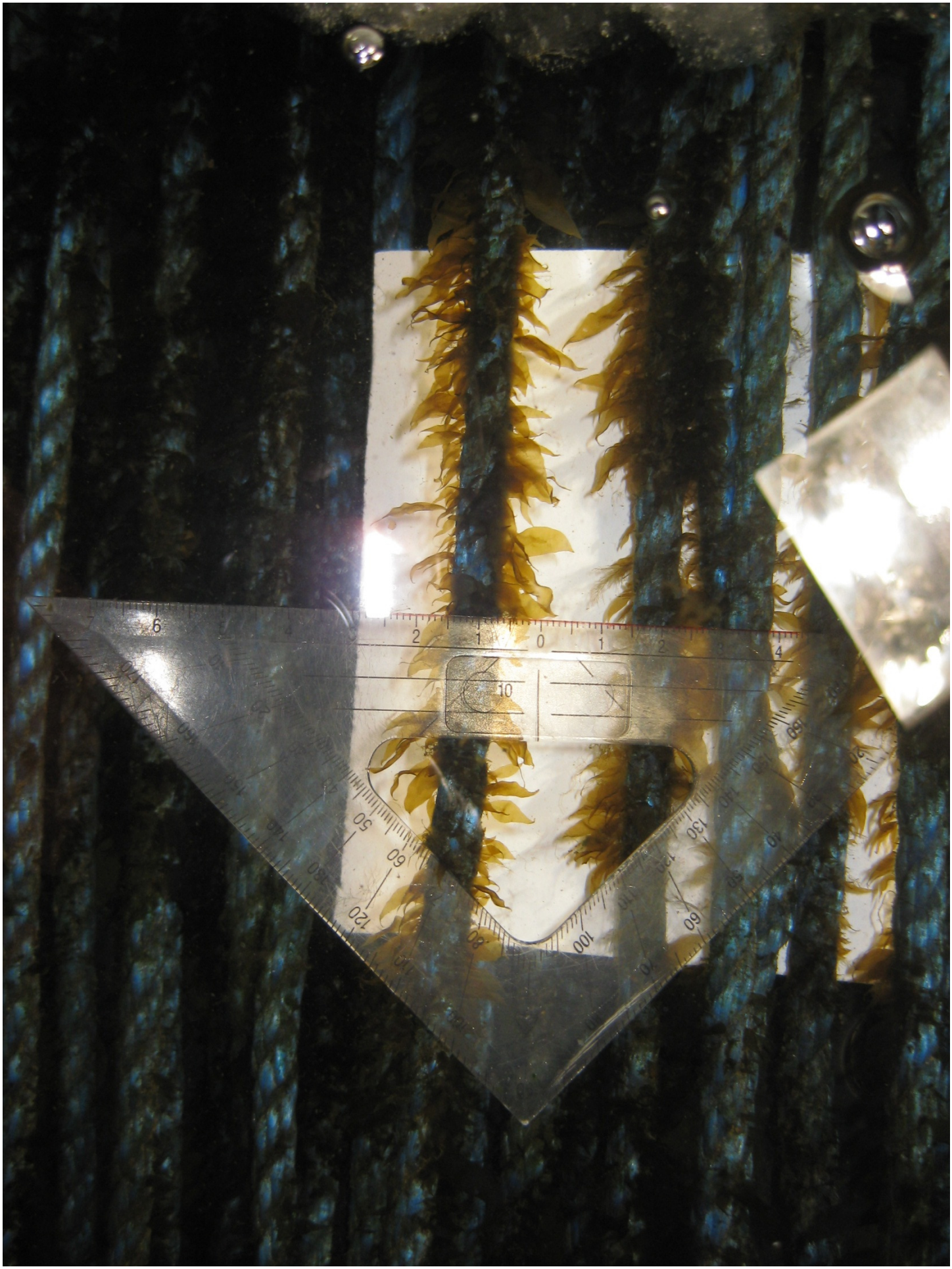
Laminaria japonica in nature:
2-5 m long at an age of 20 months

In culture with summer hatchery: 2-5 m long
11 months after seeding zoospores

The secrets of Chinese success:

---First year plants from culture are as big as two-year plants in the sea

---Chinese Laminaria is harvested in May/early June and never sees the „terrible Laminaria summer“



So we need a Saccharina summer hatchery also for European mass cultivation,

also for a second reason:

Heavy animal fouling:
The terrible summer for sea-cultivated Saccharina in Norwegian waters

The terrible summer for sea-cultivated Saccharina in Norwegian waters

From June and during the rest of the summer period, epiphytes like bryozoans, blue mussels, hydroids, and other algae were covering the sporophytes

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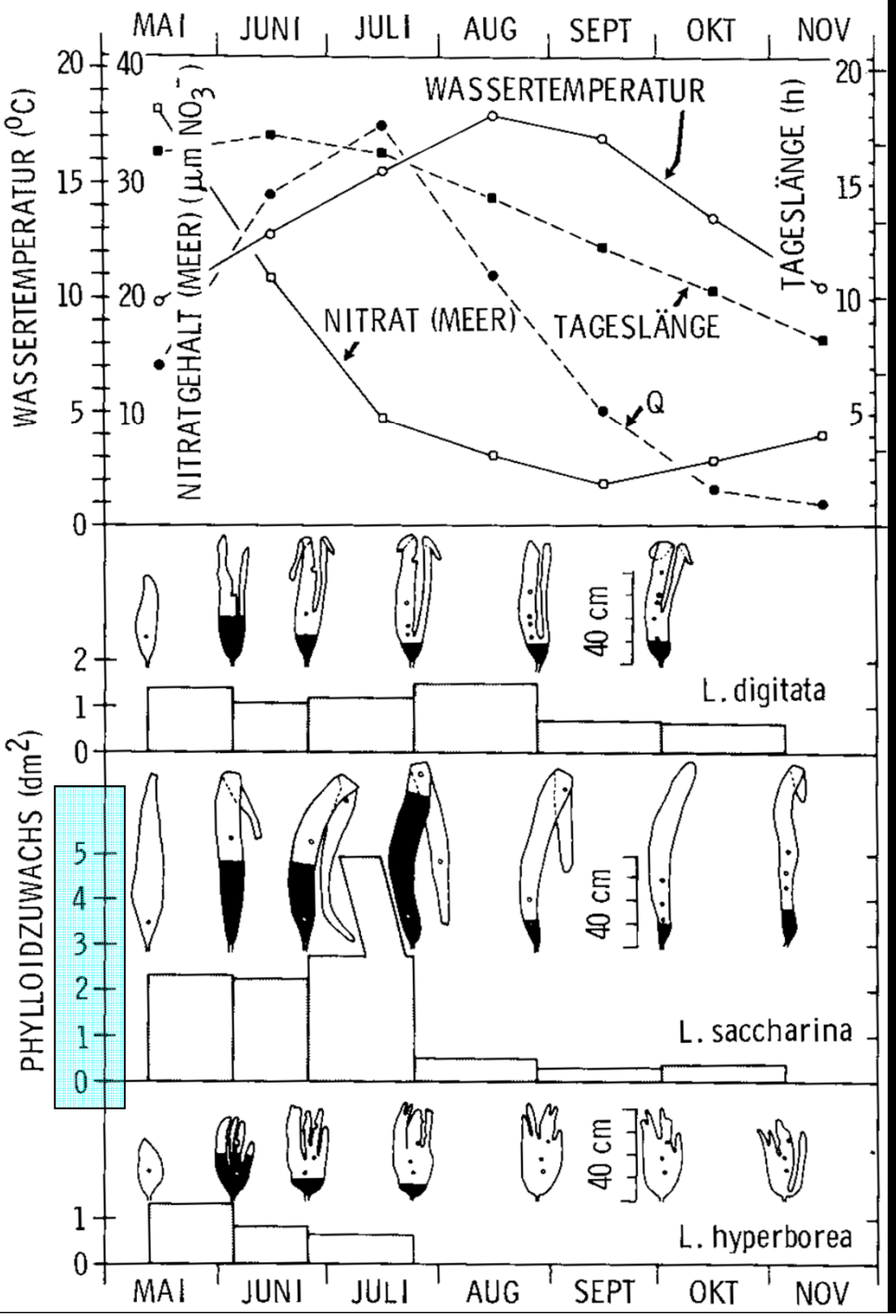
Lysefjorden, 2012, Aug 23: tank cultivated Saccharina
No animal fouling on blades

Helgoland
(rocky island in the southern North Sea):
Laminaria individuals
fixed to an iron frame directly fastened on the sublittoral rock (almost like in nature),
NO ROPE CULTURE with blades down hanging
(1) Saccharina grows well at 2 m water depth in the sea also in June and July
Lüning (1979) Mar. Ecol. Prog. Ser. 1, 195-207.



(2) No animal epiphytes on the blades in summer in the sea:
because in natural Laminaria vegetation directly on the rock there is the WHIPLASH EFFECT („Fly flap effect“) ????????

Outlook:

So let us try for Norwegian Saccharina rope cultivation (a-c like in China)

-a- to harvest in May Saccharina as big as possible,

-b- build summer kelp hatcheries on the land

-c- avoid the summer months for rope cultivation

-d- OR install SOMEHOW a whiplash effect for the HANGING DOWN blades