IOC e-learning Course on Harmful Marine Microalgae

University of Copenhagen

Introduction to Gonyaulacales

Ostreopsis and *Coolia*

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on-line session to be announced

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Ostreopsis Schmidt 1901

Outline of module

1. ***Ostreopsis*** **Schmidt 1901**
   - 1.1. Description of the genus
   - 1.2. Species diversity of *Ostreopsis*
   - 1.3. Species of *Ostreopsis* in the South Pacific
2. ***Coolia*** **Meunier 1919**
   - 2.1. Description of the genus
   - 2.2. Species of diversity of *Coolia*
   - 2.2. Species of *Coolia* in the South Pacific
3. **References**

Recommended reading:

Chomérat, N., Bilien, G., Derrien, A., Henry, K., Ung, A., Viallon, J., Darius, H. T., Mahana iti Gatti, C., Roué, M., Hervé, F., Réveillon, D., Amzil, Z. & Chinain, M. 2019. *Ostreopsis lenticularis* Y. Fukuyo (Dinophyceae, Gonyaulacales) from French Polynesia (South Pacific Ocean): A revisit of its morphology, molecular phylogeny and toxicity. Harmful Algae 84:95-111.

Karafas, S., York, R., & Tomas, C. 2015. Morphological and genetic analysis of the *Coolia monotis* species complex with the introduction of two new species, *Coolia santacroce* sp. nov. and *Coolia palmyrensis* sp. nov. (Dinophyceae). Harmful Algae 46: 18–33. doi:10.1016/j.hal.2015.05.002

Mohammad-Noor, N., Moestrup, Ø., Lundholm., Fraga, S., Adam, A., Holmes, M.J. & Saleh, E. 2013. Autecology and phylogeny of *Coolia tropicalis* and *Coolia malayensis* (Dinophyceae), with emphasis on taxonomy of C. tropicalis based on light microscopy, scanning electron microscopy and LSU rDNA. – J. Phycol. 49:536-545.

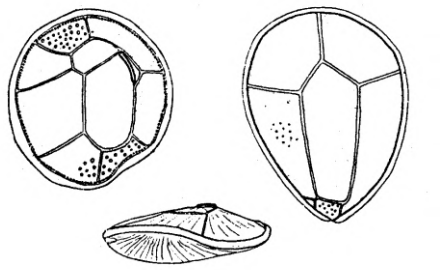
Nguyen-Ngoc, L., Doan-Nhu, H., Larsen, J., Phan-Tan, L., Nguyen, X.-V., Lundholm, N., Van Chu, T. & Huynh-Thi, D.N. 2021 Morphological and genetic analyses of *Ostreopsis* (Dinophyceae, Gonyaulacales, Ostreopsidaceae) species from Vietnamese waters with a re-description of the type species, *O. siamensis*. – J. Phycol. 57:1059-1083. doi: 10.1111/jpy.13157.

Parsons, M.L., Aligizaki, K., Dechraoui Bottein, M-Y., Fraga, S., Morton, S.L., Penna, A. & Rhodes, L. 2012. *Gambierdiscus* and *Ostreopsis*: Reassessment of the state of knowledge of their taxonomy, geography, ecophysiology, and toxicology. – Harmful Algae 14: 107-129.

1.1 Genus *Ostreopsis* Schmidt 1901

Slide 2

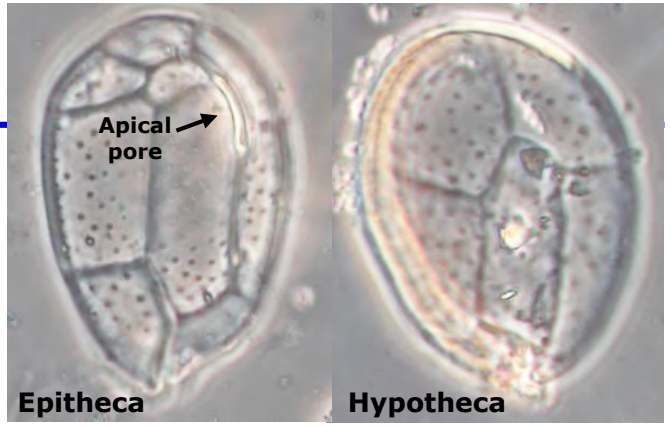
Ostreopsis siamensis Schmidt 1901



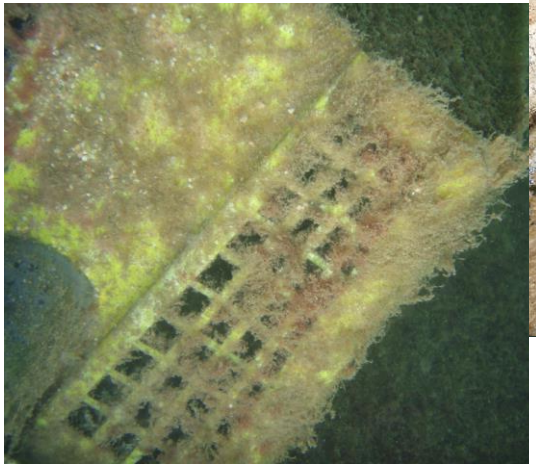
From Schmidt 1901

The first species of *Ostreopsis* to be described was *O. siamensis* from Koh Chang Island in the Gulf of Thailand (Schmidt 1901).

Species of *Ostreopsis* are widely distributed in warm temperate to tropical waters and epiphytic on macroalgae, corals, coral rubber, and in mangrove habitats.



Species of *Ostreopsis* are strongly compressed cells, and therefore almost always seen in apical or antapical view. The cells are more or less ovoid in apical and antapical view. The apical pore is a long slit, displaced to the left dorsal side.



Mats of *Ostreopsis* sp. in the aquaria at the Institute of Oceanography, Nha Trang, Vietnam.

1.2 Diversity of *Ostreopsis*

The genus currently comprises 11 recognizes species six of which may produce toxins according to the IOC Taxonomic Reference List (high-lighted). Type species: *O. siamensis* Schmidt 1901.

Ostreopsis belizeana Faust 1999	Faust 1999
O. caribbeana Faust 1999	Faust 1999
O. fattorussoi Accoroni *et al.* 2016	Accoroni *et al*. 2016, Penna *et al*. 2010
O. heptagona Norris *et al.* 1985	Norris *et al*. 1985
O. labens Faust *et* Morton 1995	Faust & Morton 1995, Moreira *et al*. 2012
O. lenticularis Fukuyo 1981	Fukuyo 1981, Larsen & Nguyen 2004, Moreira *et al*. 2012, Penna *et al*. 2012, Chomérat *et al*. 2019
O. marina Faust 1999	Faust 1999
O. mascariensis Quod 1994	Quod 1994, Lenoir *et al*. 2004, Chomérat *et al*. 2020a
O. ovata Fukuyo 1981	Fukuyo 1981, Larsen & Nguyen 2004, Penna *et al*. 2005, 2012, Selina & Orlova 2010
O. rhodesiae Verma *et al.* 2016	Verma *et al*. 2016
O. siamensis Schmidt 1901	Schmidt 1901, Fukuyo 1981, Penna *et al*. 2005, 2012, Selina & Orlova 2010, Chomérat *et al*. 2020b, Nguyen-Ngoc *et al*. 2021

Species of *Ostreopsis* may produce palytoxin (PLTX) like compounds (including ostreocin and ova-toxins) which are highly toxic. These toxins have been linked to human intoxication through con-sumption of crabs and various species of fish including tropical clupeoids (clupeotoxism) with the same symptons as CFP (Parsons *et al*. 2012, Verma *et al*. 2019, and references therein). PLTX-like toxins may also accumulate in shellfish. In addition, *O. lenti-cularis* may produce different compounds, ostreotoxins (Parsons *et al.* 2012).

In the Mediterranean, blooms of *O. cf. ovata* have been associated with asthma-like symptoms in humans presumably due to aerosol-borne toxins.

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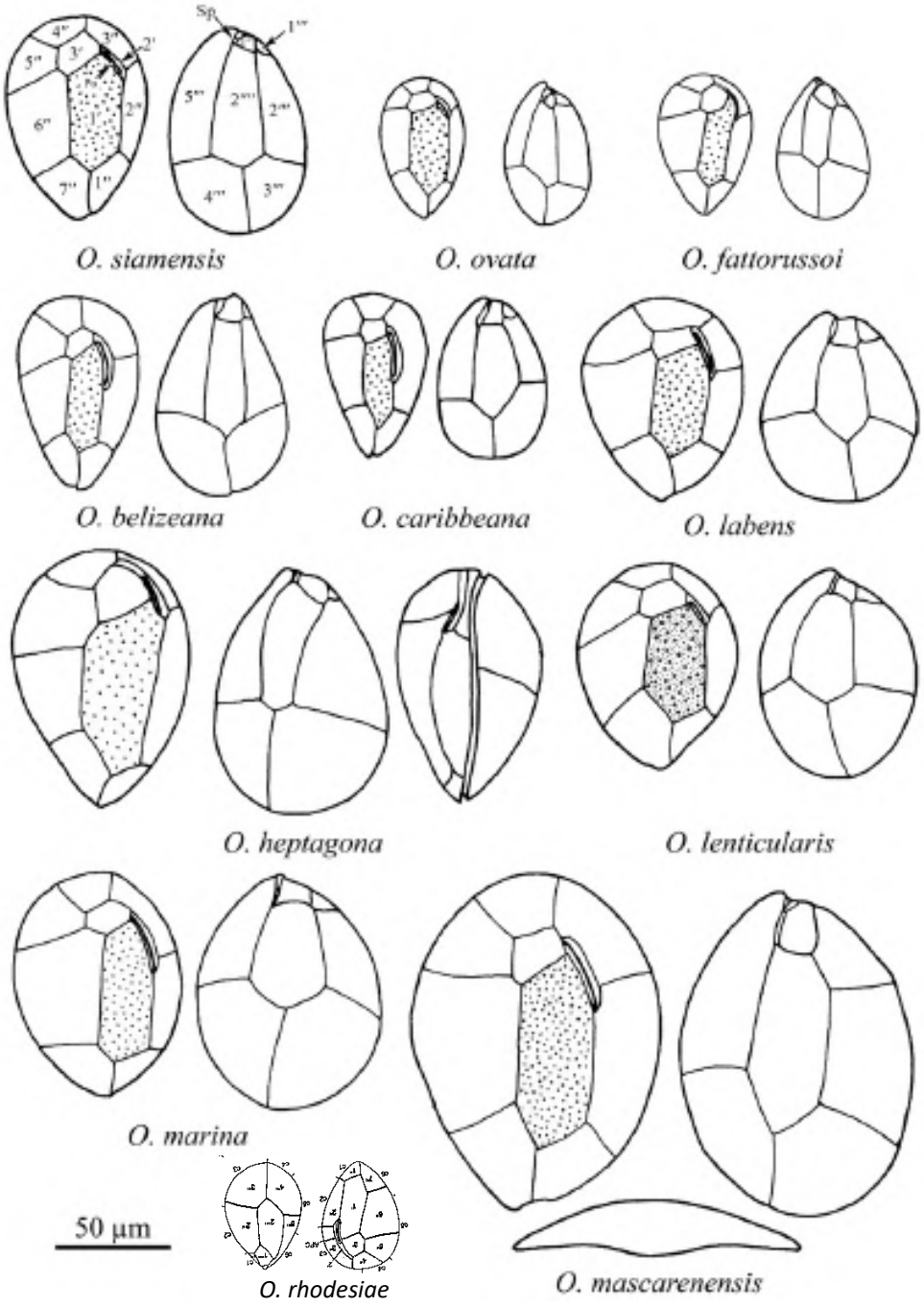
1.2 Diversity of *Ostreopsis*

Slide 4

Species	DV – range average (µm)	W – range average (µm)	Reference
O. belizeana	78-92	38-48	Faust 1999
O. caribbeana	56-81	26-47	Faust 1999
O. fattorussoi	43-73 (60)	26-50 (40)	Accaroni *et al*. 2016
O. heptagona	96-122 (108)	62-84 (70)	Norris *et al*. 1985
O. labens	81-110	70-80	Faust *et* Morton 1995
O. lenticularis	60-100	45-80	Fukuyo 1981
	73-94 (81)	58-78 (68)	Chomérat *et al*. 2019
O. marina	83-111	73-85	Faust 1999
O. mascariensis	113-195 (148)	79-138 (103)	Quod 1994
	112-142 (124)	83-109 (96)	Chomérat *et al*. 2020
O. ovata	50-56	25-35	Fukuyo 1981
O. cf. ovata	27-65	19-57	Penna *et al*. 2005
O. cf. ovata[1]	45-62 26-43	29-48 13-26	Aligizaki & Nikolaidis 2006
O. cf. ovata	55-94 (70)	30-62 (45)	David *et al*. 2013
O. cf. ovata	20-48 (35)[2] 24-59 (39)[3]	15-40 (25) 16-47 (28)	Tawong *et al*. 2014
O. rhodesiae	32-56 (44)	23-46 (32)	Verma *et al*. 2016
O. siamensis	~ 90 60-100 46-92 (73)	. 45-90 41-75 (59)	Schmidt 1901 Fukuyo 1981 Nguyen-Ngoc *et al*. 2021
O. cf. siamensis[1]	52-68 30-40	40-55 20-30	Rhodes *et al*. 2000
O. cf. siamensis[4]	63-90	34-56	Penna *et al*. 2005
O. cf. siamensis	48-65	29-50	Aligizaki & Nikolaidis 2006
O. cf. siamensis	55-75 (67)	27-56 (46)	David *et al*. 2013

1) Two size classes; 2) samples from the Gulf of Thailand; 3) samples from the South China Sea; 4) wild material. Figures in brackets indicate averages.



Illustrations to scale, modified from Accaroni *et al*. 2016

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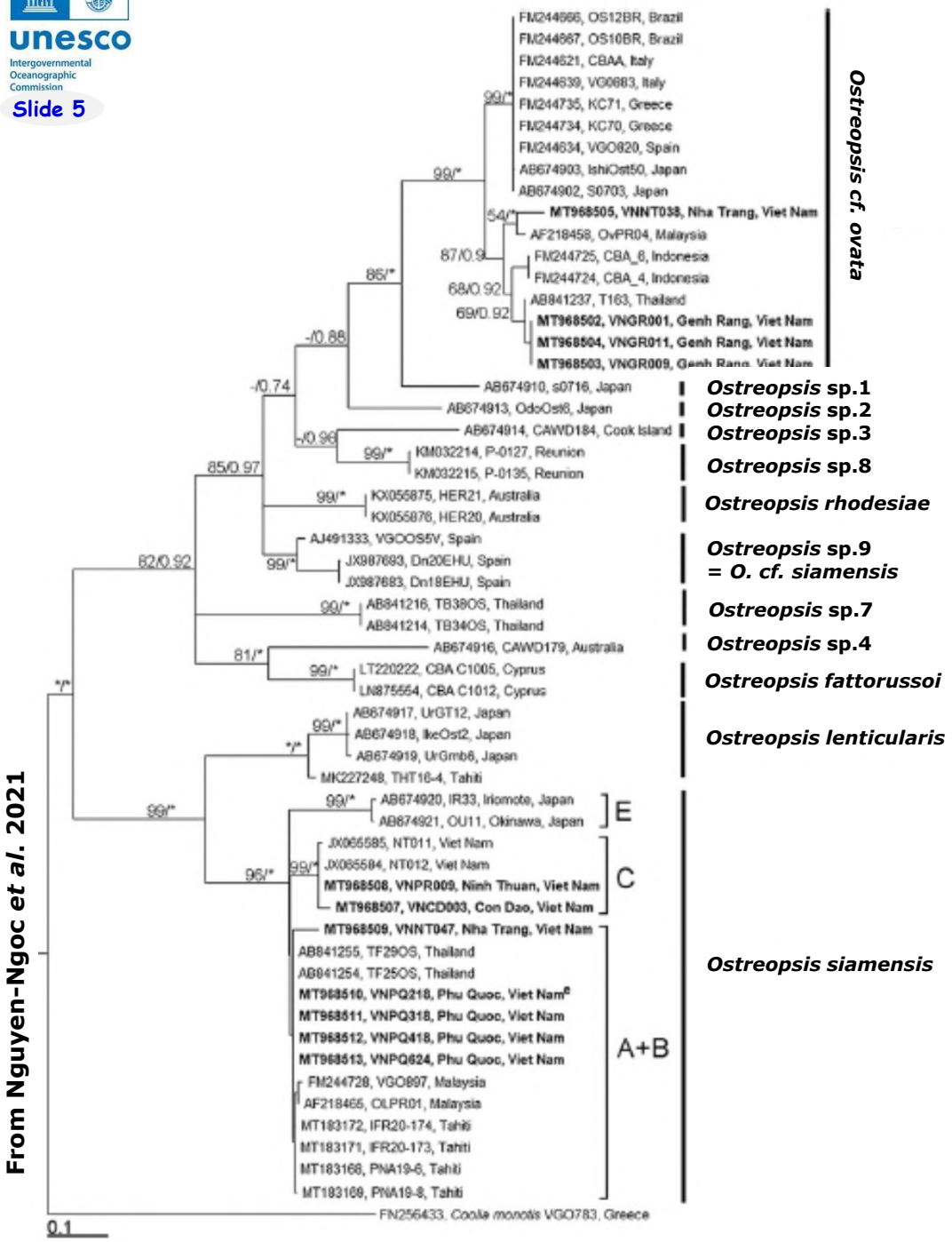
Slide 5

1.2 Diversity of *Ostreopsis*



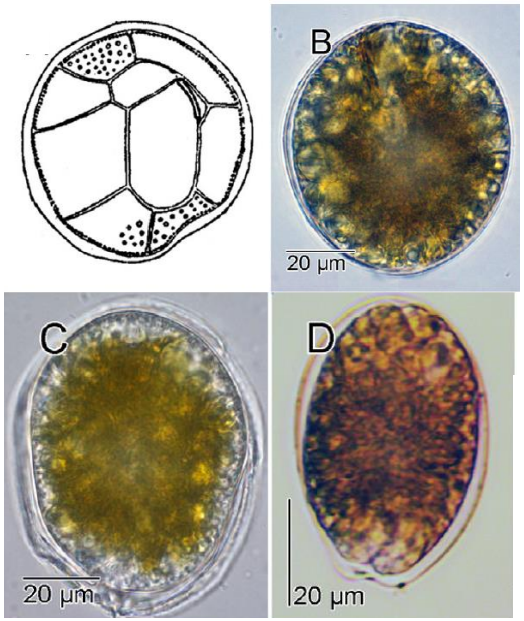
Species of *Ostreopsis* are highly variable morphologically (Parsons *et al.* 2012, Berdalet *et al*. 2017), and - with the exception of *O. lenticularis* which may be distinguished by two types of thecal pores visible in LM (Fukuyo 1981, Chomérat *el al*. 2019) and possibly *O. heptagona* (Norris *et al*. 1985), and *O. mascarenensis* (Quod 1994, Chomérat *et al*. 2020a) - cannot be identified by their morphological features.

Many species of *Ostreopsis* are poorly described which contributes to the taxonomic confusion and uncertainly in this genus. Species are often identified tentatively as cf. which is an abbreviation for the Latin: confer/conferatur, meaning 'compare`. Thus, phylogenetic analyses some authors have used tentative names such *O. cf. ovata* and *O. cf. siamensis* or attached numbers, like *Ostreopsis* sp. 1-9, to the clades which have emerged from these studies (e.g. Tawong *et al.* 2014, Chomérat *et al*. 2019, 2020b).

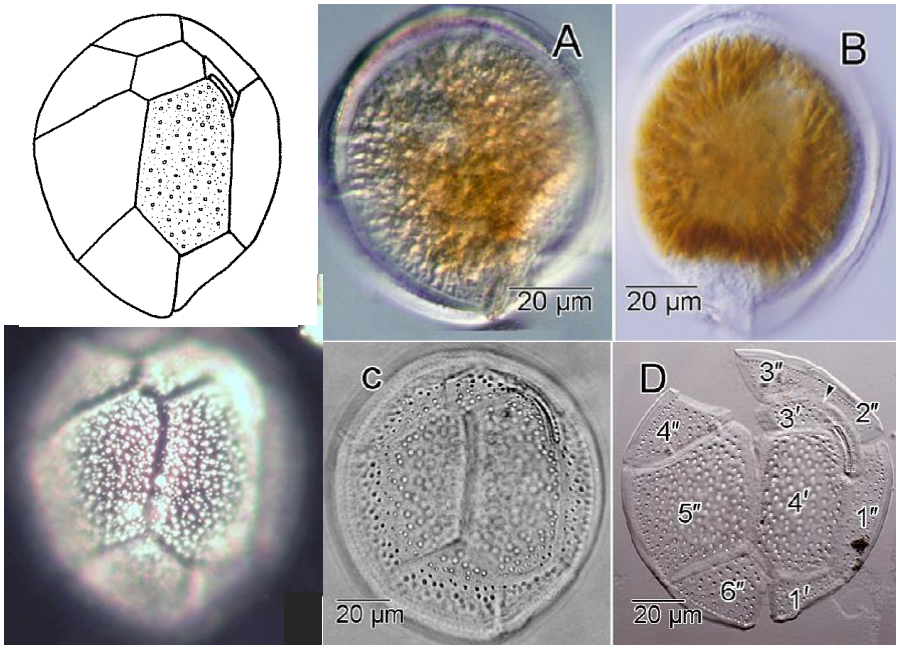
A recent study by Nguyen-Ngoc *et al.* (2021) has shown that the type species, *O. siamensis,* is identical to *Ostreopsis* sp. 6 in these phylogenetic analyses. *Ostreopsis siamensis* is a tropical species, and it may be not distinguished from other similar-sized species by its morphological features, and molecular analysis is needed for proper identification. It is genetically distinct from *O. cf. siamensis* (referred to as *Ostreopsis* sp. 9 by Nguyen-Ngoc *et al.* 2021) reported from temperate areas including the Mediterranean Sea; and this appears to be a different as yet undescribed species.

1.3 *Ostreopsis* in the South Pacific

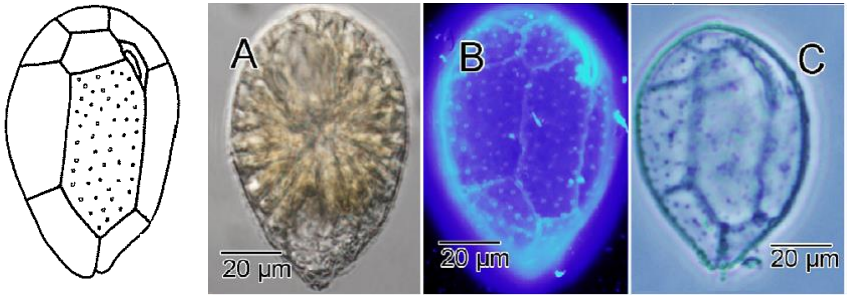
Ostreopsis siamensis **(type species),** ***O. lenticularis*** **and** ***O. ovata*** **have all been reported from the South Pacific (Fukuyo 1981, Chomérat *et al*. 2019, Chomérat *et al*. 2020b, Nguyen-Ngoc *et al*. 2021).**



Ostreopsis siamensis **(illustrations from Schmidt 1901 Nguyen-Ngoc 2021). The shape of this species is variable.**



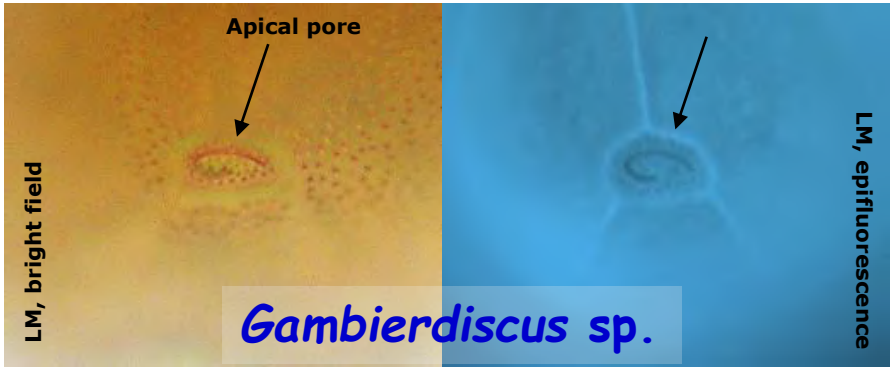
Ostreopsis lenticularis **(illustrations from Fukuyo 1981, Nguyen-Ngoc 2021, and original). Rounded shape and this species may be confused with** ***Gambierdiscus*****, see next slide.**



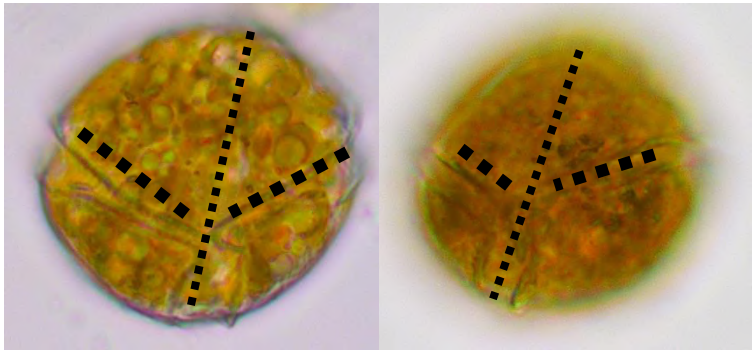
Ostreopsis ovata **(illustrations from Fukuyo 1981, Nguyen-Ngoc 2021. This species is smaller than** ***O. siamensis*** **and** ***O. lenticularis*****, and probably the most common species of** ***Ostreopsis*****.**

1.3 *Ostreopsis* in the South Pacific

Some species of *Ostreopsis* are be similar in size and shape to *Gambierdiscus* spp. Such species may be distinguished (at the genus level) by the shape of the apical pore. It is slit-like, long, slightly bending, and strongly asymmetrical on *Ostreopsis* spp. While it is fish-hook shared and located more or less centrally in *Gambierdiscus* spp.



2.1 Genus *Coolia* Meunier 1919



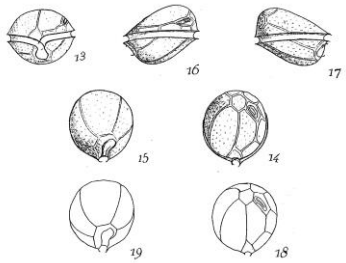
Two cells of *Coolia* sp. in ventral view. Species belonging to this genus can usually be identified by the oblique longitudinal axis and the obtuse angle formed by the girdle.

Species of *Coolia* are asymmetrical. The apical pore is an elongated slit (like in *Ostreopsis*) and displaced to the left dorsal side of the epitheca. Therefore the longitudinal axis of the cell is tilted and oblique. The cingulum is median, but tilted anteriorly so the ends of the girdle form an obtuse angle. Species of *Coolia* are smaller (about 20-50 µm long) than species of *Gambierdiscus* and *Ostreopsis*.

Coolia spp. are widely distributed in warm temperate to tropical waters and epiphytic on macro algae, corals, coral rubber, sediment, and in mangrove habitats.

C. areolata Ten-Hage *et al*. 2000	Ten-Hage *et al*. 2000
C. canariensis Fraga 2008	Fraga *et al*. 2008
Coolia guanchica David, Laza-Martínez, Rodríguez & Fraga 2020	David *et al.* 2020
C. malayensis Leaw, Lim *et* Usup 2009	Leaw, Lim *et* Usup 2009, Mohammad-Noor *et al*. 2013, Wakeman *et al*. 2015
C. monotis Meunier 1919	Meunier 1919
C. palmyrensis Karafas, Tomas *et* York	Karafas *et al*. 2015
C. santacrose Karafas, Tomas *et* York	Karafas *et al*. 2015
C. tropicalis Faust 1995	Faust 1995, Mohammad-Noor *et al*. 2013

The genus was described by Meunier (1919) from the Belgian coast with *C. monotis* as the only species.



From Meunier 1919

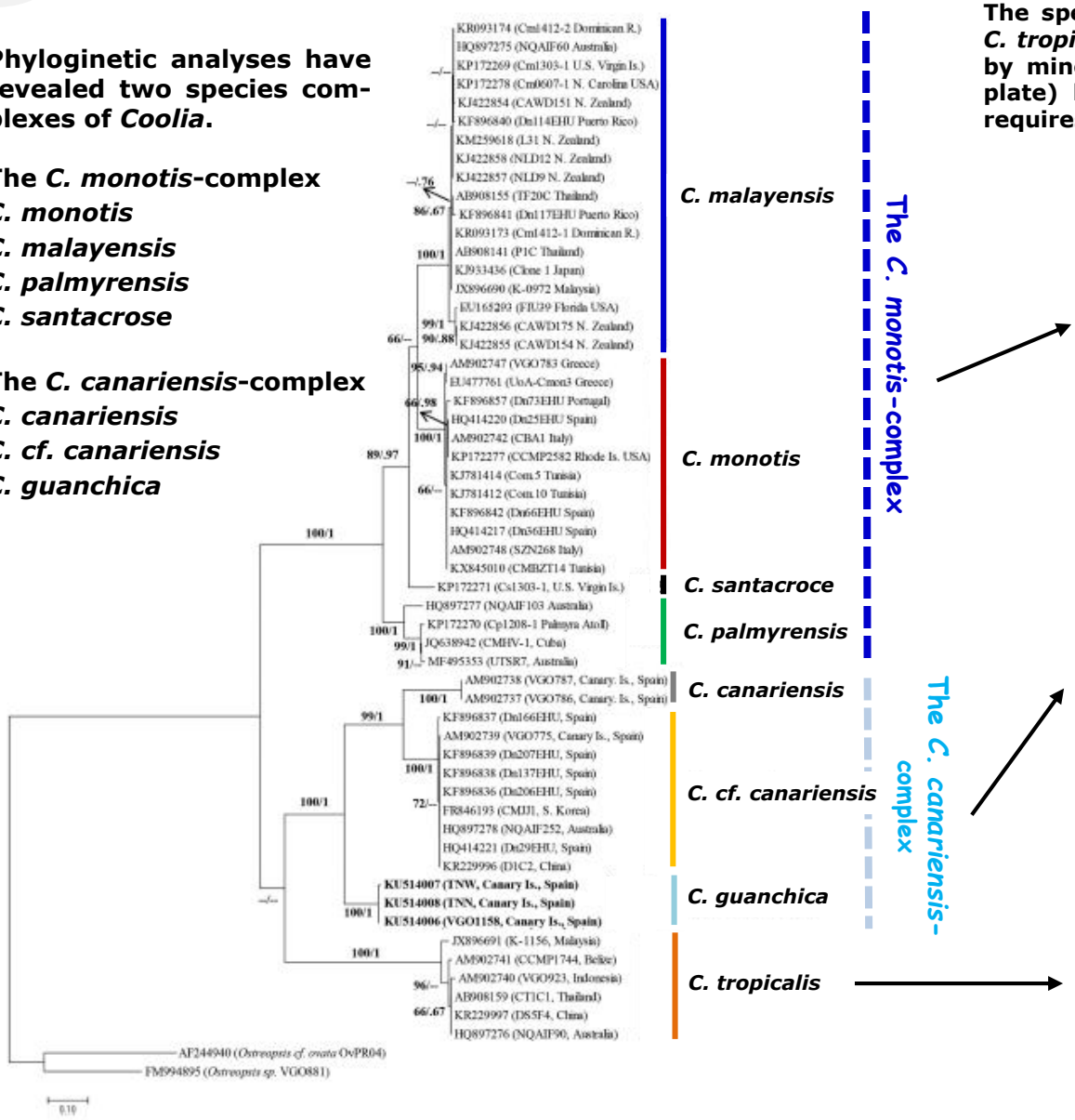
The genus currently comprises 8 recognized species two of which may produce toxins. Type species: *C. monotis* Meunier 1919.

2.2 Diversity of *Coolia*

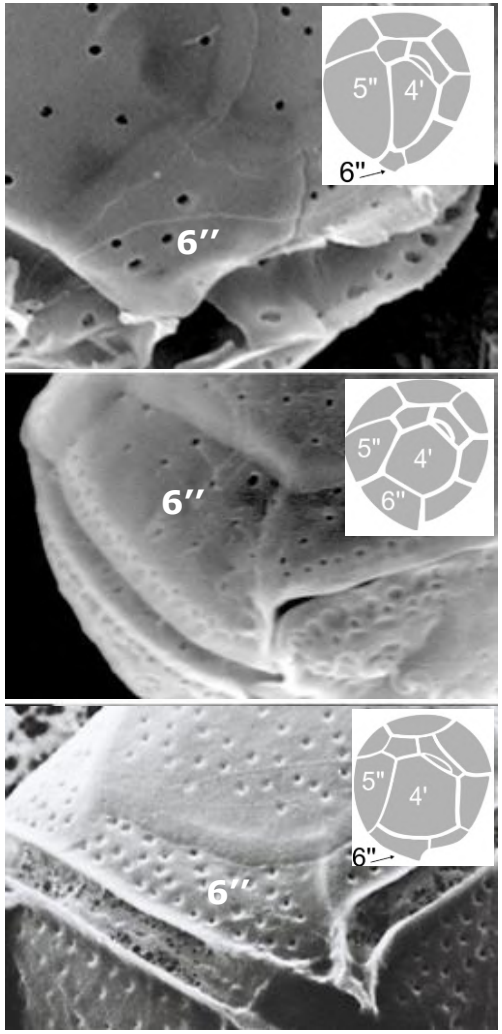
Phyloginetic analyses have revealed two species complexes of *Coolia*.

The *C. monotis*-complex
C. monotis
C. malayensis
C. palmyrensis
C. santacrose

The *C. canariensis*-complex
C. canariensis
C. cf. canariensis
C. guanchica



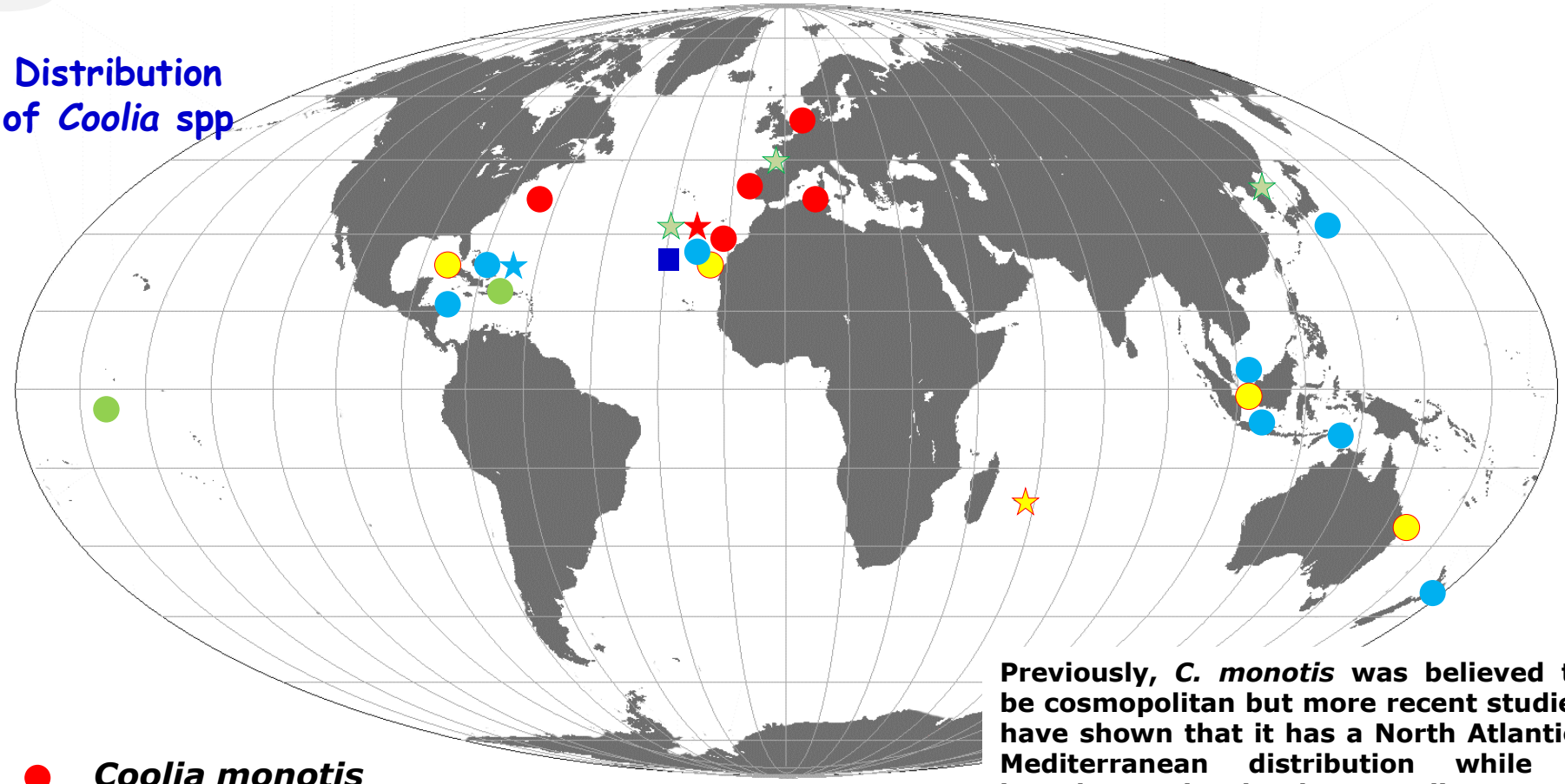
The species belonging in the two complexes and *C. tropicalis* may be distinguished morphologically by minor differences in tabulation (shape of 6''-plate) but this is difficult to observe in LM and requires considerable experience.



Phylogeny of Coolia based on D1/D2 region of the nuclear encoded LSU rDNA sequences, From David *et al*. 2020.

2.2 Diversity of *Coolia*

Distribution of *Coolia* spp



- ● *Coolia monotis*
- ● *Coolia malayensis*
- ● *Coolia tropicalis*
- ● *Coolia palmyrensis*
- ★ *Coolia areolata*
- ★ *Coolia santacroce*
- ★ *Coolia canariensis*
- ★ *Coolia* cf. *canariensis*
- ■ *Coolia* guanchica

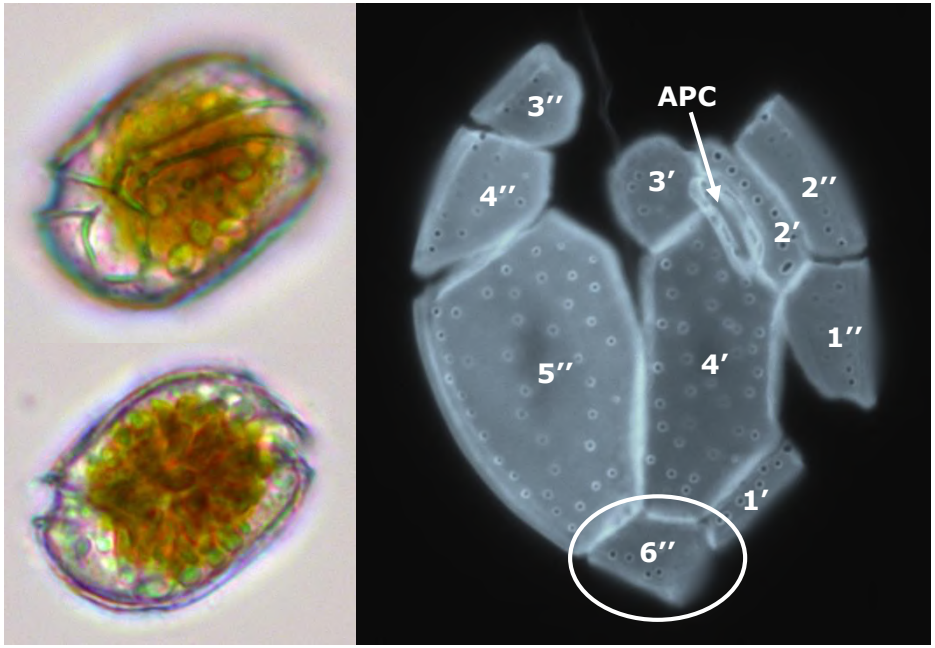
Previously, *C. monotis* was believed to be cosmopolitan but more recent studies have shown that it has a North Atlantic-Mediterranean distribution while – based on molecular data - earlier reports of this species from subtropical and tropical areas are *C. malayensis*.

***Coolia tropicalis* is found only in tropical regions.**

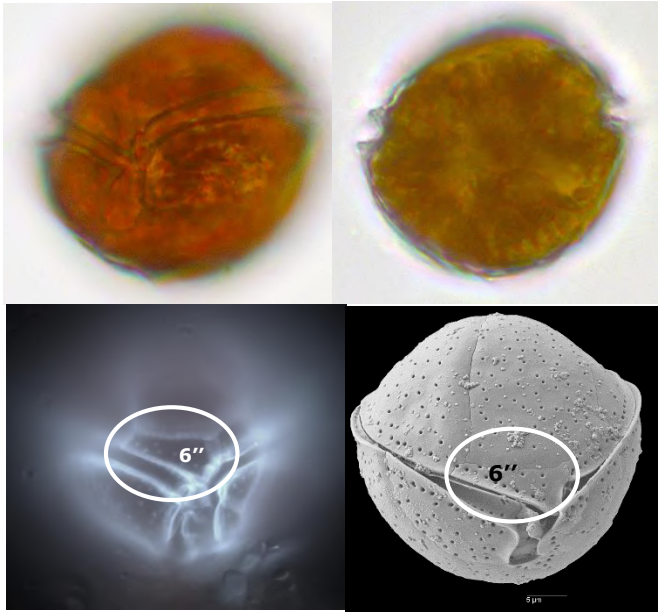
***Coolia areolata* is poorly known and has been reported only once, and it is the only species of *Coolia* which has not been studied genetically.**

2.3 Coolia in the South Pacific

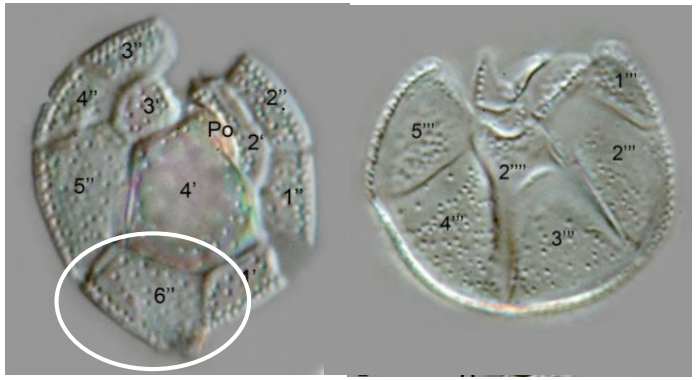
Coolia 'monotis-complex' (*C. malayensis/palmyrensis*)



Coolia tropicalis



Coolia canariensis



Four species of *Coolia,* notably *C. malayensis, C. palmyrensis, C. canariensis,* and *C. tropicalis* have been reported from Guam and may occur in the South Pacific (Phua *et al*. 2021). They found toxin production in strains of C. malayensis, C. canariensis phylogroup IV and C. palmyrensis, while *C. tropicalis* was non-toxic. However, toxin production in C. tropicalis has been but other. This study also showed that the production of toxic compounds in *Coolia* can vary in the same strain.

Holmes *et al.* (1995) reported production of cooliatoxin in a culture of *C. monotis* but this was presumably a toxic clone of *C. tropicalis* (Mohammad-Noor *et al.* (2013). Wakeman *et al*. (2015) found that *C. malayensis* may produce five different toxic compounds, which are unique to this species and different from cooliatoxin.

Tibirica *et al*. (2020) found toxicity in *Coolia malayensis* and *C. tropicalis*. They found that *C. tropicalis* may produce gambierone analogues, and this appears to be the first time that these toxins are found in dinoflagellates other than *Gambierdiscus.* Tibirica *et al.* (2020) concluded that role of *C. tropicalis* in CFP deserved to be considered in further investigations.

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Chomérat, N., Bilien, G., Derrien, A., Henry, K., Ung, A., Viallon, J., Darius, H. T., Mahana iti Gatti, C., Roué, M., Hervé, F., Réveillon, D., Amzil, Z. & Chinain, M. 2019. *Ostreopsis lenticularis* Y. Fukuyo (Dinophyceae, Gonyaulacales) from French Polynesia (South Pacific Ocean): A revisit of its morphology, molecular phylogeny and toxicity. Harmful Algae 84:95-111.

Chomérat, N., Bilien, G., Viallon, J., Hervé, F., Réveillon, D., Henry, K., Zubia, M., Vieira, C., Ung, A., Gatti, C. M. i., Roué, M., Derrien, A., Amzil, Z., Darius, H. T. & Chinain, M. 2020b. Taxonomy and toxicity of a bloom-forming Ostreopsis species (Dinophyceae, Gonyaulacales) in Tahiti island (South Pacific Ocean): one step further towards resolving the identity of O. siamensis. Harmful Algae 98.

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