CATALOGUE OF

PARASITES AND DISEASES OF THE COMMON COCKLE *Cerastoderma edule*

COCKLES PROJECT

MARCH 2021

universidade de aveiro
theoria poiesis praxis

CATALOGUE OF
PARASITES AND DISEASES OF THE COMMON COCKLE
Cerastoderma edule

"Real knowledge is to know the extent of one's ignorance"
Confucius

COCKLES PROJECT

MARCH 2021

universidade de aveiro
theoria poiesis praxis

TITLE: Catalogue of parasites and diseases of the common cockle *Cerastoderma edule*

AUTHORS: Xavier de Montaudouin, Isabelle Arzul, Asunción Cao, Maria Jesus Carballal, Bruno Chollet, Simão Correia, Jose Cuesta, Sarah Culloty, Guillemine Daffe, Susana Darriba, Seila Díaz, Marc Engelsma, Rosa Freitas, Celine Garcia, Anouk Goedknegt, Patrice Gonzalez, Ana Grade, Emily Groves, David Iglesias, Kurt T. Jensen, Sandra Joaquim, Sharon Lynch, Luísa Magalhães, Kate Mahony, Francisco Maia, Shelagh Malham, Domitília Matias, Antoine Nowaczyk, Francisco Ruano, David Thieltges & Antonio Villalba.

SCIENTIFIC ILLUSTRATIONS: Fernando Correia & Cláudia Barrocas

DESIGN: Anabela Marques

PRINTED BY: ARTIPOL – Artes Gráficas, Lda

PRINT RUN: 140 copies

PUBLISHER: UA Editora – Universidade de Aveiro

1ST EDITION: March 2021

ISBN: 978-972-789-671-4

DOI: 10.34624/9a9c-9j21

LEGAL DEPOSIT: 480176/21

LEAD PARTNER FOR OUTPUT
University of Bordeaux

Acknowledgement

The work described in this project has been funded by European Commission under the Horizon 2020 Framework Programme (http://www.cockles-project.eu/).

This catalogue is associated to website http://cockles-project.eu/gis-viewer *or* https://utmar.cetmar.org/cockles-viewer

CONTENTS


cockles

INTRODUCTION

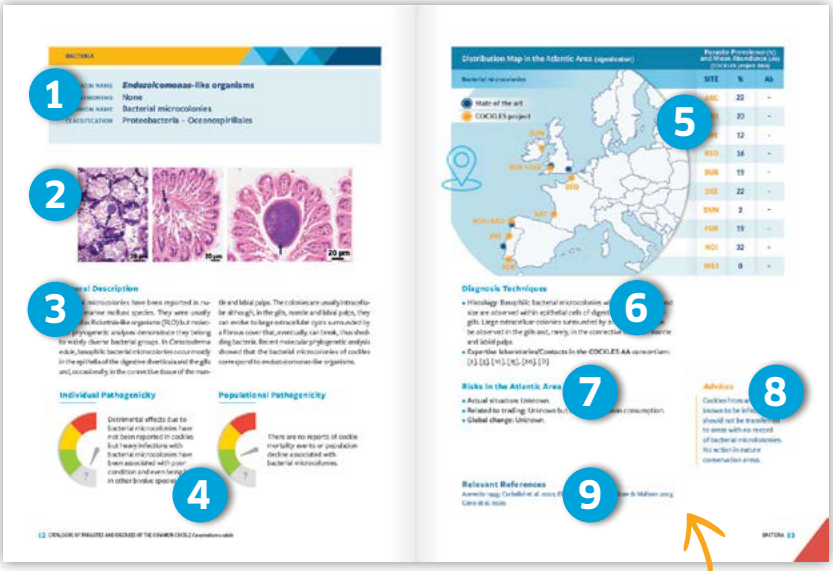
Lazy or timeless readers who wouldn't read the whole introduction should however courageously reach the end of this sentence: 1) none of the parasites/diseases of cockles (Cerastoderma edule) *is harmful for human consumers; 2) parasites are part of the biodiversity; and 3) some (few) parasites/diseases are dramatically deleterious at their host population scale.*

When COCKLES Project colleagues met the first time in Madrid, in 2017, they certainly didn't envisage that the last year(s) of their project would be in a human pandemic framework and that their discussions would be by remote means or through ugly but safe masks. Conversely, they already had many ambitions for this project, one of them being to gather all knowledge concerning symbionts sensu lato, i.e. *parasites and commensals of cockles* Cerastoderma edule, *which should be useful for cockle resource management. Considering this important challenge, decision was rapidly taken to discard* C. glaucum *and to focus on Atlantic waters. Our objective was mainly to bring knowledge to stakeholders, policy makers, fishermen, reserve managers and maybe educational staff and, why not, science-greedy public, through an ordered, synthesised, easily understandable way. During the Steering Committee in Olhão, Portugal, however, we raised the question that such a census could stimulate more panic than interest: "All these nasty parasites...". We even envisaged not to use the term "parasite". But many of them are parasites, and we are scientists who care about the meaning of words. Thus, the decision was rather to explain first that parasites, diseases and other symbionts of cockles, listed in this file, are innocuous for human beings ("are not zoonotic"). Note that this census doesn't consider either harmful toxic algae or human-pathogenic microorganisms for which cockles, as any other food, may act as vectors in the absence of safety conditions. Our list of parasites comprises trematode which is a group of parasites that could stimulate some fears because there are some terrestrial, freshwater or tropical species which can induce more or less severe human diseases. It is absolutely not the case with our edible cockle. A 200-% precaution would be to avoid consuming them raw. Then our first message is that, as far as cockles are sold within the regulation devoted to shellfish consumption, no problem at all and Bon Appétit!*

A second interesting point is the ecological aspect. Forty percent of Eucaryotic organisms in the world are parasites, and then parasites in our edible cockle significantly participate to this hidden diversity. Who would imagine than when picking a cockle you have more than a dozen of species in your hand, without evoking bacteria and viruses. It is true that the cockle is some kind of a champion to shelter more or less deleterious inhabitants (the majority being rather innocuous). Here, we described 38 taxons (+ 3 diseases). We also decided to add two species that are parasites of cockle parasites ("hyperparasites") and thus, finally, which could be rather considered as friendly for cockles, helping them to get rid of some of their enemies. Besides, some of these parasites are also indicators of larger scale diversity and environmental good health! This is the case of trematodes which presence in cockles reveals rather good water quality and the presence of many different species participating to their life cycle, including birds and finfish. Thus, this census reminds us that some parasites are very pathogenic to cockles and must highlight that cockles transfer among geographic areas shouldn't be performed or with considerable precaution, which anyway will keep risk at high level. A strong motivation to participate to this project, and in particular to the work package devoted to diseases, was related to the important crisis in Galicia associated with the cockle parasite Marteilia cochillia. *Our investigation allowed to highlight that other threats were present, in particular Disseminated Neoplasia. At the end of this document, we tried to hierarchise parasites/diseases according to their pathogenicity and the risk they represent, but we must keep in mind that this risk is also related to prevalence (=% of infected individuals), which is itself fluctuating and strongly related to complex environmental factors interactions.*

Finally, like all scientists, we must point out that this study revealed huge gaps in our knowledge and that next generation will certainly have to write the second tome! At this stage, we faced many unknown species, molecular biology is also contributing to multiply what we considered as a single species and global trading and global change will certainly bring new... surprises!

Guidelines for readers



Each parasite (or disease) is described within a double facing page

1. The accepted scientific **latin name** and the most common **synonyms** are mentioned. **Common names** are unusual, except for some diseases or macroparasites (e.g. "pea crabs"). Some elements of the **classification** were extracted from the up-to-date World Register of Marine Species and the direct link is provided.

2. **Pictures** of the parasites, pathogens or infected tissues.

3. A **general description** insisting on typical morphological traits, possible complex life-cycle of the parasite, on host and environmental factors favoring the development of the pathogen/lesion.

4. A scale of **pathogenicity** is proposed when data are available. This can be considered as an "expert opinion".

Effect	Individual	Populational
SERIOUS	Kills cockles	Mortality reported
MODERATE	Affects growth/condition	No obvious related mortality
NONE	None	None
UNKNOWN		

5. **Distribution map,** distinguishing data of the COCKLES project from data based on the state of the art. The table on the right indicates data from the project, with different cohorts and seasons being pooled. **Prevalence** is the percentage of infected cockles and **mean abundance** is the mean number of parasite individuals per cockle ("–": not evaluated; ndbp: not determined, but present).

6. **Methods of diagnosis** are indicated and a selection of gene accession numbers is proposed. A non-exhaustive list of laboratories/contacts, expert for this type of parasite is proposed (the [number] refers to a list in page 9).

7. The principal **identified risks** are mentioned, focusing on those in relation with climate change and cross-sites trading.

8. **Some advices** are provided to avoid spreading the pathogens/diseases. However, no action is generally recommended in natural conservation areas.

9. Non-exhaustive **scientific references**.

Which taxa?

OTHER DISEASES
- Disseminated neoplasia (p. 106)
- Granulomatosis (p. 108)
- Picornaviral-like disease (p. 110)

ARTHROPODA
COPEPODA
- *Herrmannella rostrata* (p. 96)
- *Mytilicola orientalis* (p. 98)

DECAPODA
- *Afropinnotheres monodi* (p. 100)
- *Pinnotheres pisum* (p. 102)

BACTERIA
- *Endozoicomonas*-like (p. 12)
- *Vibrio aestuarianus* (p. 14)
- *Vibrio tapetis* (p. 16)

PLATYHELMINTHES
TREMATODA
- *Asymphilodora demeli* (p. 50)
- *Bucephalus minimus* (p. 52)
- *Curtuteria arguinae* (p. 54)
- *Diphterostomum brusinae* (p. 56)
- *Gymnophallus choledochus* (p. 58)
- *Gymnophallus somateriae* (p. 60)
- *Himasthla continua* (p. 62)
- *Himasthla elongata* (p. 64)
- *Himasthla interrupta* (p. 66)
- *Himasthla quissetensis* (p. 68)
- *Monorchis parvus* (p. 70)
- *Parvatrema fossarum* (p.72)
- *Parvatrema minutum* (p. 74)
- *Psilostomum brevicolle* (p. 76)
- *Renicola roscovitus* (p. 78)
- Unknown metacercaria (p. 80)

CESTODA
TRYPANORHYNCHA (p. 82)

TURBELLARIA
- *Paravortex cardii* (p. 84)

NEMATODA (p. 87)

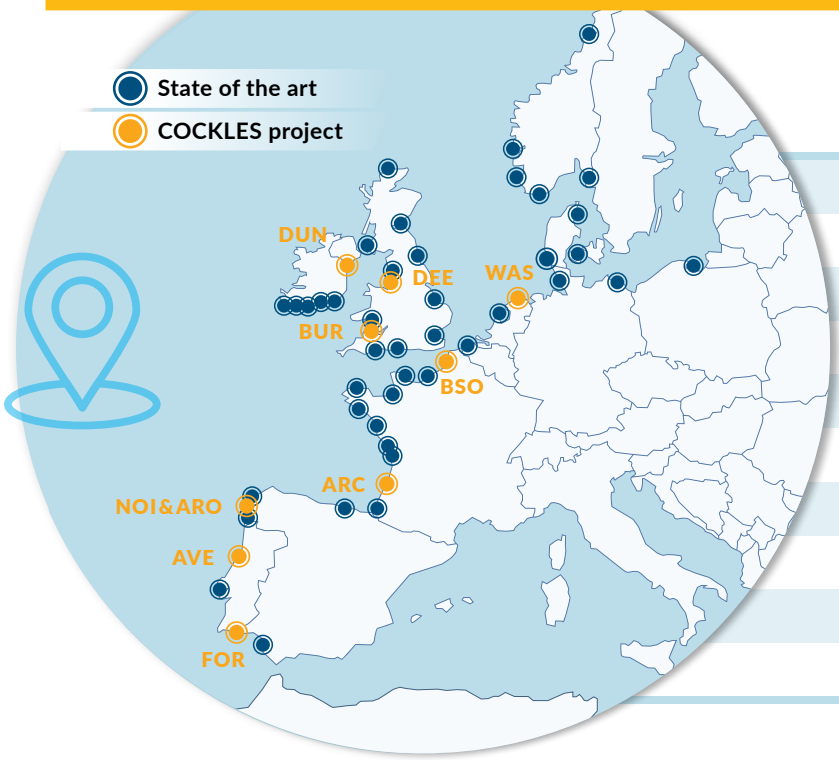
NEMERTEA
- *Malacobdella grossa* (p. 92)

FUNGI
MICROSPORIDIA
- *Hyperspora aquatica* (p. 20)
- *Steinhausia*-like (p. 22)
- *Unikaryon legeri* (p. 24)

CHROMISTA
ALVEOLATA
- *Eucoccidiorida* (p. 28)
- *Nematopsis* sp. (p. 30)
- *Perkinsus* spp. (p. 32)
- *Rynchodida*-like (p. 34)
- *Trichodina* spp. (p. 34)

RHIZARIA
- *Haplosporidium edule* (p. 36)
- *Minchinia mercenariae* (p. 38)
- *Minchinia tapetis* (p. 40)
- *Urosporidium* sp. (p. 42)
- *Marteilia cochillia* (p. 44)

Where are the parasites?



ARC	Arcachon Bay
ARO	Ria of Arousa
AVE	Ria of Aveiro
BSO	Bay of Somme
BUR	Burry Inlet
DEE	The Dee
DUN	Dundalk Bay
FOR	Ria Formosa
NOI	Ria of Noia
WAS	Texel (Wadden Sea)

Where is the expertise?

Expert laboratories within **COCKLES project** and **COCKLES collaborators**.

Numbers correspond to the partner registration numbers in the COCKLES Consortium and serve as identifiers in the expertise section of each parasite page.

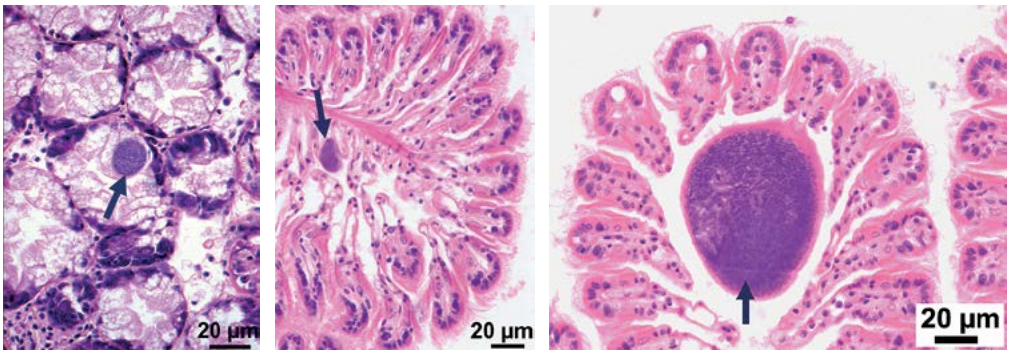
[2] **CIMA-XUGA** (Contact: antonio.villalba.garcia@xunta.gal)
[4] **University of Bordeaux** (Contact: xavier.de-montaudouin@u-bordeaux.fr)
[5] **University College Cork** (Contact: s.culloty@ucc.ie)
[6] **Bangor University** (Contact: s.malham@bangor.ac.uk)
[10] **IPMA** (Contact: fruano@ipma.pt)
[11] **University of Aveiro** (Contact: rosafreitas@ua.pt)
[15] **Ifremer La Tremblade** (Contact: isabelle.arzul@ifremer.fr)
[17] **CNRS Arcachon** (Contact: patrice.gonzalez@u-bordeaux.fr)
[20] **INTECMAR** (Contact: sdarriba@intecmar.gal)

Extra-project collaborators:

[A] **NIOZ-Texel** (Contact: david.thieltges@nioz.nl)
[B] **ICMAN-CSIC** (Contact: jose.cuesta@icman.csic.es)
[C] **Wageningen Bioveterinary Research** (Contact: marc.engelsma@wur.nl)
[D] **USC** (Contact: seiladiazcostas@gmail.com)
[E] **Arrhus University** (Contact: kthomas@bios.au.dk)

BACTERIA

LATIN NAME ***Endozoicomonas*-like organisms**
SYNONYMS None
COMMON NAME Bacterial microcolonies
CLASSIFICATION Bacteria – Hahellaceae



General Description

Bacterial microcolonies have been reported in numerous marine mollusc species. They were usually referred as Rickettsia-like organisms (RLO) but molecular phylogenetic analyses demonstrate they belong to widely diverse bacterial groups. In *Cerastoderma edule*, basophilic bacterial microcolonies occur mostly in the epithelia of the digestive diverticula and the gills and, occasionally, in the connective tissue of the mantle and labial palps. The colonies are usually intracellular although, in the gills, mantle and labial palps, they can evolve to large extracellular cysts surrounded by a fibrous cover that, eventually, can break, thus shedding bacteria. Recent molecular phylogenetic analysis showed that the bacterial microcolonies of cockles correspond to *endozoicomonas*-like organisms.

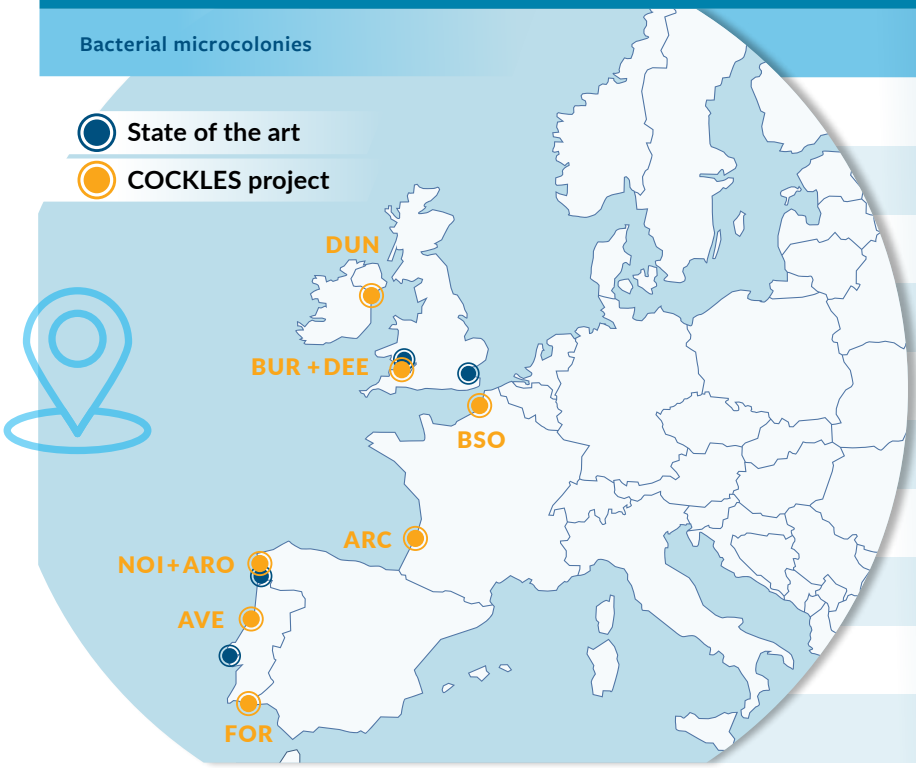
Individual Pathogenicity

Detrimental effects due to bacterial microcolonies have not been reported in cockles but heavy infections with bacterial microcolonies have been associated with poor condition and even being lethal in other bivalve species.

Populational Pathogenicity

There are no reports of cockle mortality events or population decline associated with bacterial microcolonies.

Distribution Map in the Atlantic Area (signalisation)



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	22	-
ARO	23	-
AVE	12	-
BSO	16	-
BUR	19	-
DEE	22	-
DUN	2	-
FOR	19	-
NOI	32	-
WAS	0	-

Diagnosis Techniques

- **Histology**: Basophilic bacterial microcolonies with variable shape and size are observed within epithelial cells of digestive diverticula or in gills. Large extracellular colonies surrounded by a fibrous cover can be observed in the gills and, rarely, in the connective tissue of mantle and labial palps.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown but no risk for human consumption.
- **Global change:** Unknown.

Advices

Cockles from areas known to be infected should not be transferred to areas with no record of bacterial microlononies. No action in nature conservation areas.

Relevant References

Azevedo 1993; Carballal et al. 2001; Elliot et al. 2012; Longshaw & Malham 2013; Cano et al. 2020.

LATIN NAME ***Vibrio aestuarianus*** Tison & Seidler, 1983
subsp *cardii* Garcia et al. 2021

SYNONYMS None

COMMON NAME None

CLASSIFICATION Bacteria – Vibrionaceae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=570741)

General Description

Vibrio aestuarianus cardii was associated with cockle mortality in different wild beds in France. The mortality occurred during summer and mortality events lasted from 1 to 2 months. Individuals showed no specific macroscopic signs. Moribund animals were animals lying at the surface of the sediment and characterized by a very slow closing of their valves and a limited quantity of intrapallial fluid.

Individual Pathogenicity

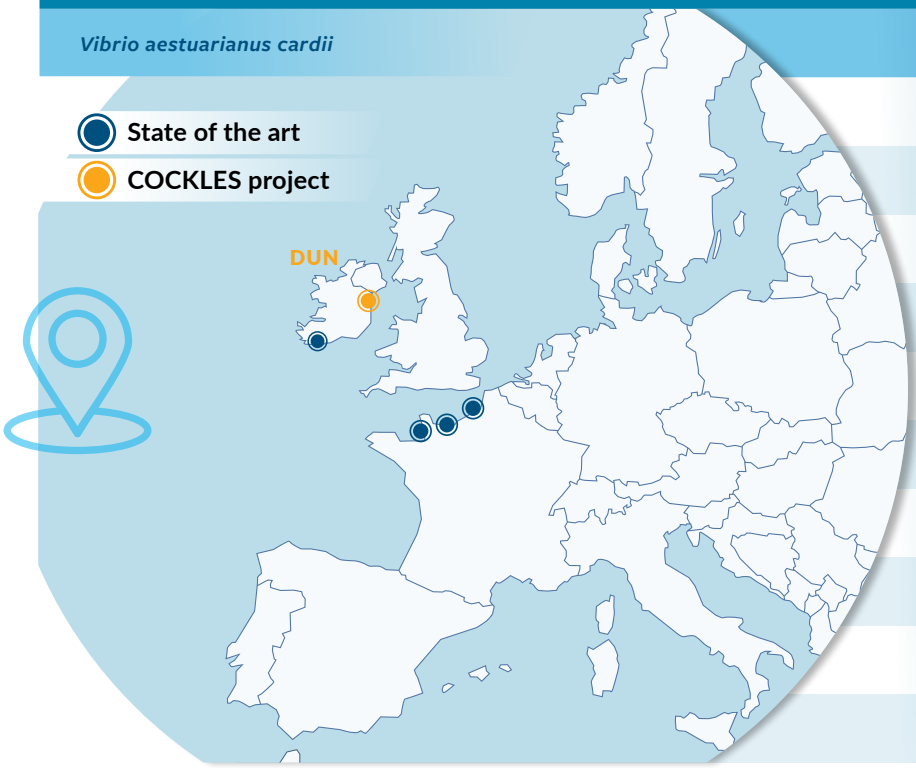
Bacteria invade the digestive tract and induce a destruction of digestive epithelia. Mortality of cockles experimentally challenged with bacteria.

Populational Pathogenicity

Prevalence is unknown but episodic high infection outbreaks has been reported with high mortality.

Distribution Map in the Atlantic Area (signalisation)

Vibrio aestuarianus cardii



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)*

SITE	%	Ab
ARC	0	–
ARO	–	–
AVE	–	–
BSO	0	–
BUR	–	–
DEE	–	–
DUN	3	–
FOR	–	–
NOI	–	–
WAS	–	–

*Only analyzed in ARC, BSO and DUN.

Diagnosis Techniques

- **Bacteriology:** Isolation of bacteria on marine agar medium after 48h at 20°C.
  Bacterial colonies appear small (1-2 mm), translucent, regular, white to cream-colored on marine agar.
- **Histology:** Bacteria can be observed in the digestive tract in association with epithelium necrosis.
- **Molecular identification:** Real time PCR specific to *V. aestuarianus* species.
  This real time PCR does not permit to distinguish the different subspecies of *V. aestuarianus*.
- **Sequencing:** 16S gene (type strain reference: MK307684), ldh gene (type strain reference: MK315026), gyrB gene (type strain reference: MK315009).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [10], [15].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence outbreak is possible and has already been observed.
- **Related to trading:** No risk for human consumption. Cockles from areas known to be infected should not be transferred to areas with no record of *Vibrio aestuarianus cardii*.
- **Global change:** Temperature, salinity, host dispersion. In owwysters, *V. aestuarianus* infection dynamics are modulated by temperature i.e. the warmer the water the faster the development of infection.

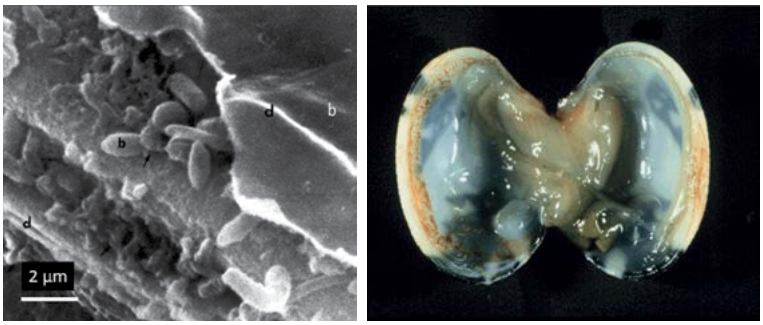
Relevant References

Saulnier et al. 2009, 2017; Garcia et al. 2021.

Advices

Cockles from areas known to be infected should not be transferred to areas with no record of *Vibrio aestuarianus cardii*. Eradicate moribund cockles at the surface of the sediment in production area. No action in nature conservation areas.

LATIN NAME ***Vibrio tapetis*** Borrego et al., 1996 **subsp *tapetis***
SYNONYMS *Vibrio* P1 group
COMMON NAME Brown ring disease
CLASSIFICATION Bacteria – Vibrionaceae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=570804)



Vibrio tapetis (b) in the Manila clam *Ruditapes philippinarum* (SEM) and macroscopc view of BRD with brown deposits in the inner side of the valve (courtesy C. Paillard & P. Maes).

General Description

Vibrio tapetis was isolated from cockle in different locations in France without mortality association. In some cases, cockles could exhibit signs of Brown Ring Disease (BRD), typical brown deposits on the inner side of the valves. Cockle could act as a carrying species of this bacterium. Experimentally, strong mortality of cockles challenged with *V. tapetis* has been observed between 7 and 14 days after inoculation.

Individual Pathogenicity

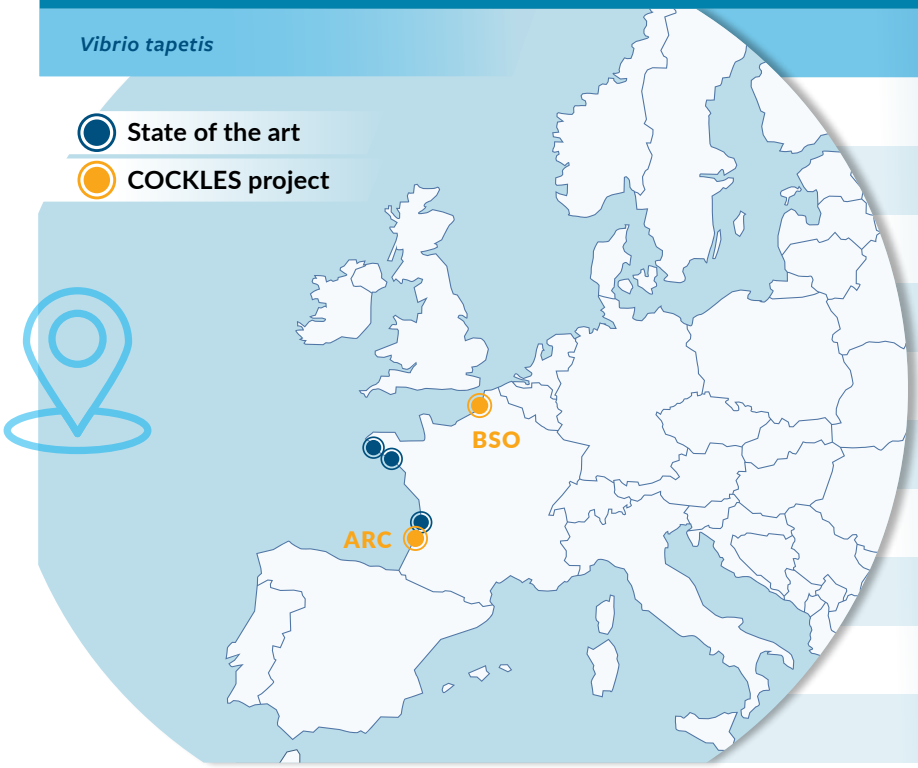
In the field, no reported effect. Experimentally, observation of mortality.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Vibrio tapetis



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)*

SITE	%	Ab
ARC	0	–
ARO	–	–
AVE	–	–
BSO	0	–
BUR	–	–
DEE	–	–
DUN	–	–
FOR	–	–
NOI	–	–
WAS	–	–

*Only analyzed in ARC and BSO.

Diagnosis Techniques

- **Gross observation:** Conchyolin deposits and malformations on the inner shell surfaces.
- **Bacteriology:** Isolation of bacteria on differential media including marine agar medium after 48 h at 20°C. Bacteria colonies appear circular, regular in shape, translucent, and unpigmented.
- **Molecular identification: 1)** Conventional PCR, and **2)** real time PCR but only detect virulent strains of *V. tapetis*.
- **Sequencing of different genes as:** 16S gene (IS9 strain: HE795138), atpA gene (IS9 strain: HE795168), ropA gene (IS9 strain: HE795349), gapA gene (IS9 strain: HE795378), fstZ gene (IS9 strain: HE795312), recA gene (IS9 strain: HE795228), rpoD gene (IS9 strain: HE795288).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [10], [15].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown but no risk for human consumption.
- **Global change:** Unknown but in Manila clams *Ruditapes philippinarum*, temperatures that are > 21 °C have been observed to inhibit BRD whereas low salinity (2) favors it.

Advices

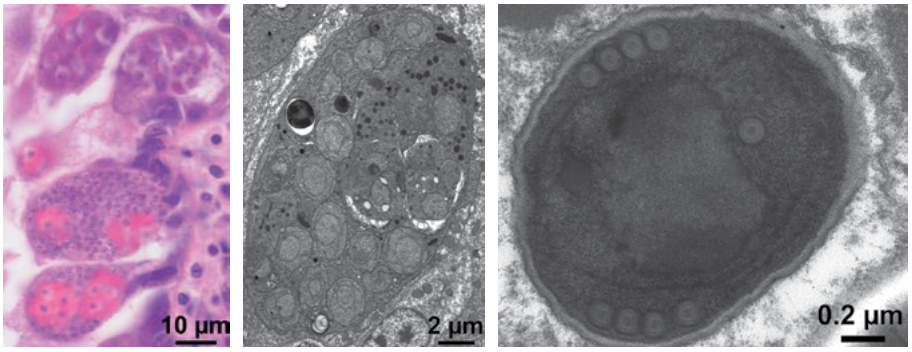
Cockles from areas known to be infected should not be transferred to areas with no record of *Vibrio tapetis*. No action in nature conservation areas.

Relevant References

Maes and Paillard 1992; Borrego et al. 1996; Paillard et al 2006; Park et al 2006; Lassalle et al. 2007; Paul-Pont et al. 2010; Bidault et al. 2015; Rodrigues et al. 2015.

FUNGI

LATIN NAME ***Hyperspora aquatica*** Stentiford et al., 2017
SYNONYMS None
COMMON NAME None
CLASSIFICATION Fungi – Microsporidia



General Description

Hyperspora aquatica is a hyperparasite of the paramyxid *Marteilia cochillia*; the latter infects the cockle digestive gland. Spores are spherical to ellipsoid, ca. 1.2 x 1.0 µm, with 4 polar filament coils in a single rank. Merogonic and sporogonic stages occur in the cytoplasm of primary cells of *M. cochillia*. Known life cycle progresses from uninucleate meronts to multi-nucleate meronts prior to initiation of sporogony. Sporogony involves thickening of the cell wall, budding of sporonts and eventual development of the spore extrusion precursors in uninucleate sporoblasts, which mature to spores.

Individual Pathogenicity

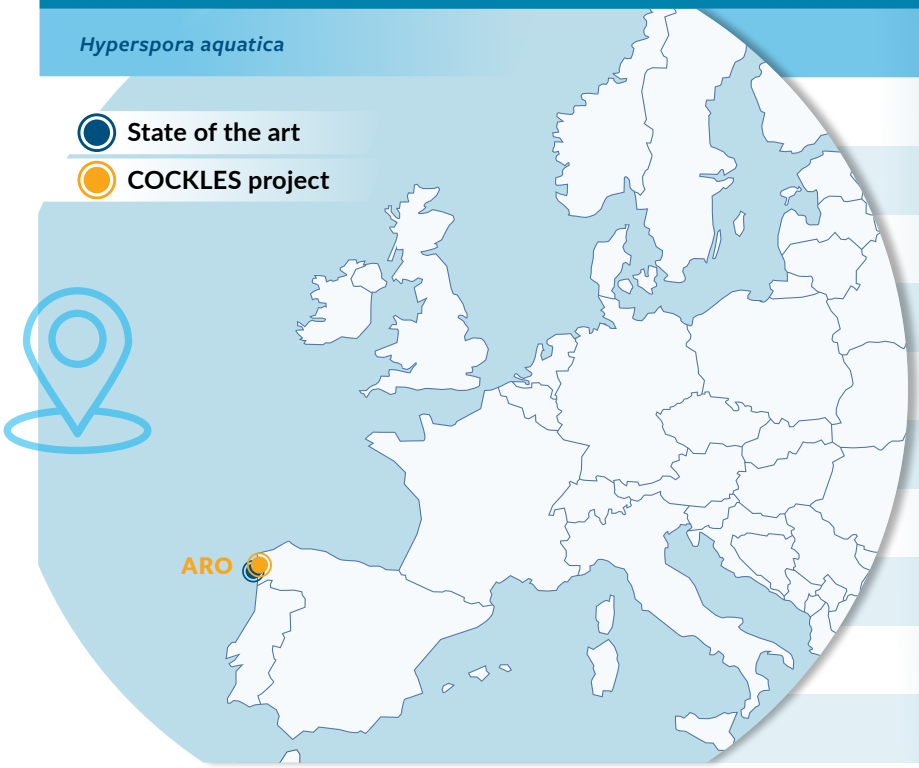
Hyperspora aquatica causes damage to its host *Marteilia cochillia*; the latter is a highly pathogenic cockle parasite, thus *H. aquatica* could benefit cockle although it has not been appropriately evaluated.

Populational Pathogenicity

None.

Distribution Map in the Atlantic Area (signalisation)

Hyperspora aquatica



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	46	–
AVE	–	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	–	–
NOI	0	–
WAS	0	–

Diagnosis Techniques

- **Histology:** Hyperparasite stages are observed in the cytoplasm of the primary cells of *Marteilia cochillia* infecting the cockle digestive gland.
- **Genes Accession number:** KX364284.1 (SSU rDNA).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** None.
- **Related to trading:** None.
- **Global change:** Unknown.

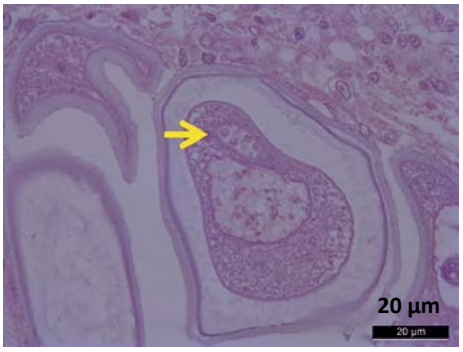
Advices

None

Relevant References

Villalba et al. 2014; Stentiford et al. 2017.

LATIN NAME	***Steinhausia*-like parasite** Sprague et al., 1972
SYNONYMS	None
COMMON NAME	Cockle egg disease, Microsporidiosis
CLASSIFICATION	Fungi – Microsporidia (WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=559168)



General Description

All infections occur in the ovocytes of cockles. The parasite mature spores or the precursor stages (sporonts or sporoblasts) occur within a single large vacuole in the cytoplasm (rarely in the nucleus) of cockle ovocytes. Occasionally, more than one vacuole enclosing parasites occur per ovocyte. The intensity of infection is low with no haemocyte infiltration and no pathological damage to the host. However, the viability of infected ova may be affected, thus influencing fecundity.

Individual Pathogenicity

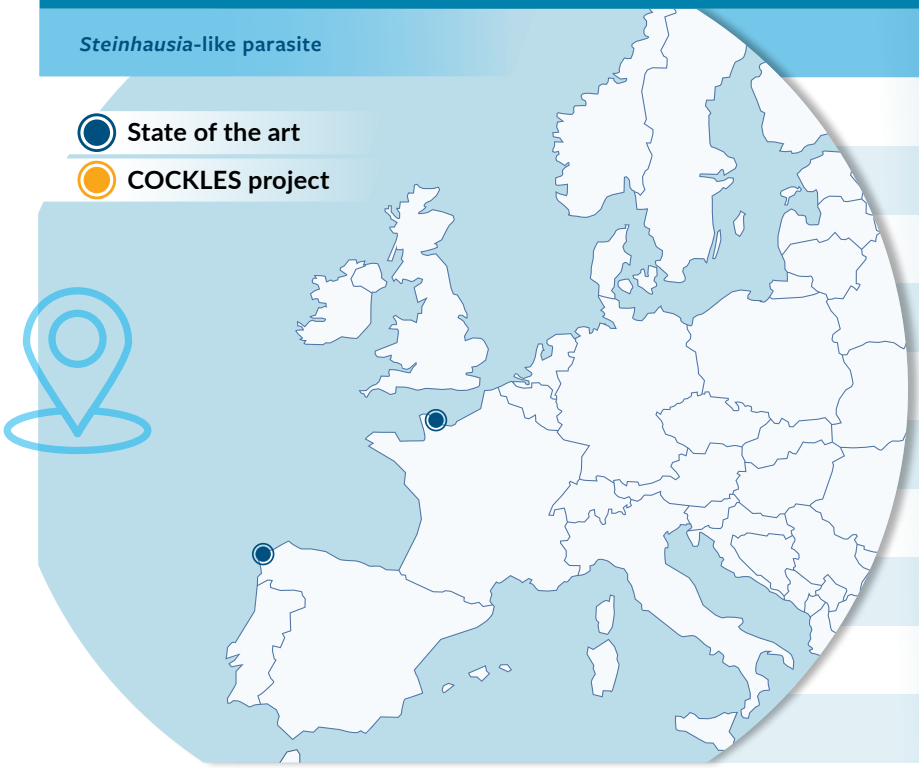
Infected ovocytes could be unviable but, if so, the low infection intensity would involve negligible effects in female fecundity.

Populational Pathogenicity

When reported, the prevalence was always low, thus detrimental population effects would not be expected.

Distribution Map in the Atlantic Area (signalisation)

Steinhausia-like parasite



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	0	–
AVE	0	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	0	–
NOI	0	–
WAS	0	–

Diagnosis Techniques

- **Squash preparations:** Microscopically evident within the ovocytes in wet mount preparations of gonadal tissue pressed between a glass slide and coverslip.
- **Histology:** Observation of parasite stages (most frequently spores) inside ovocytes. Vacuoles containing the spores are usually elliptical to circular in shape, with a mean size of 20 µm, containing up to 30 spherical spores 2.5-3 µm in diameter. Typically there is a single vacuole with parasites per ovocyte, however, two vacuoles have been observed in an ovocyte.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown but no risk for human consumption.
- **Global change:** Unknown.

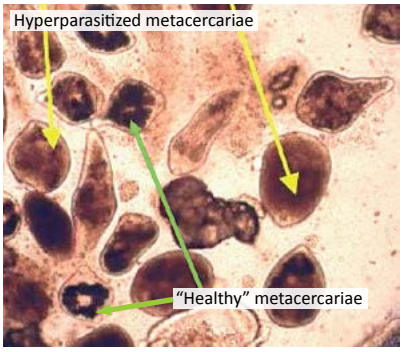
Advices

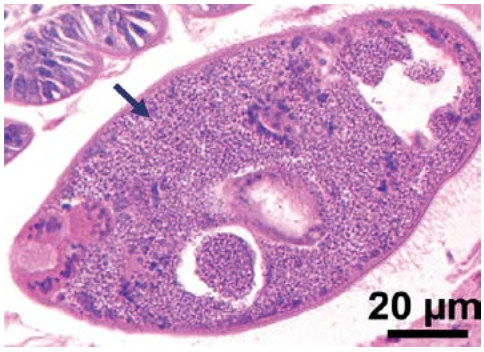
Cockles from areas known to be infected should not be transferred to areas with no record of *Steinhausia*-like parasites. No action in nature conservation areas.

Relevant References

Carballal et al. 2001; Comtet et al. 2003.

LATIN NAME ***Unikaryon legeri*** (Dollfus, 1912)
SYNONYMS *Nosema legeri*
COMMON NAME None
CLASSIFICATION Fungi – Microsporidia
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=565110)





General Description

Unikaryon legeri is a hyperparasite of the metacercariae of *Parvatrema minutum*, which infect the cockle mantle. Spores are ellipsoid, ca. 3.0 x 1.8 µm with 6-6.5 polar filament coils in a single rank. Merogonic and sporogonic stages occur in the metacercarial parenchyma. Merogonic stages include uninucleate and binucleated dividing meronts. Uninucleate sporonts become binucleate and divide giving rise to two uninucleate sporoblasts, which mature to spores.

Individual Pathogenicity

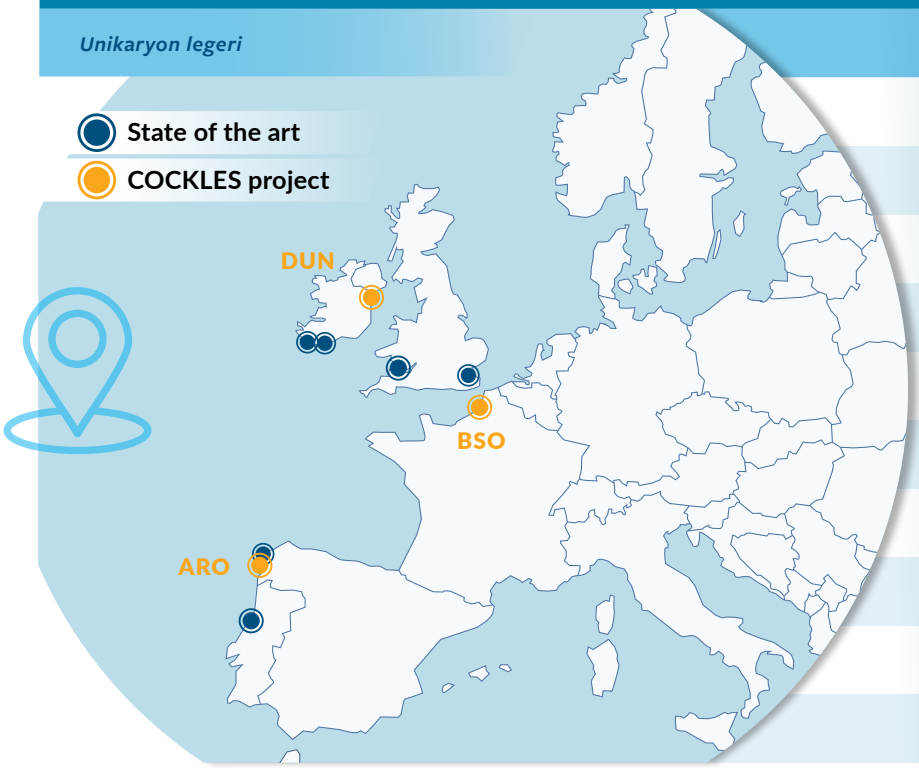
Unikaryon legeri may cause damage to or even kill its host *Parvatrema minutum*; the latter is a cockle parasite causing moderate harm to cockle, thus *U. legeri* could benefit cockle although it has not been appropriately evaluated.

Populational Pathogenicity

None.

Distribution Map in the Atlantic Area (signalisation)

Unikaryon legeri



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	% *	Ab
ARC	0	–
ARO	68	–
AVE	0	–
BSO	10	–
BUR	0	–
DEE	0	–
DUN	33	–
FOR	0	–
NOI	0	–
WAS	0	–

*Estimated by dissection, under stereomicroscope.

Diagnosis Techniques

- **Histology:** Hyperparasite stages are observed in the parenchyma of metacercariae of *Parvatrema minutum* infecting the cockle mantle.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Stages of the hyperparasite are observed within metacercariae of *P. minutum* infecting the cockle mantle.
- **Genes accession number:** KX364285.1 (SSU rDNA).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [4], [5], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** None.
- **Related to trading:** None.
- **Global change:** Unknown.

Advices

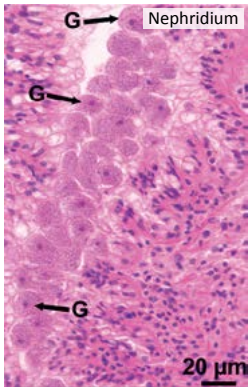
Not needed.

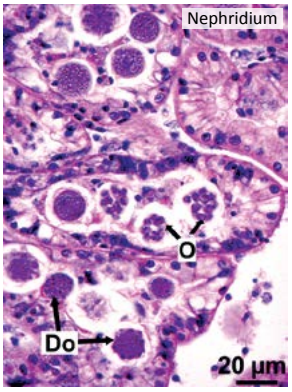
Relevant References

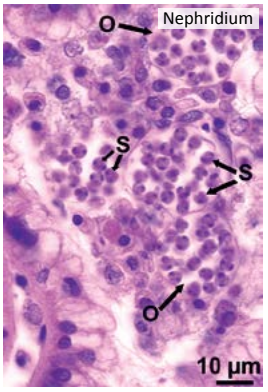
Canning and Nicholas 1974; Lauckner 1983; Russell-Pinto 1990; Fermer et al. 2011; Stentiford et al. 2017.

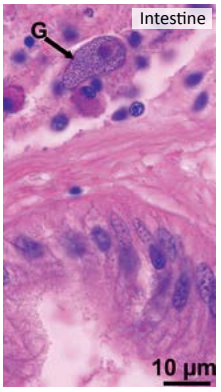
PROTOZOA

LATIN NAME None
SYNONYMS None
COMMON NAME None
CLASSIFICATION Alveolata – Eucoccidiorida









General Description

An undetermined coccidian parasite, sometimes reported as *Pseudoklossia* sp., is occasionally observed in the nephridium of the cockles. Gamonts (G) and developing (Do) and mature oocysts (O), the latter enclosing multiple sporocysts (S), occur associated with nephridial epithelium or in the lumen. Apicomplexan gamonts are occasionally observed in the intestinal epithelia or in the subjacent connective tissue, with very light intensity; whether this apicomplexan parasite of the intestine is the same as or a different species from the nephridial coccidium is not known. Light to moderate haemocytic infiltration is seldom observed in the nephridial infections.

Individual Pathogenicity

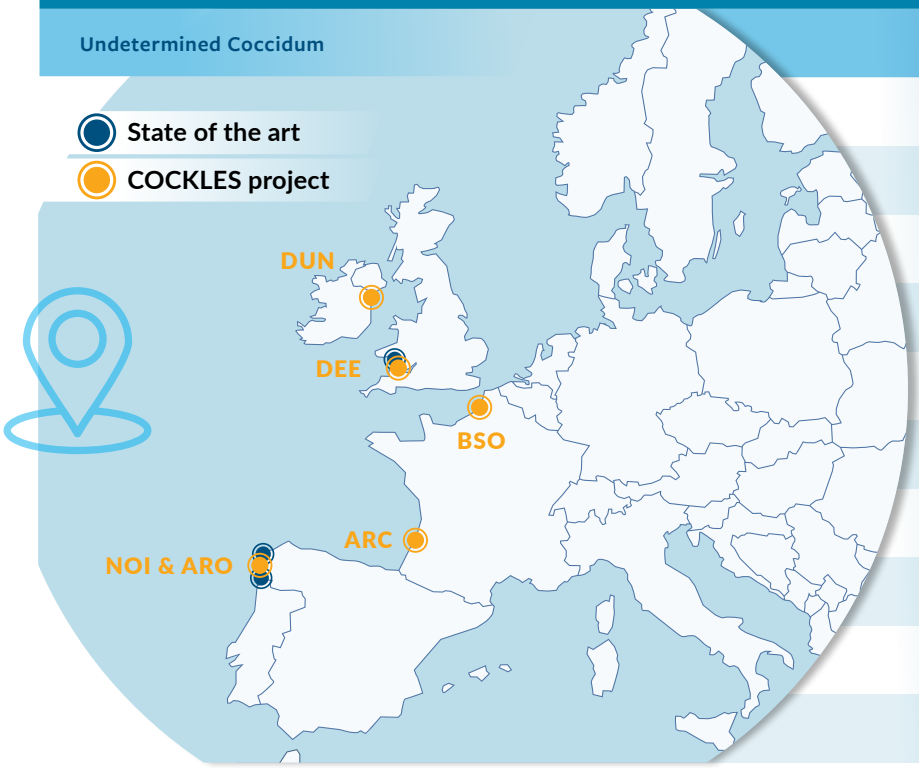
No obvious damage. Inflammatory reaction is rare but a combination of high intensity and haemocytic reaction could involve some nephridial dysfunction.

Populational Pathogenicity

Coccidian infections do not threat cockle populations although high prevalence (up to 33%) has been reported.

Distribution Map in the Atlantic Area (signalisation)

Undetermined Coccidum



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	7	–
ARO	7	–
AVE	0	–
BSO	4	–
BUR	0	–
DEE	2	–
DUN	2	–
FOR	0	–
NOI	14	–
WAS	0	–

Diagnosis Techniques

- **Histology:** Gamonts and developing and mature oocysts, the latter enclosing multiple sporocysts, can be observed in the cockle nephridia. Coccidian gamonts are occasionally observed in the intestinal epithelia or in the subjacent connective tissue.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** No Risk.
- **Related to trading:** No risk because these parasites are widespread through AA.
- **Global change:** Unknown.

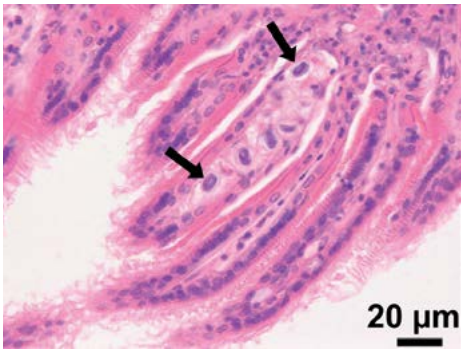
Advices

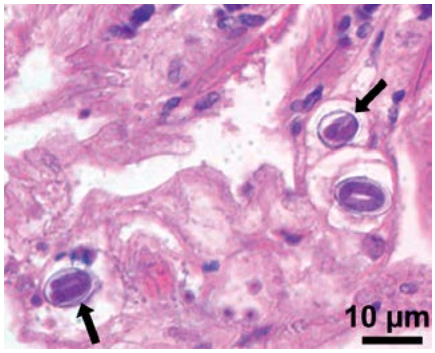
No action.

Relevant References

Carballal et al. 2001; Elliot et al. 2012; Longshaw & Malham 2013.

LATIN NAME ***Nematopsis* sp.** Schneider, 1892
SYNONYMS None
COMMON NAME None
CLASSIFICATION Alveolata – Eugregarinorida
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=390581)





General Description

Parasites of the genus *Nematopsis* have a complex life cycle involving a marine mollusc and a mollusc-predator crab. The parasite stage living in bivalves (including cockles) is the oocyst, which occurs within host haemocytes, while the other parasitic stages occur in the crabs. In cockles, haemocytes enclosing one to four (usually two) *Nematopsis* oocysts may be observed in the connective tissue of almost every organ. The prevalence usually is very high, frequently 100%. Oocysts are ellipsoid, 8-13 µm in length, consisting of a thick wall enclosing a single uninucleate basophilic sporozoite. Usually, the oocysts do not cause host damage and inflammatory reaction is rare. When intensity is high, more frequently in the gills, some dysfunction could occur.

Individual Pathogenicity

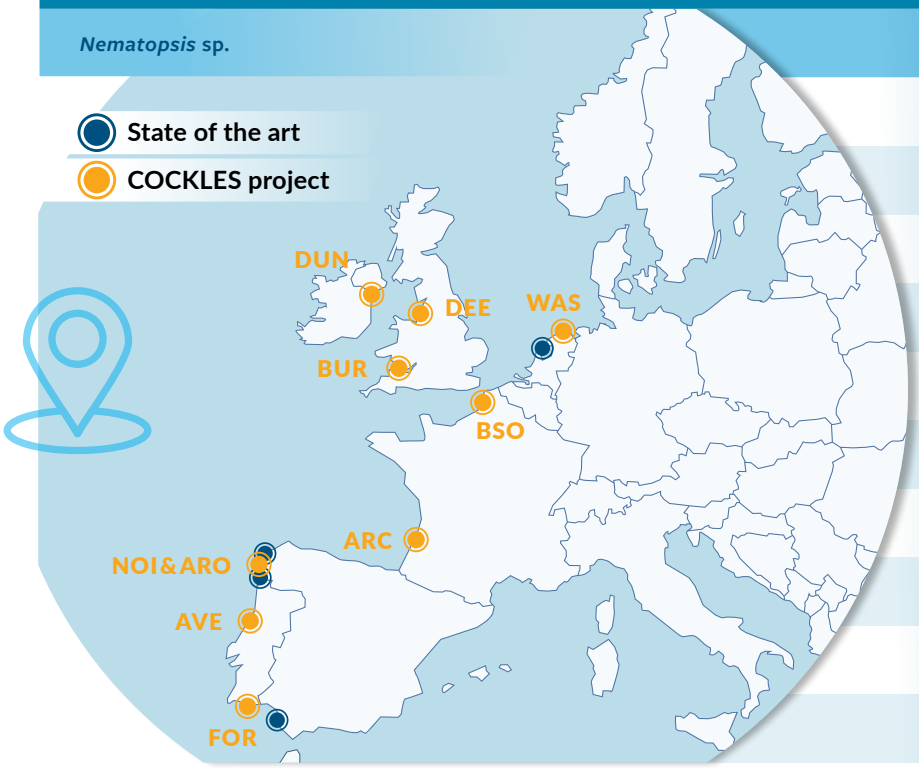
No obvious damage. Inflammatory reaction is rare but a combination of high intensity and haemocytic reaction could involve some cockle dysfunction.

Populational Pathogenicity

Parasites of this genus do not threat cockle populations even though prevalence usually is very high, because the individual pathogenicity is mostly negligible.

Distribution Map in the Atlantic Area (signalisation)

Nematopsis sp.



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	75	-
ARO	100	-
AVE	22	-
BSO	92	-
BUR	67	-
DEE	56	-
DUN	71	-
FOR	4	-
NOI	100	-
WAS	88	-

Diagnosis Techniques

- **Histology:** Oocysts with a thick cover enclosing a basophilic sporozoite can be observed within cockle haemocytes in the connective tissue of multiple organs.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** These parasites involve no risk.
- **Related to Trading:** No risk because these parasites are widespread through AA.
- **Global change:** Unknown.

Advices

No action.

Relevant References

Azevedo & Cachola 1992; Carballal et al. 2001; Elliot et al. 2012; Longshaw & Malham 2013.

LATIN NAME ***Perkinsus chesapeaki*** McLaughlin et al., 2000; ***Perkinsus olseni*** Lester and David, 1981; ***Perkinsus* sp.**

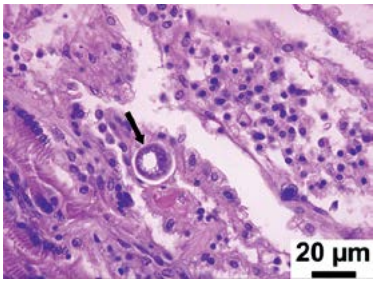
SYNONYMS *Perkinsus atlanticus* (for *P. olseni*)

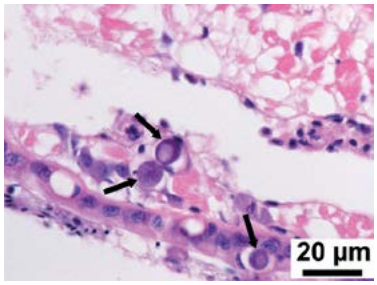
COMMON NAME None

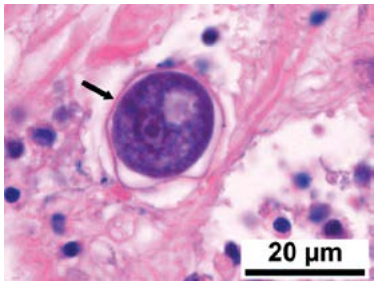
CLASSIFICATION Alveolata – Perkinsea

(WoRMS links: http://www.marinespecies.org/aphia.php?p=taxdetails&id=883642 http://www.marinespecies.org/aphia.php?p=taxdetails&id=625984)

WoRMS has recently proposed *Perkinsus olsenii* as the valid species name instead of *P. olseni*







General Description

Parasites of the genus *Perkinsus*, including *P. chesapeaki* and *P. olseni*, have a wide host range among molluscs. In histological sections of *Cerastoderma edule*, trophozoites (10-20 µm) of *P. olseni* (micrographs) are observed mainly in the connective tissue of the labial palps and less frequently in gills, mantle and visceral mass; frequently an obvious wall surrounding the trophozoite is visible (micrograph on the right). Prevalence estimated by the Ray's Fluid Thioglycollate Medium procedure may be high but the infection intensity is so low that many cases are not detected with histology. Infection with *P. chesapeaki* has been reported in cockles *C. edule* from Catalonia (NE Spain, Mediterranean Sea).

Individual Pathogenicity

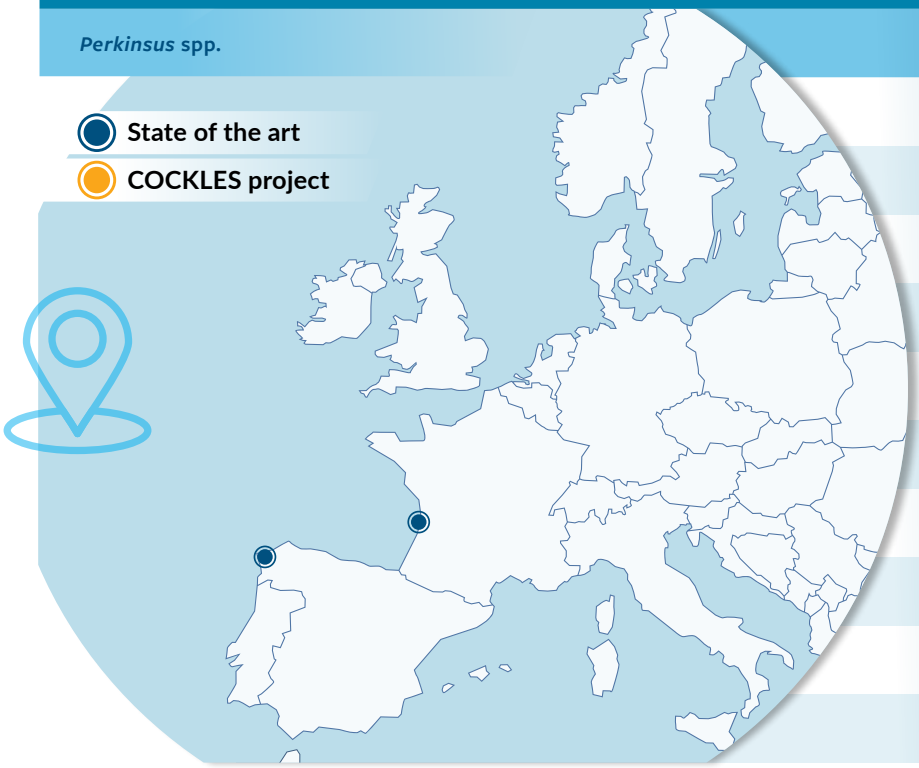
The infection intensity of *Perkinsus* spp. in *Cerastoderma edule* is usually low; serious effects on cockles have not been reported.

Populational Pathogenicity

The intensity of the infection with *Perkinsus* spp. is usually low in *Cerastoderma edule*; no populational effect has been reported.

Distribution Map in the Atlantic Area (signalisation)

Perkinsus spp.



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	-
ARO	0	-
AVE	0	-
BSO	0	-
BUR	0	-
DEE	0	-
DUN	0	-
FOR	0	-
NOI	0	-
WAS	0	-

Diagnosis Techniques

- **Histology:** Different parasite stages including mature trophozoites (10-20 µm) are observed mainly in the connective tissue of the gills, mantle and visceral mass.
- Histology does not allow to conclude about the parasite species.
- **Culture:** Examination of tissues placed in Fluid Thioglycollate Medium (FTM) for 3 to 14 days at 25 °C allows observing and eventually quantifying *Perkinsus* parasites.
- In situ hybridization, PCR and sequencing (ITS region) are needed to conclude about the parasite species.
- In *C. edule*, the only *Perkinsus* sequence available so far is *P. chesapeaki* (Genbank accession number KF314812).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown but no risk for human consumption.
- **Global change:** Unknown, however, in grooved carpet shell clams *Ruditapes decussatus* prevalence and intensity of infection with *P. olseni* increased with increasing temperatures.

Advices

Cockles from areas known to be infected should not be transferred to areas with no record of *Perkinsus spp*. No action in nature conservation areas.

Relevant References

Villalba et al. 2005; Lassalle et al. 2007; Darriba et al. 2010; Longshaw & Malham 2013; Carrasco et al. 2014.

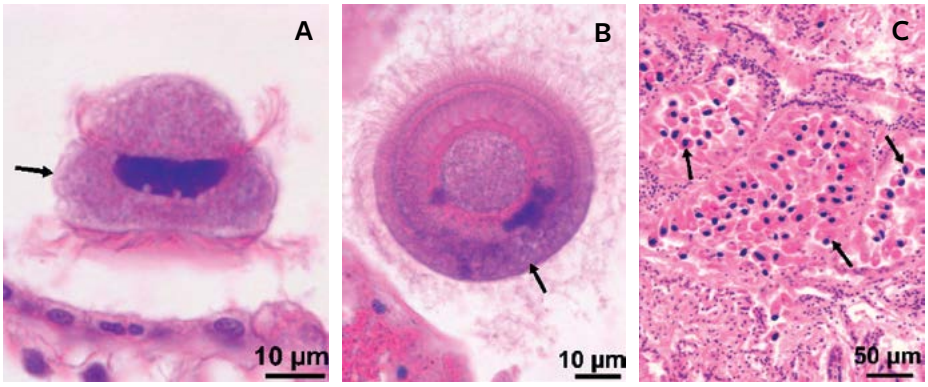
LATIN NAME ***Trichodina* spp., *Rynchodida*-like ciliates (*Hypocomella raabei=cardii; Hypocomidium fabius*, ...)**

SYNONYMS None

COMMON NAME Ciliates

CLASSIFICATION Alveolata – Cyliophora

(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=11)



Trichodina sp. (A&B); *Hypocomella*-like ciliates (C).

General Description

They generally occur as commensals on the gills and mantle surface of cockles with no obvious host-response. Although prevalence can reach 100% in some cockle populations, intensity of infection is usually low and most infections are innocuous. At Irish sites, prevalence was observed to be highest in cockles in summer and autumn.

Individual Pathogenicity

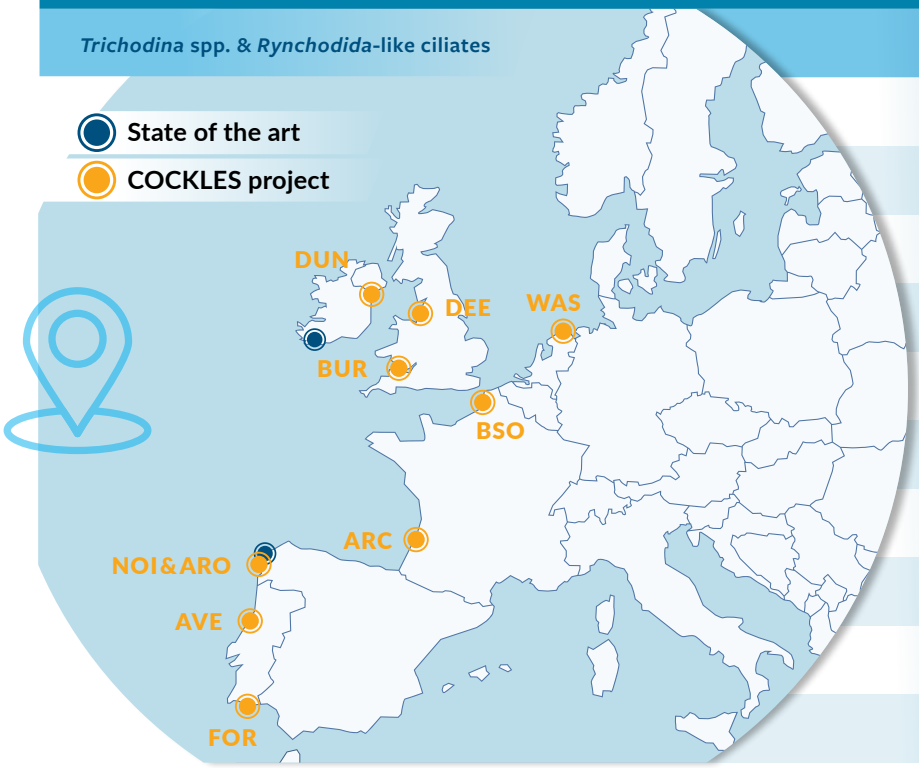
Occasionally, abundance of *Hypocomella*-like ciliates is so high that the branchial water channels are obliterated, interfering with feeding and respiration. Heavy infection by *Trichodina* spp. in less than one year old *Cerastoderma edule* was associated with emaciation and mortalities in the German and Dutch Wadden Sea.

Populational Pathogenicity

Not documented, but considering prevalence and individual pathogenicity, a populational effect is plausible.

Distribution Map in the Atlantic Area (signalisation)

Trichodina spp. & *Rynchodida*-like ciliates



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)		
SITE	%	Ab
ARC	3	–
ARO	44	–
AVE	1	–
BSO	21	–
BUR	2	–
DEE	2	–
DUN	4	–
FOR	3	–
NOI	15	–
WAS	41	–

Diagnosis Techniques

- **Wet Mounts:** Ciliates can be observed in scrapings of the mantle or gills (x100).
- **Histology:** *Trichodina* appears as disc-shaped protozoa (37 to 45 µm in length) characterized by a circlet of eosinophilic denticles, ciliary fringes, and a horse-shoe shaped macronucleus. *Rynchodida*-like ciliates appear as pear-shaped ciliates (18 to 25 µm in length) often lacking cilia during life stage that is attached to host with large, densely basophilic nuclei. Attached to the gill and palp surfaces during parasitic stage of the life cycle.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [10], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk.
- **Related to trading:** No risk.
- **Global change:** Unknown.

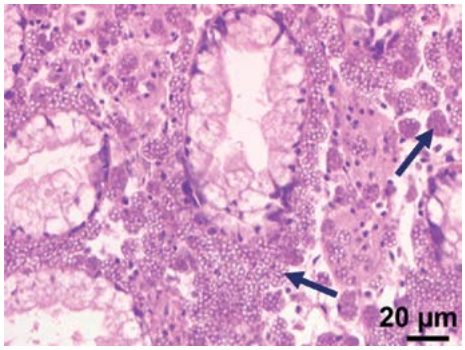
Advices

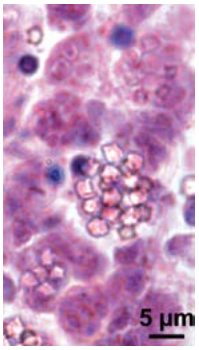
No specific recommendation.

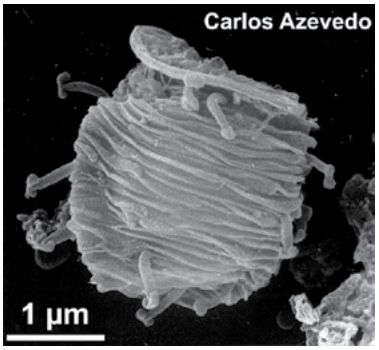
Relevant References

Lauckner 1983; Carballal et al. 2001; Longshaw & Malham 2013.

LATIN NAME ***Haplosporidium edule*** Azevedo et al., 2003
SYNONYMS None
COMMON NAME None
CLASSIFICATION Rhizaria – Haplosporida
(WORMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=395976)







General Description

Plasmodia, sporonts and sporocysts containing spores occur in the connective tissue of gills, gonad mantle and, predominantly, digestive gland. The sporogony is asynchronous. Spores are ca. 3.2 x 2.2 µm in size and show characteristic ornamentation consisting of slender wall projections with bifurcated tip. Infections induce an haemocytic response, which is heavier when the plasmodial stage is dominant. The lowest cockle length at which infection has been recorded is 13 mm.

Individual Pathogenicity

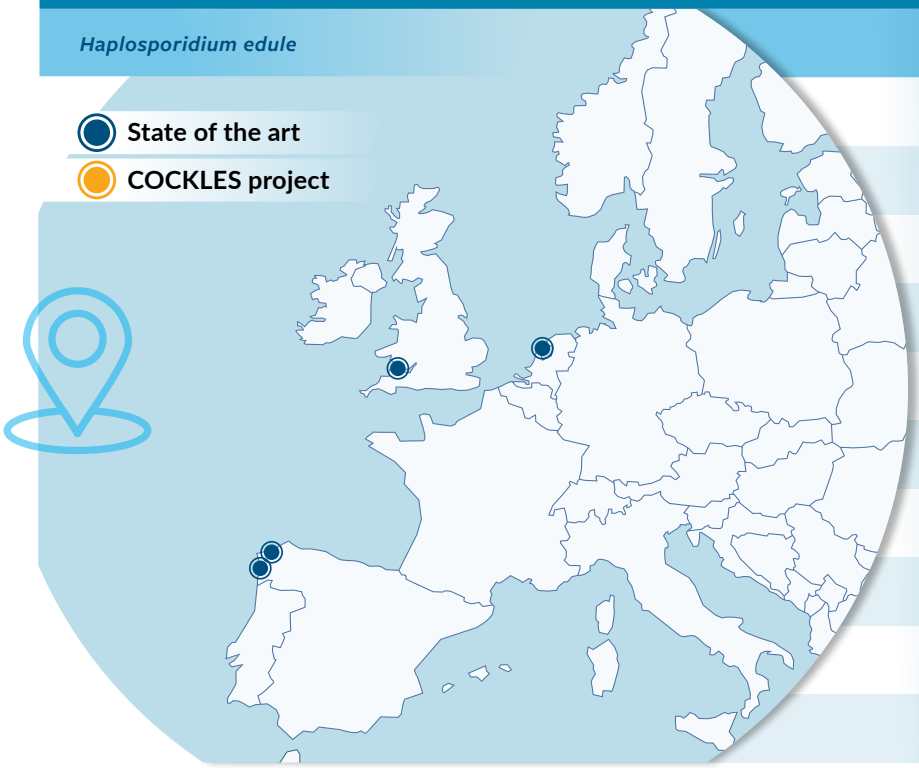
Haplosporidium edule can be lethal to cockles because, at advanced infection stage, the connective tissue of most organs of the host is heavily infiltrated by sporulation stages of the parasite and is destroyed, leading to general dysfunction.

Populational Pathogenicity

This parasite is not threatening cockle populations because its prevalence is very low. However, if the prevalence became higher for any reason, *H. edule* would be a real threat.

Distribution Map in the Atlantic Area (signalisation)

Haplosporidium edule



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	0	–
AVE	0	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	?*	–
NOI	0	–
WAS	0	–

*Undetermined haplosporidan at 1% prevalence.

Diagnosis Techniques

- **Histology:** Parasite stages are observed in histological sections of the gills, mantle and gonad, and predominantly in the digestive gland. Molecular tools should be used for species identification.
- **Scanning electron microscopy:** Spores show slender wall projections with bifurcated tip.
- **GenBank accession number:** DQ458793.1 (SSU rDNA).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [C], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Recorded prevalence has been always very low with no mortality outbreak.
- **Related to Trading:** It only has been recorded in Galicia (rias of Vigo, Arousa and O Barqueiro), the Netherlands (Oosterschelde) and Wales (Burry Inlet), thus movements could potentially contribute to spread it.
- **Global change:** Unknown.

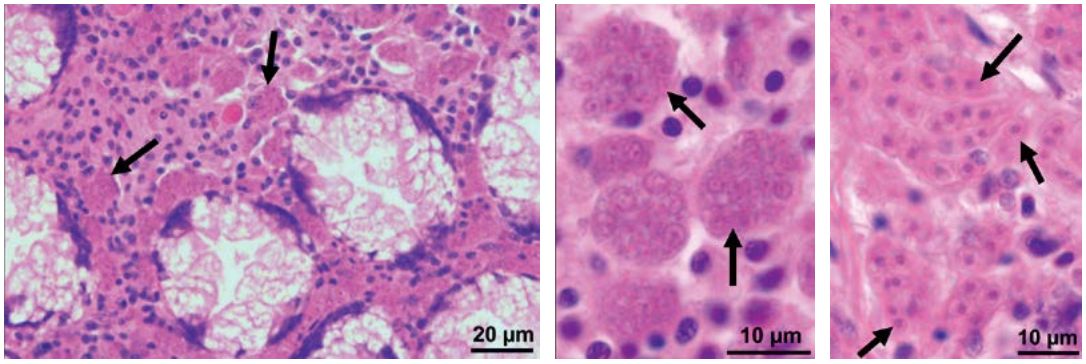
Advices

Considering its very low prevalence, no special advice for the areas with occurrence records.

Relevant References

Carballal et al. 2001; Azevedo et al. 2003; Engelsma et al. 2011; Elliot et al. 2012.

LATIN NAME ***Minchinia mercenariae*** Ford et al., 2009
SYNONYMS None
COMMON NAME None
CLASSIFICATION Rhizaria – Haplosporida
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=563582)



General Description

Uninucleate, binucleate cells and multinucleate plasmodia occur throughout the connective tissue of digestive gland, gills and gonad; the parasite has not been reported in epithelia. The multinucleate plasmodial stage is dominant and enclose 3 to 14 nuclei. Spores have been reported in cockles from various places in Ireland but they were never observed in Galicia (NW Spain). Species identification should be confirmed with molecular tools. In Ireland, the highest prevalence was observed in cockles in spring. The lowest cockle length at which infection has been recorded is 10 mm.

Individual Pathogenicity

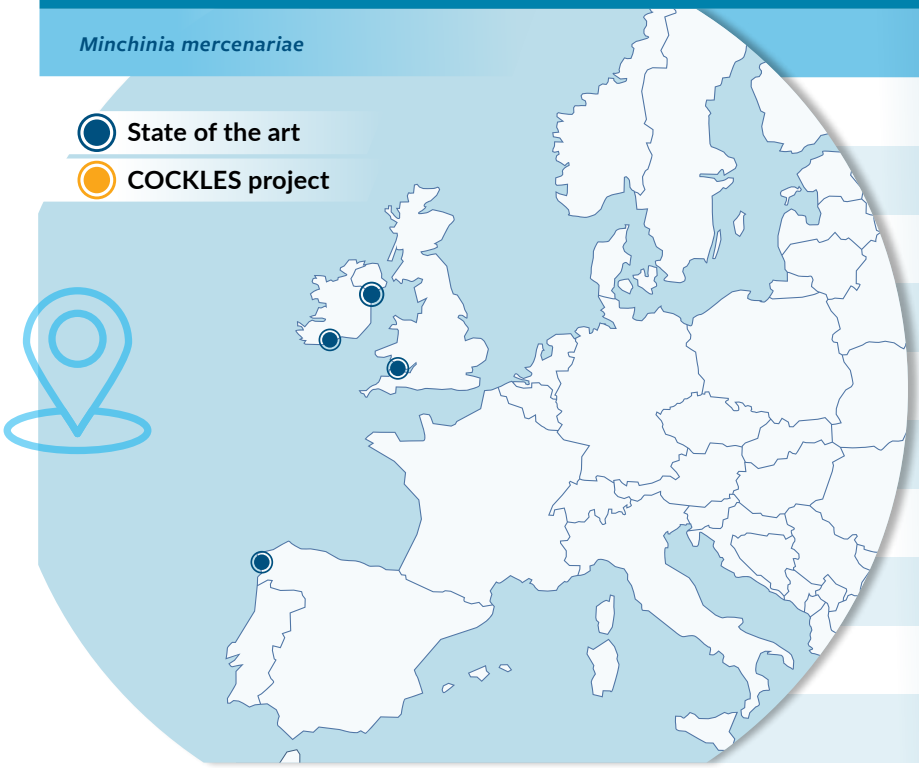
Infection intensity is moderate or heavy in most records. Cockles with abundant plasmodia show heavy inflammatory reaction, mainly in digestive area.
The lesions caused by heavy infections and the inflammatory reaction may lead to dysfunction and host weakness.

Populational Pathogenicity

The recorded prevalence has always been low. This parasite has never been associated with abnormal cockle mortality. Nevertheless, the characterisation of this parasite in cockles is recent, thus experience is reduced.

Distribution Map in the Atlantic Area (signalisation)

Minchinia mercenariae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	0	–
AVE	0	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	?*	–
NOI	0	–
WAS	0	–

*Undetermined haplosporidan at 1% prevalence.

Diagnosis Techniques

- **Histology:** The above described parasite stages are observed in histological sections of digestive gland, gills and gonad, but their morphology alone is not appropriate for species identification, for which sequencing molecular tools are required.
- **GenBank accession number:** KY522821.1 (SSU rDNA).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [C], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Prevalence may be high but infection intensity is usually light and no mortality outbreaks have been reported associated with this parasite.
- **Related to Trading:** Risk of transmission if cockles from affected areas are immersed into non-affected zones.
- **Global change:** Unknown.

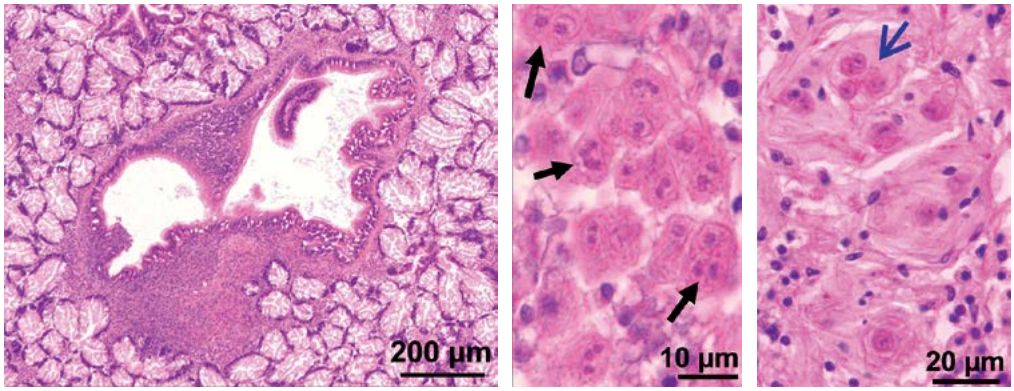
Advices

Considering its very low prevalence, no special advice for the areas with occurrence records.

Relevant References

Ford et al. 2009; Elliot et al. 2012; Ramilo et al. 2018; Albuixech-Martí et al. 2020; Lynch et al. 2020.

LATIN NAME ***Minchinia tapetis*** (Vilela, 1953)
SYNONYMS *Haplosporidium tapetis*
COMMON NAME None
CLASSIFICATION Rhizaria – Haplosporida



General Description

Uninucleate and binucleate cells and multinucleate plasmodia (3-6 nuclei) occur in the connective tissue of the digestive gland and rarely in digestive epithelia. The parasite stages appear in foci, mostly close to stomach branches or digestive primary ducts. Frequently, the parasites appear surrounded by fibrous material. Cockles show heavy haemocytic infiltration around parasite foci. Sporogonic stages have not been reported although spores are known to occur in the clam *Ruditapes decussatus*. Prevalence can reach up to 100%; it shows seasonal pattern of variation, higher in summer and lower in winter. The lowest cockle length at which infection has been recorded is 7 mm.

Individual Pathogenicity

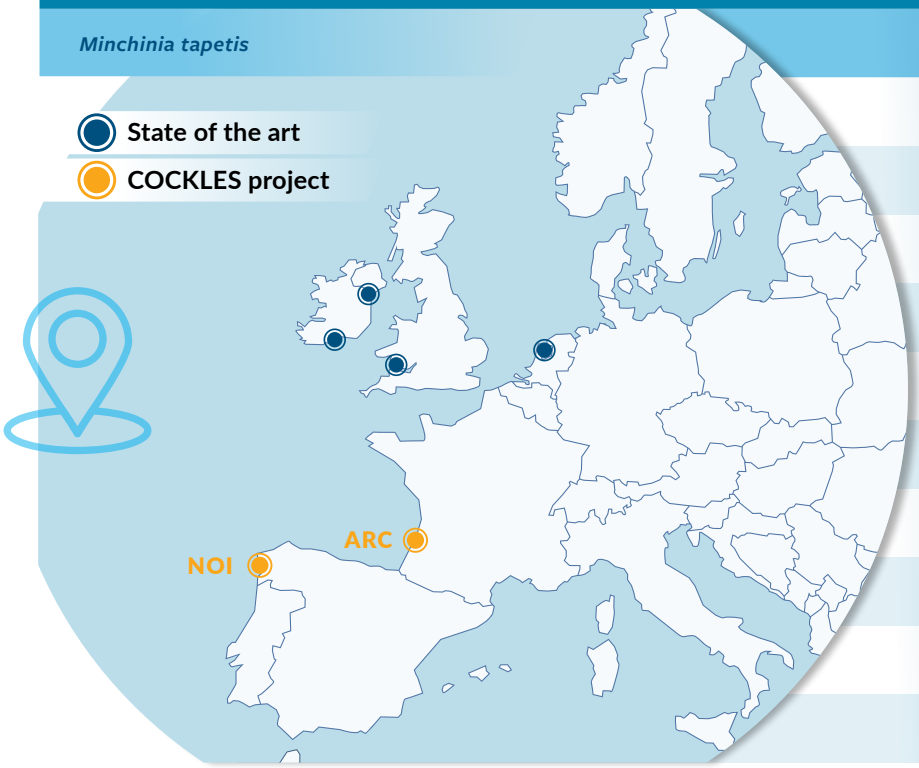
Reported infection intensity was mostly light, less frequently moderate and never heavy. The inflammatory reaction can cause some damage and host weakness.

Populational Pathogenicity

Prevalence has reached up to 100% but heavy infection intensity has never been recorded. This parasite has never been associated with abnormal cockle mortality. Nevertheless, the detection of this parasite in cockles is recent, thus experience is reduced.

Distribution Map in the Atlantic Area (signalisation)

Minchinia tapetis



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	1	–
ARO	0	–
AVE	0	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	?*	–
NOI	26	–
WAS	0	–

*Undetermined haplosporidan at 1% prevalence.

Diagnosis Techniques

- **Histology:** The above described parasite stages are observed in histological sections of digestive gland, but their morphology alone is not appropriate for species identification, for which molecular tools are required.
- **GenBank accession number:** AY449710.1 (SSU rDNA).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [10], [15], [20], [C], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Prevalence was high but infection intensity was light and no mortality outbreaks have been reported associated with this parasite.
- **Related to trading:** Risk of transmission if cockles from affected areas are immersed into not affected zones.
- **Global change:** A significant positive correlation was found between *M. tapetis* prevalence and seawater temperature. Increase of temperature due to climate change could cause increase of prevalence of this parasite in cockles.

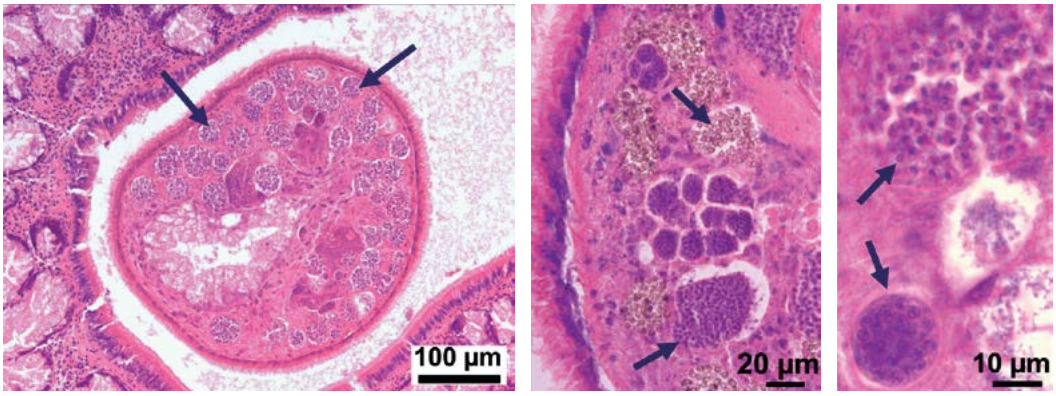
Advices

No action in affected areas.

Relevant References

Engelsma et al. 2011; Elliot et al. 2012; Albuixech-Marti et al. 2020; Carballal et al. 2020.

LATIN NAME ***Urosporidium* sp.**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Rhizaria – Haplosporida
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=562865)



General Description

Urosporidium sp. is a hyperparasite of the turbellarian *Paravortex cardii*; the latter inhabits the cockle digestive lumen. Sporocysts with spores or uninucleate sporoblasts and plasmodia occupy the connective tissue of the turbellarian host. The sporocysts are rounded with hundreds of spores present. Mature spores are uninucleate, refringent, round to oval and measure 4-5 µm in length. Prevalence is low.

Individual Pathogenicity

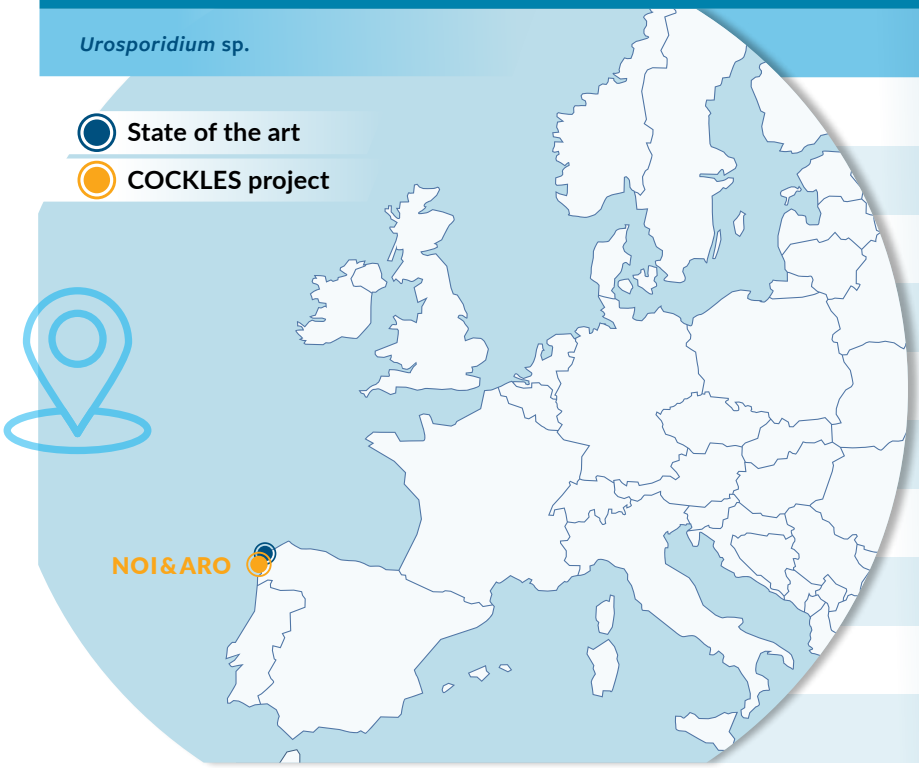
Urosporidium sp. causes damage to the turbellarian *Paravortex cardii* but without significant effects on cockles because the flatworm host could be considered a commensal rather than a cockle parasite.

Populational Pathogenicity

None.

Distribution Map in the Atlantic Area (signalisation)

Urosporidium sp.



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	-	-
ARO	4	-
AVE	-	-
BSO	-	-
BUR	-	-
DEE	-	-
DUN	-	-
FOR	-	-
NOI	1	-
WAS	-	-

Diagnosis Techniques

- **Histology:** Parasite stages are observed in histological sections of flatworms inhabiting cockle digestive lumen
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [15], [20], [C].

Risks in the Atlantic Area (AA)

- **Actual situation:** None.
- **Related to Trading:** None.
- **Global change:** Unknown.

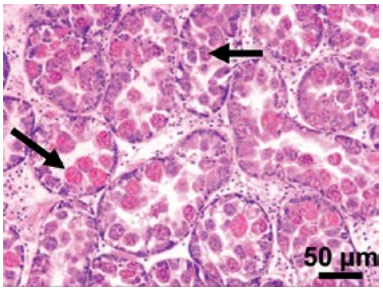
Advices

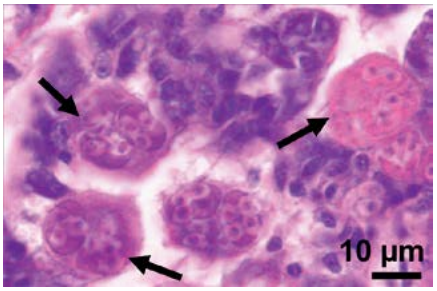
No action in affected areas.

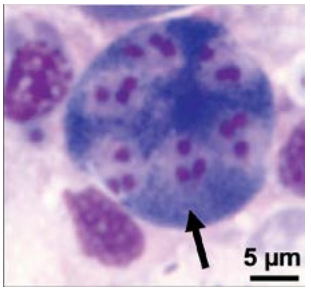
Relevant References

Carballal et al. 2005.

LATIN NAME ***Marteilia cochillia*** Carrasco et al., 2013
SYNONYMS None
COMMON NAME Cockle marteiliosis
CLASSIFICATION Rhizaria – Paramyxida







General Description

As all the *Marteilia* parasites, *M. cochillia* is characterised by the particular cells-inside-cells structure. Developmental stages of *M. cochillia* inside cockles consist of primary cells that enclose up to eight secondary cells; the secondary cells cleave internally to produce six tertiary cells, which evolve in tri-cellular spores (inner, intermediate and outer sporoplasms). Digestive gland of *C. edule* is the target organ where the sporulation of the parasite takes place. At advanced infection stage, the digestive gland epithelia appear heavily occupied by parasite sporulation stages that, eventually, are released to digestive lumina, even almost obliterating the intestinal lumen, to be discharged through whitish faeces. The life cycle of *M. cochillia* is complex (direct cockle-to-cockle transmission does not seem to occur) and may include zooplanktonic copepods as intermediate hosts.

Individual Pathogenicity

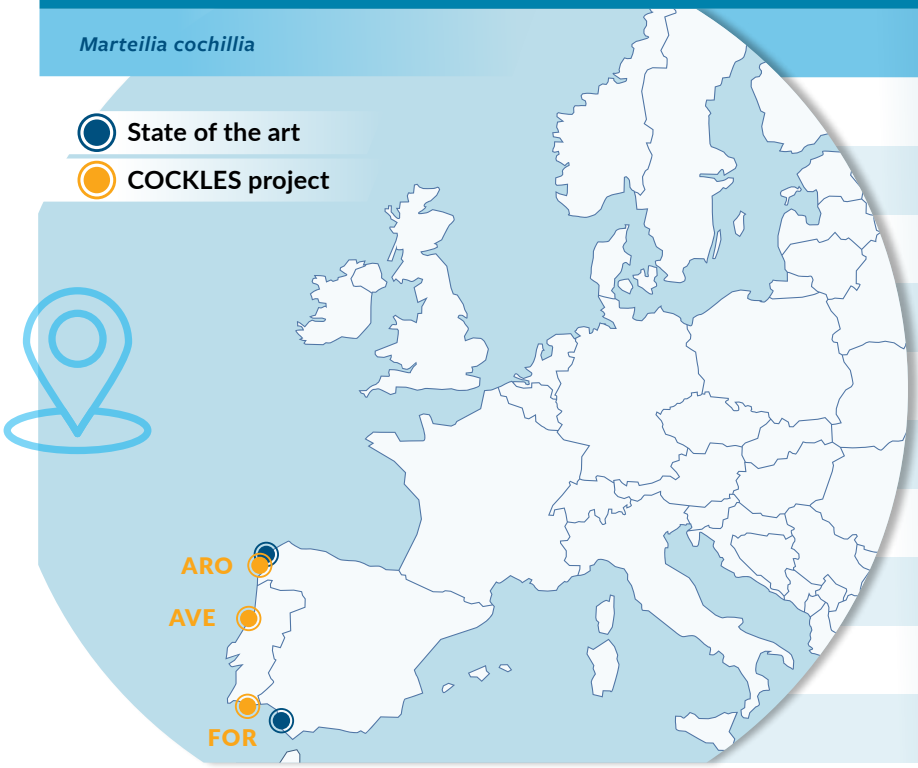
Sporulation process causes the complete destruction of digestive diverticula of cockles, leading to cockle death by starvation. *M. cochillia* infection also reduces cockle fecundity because the host cannot fuel gametogenesis or even retrieve gonad reserves to meet other priorities.

Populational Pathogenicity

Recurrent mass mortalities in cockle beds of southern Galician rias occur since the first detection of *M. cochillia* in 2012. It is highly prevalent (up to 100% in outbreaks) affecting both juvenile and adult cockles, causing cockle fishery collapse. Recently, prevalence and host mortality tended to decrease there, likely due to resistance increase through natural selection.

Distribution Map in the Atlantic Area (signalisation)

Marteilia cochillia



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	73	–
AVE*	1	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR*	11	–
NOI	0	–
WAS	0	–

*Occurrence of *M. cochillia* has not been confirmed with molecular tools (AVE and FOR).

Diagnosis Techniques

- **Gross observation:** Cockles suffering heavy infections show extremely emaciated meat with pale digestive gland, but these observations are not clinical signs because they are not specific.
- **Digestive gland imprints:** Rapid diagnostic method showing parasite sporulation stages but only sensitive enough in advanced infections.
- **Histology:** Different stages of the parasite are observed in the digestive gland epithelia; at advanced infection stage, parasite sporulation stages may fill the intestinal lumen.
- **GenBank accession number:** KF278722.1 (SSU rDNA + ITS1).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [10], [15], [20], [C], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Cockle fisheries of southern Galician rias are in risk.
- **Related to trading:** High risk if cockles from affected areas are immersed into non-affected zones. No risk for human consumption.
- **Global change:** Unknown.

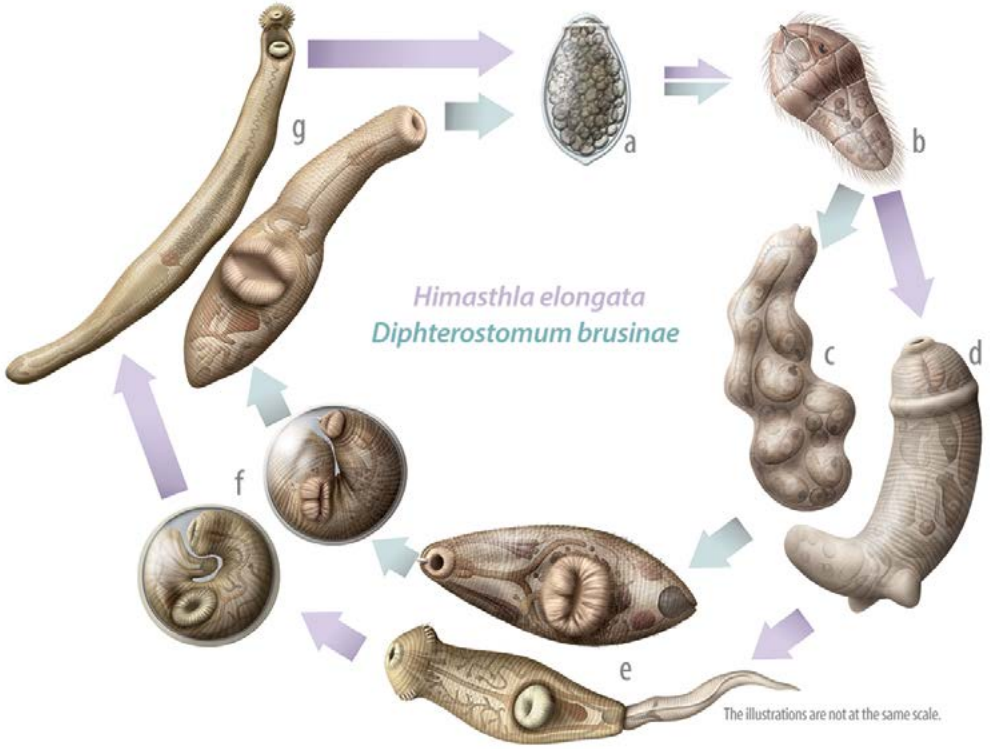
Advices

Cockles from areas known to be infected should not be transferred to areas with no record of *M. cochillia*.

Relevant References

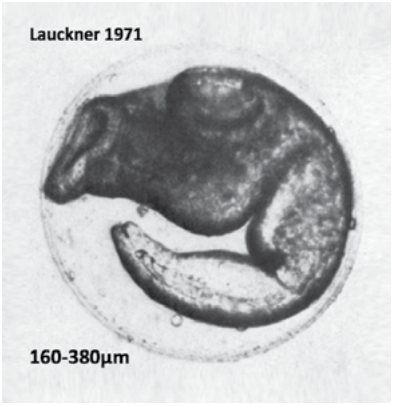
Carrasco et al. 2013, Villalba et al. 2014, Navas et al. 2018, Carballal et al. 2019, Iglesias et al. 2019, Darriba et al. 2020.

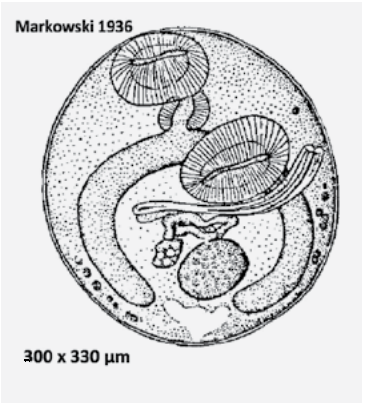
PLATYHELMINTHES

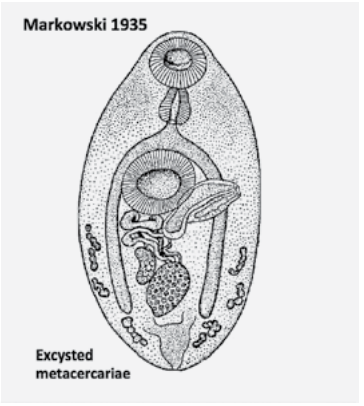


Digenetic trematodes are a large group of metazoan parasites belonging to the Platyhelminthes phylum. These parasites have been reported to infect almost every known mollusc bivalve species and are considered the most important macroparasites of these organisms. They display a complex and heteroxenous life cycle, i.e. they infect more than one host, and exhibit alternations between asexual multiplication and sexual reproduction phases. As a result of their transition among different hosts, they also present parasitic and free-living stages in their life cycle. The typical life cycle of a trematode begins when an egg **(a)** hatches releasing the miracidium **(b)**. This first free-living stage penetrates the tissue of the first intermediate host, a mollusc, where it transforms into a sac-like sporocyst **(c)** or a redia **(d)**, a developed form with the presence of a mouth, depending on the trematode species. The mother sporocyst (or redia) will develop into a more mature daughter sporocyst (or daughter redia) that will asexually produce cercariae. Cercariae **(e)**, the second free-living stage, emerge from the first intermediate host and swim actively to infect the second intermediate host, a vertebrate or invertebrate, usually through their feeding activity. At this stage, the cercariae transform into metacercariae **(f)** and the transmission to the definitive host, a vertebrate (usually shorebirds or fish), occurs when the second intermediate host is predated. In the final host, the metacercariae metamorphose into adult stages **(g)** that will reproduce sexually, generating eggs that will be released into the environment through the faeces of the final host, originating a new cycle. A total of 15 species of digenetic trematodes have been identified (+ at least 2 unidentified) infecting the edible cockle, *Cerastoderma edule*, as first and/or second intermediate host.

LATIN NAME ***Asymphylodora demeli*** **Markowski, 1935**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Lissorchiidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109116)







General Description

Asymphylodora demeli needs 3 different hosts to accomplish its life-cycle (hydrobid snails, gastropods/cockles, cyprinid/gobiid fishes). In the cockle (2nd intermediate host), the encysted metacercariae can be found in the hepatopancreas, mantle and gills. Several polychaete species may serve as alternative 2nd intermediate hosts and the polychaete *Hediste diversicolor* may be an alternative definitive host.

Individual Pathogenicity

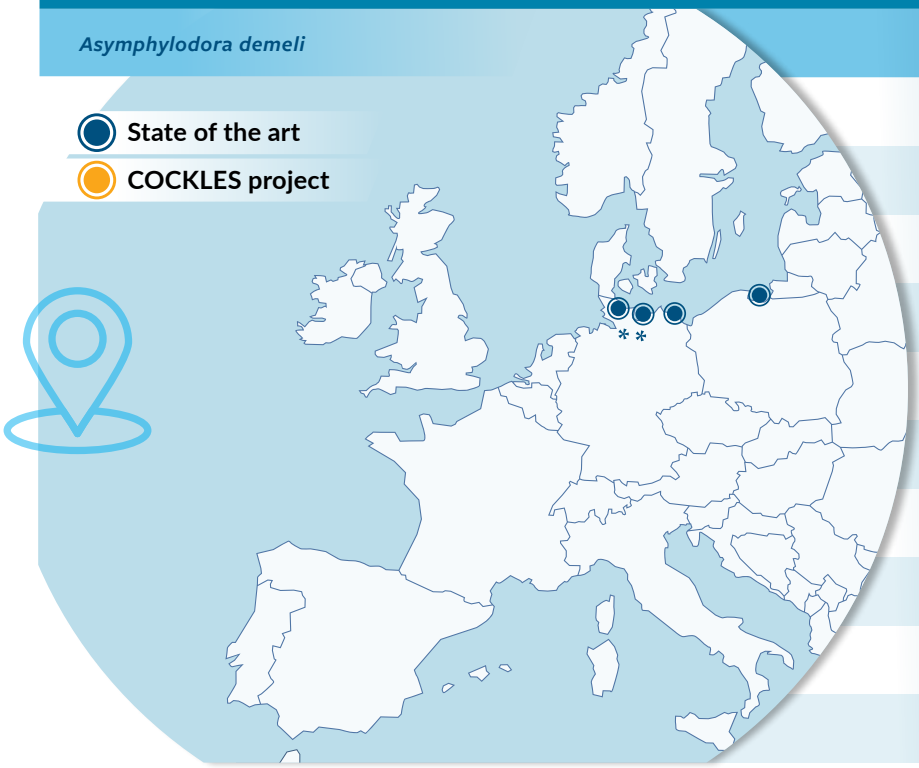
Unknown

Populational Pathogenicity

Prevalence in cockles can be locally high in the Baltic Sea (64%) but populational pathogenicity has not been reported.

Distribution Map in the Atlantic Area (signalisation)

Asymphylodora demeli



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

*Only in *Cerastoderma glaucum*.

Diagnosis Techniques

- **Histology:** Possible to detect metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession number:** No sequences available in genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Distribution probably restricted to the Baltic Sea. However, *Asymphylodora demeli* has apparently been observed in fish and gastropods in Belgium but not in cockles.
- **Related to Trading:** No risk within AA, at least between 28°N (Morocco) and 60°N (Norway).
- **Global change:** Change of temperature can modify host dispersion and infection success.

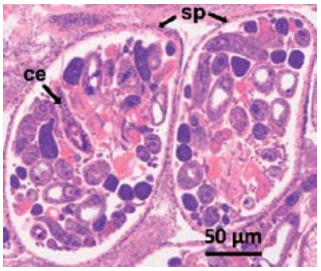
Advices

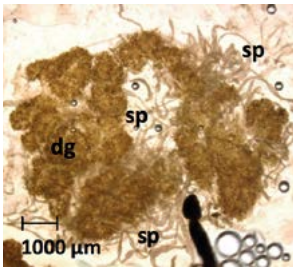
No action in nature conservation areas.

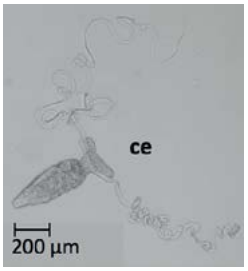
Relevant References

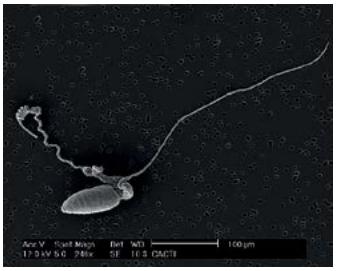
Reimer 1970; Lauckner 1971; Reimer 1973; Kesting et al. 1996.

LATIN NAME	***Bucephalus minimus*** **(Stossich, 1887) Nicoll, 1914**
SYNONYMS	*Labratrema minimus*
COMMON NAME	None
CLASSIFICATION	Trematoda – Bucephalidae (WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=238036)









General Description

Bucephalus minimus needs 3 different hosts to accomplish its complete life-cycle: cockle (mollusc), gobiid (fish) and seabass (fish, final host). In the cockle (1st intermediate host), the sporocyst stage (sp) progressively invades the whole flesh, starting with the gonad/digestive gland (dg), leading to a gradual destruction and replacement of the molluscan tissue. Sporocysts are completely filled with developing cercariae, from the early stage so-called germ balls to fully developed cercariae. When mature, the cercariae (ce) are clearly visible by breaking the sporocyst wall. Cockles can potentially be infected when shell length > 16 mm.

Individual Pathogenicity

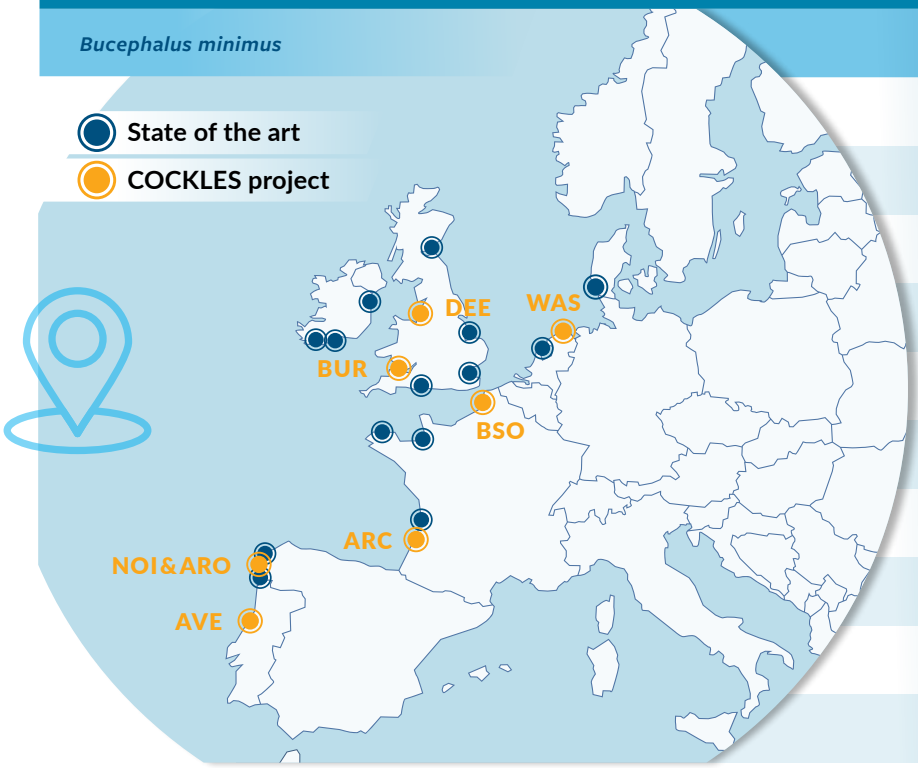
Sporocyst invades the whole body with negative effect on cockle fecundity, growth, condition and survival. Severe castration has been reported.

Populational Pathogenicity

Prevalence is generally low (< 1%) but episodic high infection breakdown have been reported with high mortality.

Distribution Map in the Atlantic Area (signalisation)

Bucephalus minimus



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)		
SITE	%	Ab
ARC	6	–
ARO*	1	–
AVE	1	–
BSO	6	–
BUR	7	–
DEE	2	–
DUN	0	–
FOR	0	–
NOI	5	–
WAS	1	–

*Detected by histology.

Diagnosis Techniques

- **Histology:** Possible to detect sporocysts but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession number:** MT019830 (*COI*), MN876028 (*ITS1*), MN879354 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [5], [6], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence outbreak is possible and has already been observed.
- **Related to Trading:** No risk within AA, at least between 21°N (Morocco) and 54°N (Scotland/Germany).
- **Global change:** Change of temperature can modify host dispersion and infection success. But life cycle is still unknown.

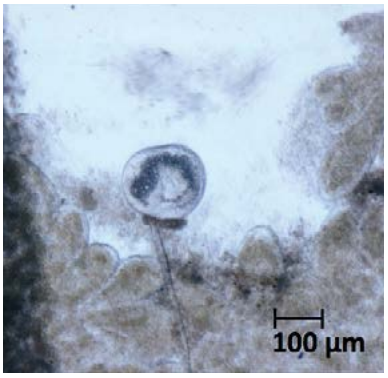
Advices

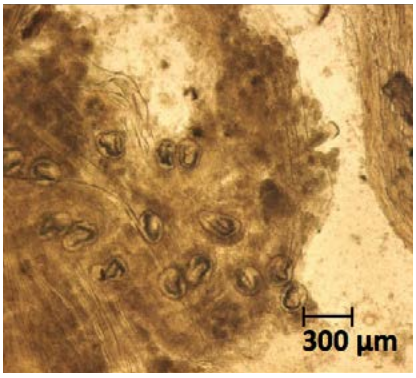
No action in nature conservation areas.

Relevant References

Desclaux et al. 2002; de Montaudouin et al. 2009; Pina et al. 2009; Feis et al. 2015; Magalhães et al. 2015, 2017.

LATIN NAME ***Curtuteria arguina*** **Desclaux et al., 2006**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Himasthlidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=736156)





General Description

Curtuteria arguinae certainly needs 3 different hosts to accomplish its complete life-cycle, but has so far only be identified as metacercariae in the cockle (2nd intermediate host). Metacercariae generally infect the mantle (but not its margin) and the proximal part of the foot. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 850 per cockle.

Individual Pathogenicity

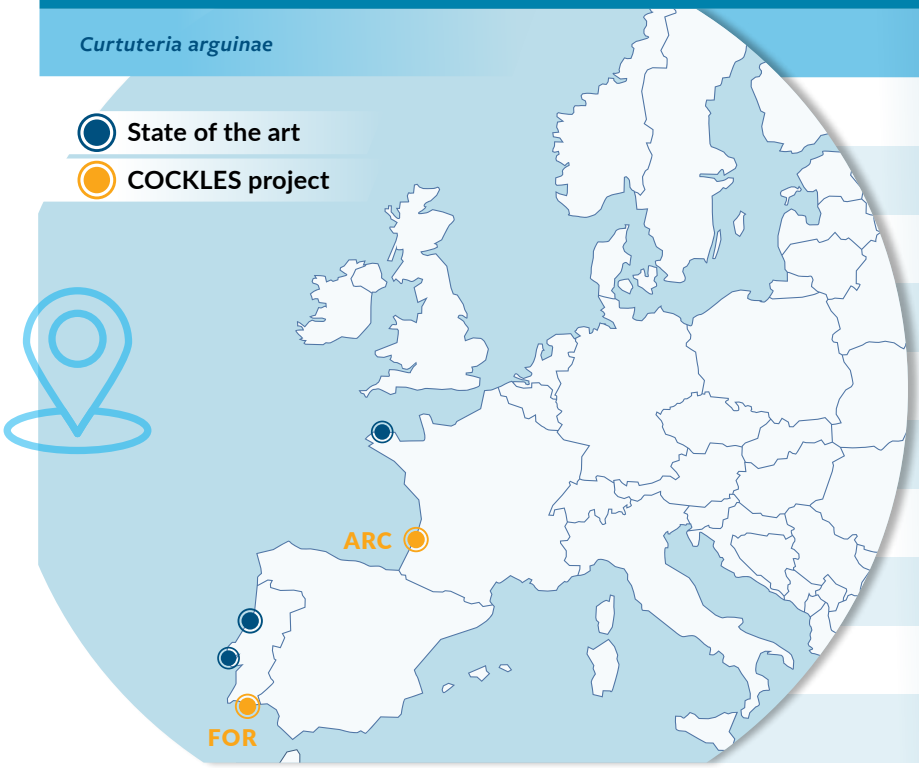
No reported effect.

Populational Pathogenicity

May contribute to «natural» mortality, by decreasing fitness of the most parasitized cockles.

Distribution Map in the Atlantic Area (signalisation)

Curtuteria arguinae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	85	4.7
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	100	70.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Metacercariae extraction is compulsory to distinguish, under microscope, from *H. quissetensis* (33 oral spines vs. 31 in *H. quissetensis*).
- **Genes Accession numbers:** MT002920 (*COI*), MN876025 (*ITS1*), MN879358 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17].

Risks in the Atlantic Area (AA)

- **Actual situation:** Low risk. At high intensity, it participates to natural mortality.
- **Related to Trading:** Risk within AA, because it has been detected only in few sites, with the highest intensities South to Arcachon Bay.
- **Global change:** Change of temperature can modify host dispersion and infection success. But life cycle is still unknown.

Advices

No action in nature conservation areas.

Relevant References

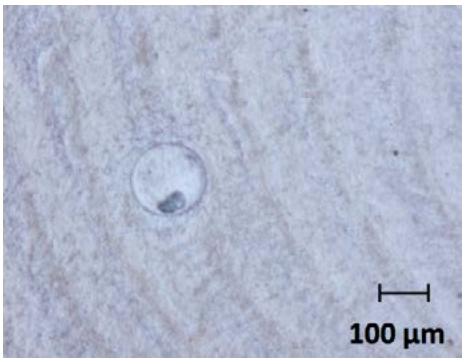
Desclaux et al. 2006; de Montaudouin et al. 2009.

LATIN NAME ***Diphterostomum brusinae*** **brusinae (Stossich, 1889) Stossich, 1904**

SYNONYMS *D. anisotremi, D. israelense, D. macrosaccum, D. sargusannularis, D. spari, D. tropicum*

COMMON NAME None

CLASSIFICATION Trematoda – Zoogonidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109132)



General Description

Diphterostomum brusinae needs 3 different hosts to accomplish its complete life-cycle (*Tritia reticulata*, cockle and finfish). In the cockle (2nd intermediate host), metacercariae generally infect the palps. Juvenile and adult cockles can be infected, and metacercariae abundance is usually low (< 10 per cockle) but can reach 100 per cockle.

Individual Pathogenicity

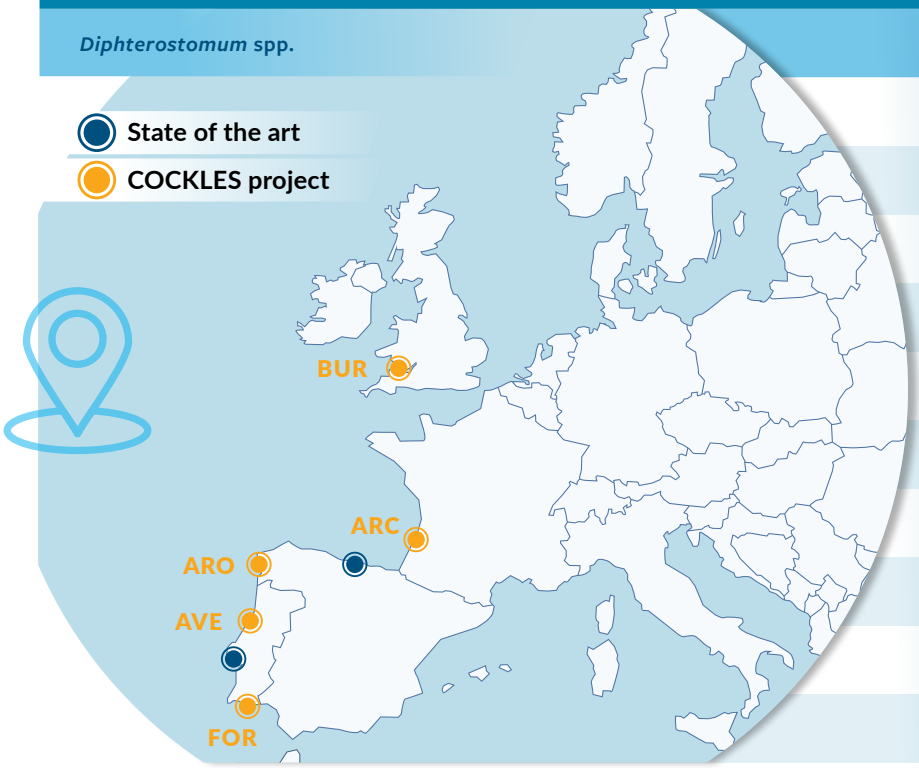
No reported effect.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Diphterostomum spp.



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC*	21	0.3
ARO	3	0.03
AVE*	68	3.1
BSO	0	0.0
BUR	5	0.1
DEE	0	0.0
DUN	0	0.0
FOR*	68	2.3
NOI	0	0.0
WAS	0	0.0

*Different molecular signature.

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession numbers:** MT002923 (*COI*), EU979527 (*ITS1*), MN879361 (*18S*).
- *D. brusinae* is found in AVE and ARC. Another close molecular signature is found in ARC and a third one in AVE.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk.
- **Related to trading:** Risk within AA, because it has been detected only in few sites, with the highest intensities South to Arcachon Bay.
- **Global change:** Change of temperature can modify host dispersion and infection success.

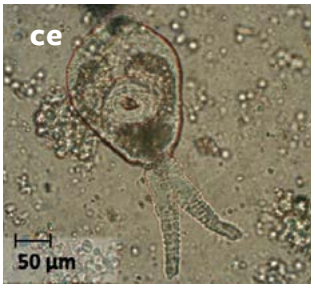
Advices

No action in nature conservation areas.

Relevant References

Palombi 1930; de Montaudouin et al. 2009; Pina et al. 2009.

LATIN NAME ***Gymnophallus choledochus*** Odhner, 1900
SYNONYMS *Cercaria fulbrighti, C. dichotoma, G. fulbrighti*
COMMON NAME None
CLASSIFICATION Trematoda – Gymnophallidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109223)



General Description

Gymnophallus choledochus needs two to three different hosts to accomplish its complete life-cycle (cockle, cockle/polychaete, water bird). In the cockle (1st intermediate host), the sporocysts (sp) progressively invades the whole flesh, starting with the gonad/digestive gland. Cercariae (ce) can transform in metacercariae (me) in the cockle or in a polychaete as 2nd intermediate host. Cockles can potentially be infected when shell length >16 mm.

Individual Pathogenicity

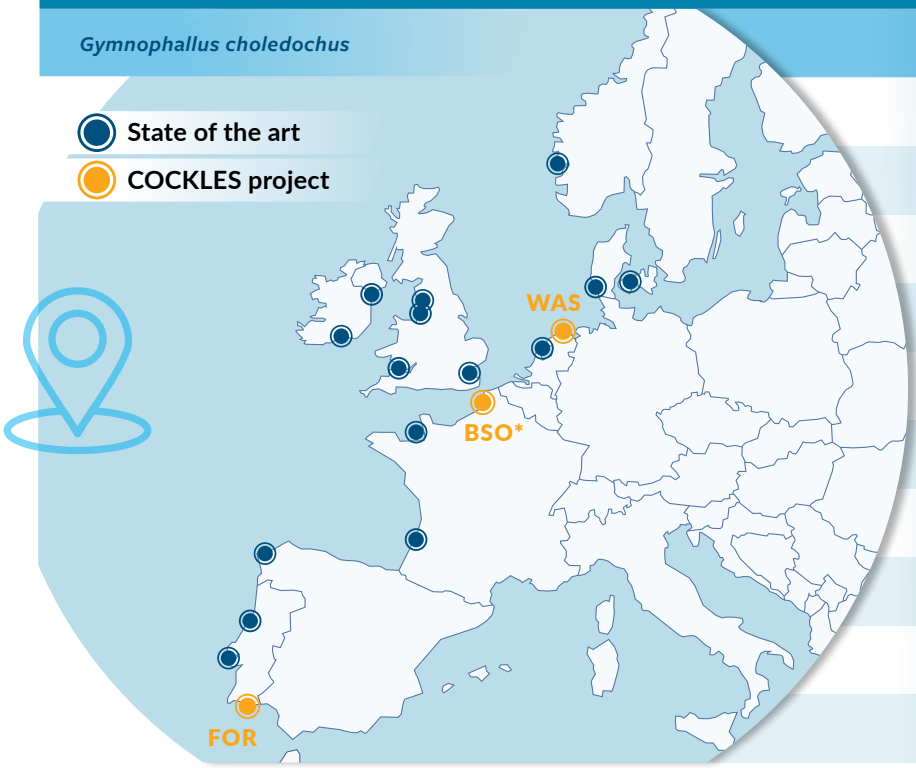
Sporocyst invades the whole body with negative effect on cockle fecundity and survival.

Populational Pathogenicity

Prevalence is generally low (< 1%) but episodic high infection breakdown have been reported with high mortality.

Distribution Map in the Atlantic Area (signalisation)

Gymnophallus choledochus



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	–
ARO	0	–
AVE	0	–
BSO*	(8)	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	1	–
NOI	0	–
WAS	4	–

*Different molecular signature.

Diagnosis Techniques

- **Histology:** Possible to detect sporocysts but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession numbers:** MN547969 (*COI*), MN592818 (*ITS1*), MN544854 (*18S*).
- Different molecular signature in Bay of Somme (BSO).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence outbreak is possible and has already been observed.
- **Related to trading:** no risk within AA, at least between 28°N (Morocco) and 60°N (Norway).
- **Global change:** Change of temperature can modify host dispersion and infection success.

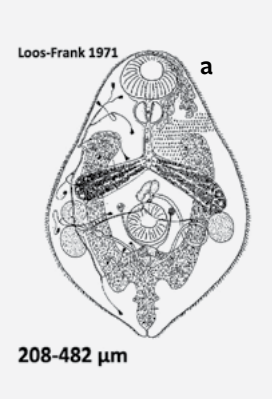
Advices

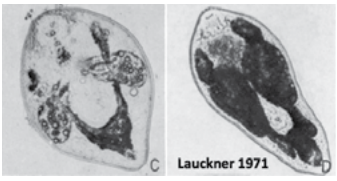
Eradicate moribund cockles at the surface of the sediment in production areas. No action in nature conservation areas.

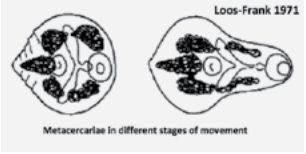
Relevant References

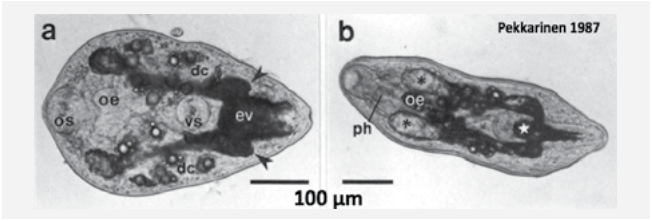
James & Bowers 1967; Loos-Frank 1971; Thieltges 2006; Thieltges et al. 2006; de Montaudouin et al. 2009; Rangel & Santos 2009; Magalhães et al. 2020.

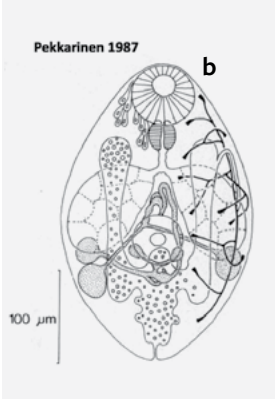
LATIN NAME	***Gymnophallus somateriae*** **(Levinsen, 1881)**
SYNONYMS	*Gymnophallus gibberosus*
COMMON NAME	None
CLASSIFICATION	Trematoda – Gymnophallidae (WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109227)











General Description

Gymnophallus somateriae needs 3 different hosts to accomplish its life-cycle (Baltic tellins *Limecola balthica*, cockle/Baltic tellins, sea ducks). In the cockle (2nd intermediate host), the unencysted metacercariae can be found in between the shell and the anterior shell adductor and neighbouring foot retractor muscles. Metacercariae grow inside their host.

Individual Pathogenicity

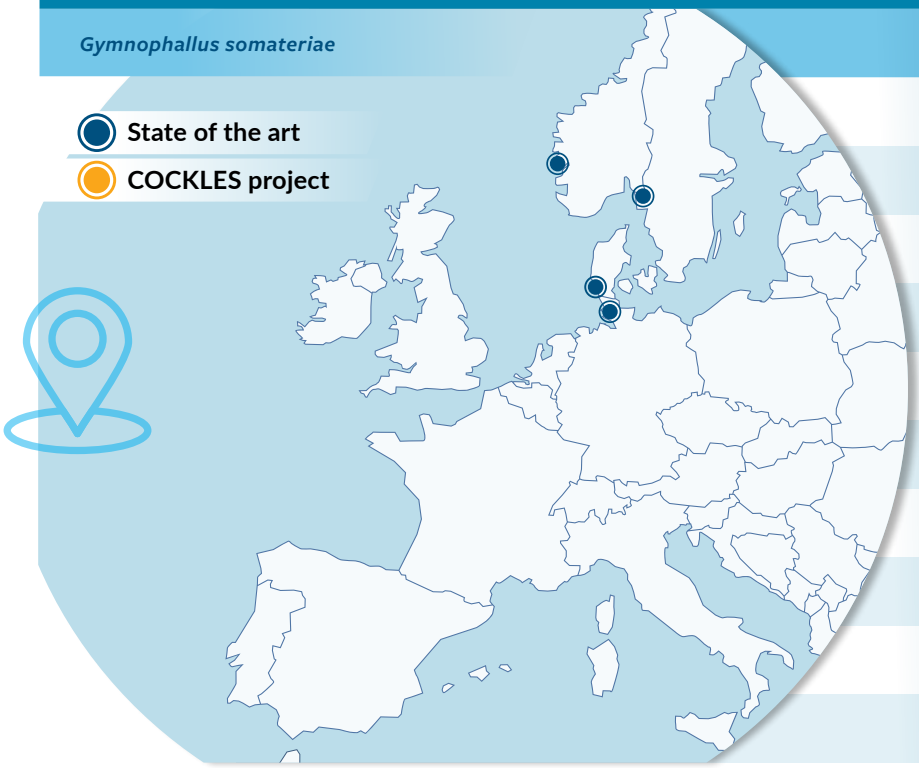
Metacercariae infections in between shell and muscle lead to the development of calcareous concrements on muscle scars on the host's shell which may reduce the burrowing behaviour.

Populational Pathogenicity

Prevalence and intensities can locally be high and associated mortality has been suggested.

Distribution Map in the Atlantic Area (signalisation)

Gymnophallus somateriae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession number:** No sequences available in Genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Distribution is very patchy, high prevalences have only been observed locally.
- **Related to trading:** No risk within AA, at least between 28°N (Morocco) and 60°N (Norway).
- **Global change:** Change of temperature can modify host dispersion and infection success.

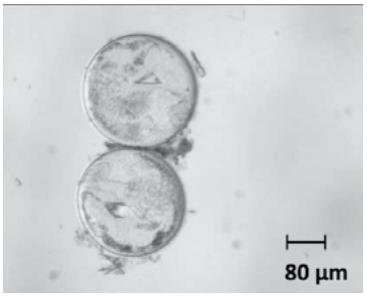
Advices

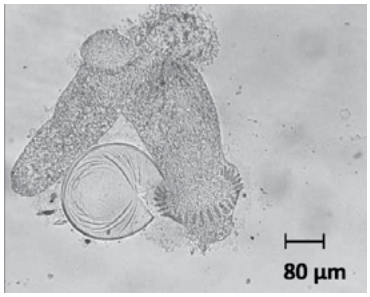
No action in nature conservation areas.

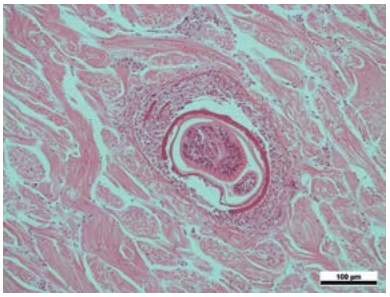
Relevant References

Loos-Frank 1971a,b; Pekkarinen 1987; Thieltges & Reise 2006; Thieltges et al. 2006; de Montaudouin et al. 2009.

LATIN NAME ***Himasthla continua*** **Loos-Frank, 1967**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Himasthlidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=108796)







General Description

Himasthla continua needs 3 different hosts to accomplish its complete life-cycle (mudsnail *Peringia ulvae*, cockle/mussel and bird). In the cockle (2nd intermediate host), metacercariae generally infect the foot. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 400 per cockle.

Individual Pathogenicity

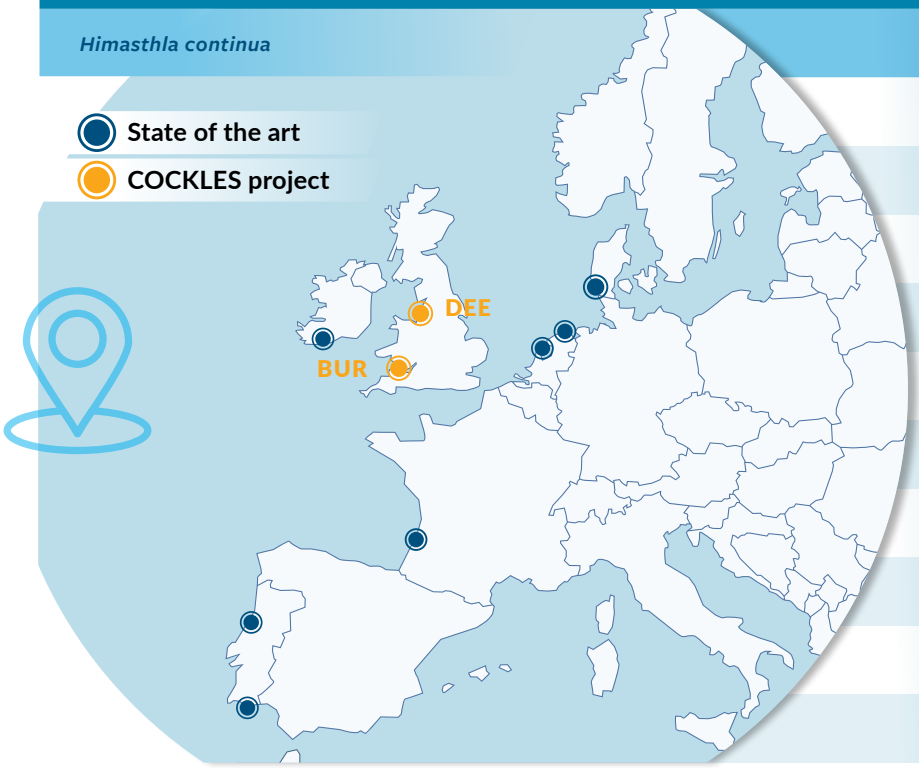
No reported effect.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Himasthla continua



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	38	0.7
DEE	7	0.1
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Metacercariae extraction is compulsory to distinguish, under microscope, from *H. quissetensis* (31 oral spines vs. 29 in *H. continua*). Confusion with *H. interrupta* and *H. elongata* is also frequent (same spine number, i.e. 29).
- **Genes Accession number:** No sequences available in Genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** Low risk. At high intensity, it participates to baseline mortality.
- **Related to trading:** No risk within AA, because it has been detected almost everywhere, at least between 21°N (Morocco) and 54°N (Germany). It should occur at higher latitudes due to its presence in Arctic in the other hosts of the cycle.
- **Global change:** Change of temperature can modify host dispersion and infection success.

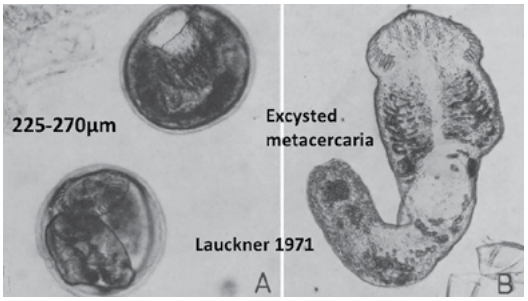
Advices

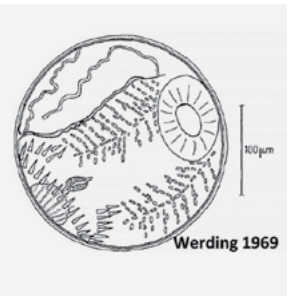
No action in nature conservation areas.

Relevant References

Loos-Frank 1967; Jensen et al. 1999; Wegeberg et al. 1999; de Montaudouin et al. 2009.

LATIN NAME ***Himasthla elongata*** **(Mehlis, 1831) Dietz, 1909**
SYNONYMS *Distoma elongatum*
COMMON NAME None
CLASSIFICATION Trematoda – Himasthlidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=108797)





General Description

Himasthla elongata needs 3 different hosts to accomplish its life-cycle (*Littorina littorea*, cockles/bivalves, gulls). In the cockle (2nd intermediate host), the encysted metacercariae can be found mainly in the foot.

Individual Pathogenicity

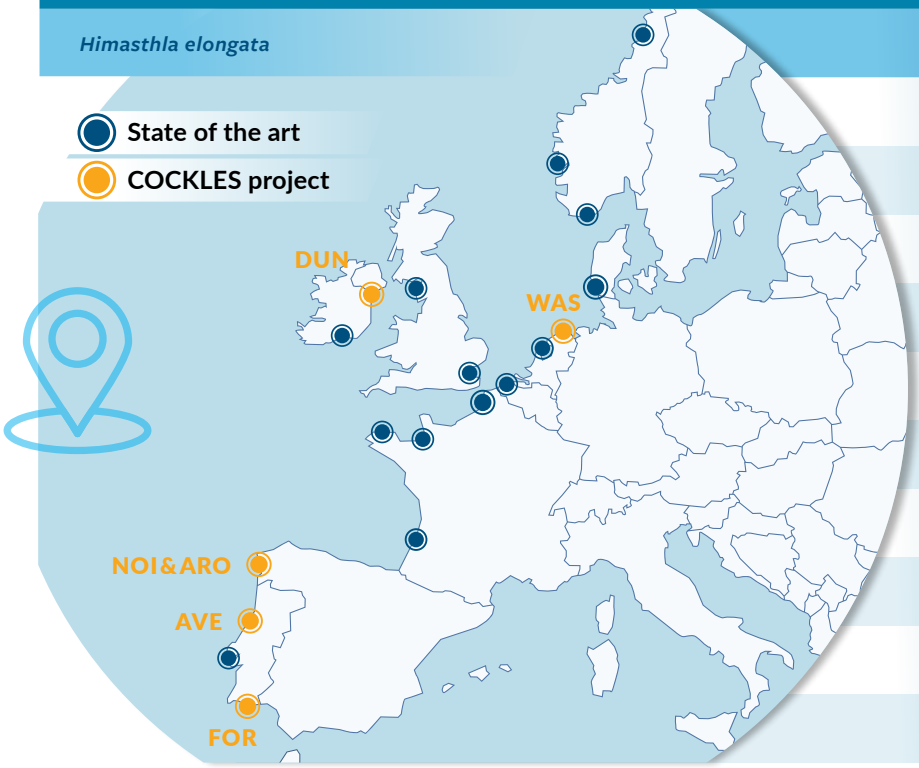
Infection of the foot is considered to impair the burrowing capability of cockles with effects on survival. However, experimental evidence has not been conclusive.

Populational Pathogenicity

Prevalence and intensities in cockles can be locally high, supposedly exposing cockles on the surface to high predation by birds and thus to increase population mortality. However, experimental evidence for this is missing.

Distribution Map in the Atlantic Area (signalisation)

Himasthla elongata



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	70	1.1
AVE	50	0.9
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	23	0.3
FOR	13	0.2
NOI	97	4.7
WAS	20	0.5

Diagnosis Techniques

- **Histology:** Possible to detect metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Metacercariae extraction is compulsory to distinguish, under microscope, from *H. quissetensis* (31 oral spines vs. 29 in *H. elongata*). Confusion with *H. interrupta* and *H. continua* is also frequent (same spine number, i.e. 29).
- **Genes Accession numbers:** MT002921 (*COI*), MN876024 (*ITS1*), MN879359 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence and intensities have been observed locally but seem to be restricted to northern regions, linked to the distribution of the upstream host *L. littorea*.
- **Related to trading:** No risk within AA, at least between 28°N (Morocco) and 60°N (Norway).
- **Global change:** Change of temperature can modify host dispersion and infection success.

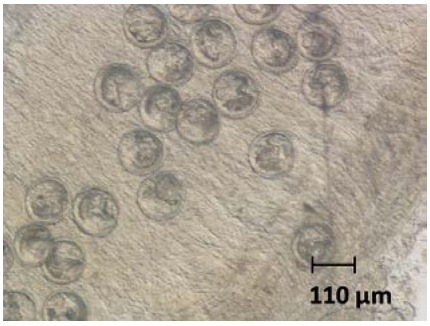
Advices

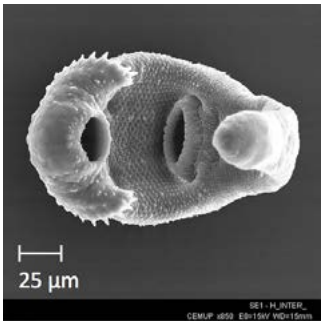
No action in nature conservation areas.

Relevant References

Lauckner 1971; de Montaudouin et al. 1998; Wegeberg & Jensen 1999; Wegeberg et al. 1999.

LATIN NAME ***Himasthla interrupta*** **Loos-Frank, 1967**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Himasthlidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=736169)





General Description

Himasthla interrupta needs 3 different hosts to accomplish its complete life-cycle (mudsnail *Peringia ulvae*, cockle and sandpiper (bird)). In the cockle (2nd intermediate host), metacercariae generally infect the mantle margin, with higher concentration in the anterior area (i.e. opposite to siphons). Juvenile and adult cockles can be infected, and metacercariae abundance can reach 500 per cockle.

Individual Pathogenicity

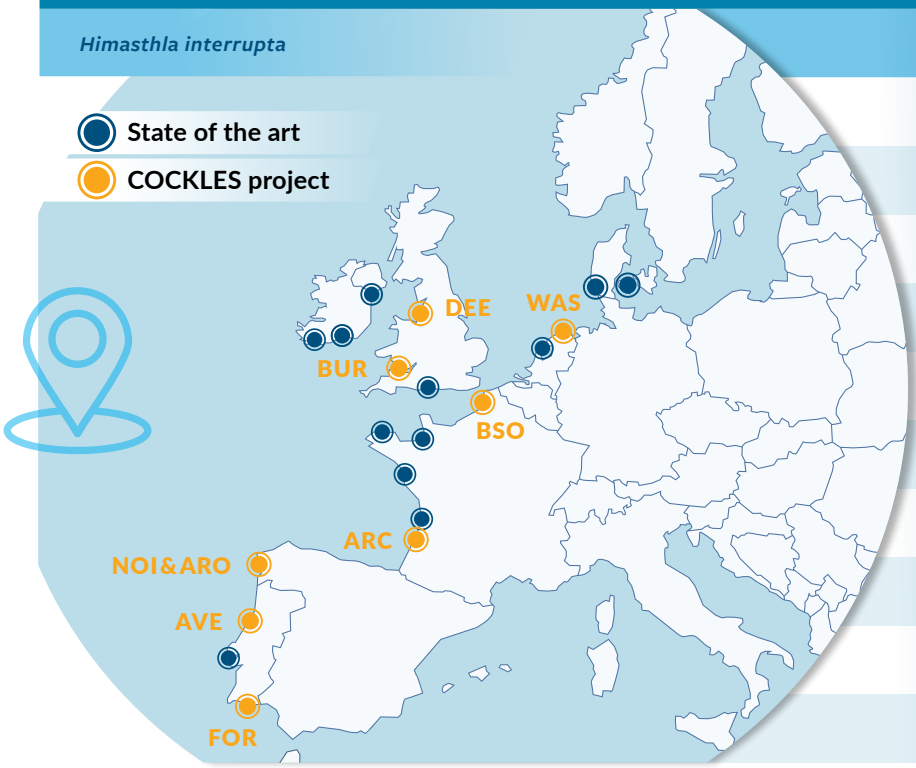
At high level of infection, *Himasthla interrupta* can moderately impair cockle growth.

Populational Pathogenicity

No effect at the population scale has been documented but can probably slightly impair production when mean abundance > 100 metacercariae per cockle.

Distribution Map in the Atlantic Area (signalisation)

Himasthla interrupta



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	100	87.9
ARO	70	1.8
AVE	55	3.1
BSO	75	10.9
BUR	100	31.9
DEE	87	4.8
DUN	0	0.0
FOR	10	0.1
NOI	77	3.4
WAS	77	5.0

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Confusion with *H. continua* and *H. elongata* is also frequent (same spine number, i.e. 29).
- **Genes Accession numbers:** No sequences available in Genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** Low risk. At high prevalence, it could moderately impair individual growth.
- **Related to trading:** No risk within AA, at least between 21°N (Morocco) and 54°N (Germany).
- **Global change:** Change of temperature can modify host dispersion and infection success.

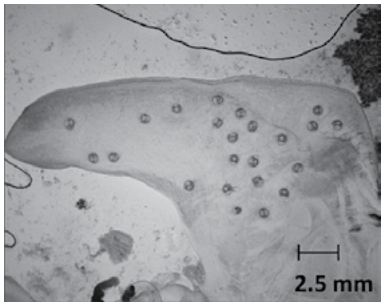
Advices

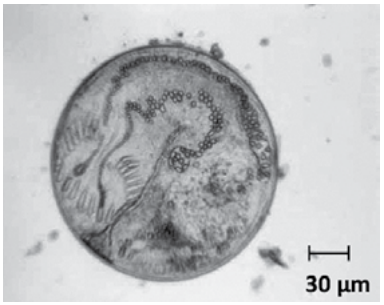
No action in nature conservation areas.

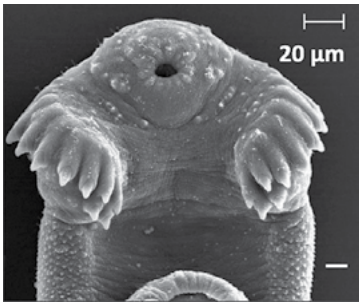
Relevant References

Loos-Frank 1967; Wegeberg et al. 1999; Wegeberg & Jensen 2003; de Montaudouin et al. 2009, 2012.

LATIN NAME ***Himasthla quissetensis*** **(Miller & Northup, 1926) Stunkard, 1938**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Himasthlidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=736173)







General Description

Himasthla quissetensis needs 3 different hosts to accomplish its complete life-cycle (nassariid snail (*Tritia reticulata* or *Tritia neritea* along Northeastern Atlantic coasts), cockle and seagull). In the cockle (2nd intermediate host), metacercariae generally infect the foot. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 400 per cockle.

Individual Pathogenicity

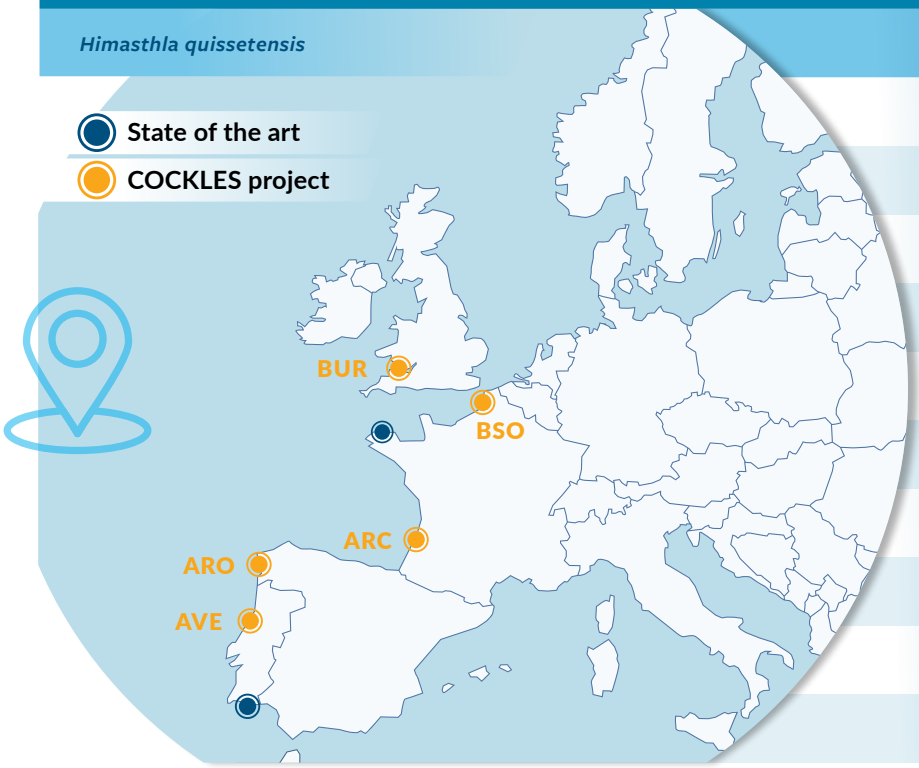
No reported direct effect.

Populational Pathogenicity

Could contribute to «natural» mortality, by decreasing fitness of the most parasitized cockles.

Distribution Map in the Atlantic Area (signalisation)

Himasthla quissetensis



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	100	22.1
ARO	10	0.1
AVE	78	2.4
BSO	25	1.0
BUR	8	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Metacercariae extraction is compulsory to distinguish, under microscope, from *H. continua* (29 oral spines vs. 31 in *H. quissetensis*) and from *Curtuteria arguinae* (33 spines).
- **Genes Accession numbers:** MT002920 (*COI*), MN876025 (*ITS1*), MN879358 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** Low risk. At high intensity, it participates to baseline mortality.
- **Related to trading:** Risk within AA, because it has been detected only in few sites, with the highest intensities South to Arcachon Bay.
- **Global change:** Change of temperature can modify host dispersion and infection success.

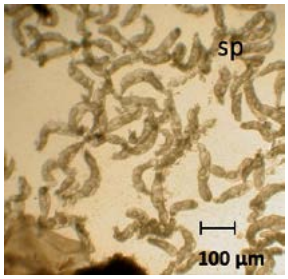
Advices

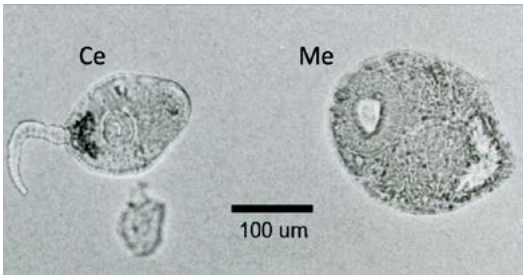
No action in nature conservation areas.

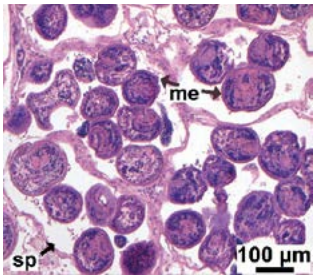
Relevant References

Stunkard 1938; Desclaux et al. 2004; de Montaudouin et al. 2005; Russell-Pinto et al. 2006; de Montaudouin et al. 2009, 2016a,b.

LATIN NAME ***Monorchis parvus*** **Looss, 1902**
SYNONYMS *Cercaria cerastodermae*
COMMON NAME None
CLASSIFICATION Trematoda – Monorchiidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109122)







General Description

Monorchis parvus needs 2 different hosts to accomplish its complete life-cycle (cockle as 1st and 2nd intermediate hosts, and fish (like *Diplodus*) as final host). In the cockle, the sporocyst forms cercariae (Ce) which can remain in the host or infest another cockle. In both situation they develop into metacercariae (Me). Sporocyst invades all the visceral mass causing severe damages to cockle´s tissues. Cockles can potentially be infected when shell length > 18 mm (there are rare cases of infection in 6 to 17 mm shell length cockles).

Individual Pathogenicity

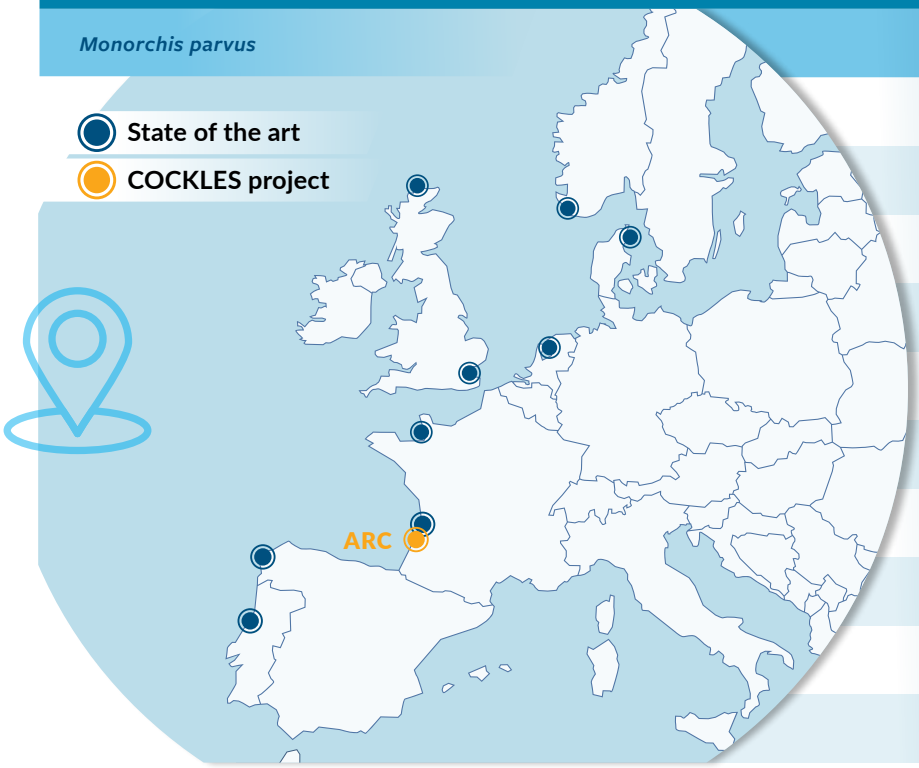
Sporocyst invades the whole body, causing castration and negative effect on cockle survival.

Populational Pathogenicity

Prevalence is generally low (< 0,1%) but episodic high infection breakdown have been reported with high mortality.

Distribution Map in the Atlantic Area (signalisation)

Monorchis parvus



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	2	–
ARO	0	–
AVE	0	–
BSO	0	–
BUR	0	–
DEE	0	–
DUN	0	–
FOR	0	–
NOI	0	–
WAS	0	–

Diagnosis Techniques

- **Histology:** Possible to detect sporocysts but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession numbers:** MN547970 (*COI*), MN592817 (*ITS*), MN544855 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A], [E].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence outbreak is possible and has already been observed.
- **Related to trading:** Possible risk within AA, because it seems yet absent in many sites.
- **Global change:** Change of temperature can modify host dispersion and infection success.

Advices

Eradicate moribund cockles at the surface of the sediment in production areas. No action in nature conservation areas.

Relevant References

Sannia & James 1978a,b; Jonsson & André 1992; Bartoli et al. 2000; Jousson & Bartoli 2002; de Montaudouin et al. 2009; Magalhães et al. 2020.

LATIN NAME ***Parvatrema fossarum*** **(Bartoli, 1965)**

SYNONYMS *Gymnophallus fossarum, Meiogymnophallus fossarum*

COMMON NAME None

CLASSIFICATION Trematoda – Gymnophallidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=708800)

General Description

Parvatrema fossarum needs 3 different hosts to accomplish its complete life-cycle (peppery furrow shell *Scrobicularia plana*, cockle and oystercatcher). In the cockle (2n^{d} intermediate host), metacercariae generally infect the outer part of the mantle margin. These are easily confused with *P. minutum*. Actually, there are some strong doubts about the presence of this parasite in Atlantic cockles. All suspected individuals in this Project (according to morphology and tissues locations) were considered *P. minutum* after molecular analysis.

Individual Pathogenicity

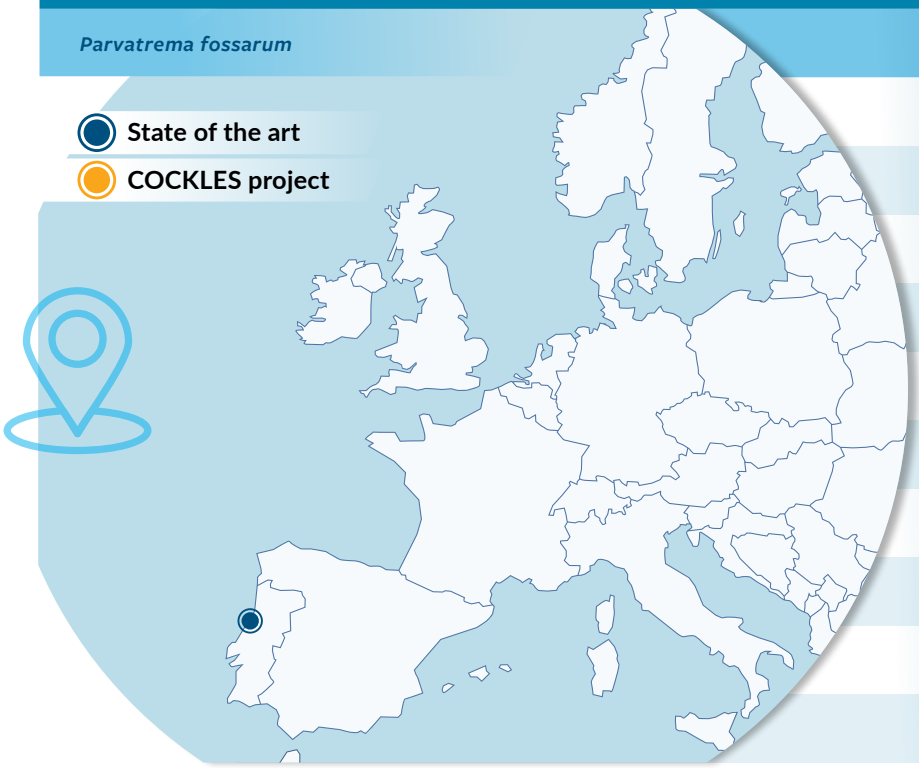
Controversial results on the possibility for the parasite to change host behaviour (migration at the surface of the sediment) and to alter growth.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Parvatrema fossarum



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect metacercariae but difficult species identification.
- **Dissection:** squeeze between two thick glass slides, under stereomicroscope. Possible confusion with *P. minutum*.
- **Genes Accession number:** No sequences available in Genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk. Not detected (occurrence in Aveiro is doubtful and it should be diagnosed with molecular tools).
- **Related** to trading: no risk within AA because not detected.
- **Global** change: Change of temperature can modify host dispersion and infection success.

Advices

No action in nature conservation areas.

Relevant References

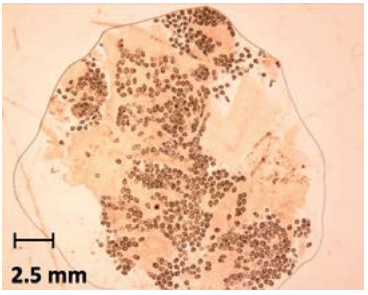
Russell-Pinto & Bartoli 1992; Bowers et al. 1996; Russell-Pinto et al. 2006.

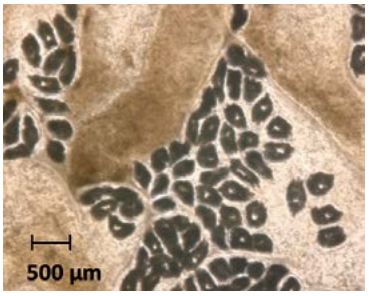
LATIN NAME ***Parvatrema minutum*** **(Cobbold, 1859)**

SYNONYMS *Distoma minutus, Gymnophallus margaritum, G. nereicola, Meiogymnophallus minutus*

COMMON NAME None

CLASSIFICATION Trematoda – Gymnophallidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=708801)





General Description

Parvatrema minutum needs 3 different hosts to accomplish its complete life-cycle (peppery furrow shell *Scrobicularia plana*, cockle and oystercatcher). In the cockle (2nd intermediate host), metacercariae generally appear enclosed by cockle epithelial tissue proliferations under the umbo of the shell. Metacercariae are not encysted but enveloped in translucid pouches, corresponding to host tissue proliferations. The outer part of the mantle margin can also be infected, with metacercariae included in the host tissues and are easily confused with *P. fossarum*. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 2000 per cockle. Metacercariae may be hyperparasitized by *Unikaryon legeri*.

Individual Pathogenicity

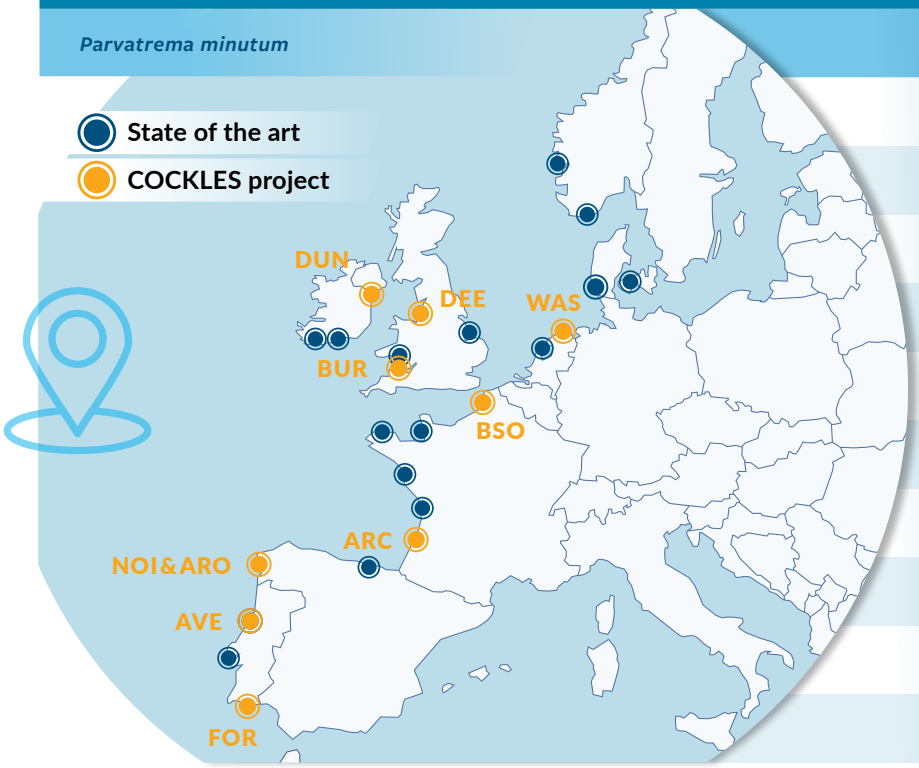
Some results on the possibility for the parasite to change host behaviour (migration at the surface of the sediment).

Populational Pathogenicity

Could contribute to natural mortality, by decreasing fitness of the most parasitized cockles.

Distribution Map in the Atlantic Area (signalisation)

Parvatrema minutum



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	100	189.2
ARO	100	89.4
AVE	58	4.1
BSO	90	317.7
BUR	98	27.9
DEE	100	1040
DUN	98	52.5
FOR	10	0.2
NOI	13	0.1
WAS	97	375.8

Diagnosis Techniques

- **Histology:** Possible to detect metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Possible confusion with *P. fossarum*.
- **Genes Accession numbers:** MT002918 (*COI*), KM268111 (*ITS*), MN879355 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [5], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Low risk. At high intensity, it participates to baseline mortality.
- **Related to trading:** No risk within AA because it is already present everywhere.
- **Global change:** Change of temperature can modify host dispersion and infection success.

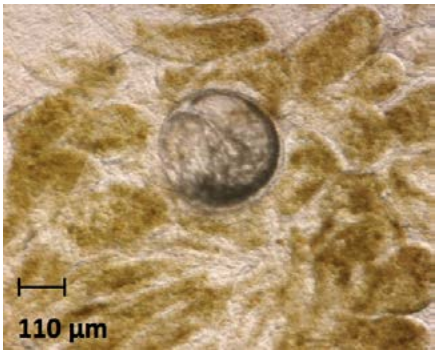
Advices

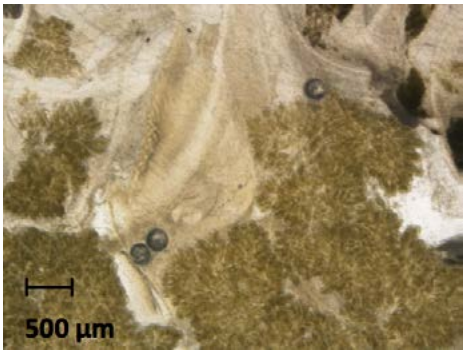
No action in nature conservation areas.

Relevant References

Loos-Frank 1971; Russell-Pinto 1990; Bowers et al. 1996; de Montaudouin et al. 2009; Gam et al. 2009; Fermer et al. 2009, 2010, 2011.

LATIN NAME ***Psilostomum brevicolle*** (Cobbold, 1859)
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda – Psilostomidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=108833)





General Description

Psilostomum brevicolle needs 3 different hosts to accomplish its complete life cycle (mudsnail *Peringia* sp., cockle and seagull). In the cockle (2nd intermediate host), metacercariae are large and dark, and generally infect the digestive gland. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 30 per cockle.

Individual Pathogenicity

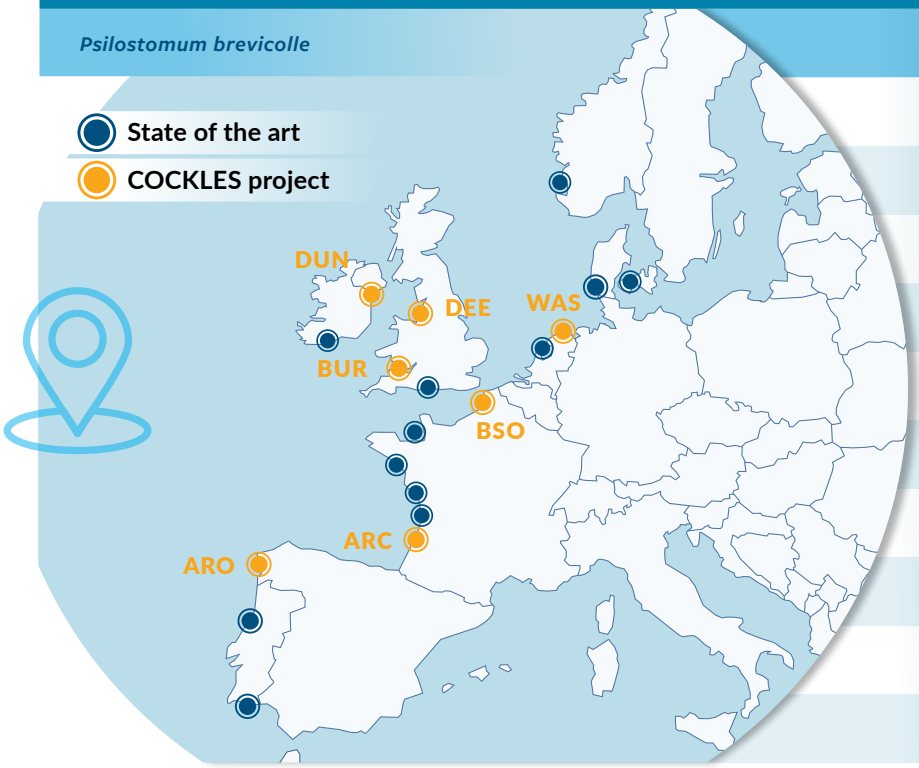
No reported effect.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Psilostomum brevicolle



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	48	0.7
ARO	10	0.1
AVE	0	0.0
BSO	10	0.1
BUR	15	0.2
DEE	10	0.1
DUN	5	0.1
FOR	0	0.0
NOI	0	0.0
WAS	40	0.8

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes** Accession numbers: MT019831 (*COI*), MN876027 (*ITS1*), MN879356 (*18S*).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:**[4], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown risk.
- **Related to trading:** Low risk within AA because it is already present everywhere. It is rather a Northern parasite but has been also found up to 22°N.
- **Global change:** Change of temperature can modify host dispersion and infection success.

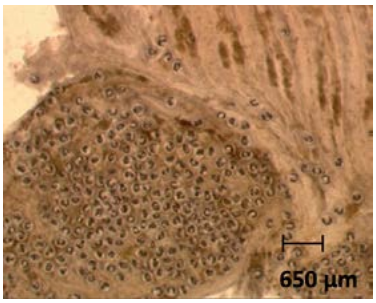
Advices

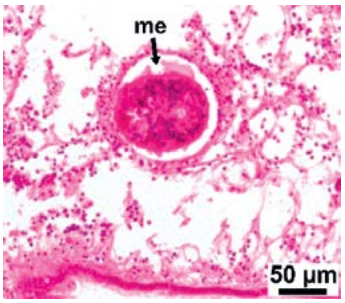
No action in nature conservation areas.

Relevant References

Loos-Frank 1968; de Montaudouin et al. 2009.

LATIN NAME ***Renicola roscovitus*** **(Stunkard, 1932)**
SYNONYMS *Cercaria roscovita, R. roscovita*
COMMON NAME None
CLASSIFICATION Trematoda – Renicolidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=109106)





General Description

Renicola roscovitus needs 3 different hosts to accomplish its complete life-cycle (periwinkle *Littorina littorea*, bivalves including cockle and seagull). In the cockle (2nd intermediate host), metacercariae have a thick cyst, and generally infect the palps. Juvenile and adult cockles can be infected, and metacercariae abundance can reach 100 per cockle.

Individual Pathogenicity

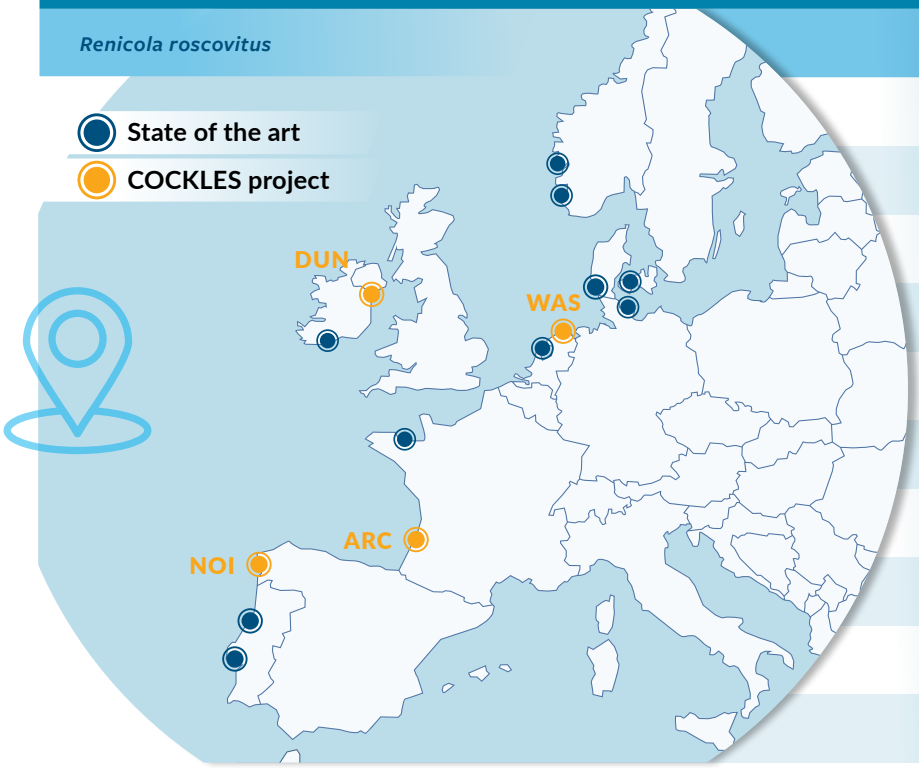
Reported effects on mussel growth.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)

Renicola roscovitus



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	8	0.1
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	3	0.03
FOR	0	0.0
NOI	3	0.2
WAS	3	0.1

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Genes Accession number:** No sequences available in Genbank.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:**[4], [11], [17], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown risk.
- **Related to trading:** Risk within AA because it is absent/rare in southern areas.
- **Global change:** Change of temperature can modify host dispersion and infection success.

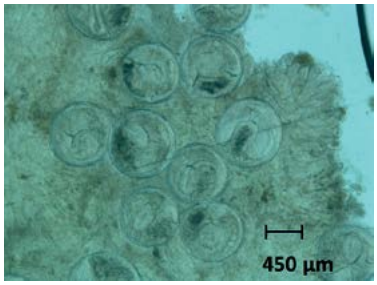
Advices

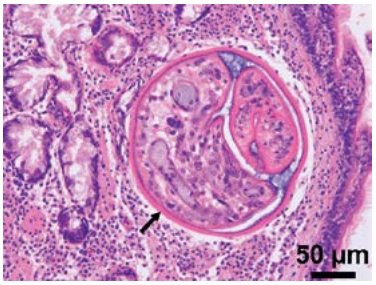
No action in nature conservation areas.

Relevant References

Werding 1969; Thieltges 2006; de Montaudouin et al. 2009; Stier et al. 2015.

LATIN NAME **Unknown**
SYNONYMS None
COMMON NAME None
CLASSIFICATION Trematoda





General Description

These large metacercariae have been found only in cockles from Arousa. They are mostly distributed in the digestive gland. The cyst seems fragile (center photo: excysted metacercariae). The highest observed intensity was 100 metacercariae in a cockle.

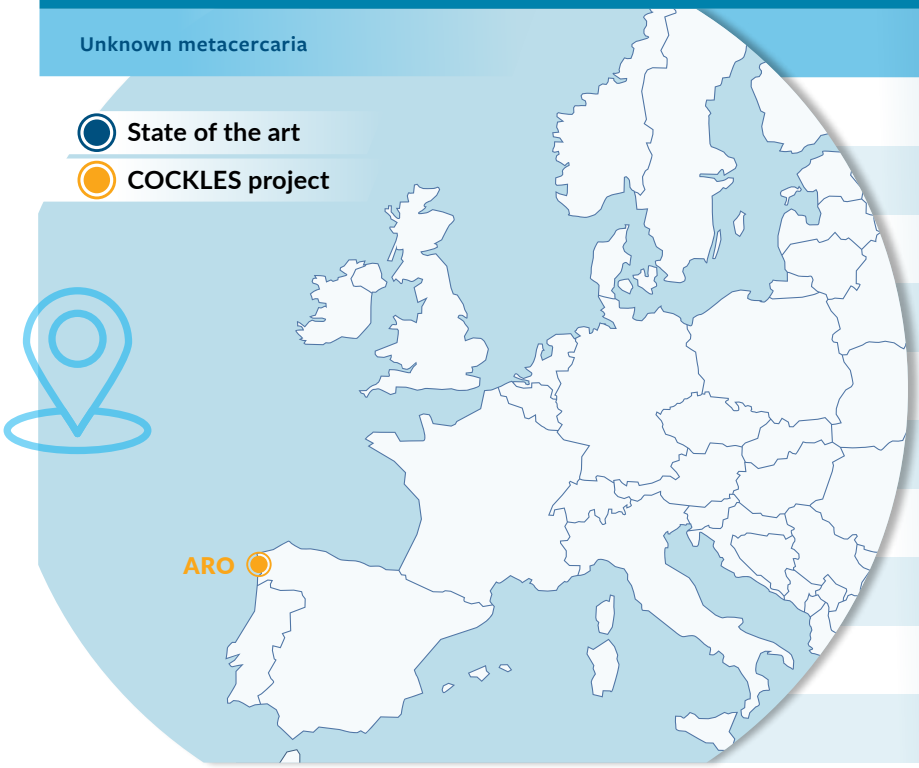
Individual Pathogenicity

No reported effect.

Populational Pathogenicity

No reported effect.

Distribution Map in the Atlantic Area (signalisation)



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	45	7.1
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect encysted metacercariae.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [17].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown risk.
- **Related to trading:** Risk within AA because it seems absent everywhere except Arousa.
- **Global change:** Change of temperature can modify host dispersion and infection success.

Advices

No action in nature conservation areas.
Avoid transfer of cockles in other areas.

Relevant References

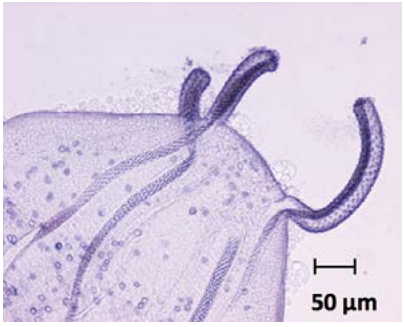
None.

LATIN NAME

SYNONYMS

COMMON NAME None

CLASSIFICATION Cestoda – Trypanorhyncha
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=104922)



General Description

These tentaculo-neoplerocercoide larvae of cestode utilizes the cockle as intermediate host and a finfish as final host. In Arcachon bay, only 3 infested cockles were found out of 6000 dissected cockles within a 20-yr survey. The parasite larvae was in the foot of cockles > 24 mm. No cyst.

Individual Pathogenicity

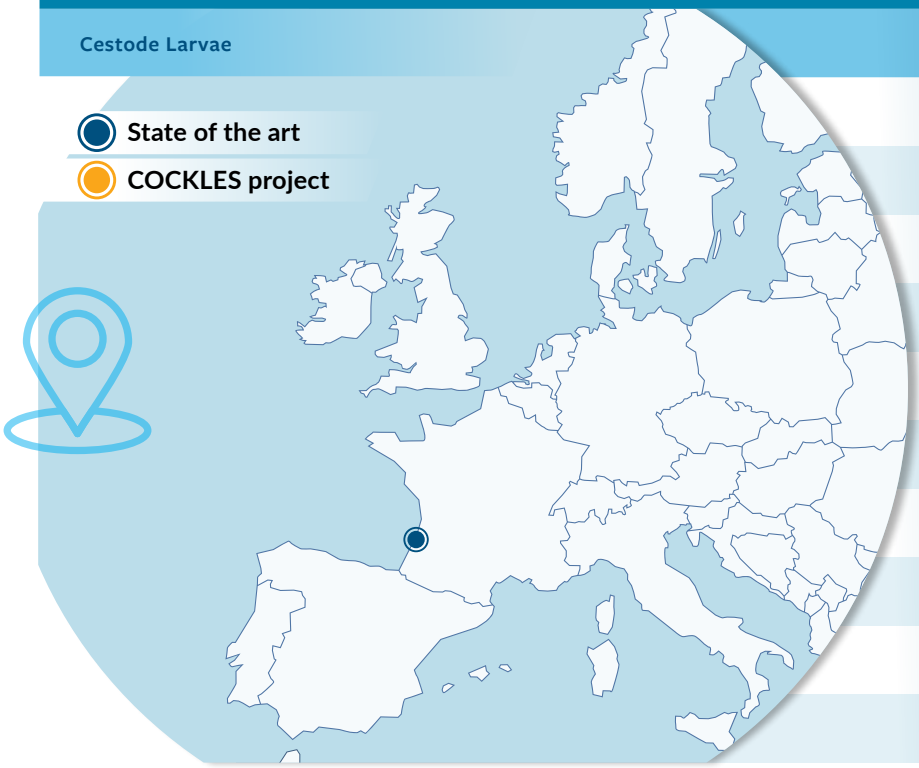
No reported effect.

Populational Pathogenicity

No reported effect and extremely low prevalence.

Distribution Map in the Atlantic Area (signalisation)

Cestode Larvae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect larvae but difficult species identification.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** None.

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk. Very rare.
- **Related to trading:** Little risk within AA because it is very rare.
- **Global change:** Change of temperature can modify host dispersion and infection success.

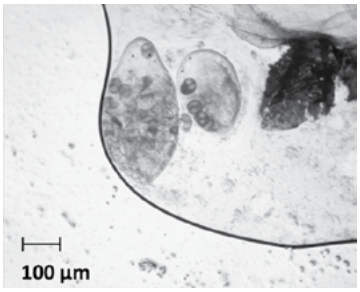
Advices

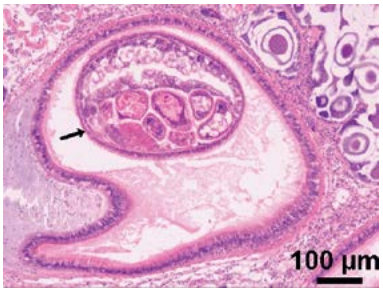
No action in nature conservation areas.

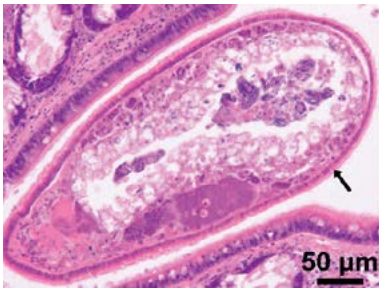
Relevant References

Lauckner 1983.

LATIN NAME ***Paravortex cardii*** Hallez, 1908
SYNONYMS *Proderostoma cardii*
COMMON NAME None
CLASSIFICATION Turbellaria – Graffillidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=142976)







General Description

These flatworms undergo their whole life-cycle in the gut of cockles. Frequently, they enclosed developing embryos. They could be commensals rather than parasites because pathological effects on the cockle are not evident. Infestation among cockles is believed to be horizontal. They can be hyperparasitized by *Urosporidium* sp.. Juveniles cockles (4-mm shell length) and older can be hosts.

Individual Pathogenicity

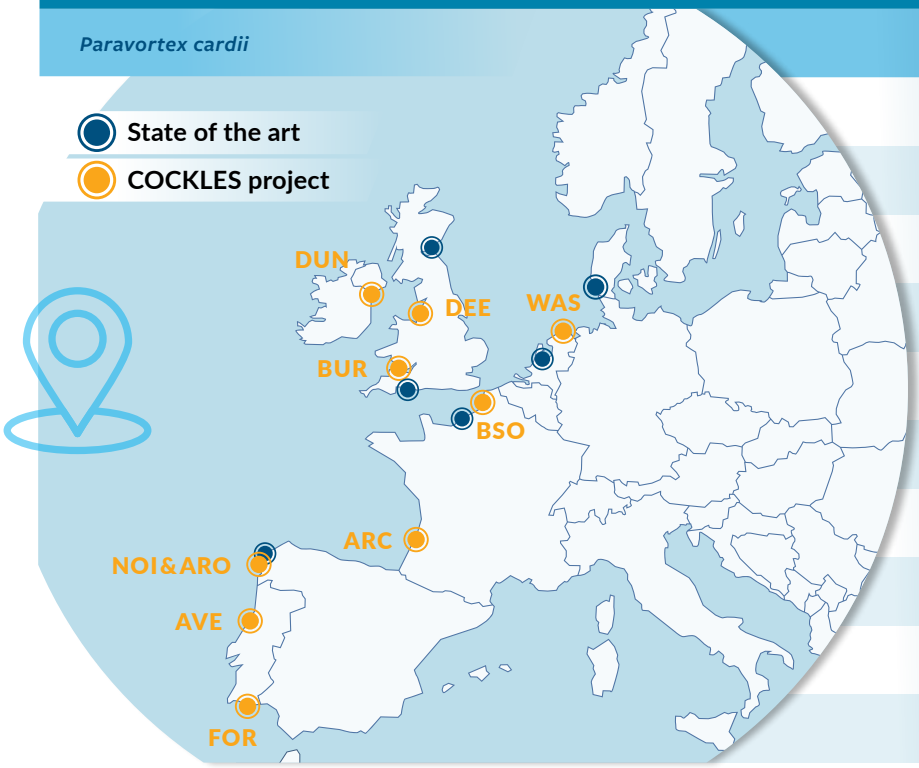
No evident detrimental effect.

Populational Pathogenicity

No evident detrimental effect.

Distribution Map in the Atlantic Area (signalisation)

Paravortex cardii



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	25	-
ARO	57	-
AVE	38	-
BSO	55	-
BUR	33	-
DEE	30	-
DUN	18	-
FOR	25	-
NOI	17	-
WAS	23	-

Diagnosis Techniques

- **Histology:** These Platyhelminthes appear as ciliated ovoid metazoans, showing two eyes in favourable sections. One or two individuals were frequently seen per histological section. Neither host injury nor host haemocytic reaction is observed.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. Two eyes are clearly visible.
- **Genes Accession number:** None.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [4], [15], [17], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk.
- **Related to trading:** No risk.
- **Global change:** No risk.

Advices

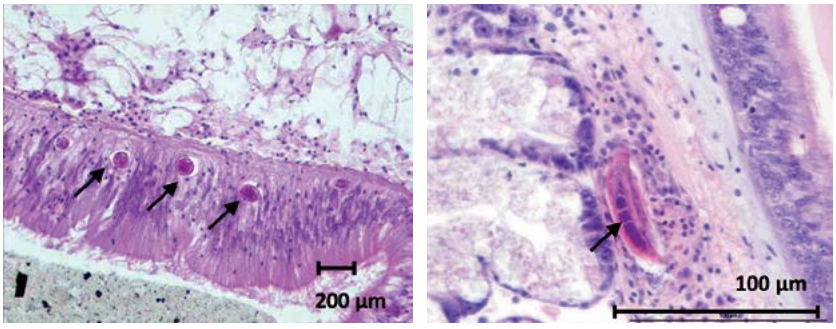
No action.

Relevant References

Atkins 1934; Carballal et al. 2001; Thieltges et al. 2006; Gam et al. 2008.

NEMATODA

LATIN NAME
SYNONYMS
COMMON NAME None
CLASSIFICATION Nematoda



Photos by M. Longshaw, cockles from Burry Inlet.

General Description

Observed in Formosa. Infestation by nematodes seems fluctuating, since prevalence was 20% in February 2018 and null in November. The maximal intensity was 7 nematodes in a single cockle, rather in the digestive gland. Unidentified nematodes were also reported in cockles from the Wadden Sea.

Individual Pathogenicity

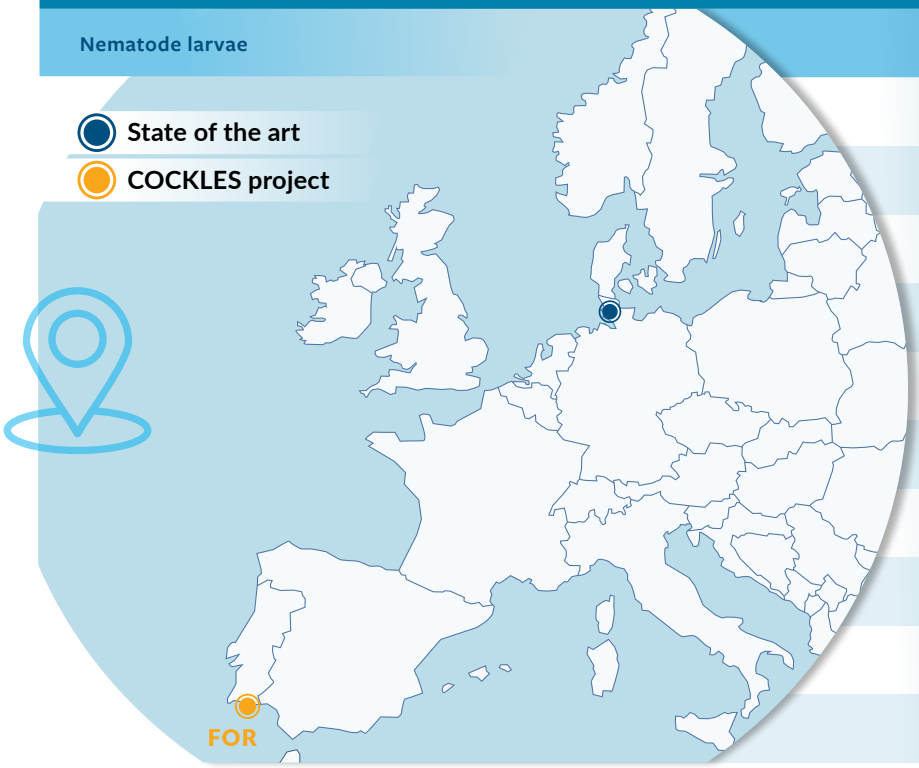
No available data, but considering the large size (up to 1 cm) and the abundance in the digestive gland, pathological effects are expected.

Populational Pathogenicity

There are not previous reports of nematodes infecting cockles. They were detected in one location only in the context of COCKLES surveys with no association of abnormal cockle mortality.

Distribution Map in the Atlantic Area (signalisation)

Nematode larvae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	10	0.2
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect larvae.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** None.

Risks in the Atlantic Area (AA)

- **Actual situation:** No risk.
- **Related to trading:** No risk..
- **Global change:** No risk.

Advices

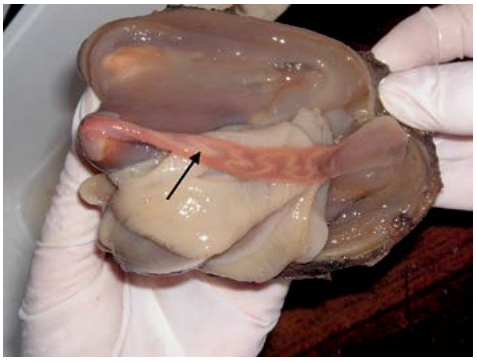
No action in nature conservation areas.

Relevant References

Thieltges et al. 2006; Longshaw & Malham 2013.

NEMERTEA

LATIN NAME ***Malacobdella grossa*** **(Müller, 1776)**
SYNONYMS Hirudo grossa
COMMON NAME None
CLASSIFICATION Nemertea – Malacobdellidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=122641)



Malacobdella arrokeana in the geoduck clam *Panopea abbreviata* (courtesy of N.N. Vásquez, C. Ituarte, F. Cremonte).

General Description

This endocommensal of the mantle cavity was not observed in COCKLES project. Infection is null for cockle shell < 15 mm but can increase to 100% for adults. The size of this worm ranges between 6 and 18 mm.

Individual Pathogenicity

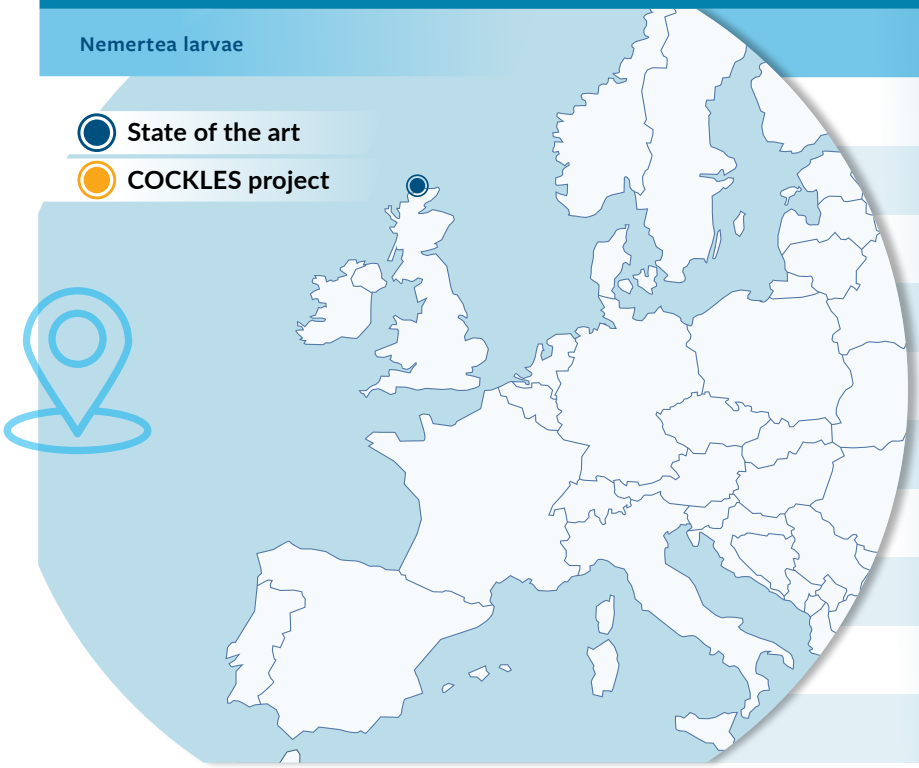
No reported effect.

Populational Pathogenicity

Except local signalisation, prevalence is very low and no detrimental effect is reported.

Distribution Map in the Atlantic Area (signalisation)

Nemertea larvae



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect larvae.
- **Dissection:** Squeeze between two thick glass slides, under stereomicroscope. However, it can be detected with naked eye.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** None.

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown.
- **Global change:** Unknown.

Advices

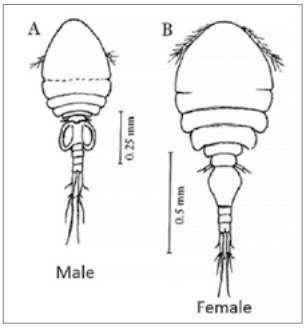
No action in nature conservation areas.

Relevant References

Jones et al. 1979.

ARTHROPODA

LATIN NAME ***Herrmannella rostrata*** **Canu, 1891**
SYNONYMS *Paranthessius rostratus*
COMMON NAME None
CLASSIFICATION Copepoda – Lichomolgidae
(WoRMS link: http://marinespecies.org/aphia.php?p=taxdetails&id=128864)



General Description

Herrmannella rostrata is a parasitic (or commensal?) crustacean undergoing 6 larval stages (naupliar), 5 juvenile stages (copepodit) and a single adult stage. Nauplii are planktonic. Their development time lasts ~ 2 weeks to the first copepodit stage. Parasitic stages correspond to copepodit and adult forms, and are localized in the pallial cavity, often close to the mantle and gills. This is a gonochoric species. Eggs are enclosed within two sacs attached to the female's abdomen until hatching. Female: ~1.2 mm; male: ~0.85 mm.

Individual Pathogenicity

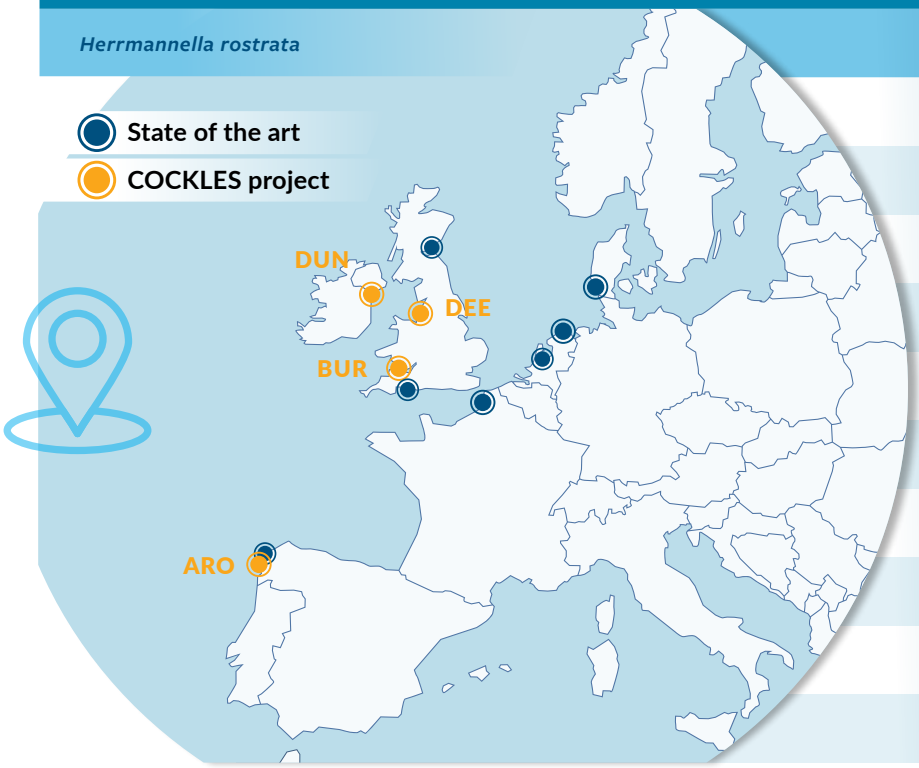
No identified pathology.

Populational Pathogenicity

No detrimental effect as a result of *Herrmannella rostrata* infections has been reported.

Distribution Map in the Atlantic Area (signalisation)

Herrmannella rostrata



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	7	0.3
AVE	0	0.0
BSO	0	0.0
BUR	33	0.8
DEE	13	0.3
DUN	23	0.8
FOR	0	0.0
NOI	0	0.0
WAS	0	0.0

Diagnosis Techniques

- **Histology:** Possible to detect but difficult species identification.
- **Dissection:** General morphology using dissecting microscope. Species determination: dissection of swimming legs and squeeze between two thick glass slides under microscope.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [4], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** Very low prevalence.
- **Related to trading:** No risk within AA.
- **Global change:** Temperature and host dispersion.

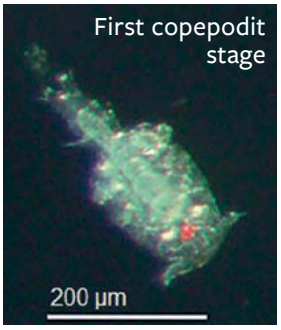
Advices

No action in nature conservation areas.

Relevant References

Fraser 1932; Monod & Dollfus 1932; Atkins 1934; Stock 1993; Diaz et al. 2011; Longshaw & Malham 2013.

LATIN NAME ***Mytilicola orientalis*** Mori, 1935
SYNONYMS None
COMMON NAME None
CLASSIFICATION Copepoda – Mytilicolidae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=128901)



General Description

It has a direct life cycle with a free-living larvae stage which spends 2-3 weeks in the water column. After development into the first copepodit stage it infects its bivalve host by ingestion. Inside the host the parasite attaches to the gut wall and resides in the intestines of its host. The smallest cockle infected with the parasite was 18 mm. *Mytilicola orientalis* is invasive and predominantly occurs in oysters (*Crassostrea gigas*) and mussels (*Mytilus edulis*). *Mytilicola orientalis* is morphologically hard to distinguish from *Mytilicola intestinalis*, which only occurs in mussels (*Mytilus edulis* and *M. galloprovincialis*).

Individual Pathogenicity

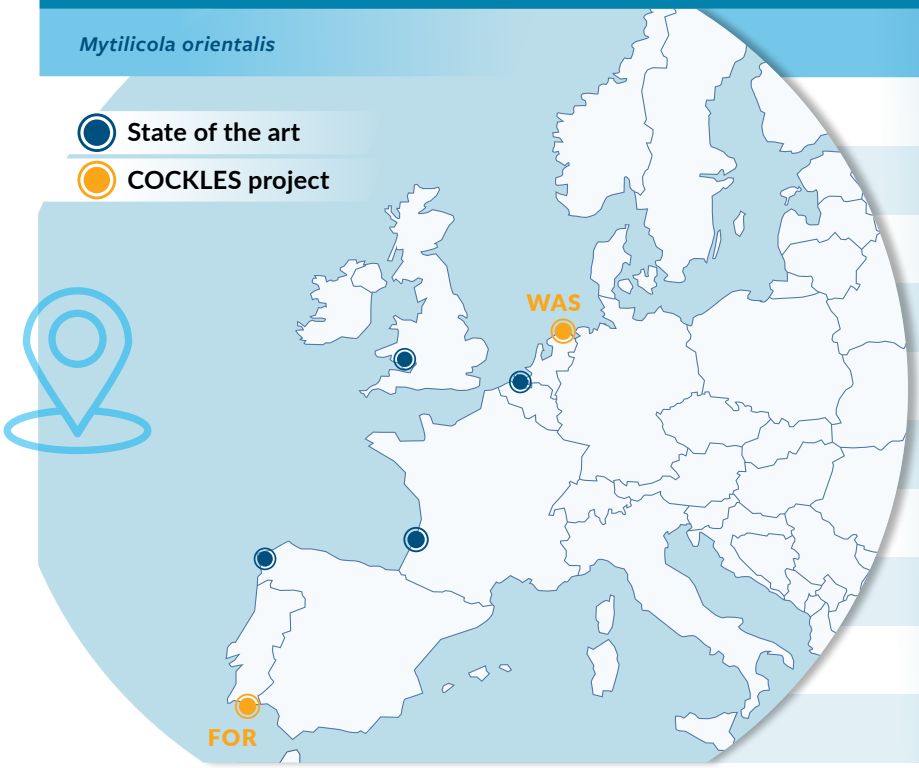
Localized pathology (metaplasia), limited effect on survival.

Populational Pathogenicity

Prevalence is generally low (< 15%) and no mass mortality as a result of *Mytilicola orientalis* infections has been reported.

Distribution Map in the Atlantic Area (signalisation)

Mytilicola orientalis



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	0	0.0
ARO	0	0.0
AVE	0	0.0
BSO	0	0.0
BUR	0	0.0
DEE	0	0.0
DUN	0	0.0
FOR	3	0.03
NOI	0	0.0
WAS	8	0.2

Diagnosis Techniques

- **Histology:** Possible to detect sections of *Mytilicola* in the digestive tissue, but impossible to identify on species level.
- **Dissection:** Squeeze between two thick glass slides, under binocular (x 10-30 magnification).
- **Genbank Accession numbers:** *COI* (HM775191-HM775197), *18S* (HM775190.1).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [4], [A].

Risks in the Atlantic Area (AA)

- **Actual situation:** Very low.
- **Related to trading:** This is an invasive species, trading increases the risk of spreading the species.
- **Global change:** Temperature and host dispersion (by trading).

Advices

No action.

Relevant References

Bernard 1969; Goedknegt et al. 2017, 2018; Mori 1935.

LATIN NAME ***Afropinnotheres monodi*** Manning, 1993
SYNONYMS *Pinnotheres pisum* (Linnaeus, 1767)
COMMON NAME African pea crab
CLASSIFICATION Decapoda – Pinnotheridae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=241175)

General Description

Afropinnotheres monodi presents 3 different phases in its life-cycle, (1) planktonic free phase as larval stages, its main dispersive phase; (2) males and hard females, facultative symbionts of bivalves, that can swim in the water column and also live inside different hosts; (3) soft females, mature females that are obligate symbionts of bivalves, mainly mussels. In cockles, the males and hard females stages are frequent, and are their primary host, but soft females only in a low proportion.

Individual Pathogenicity

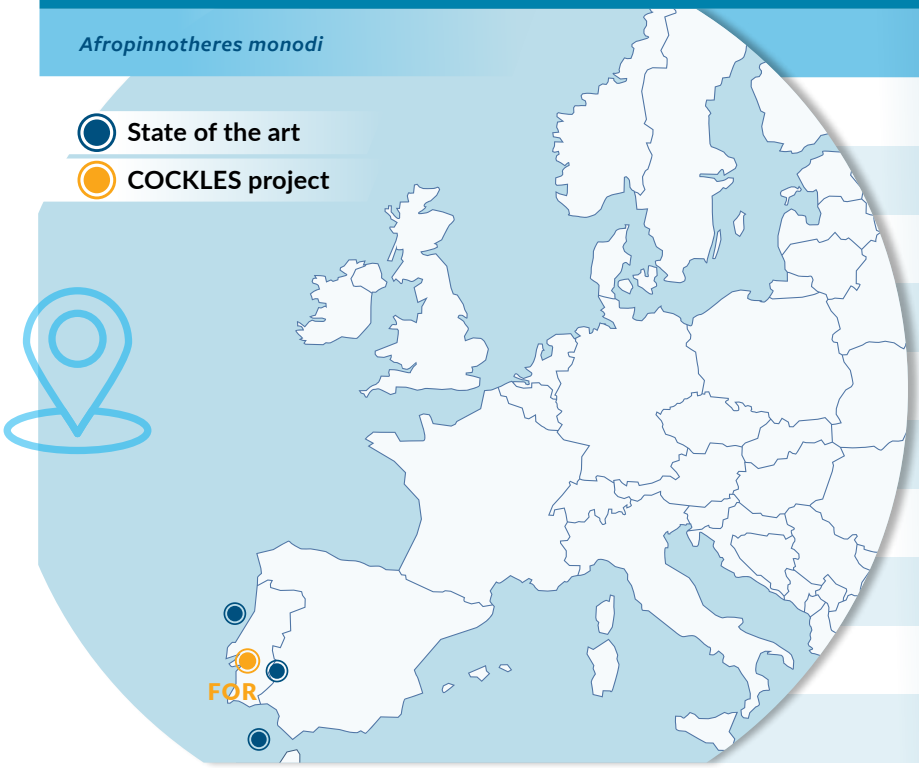
Mainly males and hard females use cockles as primary host. They are situated close to gills, with partial negative effect on cockle growth, condition and survival. Major negative effects occur when cockles are infected by soft females or more than one crab.

Populational Pathogenicity

Prevalence varies, depending on zone or period, from low (< 1%) to high (90-100%). No mortality has been reported related to African pea crabs in the field.

Distribution Map in the Atlantic Area (signalisation)

Afropinnotheres monodi



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	-	-
ARO	-	-
AVE	-	-
BSO	-	-
BUR	-	-
DEE	-	-
DUN	-	-
FOR	100	1.1
NOI	-	-
WAS	-	-

Diagnosis Techniques

- External morphology allows identification. A key for identification of European pea crabs is available at Perez-Miguel et al. (2019).
- **Genes Accession numbers:** *16S* (KT364714, KT364713), *COI* (MF134397), *H3* (KU679740), *12S* (KU679462), *16S+tRNA Leu+NADH1* (KU679625).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [B].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence has been observed in cockles (primary host) at Ria Formosa (cases of 100% prevalence), as well in other hosts like *Mytilus galloprovincialis* (Perez-Miguel et al., 2019).
- **Related to trading:** Risk of transferring infected bivalves (mainly cockles, clams and mussels) from Gulf of Cádiz to other areas within AA.
- **Global change:** High temperature does not strongly affect this species.

Advices

No action.

Relevant References

Perez-Miguel et al. 2018, 2019, 2020; Cuesta et al. 2020.

LATIN NAME ***Pinnotheres pisum*** **(Linnaeus, 1767)**
SYNONYMS *Cancer nutrix Scopoli*, 1763
COMMON NAME Pea crab
CLASSIFICATION Decapoda – Pinnotheridae
(WoRMS link: http://www.marinespecies.org/aphia.php?p=taxdetails&id=107473)

General Description

Pinnotheres pisum presents three different phases in its life-cycle, (1) planktonic free phase as larval stages, its main dispersive phase; (2) males and hard females, facultative symbionts of bivalves, that can swim in the water column and also live inside different hosts; (3) soft females, mature females that are obligate symbionts of bivalves. In cockles, the males and hard females stages are frequent, but soft females only in a low proportion.

Individual Pathogenicity

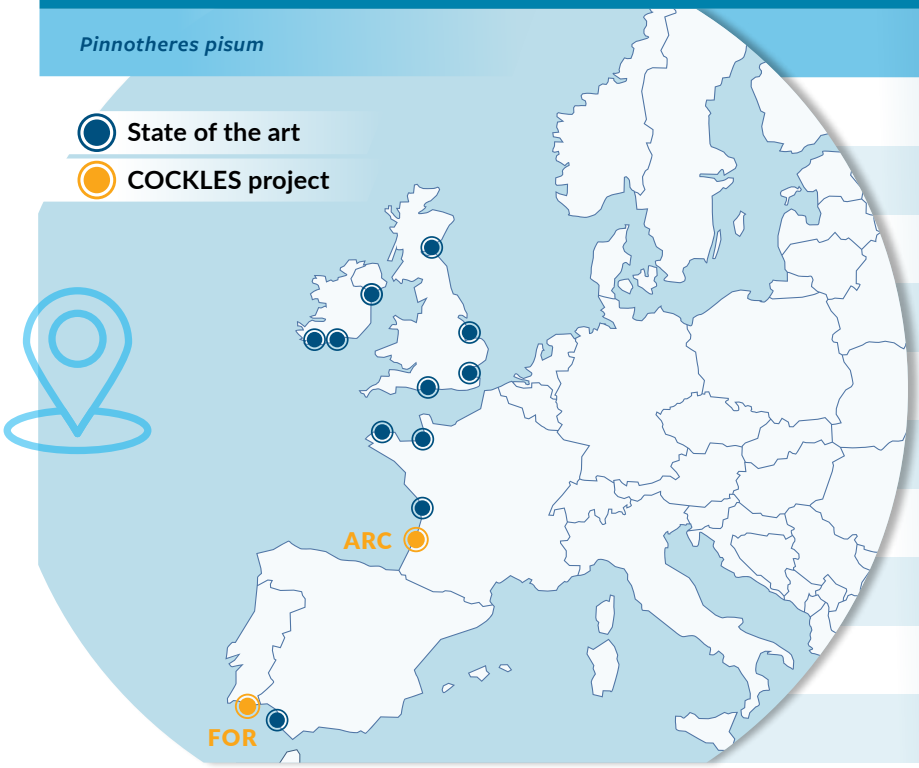
Mainly males and hard females use cockles as host. They are situated close to gills, with low negative effect on cockle growth, condition and survival. Major negative effects occur when infected by soft females or more than one crab.

Populational Pathogenicity

Prevalence varies, depending on zone or period, from low (< 1%) to high (90-100%). No mortality has been reported related to pea crabs.

Distribution Map in the Atlantic Area (signalisation)

Pinnotheres pisum



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	19	0.2
ARO	0	0
AVE	0	0
BSO	0	0
BUR	0	0
DEE	0	0
DUN	0	0
FOR	3	0.03
NOI	0	0
WAS	0	0

Diagnosis Techniques

- External morphology allows identification. A key for identification of European pea crabs is available at Perez-Miguel et al. (2019).
- **Genes Accession numbers:** *16S* (AF946024, MF069151, MH553295), *COI* (KF369177/78, KT208681, KT208972, KT209135, KT209256, KT209326, MG935227, MG935291), *H3* (KU679863/63), *12S* (DQ343272, KU679586/87), *16S+tRNA Leu+NADH1* (AM180694, KU679724/25).
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [B].

Risks in the Atlantic Area (AA)

- **Actual situation:** High prevalence has been observed in other hosts like *Mytilus edulis* (Becker, 2010).
- **Related to trading:** No risk within AA.
- **Global change:** High temperature affect this species that prefers colder waters.

Advices

No action.

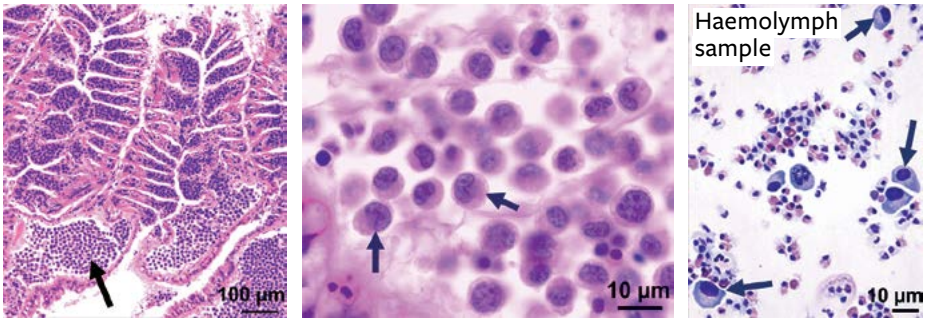
Relevant References

Haines et al. 1994; Becker 2010; Triay-Portella et al. 2018; Perez-Miguel et al. 2019.

OTHER DISEASES

DISEASE NAME **Disseminated neoplasia of cockles**

SYNONYMS Neoplastic disease, cockle cancer, leukemia-like disease



General Description

Disseminated neoplasia (DN) is a malignant type of neoplasia characterised by excessive, uncontrolled proliferation of abnormal cells invading the connective tissue and vessels of most organs, resembling leukaemia of vertebrates. Neoplastic cells are large, with very large, pleomorphic nuclei. Abundant mitotic figures occur in histological sections. DN is transmitted from sick cockles, which release cancerous cells that are "captured" by other cockles, in which the cancerous cells proliferate. Various contagious cancer cell clones have been identified. DN has been reported in cockles ranging from 10 to 40 mm in length, with the highest prevalence and severity in cockles of intermediate size/age. Cockle sex does not influence susceptibility to DN.

Individual Pathogenicity

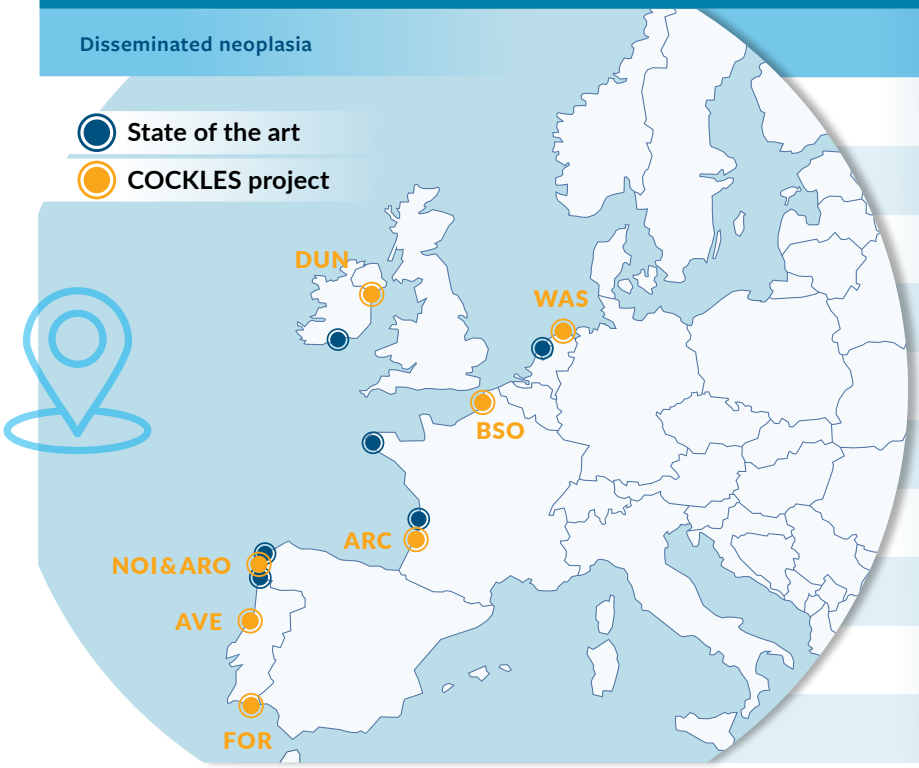
DN is a proliferative disease; the high mitotic ratio of the cancerous cells consumes much energy; the heavy infiltration of most organs by cancerous cells cause loss of their normal architecture and obliteration of vessels, leading to general dysfunction and, often, death. DN also reduces cockle fecundity due to inhibition of gametogenesis.

Populational Pathogenicity

DN may reach high prevalence in cockle populations and, owing to its lethal potential, cause high mortality in the affected beds.

Distribution Map in the Atlantic Area (signalisation)

Disseminated neoplasia



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	28	–
ARO	20	–
AVE	2	–
BSO	2	–
BUR	0	–
DEE	0	–
DUN	<1	–
FOR	7	–
NOI	18	–
WAS	2	–

Diagnosis Techniques

- **Histology and haemocitology:** Observation of neoplastic cells (with the above described features).
- **Immunoassays:** Detection of antibodies raised against specific antigens of the neoplastic cells.
- **Flow cytometry:** Detection of a significant proportion of cells with abnormal (mostly higher than normal, less frequently lower) DNA content.
- **Molecular techniques:** Cancer-related genes used as molecular markers of DN.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [5], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** High mortality events during DN epidemic outbreaks.
- **Related to trading:** Risk of transmission if cockles from affected areas are immersed into non-affected zones. No risk for human consumption.
- **Global change:** Unknown.

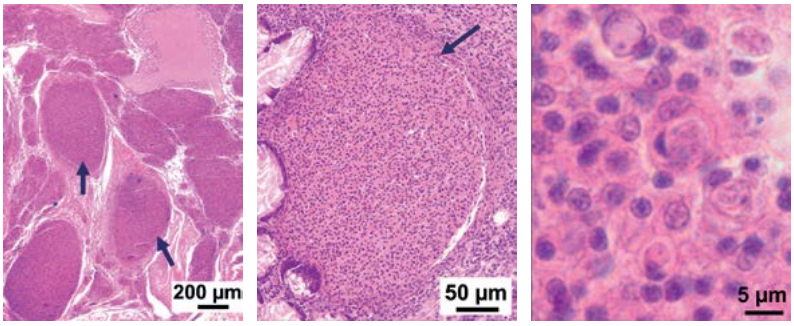
Advices

Cockles from areas known to be affected should not be transferred to areas with no record of disseminated neoplasia. Reduction of population densities in exploited beds could reduce DN transmission and epidemic outbreaks.

Relevant References

Twomey & Mulcahy 1984; Le Grand et al. 2010; Carballal et al. 2015; Díaz et al. 2016; Metzger et al. 2016; Díaz et al. 2017.

LATIN NAME **Granulomatosis**
SYNONYMS Large foci of heavy haemocytic infiltration
COMMON NAME None



General Description

Granulomatosis refers to a syndrome involving the occurrence of abundant large granulomas in most cockle organs (gills, gonad, digestive gland, kidney, heart, mantle, foot). Frequently, necrotic and apoptotic cells occur in the granulomas as well as haemocytes with phagocytosed cells. Granulomas result from heavy haemocytic reaction potentially associated by different stressing factors, such as pathogens, pollutants or adverse environmental conditions. The cause/s of cockle granulomatosis has not been stated yet. The heavy inflammation causes loss of the normal architecture and destruction of tissues and organs.

Individual Pathogenicity

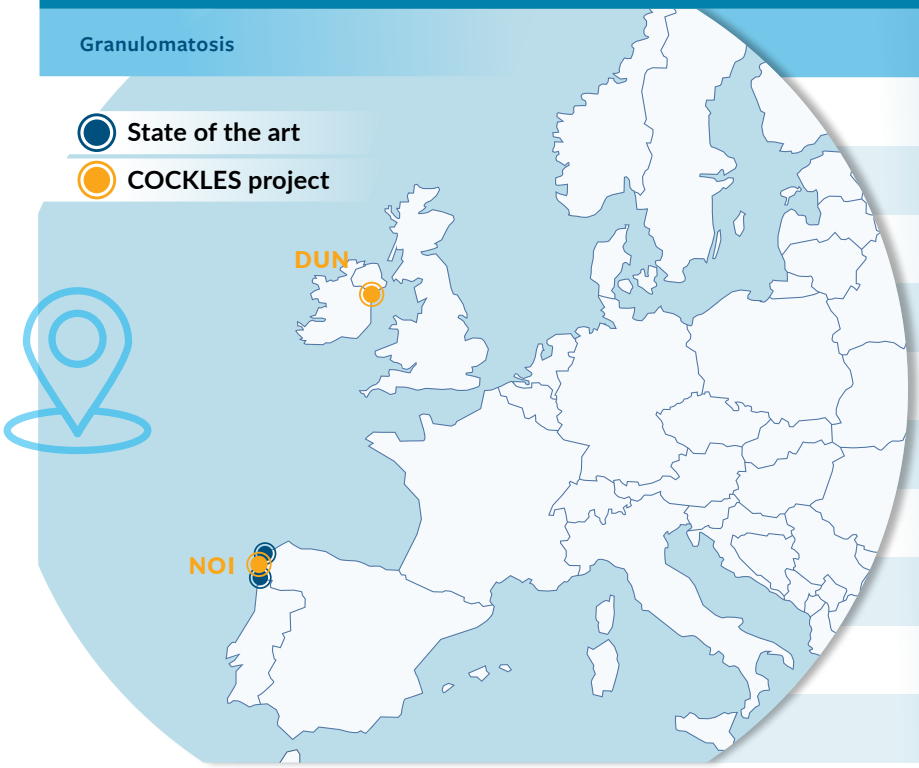
Granulomatosis may involve extensive destruction of tissues and organs, thus causing severe detrimental effect on the cockle.

Populational Pathogenicity

Granulomatosis may reach high prevalence in some cockle beds, associated with high cockle mortality.

Distribution Map in the Atlantic Area (signalisation)

Granulomatosis



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)

SITE	%	Ab
ARC	-	-
ARO	0	-
AVE	-	-
BSO	-	-
BUR	-	-
DEE	-	-
DUN	34	-
FOR	-	-
NOI	7	-
WAS	-	-

Diagnosis Techniques

- **Histology:** Abundant large granulomas are observed in various organs (gills, gonad, digestive gland, kidney, heart, mantle, foot) of the cockle.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [15], [20], [D].

Risks in the Atlantic Area (AA)

- **Actual situation:** High mortality when the prevalence of granulomatosis is high.
- **Related to trading:** Unknown, because the cause/s have not been stated yet.
- **Global change:** Unknown.

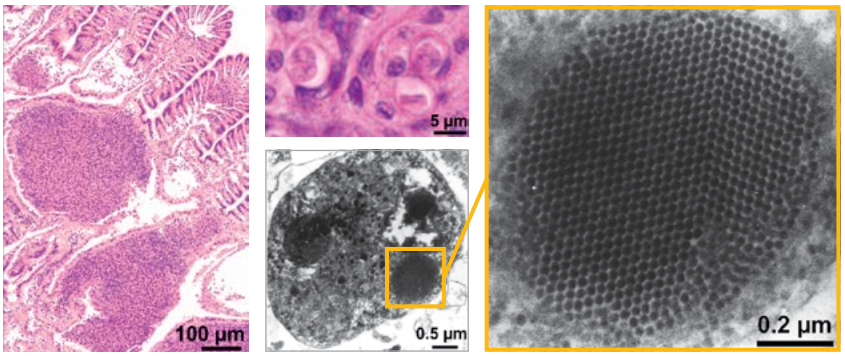
Advices

Research is required to state the cause/s of this syndrome before any possibility of advising.

Relevant References

Carballal et al. 2001; Villalba et al. 2001; Carballal et al. 2003.

LATIN NAME **Picornaviral-like infection associated with granulomatosis**
SYNONYMS None
COMMON NAME None



General Description

Virus-like particles in paracrystalline arrays (VPCA) were observed in the cytoplasm of free and phagocytosed cells, both within abundant large granulomas occurring in the visceral mass and the foot of cockles. The VPCAs were unenveloped, with icosahedral capsid, and measured 19 to 21 nm in length. The morphology of the VPCA and staining of intracytoplasmic inclusions compatible with RNA content suggest the VPCAs correspond to picornaviridae. It is not known whether the granulomas are directly caused by the viral-like infection or the virus is a secondary invader taking advantage of cockle weakness due to granulomatosis.

Individual Pathogenicity

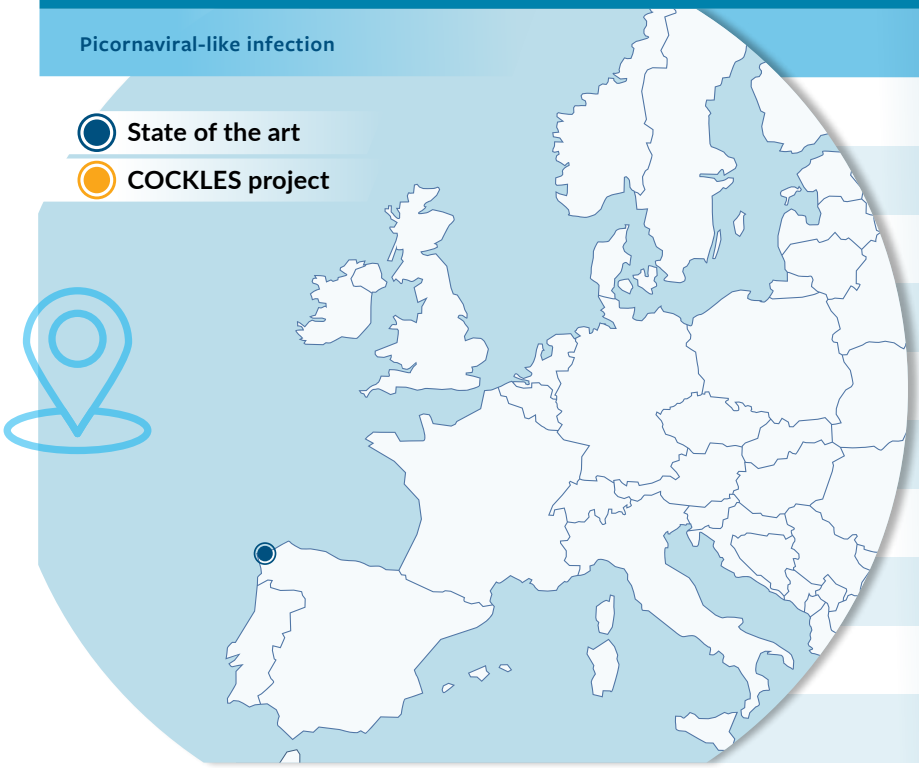
Granulomatosis causes deep detrimental effect on the cockle. Granulomas are non-specific lesions that can be induced by multiple factors other than viral infections. It is not known if granulomatosis is directly caused by the picornaviral-like infection.

Populational Pathogenicity

Granulomatosis is a highly prevalent condition in some cockle beds associated with high mortality. However, the percentage of cases of granulomatosis directly caused by the picornaviral-like infection is unknown.

Distribution Map in the Atlantic Area (signalisation)

Picornaviral-like infection



Parasite Prevalence (%) and Mean Abundance (Ab) (COCKLES project data)*

SITE	%	Ab
ARC	-	-
ARO	-	-
AVE	-	-
BSO	-	-
BUR	-	-
DEE	-	-
DUN	-	-
FOR	-	-
NOI	-	-
WAS	-	-

*Not evaluated in COCKLES; TEM is required.

Diagnosis Techniques

- **Histology:** It is a non-resolutive procedure to detect the picornaviral-like infection. Transmission electron microscopy is required to detect the viral particles. Histology just shows the occurrence of abundant large granulomas in the visceral mass and foot of the cockle.
- **Expertise laboratories/Contacts in the COCKLES AA consortium:** [2], [15].

Risks in the Atlantic Area (AA)

- **Actual situation:** Unknown.
- **Related to trading:** Unknown.
- **Global change:** Unknown.

Advices

Research is required to understand the relevance and dynamics of the picornaviral-like infection before any possibility of advising.

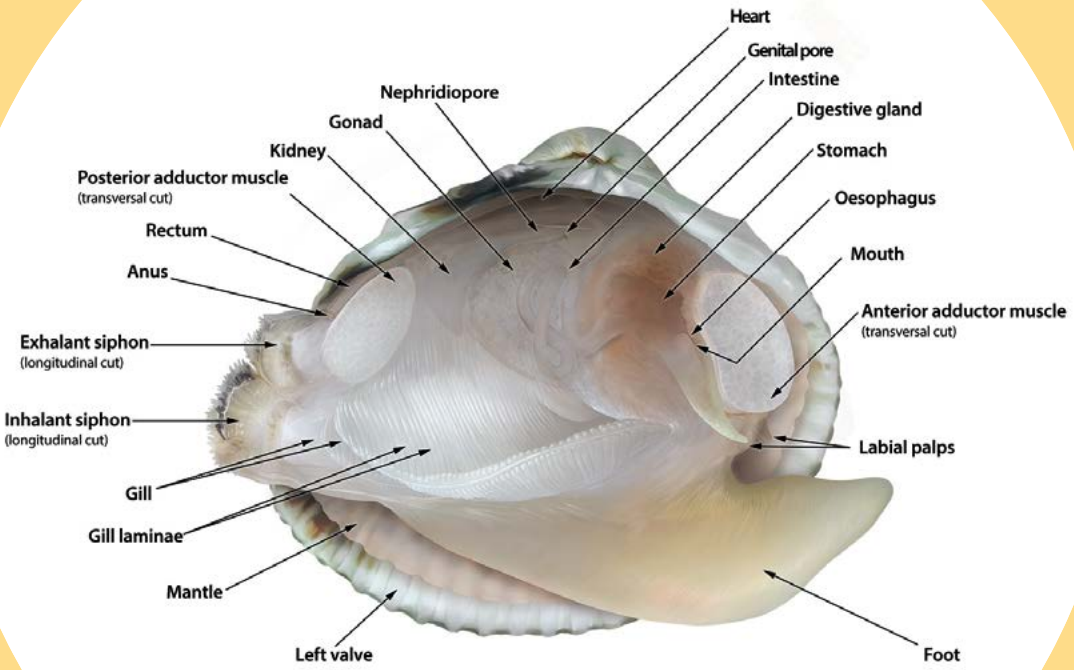
Relevant References

Carballal et al. 2003.

CONCLUSION – RISKS IN THE ATLANTIC AREA SITES

Pooling COCKLES project and state of the art data, the infectious risks for cockle populations at the COCKLES sites have been hierarchized from low to high risk (right side), according to the presence of pathogens and diseases (left side), also classified from innocuous to deleterious. Each parasite/disease is numbered and this number is used to list parasites/diseases reported in each site. Red numbers correspond to confirmed deleterious parasites/diseases.

Cockle Anatomy



5 mm

GLOSSARY

Abundance – The number of parasite individuals in a host. "Mean abundance" is the mean number of parasites per host in the host population.

Apoptosis – Cell death as a result of activation of an intracellular "suicide" programme that occurs in multicellular organisms. It is a normal and essential event. In contrast to necrosis, apoptosis is a highly regulated and controlled process that confers advantages during an organism's life cycle. Apoptosis does not lead to cell lysis and thus avoids damage to neighbouring cells.

Basophillic – Staining strongly with basic dyes (histological technique).

Binucleate – Having two nuclei.

Branchia (plural: branchiae) **–** Technical name of the gills.

Cercaria (plural cercariae) **–** Larval free-living stage of a trematode produced in the first intermediate mollusc host.

Cilium (plural: cilia) **–** Motile hair-like outgrowth present on the surface of many eukaryotic cells, which makes whip-like beating movements and produces a flow of material over the cell surface.

Commensalism – A relationship between individuals of two species in which one species obtains food or other benefits from the other without either harming or benefiting the latter.

Complex life cycle – A life cycle of a parasite with more than one host species.

Conchiolin – The protein component of ligaments and external layer of mollusc shells.

Connective tissue – Tissue found between other tissues everywhere in the body, providing support, binding together, and protecting tissues and organs. It consists of three main components: fibers, ground substance and cells.

Copepodit – Juvenile stage of the copepods that gives rise to the adult by successive moulting through various intermediate steps; usually five copepodit stages (from I to V) occur before arising the adult stage.

Cyst – (1) A closed sac, usually spherical, surrounding an organism that has passed into a dormant condition. (2) Such a sac plus the contained organism. (3) A capsule or resistant covering.

Cytoplasm – All the living part of a cell inside the cell membrane and excluding the nucleus.

Digestive gland – Organ of the digestive apparatus in molluscs and other invertebrates that produces digestive enzymes and in which food is digested. It is also called hepatopancreas or digestive diverticula. It consists of branching ducts arising from the stomach ending on blind "digestive tubules".

Emaciation – The state of being abnormally thin or weak.

Encysted – Said of organisms occurring within a cyst, that is to say surrounded by a close, usually, thick, resistant cover. The encysted stages frequently correspond to dormant stages in the life cycle of an organism.

Eosinophilic – Staining readily with eosin (Red/Brown acidic dye sodium or potassium salt of eosin).

Epithelium (plural: epithelia) **–** A type of tissue consisting of sheet/s of cells tightly bound together lining all external surfaces of organs and blood vessels through the body, as well as internal surfaces of cavities of many organs in multicellular animals.

Excysted – Said of organisms emerged from a cyst. Excystment usually requires appropriate environmental conditions and it involves transition from dormant to an active stage.

Flow cytometry – Technique for counting and distinguishing different types of cells in a mixed cell population. Cells in the mix are usually stained with fluorescent markers. A stream of labelled cells is then run through laser beams that detect fluorescence intensity and another optical parameters of each cell, thus counting the numbers of cells of each type. In the case of the diagnosis of disseminated neoplasia, a fluorescent marker specific for DNA is used in order to assess the percentage of cells with abnormal quantity of DNA in an haemolymph sample, because most cancer cells have higher (much less frequently lower) DNA content than normal cells.

Foot – Muscular organ of many bivalves; in those bivalves living buried in the sediment (including cockles), the foot is adapted for burrowing into the sediment.

Gametogenesis – Process by which diploid or haploid

precursor cells undergo cell division and differentiation to form mature haploid gametes.

Gill – Paired organ that in bivalve molluscs is specialized for feeding and breathing. Gills are frequently referred with the more technical term "branchiae". Gills are permeable, with holes (called ostia) and water tubes or channels, thus allowing seawater passing through, filtering the particles that are acceptable as food and rejecting those unacceptable, as well as performing the gas exchange (respiration). The branchial surface is covered with cilia that harmonically beat to create water currents; particles acceptable as food are conveyed to the labial pals and mouth, whereas non acceptable particles are rejected to the pallial cavity.

Granuloma – Structure produced in some inflammatory processes consisting of the accumulation of immune cells (haemocytes in the case of bivalve molluscs) attempting to wall off pathogens or harmful substances.

Haemocyte – Invertebrate blood cell.

Haemocytology – Set of procedures to examine the blood cells with light microscopy.

Hepatopancreas – See "digestive gland".

Heteroxenous – Said of parasites requiring more than one host species to complete their life cycle.

Host – (1) A living organism in which a parasite lives. (2) The larger, stronger, or dominant member of a commensal pair.

Hyperparasite – Organism which is a parasite of, or in, another parasite.

Immunoassay – Any qualitative or quantitative essay of a substance using its binding to specific antibody as the measuring technique.

Imprint – Mark made by pressuring a piece of an organ onto a slide for subsequent observation with a light microscope; it usually involves fixing and staining the mark. It is a quick and cheap procedure for diagnosis, particularly useful for some diseases.

Inflammation – Biological response of body tissues to harmful stimuli, such as pathogens, damaged cells, or irritants. It is a protective response, involving immune cells and molecular mediators, to eliminate the initial cause of cell injury, clear out necrotic cells and tissues damaged from the original insult and from the inflammatory process itself, and initiate tissue repair.

Inflammatory reaction – See "inflammation".

Labial palps – Organ consisting of protrusions of the mantle and located surrounding the mouth, nearby the end of the gills. Their internal surface consists of a succession of ridges and grooves covered with cilia that give continuity to the currents from the gills transporting food to the mouth; on that internal surface, food selection takes place, chaneling acceptable particles to the mouth and rejecting non-acceptable particles to the mantle cavity.

Lumen (plural: lumina) **–** The cavity or channel within a tube or tubular organ such as a blood vessel or the intestine.

Mantle – Organ of molluscs also called **pallium**: it is the body wall, below the shell, covering the visceral mass. In bivalve molluscs (including cockles) this wall protrudes in the form of flaps (called mantle lobes) well beyond the visceral mass itself, thus delimiting a cavity called mantle or pallial cavity also called mantle or pallial chamber.

Merogony – A type of asexually reproductive process of some protozoans by which a cell, called meront, increases in size while repeatedly dividing its nucleus and other organelles giving rise to a multinucleate structure; subdivision of that multinucleate structure gives rise to numerous identical daughter cells called merozoites.

Meront – A stage in the life cycle of some protozoans in which nucleus division as well as replication of other organelles occur, giving rise to a multinucleate structure.

Metacercaria (plural: metacercariae) **–** The stage in the life-cycle of endoparasitic trematodes that develops from a cercaria, in which the cercaria loses its tail (if present) after penetrating in the second intermediate host.

Metaplasia – Abnormal change in the nature of a tissue, which losses its original morphology becoming another tissue type.

Miracidium – Trematode larvae developing from the eggs which are produced and emitted out the final host, after sexual reproduction of these parasites.

Mitotic figure – Specific morphological features of a cell in the process of mitosis (cell division).

Mitotic ratio – The ratio of cells in the process of mitosis (cell division) to the total number of cells.

Moribund – An organism at the point of death.

Multinucleate – Having multiple nuclei.

Natural selection – Evolutionary process by which a character that is favourable under particular environmental circumstances becomes more frequent in a population when the population is exposed to such particular circumstances for a sustained period. For instance, sustained exposure to a disease may result in increasing percentage of disease-resistant individuals.

Nauplius (plural: nauplii) **–** One of the larval stages in the life cycle of many crustaceans; it is a zooplanktonic stage.

Necrosis – Death of cells or tissues as a result of external trauma such as physical damage or lack of oxygen. It results in cell lysis and damage to surrounding cells or tissues.

Neoplasia – Abnormally high proliferation of the cells of a tissue, uncoordinated with that of the normal surrounding tissue, that persists even if the original trigger disappears. Neoplasia is considered **benign** if the abnormally proliferating cells do not invade other tissues (do not spread to other parts of the body) and keep the original morphology of the tissue from which they derive. Neoplasia is considered **malignant** (synonym of **cancer**) if the abnormally proliferating cells invade other tissues and/or organs (spread through the body) and loss the original morphology of the tissue from which they derive, becoming poorly – or undifferentiated cells.

Nephridium (plural: nephridia) **–** Organ of invertebrates found in pairs and performing a function similar to the vertebrate kidney. Nephridia remove metabolic wastes from an animal's body.

Oocyst – Name given to the spore stage in the life cycle of some apicomplexan protozoans.

Ovocyte – Female germ cell in which meiosis occurs in animals. Female cockles release mature ovocytes from their gonads through spawning and, eventually, some ovocytes can be fecundated in the water column by spermatozoa released from male cockles.

Pallial cavity – Inner space of molluscs, particularly well delimited by the mantle in bivalves.

Parasite – Organism that for all, or some part, of its life derives its food or other kind of benefit from a living organism of another species (the host). It usually lives in or on the body or cells of the host, which is usually harmed to some extent by the association.

Parenchyma – Solid layer of tissue between muscle layer and guts in platyhelminths composed of many different types of cells.

Phagocytosis – Uptake of large solid particles (including other cells) into a cell by the process of endocytosis. It is seen e.g. in macrophages which ingest and destroy invading microorganisms and scavenge damaged and dying cells.

Planktonic – Said of organisms being part of **plankton**. Plankton is defined as the diverse collection of organisms that live in large bodies of water and are unable to swim against a current.

Plasmodium (plural: plasmodia) **–** Cell with more than one nucleus.

Pleomorphic – Occurring in various distinct forms. In terms of cells, having variation in the size and shape of cells or their nuclei.

Polar tube – Long structure coiled within spores of the microsporidians that, upon appropriate environmental stimulation, discharges out of the spore, pierces a cell membrane and serves as a conduit for sporoplasm passage into the new host cell.

Prevalence – The ratio of infected to total number of individuals in a population (or in a sample), usually expressed in percentage.

Protozoa (also protozoans) **–** Term generally applied to a large group of heterotrophic, non-photosynthetic, either free-living or parasitic, unicellular eukaryotes.

Redia – One of the larval stages in the life-cycle of

trematodes which develops from the miracidium in the first intermediate host. It has a mouth and a gut and multiplies asexually to produce cercariae.

Refringent – This term is used in histology referring to structures showing a particular, striking bright, due to their way of refracting light, different from the other visible structures.

Spore – Stage adapted for dispersal and for survival, often for extended periods of time, in unfavourable conditions in the life cycle of multiple organisms including many plants, algae, fungi and protozoa.

Sporoblast – Intermediate stage in the process of sporogony of some protozoans that will transform into spore.

Sporocyst – 1) One of the larval stages in the life-cycle of trematodes which develops from the miracidium in the first intermediate host. It has no mouth or gut and multiplies asexually to produce rediae or cercariae. 2) Stage of some protozoans in which spores are produced and from which, eventually, spores are released.

Sporogony – Proliferative process in the life cycle of some protozoa (Apicomplexa, Haplosporida,…) and some fungi (Microsporida,…), involving the production of spores. There are marked differences in the process between microorganism groups. In **Apicomplexa**, sporogony follows gametogony or gamete production; sporogony involves fusion of female and male gametes giving rise to a zygote, which becomes a resistant stage, the spore, frequently called "oocyst"; within the spore, multiple nuclear division followed by fission of the resulting multinucleate structure gives rise to multiple sporozoites, wich eventually are released from the spore and infect new hosts. In **Haplosporida**, sporogony involves the compartmentalisation of the cytoplasm of plasmodia in uninucleate areas surrounded by membrane, called sporoblasts; each sporoblast develops into a mature spore without further multiplication; the plasmodia involved in the sporogony process are called sporocysts. In **Microsporida**, sporogony follows merogony, and the meront cell membranes thicken forming sporonts; after dividing, sporonts give rise to sporoblasts that develop into mature spores without additional multiplication; the host cell becomes distended with mature spores, ruptures, and releases spores into the environment.

Sporont – Early stage in the process of sporogony of some protozoans that divides giving rise to sporoblasts.

Sporoplasm – Cytoplasm of a spore.

Sporozoite – Final stage in the sporogony of Apicomplexa protozoans, which are formed within spores and, once released, may infect new hosts.

Sporulation – The process of spore production.

Symbiosis – Close and usually obligatory association of two organisms of different species living together, not necessarily to their mutual benefit. Symbiosis, in its original sense, included the following types of association: parasitism, commensalism, mutualism and phoresis.

Umbo – The beak of a bivalve shell; the protuberance of each valve above the hinge.

Uninucleate – Having one nucleus.

Zooplanktonic – Said of organisms being part of zooplankton. The zooplankton is the portion of plankton comprising the heterotrophic (those that cannot produce their own food) organisms.

REFERENCES

1. *Rickettsia*-like & *Mycoplasma*-like

Azevedo C. et al. 1993. Occurrence of an unusual branchial mycoplasma-like infection in cockle *Cerastoderma edule* (Mollusca, Bivalvia). Diseases of Aquatic Organisms **16**:55-59.

Cano, I., D. Ryder, S. C. Webb, J. B. Jones, C. L. Brosnahan, N. Carrasco, B. Bordinier, D. Furones, T. Pretto, F. Carella, B. Chollet, I. Arzul, D. Cheslett, E. Collins, K. B. Lohrmann, A. L. Valdivia, G. Ward, M. J. Carballal, A. Villalba, I. Marigómez, S. Mortensen, K. Christison, K. C. Wakeman, E. Bustos, L. Christie, M. Green, and S. W. Feist. 2020. Cosmopolitan distribution of *Endozoicomonas*-like organisms and other intracellular microcolonies of bacteria causing infection in marine molluscs. Frontiers in Microbiology. DOI:10.3389/fmicb.2020.577481.

Carballal, M. J., D. Iglesias, J. Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**:87-97. DOI:10.1006/jipa.2001.5049.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**:227-247.

2. *Vibrio aestuarianus*

Garcia, C., A. Mesnil, D. Tourbiez, C. Dubreuil, A. Gonçalves de Sa, B. Chollet, Y. Godfrin, L. Degrémont, D. Serpin and M.A. Travers. 2021. Description of *Vibrio aestuarianus* subsp. *cardii* subsp. nov. pathogenic to the edible cockles, *Cerastoderma edule* in France and establishment of *Vibrio aestuarianus* subsp. *aestuarianus* subsp. nov. and *Vibrio aestuarianus* subsp. *francensis* subsp. nov..International Journal of Systematic and Evolutionary Microbiology. DOI:10.1099/ijsem.0.004654.

Saulnier, D., S. De Decker, and P. Haffner. 2009. Real-time PCR assay for rapid detection and quantification of *Vibrio aestuarianus* in oyster and seawater: A useful tool for epidemiologic studies. Journal of Microbiological Methods **77**:191-197. DOI:10.1016/j.mimet.2009.01.021.

Saulnier, D., S. De Decker, D. Tourbiez, and M.A. Travers. 2017. Development of a duplex Taqman real-time PCR assay for rapid identification of *Vibrio splendidus*-related and *V. aestuarianus* strains from bacterial cultures. Journal of Microbiological Methods **140**:67-69. DOI:10.1016/j.mimet.2017.07.002.

3. *Vibrio tapetis*

Bidault, A., G. G. Richard, C. Le Bris, and C. Paillard. 2015. Development of a Taqman real-time PCR assay for rapid detection and quantification of *Vibrio tapetis* in extrapallial fluids of clams. PeerJ 3:e1484 https://doi.org/10.7717/peerj.1484.

Borrego, J. J., D. Castro, A. Luque, C. Paillard, P. Maes, M. T. Garcia, and A. Ventosa. 1996. *Vibrio tapetis* sp nov, the causative agent of the brown ring disease affecting cultured clams. International Journal Of Systematic Bacteriology **46**: 480-484. DOI:10.1099/00207713-46-2-480.

Lassalle, G., X. de Montaudouin, P. Soudant, and C. Paillard. 2007. Parasite co-infection of two sympatric bivalves, the Manila clam (*Ruditapes philippinarum*) and the cockle (*Cerastoderma edule*) along a latitudinal gradient. Aquatic Living Resources **20** (1): 33-42. DOI:10.1051/alr:2007013.

Maes, P. and C. Paillard. 1992. Effect du Vibrio P1, pathogène de *Ruditapes philippinarum*, sur d'autres espèces de bivalves. Les Mollusques marins, Biologie et Aquaculture. Ifremer, Actes de Colloques **14**: 141-148. https://archimer.ifremer.fr/doc/00000/926/

Paillard, C., S. Gausson, J.-L Nicolas, J. P. le Pennec, and D. Haras. 2006. Molecular identification of *Vibrio tapetis*, the causative agent of the brown ring disease of *Ruditapes philippinarum*. Aquaculture **253** (1-4): 25-38. DOI:10.1016/j.aquaculture.2005.03.047.

Park, K.I., C. Paillard, P. Le Chevalier, and K.S. Choi. 2006. Report on the occurrence of brown ring disease (BRD) in Manila clam, *Ruditapes philippinarum*, on the west coast of Korea. Aquaculture **255** (1-4): 610-613. DOI:10.1016/j.aquaculture.2005.12.011.

Paul –Pont, I., P. Gonzalez, M. Baudrimont, F. Jude, N. Raymond, L. Bourrasseau, N. Le Goïc, F. Haynes, A. Legeay, C. Paillard, and X. de Montaudouin. 2010. Interactive effects of metal contamination and pathogenic organisms on the marine bivalve *Cerastoderma edule*. Marine Pollution Bulletin. **60**: 515-25. DOI:10.1016/j.marpolbul.2009.11.013.

Rodrigues, S., C. Paillard, G. Le Pennec, A. Dufour, and A. Bazire. 2015. *Vibrio tapetis*, the causative agent of Brown Ring Disease, forms biofilms with spherical components. Frontiers in Microbiology. **6**: 1384, 1-10. DOI:10.3389/fmicb.2015.01384.

4. *Hyperspora aquatica*

Stentiford, G. D., A. Ramilo, E.Abollo, R. Kerr, K. S. Bateman, S. W. Feist, D. Bass, and A. Villalba. 2017. *Hyperspora aquatica* n.gn., n.sp. (Microsporidia), hyperparasitic in *Marteilia cochillia* (Paramyxida) is closely related to crustacean-infecting microsporidian taxa. *Parasitology* **144**:186-199. DOI:10.1017/S0031182016001633.

Villalba, A., D. Iglesias, A. Ramilo, S. Darriba, J. M. Parada, E. No, E. Abollo, J. Molares, and M. J. Carballal. 2014. Cockle *Cerastoderma edule* fishery collapse in Ría de Arousa (Galicia, NW Spain) associated with the protistan parasite *Marteilia cochillia*. Diseases of Aquatic Organisms **109**: 55-80. DOI:10.3354/da002723.

5. *Steinhausia*-like

Carballal, M. J., D. Iglesias, J.Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**:87-97. DOI:10.1006/jipa.2001.5049.

Comtet, T., C. Garcia, Y. Le Coguic, and J.P. Joly. 2003. Infection of the cockle *Cerastoderma edule* in the Baie des Veys (France) by the microsporidian parasite *Steinhausia* sp. Diseases of Aquatic Organisms **57**: 135-139.

6. *Unikaryon legeri*

Canning, E. U., and J. P. Nicholas. 1974. Light and electron microscopy observations on *Unikaryon legeri* (Microsporida, Nosematidae), a parasite of the metacercaria of *Meigymnophallus minutus* in *Cardium edule*. Journal of Invertebrate Pathology **23**: 92–100. DOI:10.1016/0022-2011(74)90078-0.

Fermer, J., S. C. Culloty, T. C. Kelly, and R.M. O'Riordan. 2011. Parasitological survey of the edible cockle *Cerastoderma edule* (Bivalvia) on the south coast of Ireland. Journal of the Marine Biological Association of the United Kingdom **91**: 923–928. DOI:10.1017/S0025315410001839.

Lauckner, G. 1983. Diseases of Mollusca: Bivalvia. In: Kinne O (ed.) Diseases of Marine Animal, Vol II, Bivalvia to Scaphopoda. Biologische Anstat Helgoland, Hamburg, p. 477-961.

Russell-Pinto, F. 1990. Differences in infestation intensity and prevalence of hinge and mantle margin *Meiogymnophallus minutus* metacercariae (Gymnophallidae) in *Cerastoderma edule* (Bivalvia): Possible species coexistence in Ria de Aveiro. Journal of Parasitology **76**: 653-659.

Stentiford, G. D., A. Ramilo, E. Abollo, R. Kerr, K. S. Bateman, S. W. Feist, D. Bass, and A. Villalba. 2017. *Hyperspora aquatica* n.gn., n.sp. (Microsporidia), hyperparasitic in *Marteilia cochillia* (Paramyxida) is closely related to crustacean-infecting microsporidian taxa. *Parasitology* **144**:186-199. DOI:10.1017/S0031182016001633.

7. Coccidium (Undetermined)

Carballal, M. J., D. Iglesias, J.Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**:87-97. DOI:10.1006/jipa.2001.5049.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**:227-247.

8. *Nematopsis* sp.

Azevedo, C., and R. Cachola. 1992. Fine structure of the apicomplexa oocyst of *Nematopsis* sp. of two marine bivalve molluscs. Diseases of Aquatic Organisms **14:**69-73.

Carballal, M. J., D. Iglesias, J.Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**:87-97. DOI:10.1006/jipa.2001.5049.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**:227-247.

9. *Perkinsus chesapeaki*

Carrasco, N., M. Rojas, P. Aceituno, K.B. Andree, B. Lacuesta, and M.D. Furones. 2014. *Perkinsus chesapeaki* observed in a new host, the European common edible cockle *Cerastoderma edule*, in the Spanish Mediterranean coast. Journal of Invertebrate Pathology **117** : 56-60 https://doi.org/10.1016/j.jip.2014.01.009.

Lassalle, G., X. de Montaudouin, P. Soudant, and C. Paillard. 2007. Parasite coinfection of two sympatric bivalves, the Manila clam (*Ruditapes philippinarum*) and the cockle (*Cerastoderma edule*) along a latitudinal gradient. Aquatic Living Resources **20**: 33-42.

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**: 227-247.

10. *Trichodina* spp. & *Rhynchoda*-like

Carballal, M. J., D. Iglesias, J. Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathologic conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**: 87-97.

Lauckner, G. 1983. Diseases of Mollusca: Bivalvia. In: Kinne O (ed.) Diseases of Marine Animal, Vol II, Bivalvia to Scaphopoda. Biologische Anstat Helgoland, Hamburg, p. 477-961.

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**: 227-247.

11. *Haplosporidium edule*

Azevedo, C., R. F. Conchas, and J. Montes. 2003. Description of *Haplosporidium edule* n. sp. (Phylum *Haplosporidia*), a parasite of *Cerastoderma edule* (Mollusca, Bivalvia) with complex spore ornamentation. 2003. European Journal of Protistology **39**: 161–167. https://doi.org/10.1078/0932-4739-00905.

Carballal, M. J., D. Iglesias, J. Santamarina, B. Ferro-Soto, and A. Villalba. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**: 87-97. DOI:10.1006/jipa.2001.5049.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment

Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Engelsma, M. Y., I. Roozenburg, M. Voorbergen-Laarmen, A. Van den Brick, K. Troost, T. Ysebaert, K. Bateman, and M. Longshaw. 2011. Digenean trematodes and haplosporidian protozoans associated with summer mortality of cockles *Cerastoderma edule* in the Oosterschelde, The Netherlands. *Abstract book*, European Association of Fish Pathologists, Split, Croatia, pp. 37.

12. *Minchinia mercenariae*

Albuixech-Martí, S., S. A. Lyncha, and S. C. Culloty. 2020. Biotic and abiotic factors influencing haplosporidian species distribution in the cockle *Cerastoderma edule* in Ireland. Journal of Invertebrate Pathology 174, 107425. DOI:10.1016/j.jip.2020.107425.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Ford, S. E., N. A. Stokes, E. M. Burreson, E. Scarpa, R. B. Carnegie, J. N. Kraeuter, and D. Bushek. 2009. *Minchinia mercenariae* n. sp (Haplosporidia) in the hard clam *Mercenaria mercenaria*: Implications of a rare parasite in a commercially important host. Journal of Eukaryotic Microbiology **56**: 542–551. DOI:10.1111/j.1550-7408.2009.00432.x.

Lynch, S. A., S. Lepé-Riveiro, R. Kelly, E. Quinn, A. Coghlan, B. Bookelaar, E. Morgan, J. A. Finarelli, J. Carlsson, and S. C. Culloty. 2020. Detection of haplosporidian protistan parasites supports an increase to their known diversity, geographic range and bivalve host specificity. *Parasitology* **147**: 584-592.

Ramilo A., E. Abollo, A. Villaba, and L. J. Carballal. 2018. A *Minchinia* mercenariae-like parasite infects cockles *Cerastoderma edule* in Galicia (NW Spain). Journal of Fish Diseases **41**: 41-48. DOI:10.1111/jfd.12668.

13. *Minchinia tapetis*

Albuixech-Martí, S., S. A. Lyncha, and S. C. Culloty. 2020. Biotic and abiotic factors influencing haplosporidian species distribution in the cockle *Cerastoderma edule* in Ireland. Journal of Invertebrate Pathology **174:** 107425. DOI:10.1016/j.jip.2020.107425.

Carballal, M. J., A.Cao, D. Iglesias, A. I. González, and A. Villalba. 2020 Temporal dynamics of the infection of cockles *Cerastoderma edule* with the protistan parasite *Minchinia tapetis* (Rhizaria: Haplosporida) in Galicia (NW Spain). Journal of Invertebrate Pathology **172**: 107349. DOI:10.1016/j.jip.2020.107349.

Elliott, M., D. Burdon, R. Callaway, A. Franco, T. Hutchinson, M. Longshaw, S. Malham, K. Mazik, Z. Otto, D. Palmer, C. Firmin, T. Smith, and A. Wither. 2012. Burry Inlet cockle mortalities investigation 2009-2011. Final technical report to Environment Agency (Wales), 17 January 2012. Available online: https://webarchive.nationalarchives.gov.uk/20140404213951/http://cdn.environment-agency.gov.uk/gewa0112bwap-e-e.pdf

Engelsma, M. Y., I. Roozenburg, M. Voorbergen-Laarmen, A. Van den Brick, K. Troost, T. Ysebaert, K. Bateman, and M. Longshaw. 2011. Digenean trematodes and haplosporidian protozoans associated with summer mortality of cockles *Cerastoderma edule* in the Oosterschelde, The Netherlands. *Abstract book*, European Association of Fish Pathologists, Split, Croatia, pp. 37.

14. *Urosporidium* sp.

Carballal, M. J., S. Díaz, and A.Villalba. 2005. *Urosporidium* sp. hyperparasite of the cockle *Paravortex cardii* in the cockle *Cerastoderma edule*. Journal of Invertebrate Pathology **90**: 104-107. DOI:10.1016/j.jip.2015.08.003.

15. *Marteilia cochillia*

Carrasco, N., P. M. Hine, P.M., M. Durfort, M., K. B. Andree, K.B., N. Malchus, N., B. Lacuesta, B., M. González, M., A. Roque, A., C. Rodgers, C., and M. D. Furones, M.D. 2013. *Marteilia cochillia* sp. nov., a new *Marteilia* species affecting the edible cockle *Cerastoderma edule* in European Waters. Aquaculture **412-413**: 223-230. DOI:10.1016/j.aquaculture.2013.07.027.

Carballal, M. J., D. Iglesias, D., E. Abollo, E., A. Cao, A., L. García, L., A. Ramilo, A., A. I. González, A.I., A. González, A., S. Pascual del Hierro, S., and A. Villalba, A., 2019. Looking for hosts of *Marteilia cochillia* in the zooplankton. Abstract book, European Association of Fish Pathologists, Porto, Portugal, pp. 502.

Darriba, S., D. Iglesias, D., M. J. Carballal, M.J. 2020. *Marteilia cochillia* is released into seawater via cockle *Cerastoderma edule* faeces. Journal of Invertebrate Pathology **172**: 107364. DOI:10.1016/j.jip.2020.107364.

Iglesias, D., A. Villalba, A., A. Cao, A., M. J. Carballal, M.J. 2019. Is natural selection enhancing resistance against marteiliosis in cockles recruited in the inner side of the ría of Arousa? Abstract book, European Association of Fish Pathologists, Porto, Portugal, pp. 184.

Navas, J. I., M. López-Sanmartín, M., M. Perez-Miguel, M., and P. Drake, P. 2018. Detection of *Marteilia cochillia* in *Cerastoderma edule* from Huelva coast (Andalusia Spain). In: Aqua 2018 We R Aquaculture, Abstract Book, p. 463.

Villalba, A., D. Iglesias, A. Ramilo, S. Darriba, J. M. Parada, E. No, E. Abollo, J. Molares, M. J. Carballal. 2014. Cockle *Cerastoderma edule* fishery collapse in Ría de Arousa (Galicia, NW Spain) associated with the protistan parasite *Marteilia cochillia*. Diseases of Aquatic Organisms **109**: 55-80. DOI:10.3354/dao02723.

16. *Asymphylodora demeli*

Kesting, V., S. Gollasch, and C. D. Zander. 1996. Parasite communities of the Schlei Fjord (Baltic coast of northern Germany). Helgoländer Meeresuntersuchungen **40**:477-496.

Lauckner, G. 1971. Zur Trematodenfauna der Herzmuscheln *Cardium edule* und *Cardium lamarcki*. Helgoländer wissenchaft Meeresuntersuchungen **22**:377-400.

Reimer, L. W. 1970. Digene Trematoden und Cestoden der Ostseefische als natürliche Fischmarken. Parasitologische Schriftenreihe **20**:1-144.

Reimer, L. W. 1973. Das Auftreten eines Fischtrematoden der Gattung *Asymphylodora* Looss, 1899, bei *Nereis diversicolor* O.F. Müller als Beispiel für einen Alternativzyklus. Zoologischer Anzeiger **191**:187-196.

17. *Bucephalus minimus*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Desclaux, C., X. de Montaudouin, and G. Bachelet. 2002. Cockle emergence at the sediment surface: 'favourization' mechanism by digenean parasites? Diseases of Aquatic Organisms **52**:137-149.

Feis, M. E., D. W. Thieltges, J. L. Olsen, X. de Montaudouin, K. T. Jensen, H. Bazairi, S. C. Culloty, and P. C. Luttikhuizen. 2015. The most vagile host as the main determinant of population connectivity in marine macroparasites. Marine Ecology Progress Series **520**:85-99.

Magalhães, L., X. de Montaudouin, and R. Freitas. 2015. Review: *Bucephalus minimus*, a deleterious trematode parasite of cockles *Cerastoderma* spp. Parasitology Research **114**:1263-1278.

Magalhães, L., X. de Montaudouin, R. Freitas, G. Daffe, E. Figueira, and P. Gonzalez. 2017. Seasonal variation of transcriptomic and biochemical parameters of cockles (*Cerastoderma edule*) related to their infection by trematode parasites. Journal of Invertebrate Pathology **148**:73-80.

Pina, S., T. Barandela, M. J. Santos, F. Russell-Pinto, and P. Rodrigues. 2009. Identification and description of *Bucephalus minimus* (Digenea: Bucephalidae) life cycle in Portugal: morphological, histopathological, and molecular data. Journal of Parasitology **95**:353-359.

18. *Curtuteria arguinae*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Desclaux, C., F. Russell-Pinto, X. de Montaudouin, and G. Bachelet. 2006. First record and description of metacercariae of

Curcuteria arguinae n. sp. (Digenea: Echinostomatidae), parasite of cockles *Cerastoderma edule* (Mollusca: Bivalvia) in Arcachon Bay, France. Journal of Parasitology **92**:578-587.

19. *Diphterostomum brusinae*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Palombi, A. 1930. Il ciclo biologico di *Diphterostomum brusinae* Stossich (Trematode digenetico: fam. Zoogonidae Odhner). Pubblicazioni della Stazione Zoologica di Napoli **10**:111-149.

Pina, S., J. Tajdari, F. Russell-Pinto, and P. Rodrigues. 2009. Morphological and molecular studies on life cycle stages of *Diphterostomum brusinae* (Digenea: Zoogonidae) from northern Portugal. Journal of Helminthology **83**:321-331.

20. *Gymnophallus choledochus*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

James, B. L., and E. A. Bowers. 1967. Reproduction in the daughter sporocyst of *Cercaria bucephalopsis haimeana* (Lacaze-Duthiers, 1854) (Bucephalidae) and *Cercaria dichotoma* Lebour, 1911 (non Müller) (Gymnophallidae). Parasitology **57**:607-625.

Loos-Frank, B. 1971. Zur Kenntis der gymnophalliden Trematoden des Nordseeraumes. IV. Übersicht über die gymnophalliden Larven aus Mollusken der Gezeitenzone. Zeitschrift für Parasitenkunde **36**:206-232.

Magalhães, L., G. Daffe, R. Freitas, and X. de Montaudouin. 2020. *Monorchis parvus* and *Gymnophallus choledochus*: two trematode species infecting cockles as first and second intermediate host. Parasitology **147**:643-658.

Rangel, L. F., and M. J. Santos. 2009. *Diopatra neapolitana* (Polychaeta: Onuphidae) as a second intermediate host of *Gymnophallus choledochus* (Digenea; Gymnophallidae) in the Aveiro estuary (Portugal): distribution within the host and histopathology. Journal of Parasitology **95**:1233-1236.

Thieltges, D. W. 2006. Parasite induced summer mortality in the cockle *Cerastoderma edule* by the trematode *Gymnophallus choledochus*. Hydrobiologia **559**:455-461.

Thieltges, D. W., M. Krakau, H. Andresen, S. Fottner, and K. Reise. 2006. Macroparasite community in molluscs of a tidal basin in the Wadden Sea. Helgoland Marine Research **60**:307-316.

21. *Gymnophallus somateriae*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Loos-Frank, B. 1971a. Zur Kenntis der gymnophalliden Trematoden des Nordseeraumes. III. *Gymnophallus gibberosus* n. sp. und seine Metacercarie. Zeitschrift für Parasitenkunde **35**:270-281.

Loos-Frank, B. 1971b. Zur Kenntis der gymnophalliden Trematoden des Nordseeraumes. IV. Übersicht über die gymnophalliden Larven aus Mollusken der Gezeitenzone. Zeitschrift für Parasitenkunde **36**:206-232.

Pekkarinen, M. 1987. The cercaria and metacercaria of *Gymnophallus gibberosus* Loos-Frank, 1971 (Trematoda: Gymnophallidae) in *Macoma balthica* (L.) (Bivalvia) in the Baltic brackish water (southern Finland). Annales Zoologici Fennici **24**:123-136.

Thieltges, D. W., M. Krakau, H. Andresen, S. Fottner, and K. Reise. 2006. Macroparasite community in molluscs of a tidal basin in the Wadden Sea. Helgoland Marine Research **60**:307-316.

Thieltges, D. W., and K. Reise. 2006. Metazoan parasites in intertidal cockles *Cerastoderma edule* from the northern Wadden Sea. Journal of Sea Research **56**:284-293.

22. *Himasthla* spp.

de Montaudouin, X., H. Bazairi, and S. Culloty. 2012a. Effect of trematode parasites on cockle *Cerastoderma edule* growth and condition index: a transplant experiment. Marine Ecology Progress Series **471**:111-121.

de Montaudouin, X., H. Blanchet, C. Desclaux-Marchand, H. Bazairi, N. Alfeddy, and G. Bachelet. 2016a. Cockle infection by *Himasthla quissetensis* - II. The theoretical effects of climate change. Journal of Sea Research **113**:108-114.

de Montaudouin, X., H. Blanchet, C. Desclaux-Marchand, N. Lavesque, and G. Bachelet. 2016b. Cockle infection by *Himasthla quissetensis* - I. From cercariae emergence to metacercariae infection. Journal of Sea Research **113**:99-107.

de Montaudouin, X., K. T. Jensen, C. Desclaux, A. M. Wegeberg, and M. C. Sajus. 2005. Effect of intermediate host size (*Cerastoderma edule*) on infectivity of cercariae of *Himasthla quissetensis* (Echinostomatidae, Trematoda). Journal of the Marine Biological Association of the United Kingdom **85**:809-812.

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

de Montaudouin, X., A. M. Wegeberg, K. T. Jensen, and P. G. Sauriau. 1998. Infection characteristics of *Himasthla elongata* cercaria in cockles as a function of water current. Diseases of Aquatic Organisms **34**:63-70.

Desclaux, C., X. de Montaudouin, and G. Bachelet. 2004. Cockle (*Cerastoderma edule*) population mortality: the role of the digenean parasite Himasthla quissetensis. Marine Ecology Progress Series. **279**:141-150.

Jensen, K. T., N. Fernández Castro, and G. Bachelet. 1999. Infectivity of *Himasthla* spp. (Trematoda) in cockle (*Cerastoderma edule*) spat. Journal of the Marine Biological Association of the United Kingdom **79**:265-271.

Lauckner, G. 1971. Zur Trematodenfauna der Herzmuscheln *Cardium edule* und *Cardium lamarcki*. Helgoländer wissenchaft Meeresuntersuchungen **22**:377-400.

Loos-Frank, B. 1967. Experimentelle Untersuchungen über Bau, Entwicklung und Systematik der Himasthlinae (Trematoda, Echinostomatidae) des Nordseeraumes. Zeitschrift für Parasitenkunde **28**:299-351.

Russell-Pinto, F., J. F. Gonçalves, and E. Bowers. 2006. Digenean larvae parasitizing *Cerastoderma edule* (Bivalvia) and *Nassarius reticulatus* (Gastropoda) from Ria de Aveiro, Portugal. Journal of Parasitology **92**:319-332.

Stunkard, H. W. 1938. The morphology and life cycle of the trematode *Himasthla quissetensis* (Miller and Northup, 1926). Biological Bulletin of the Marine Laboratory, Woods Hole **75**:145-164.

Wegeberg, A. M., X. de Montaudouin, and K. T. Jensen. 1999. Effect of intermediate host size (*Cerastoderma edule*) on infectivity of cercariae of three *Himasthla* species (Echinostomatidae, Trematoda). Journal of Experimental Marine Biology and Ecology **238**:259-269.

Wegeberg, A. M., and K. T. Jensen. 1999. Reduced survivorship of *Himasthla* (Trematoda, Digenea)-infected cockles (*Cerastoderma edule*) exposed to oxygen depletion. Journal of Sea Research **42**:325-331.

Wegeberg, A. M., and K. T. Jensen. 2003. In situ growth of juvenile cockles, *Cerastoderma edule*, experimentally infected with larval trematodes (*Himasthla interrupta*). Journal of Sea Research **50**:37-43.

23. *Monorchis parvus*

Bartoli, P., O. Jousson, and F. Russell-Pinto. 2000. The life cycle of *Monorchis parvus* (Digenea: Monorchiidae) demonstrated by developmental and molecular data. Journal of Parasitology **86**:479-489.

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Jonsson, P. R., and C. André. 1992. Mass mortality of the bivalve *Cerastoderma edule* on the Swedish west coast caused by infestation with the digenean trematode *Cercaria cerastodermae* I. Ophelia **36**:151-157.

Jousson, O., and P. Bartoli. 2002. Species diversity among the genus *Monorchis* (Digenea: Monorchiidae) parasitic in marine teleosts: molecular, morphological and morphometrical studies with a description of *Monorchis blennii* n. sp. Parasitology Research.

Magalhães, L., G. Daffe, R. Freitas, and X. de Montaudouin. 2020. *Monorchis parvus* and *Gymnophallus choledochus*: two trematode species infecting cockles as first and second intermediate host. Parasitology **147**:643-658.

Sannia, A., and B. L. James. 1978. The occurrence of *Cercaria cerastodermae* I Sannia, James, and Bowers, 1978 (Digenea: Monorchiidae) in populations of *Cerastoderma edule* (L.) from the commercial beds of the Lower Thames Estuary. Zeitschrift für Parasitenkunde **56**:1-11.

Sannia, A., B. L. James, and E. A. Bowers. 1978. The morphology of *Cercaria cerastodermae* I nom. nov. (Monorchiidae) (=*Cercaria lepidapedon rachion* (Cobbold, 1858) *sensu* Lebour, 1908) a rare digenean parasite of the cockle in Britain. Journal of Natural History **12**:487-500.

24. *Parvatrema fossarum*

Bowers, E. A., P. Bartoli, F. Russell-Pinto, and B. L. James. 1996. The metacercariae of sibling species of *Meiogymnophallus*, including *M. rebecqui* comb. nov. (Digenea: Gymnophallidae), and their effects on closely related *Cerastoderma* host species (Mollusca: Bivalvia). Parasitology Research **82**:505-510.

Russell-Pinto, F., and P. Bartoli. 1992. Sympatric distribution of *Meiogymnophallus minutus* and *M. fossarum* (Digenea: Gymnophallidae) in *Cerastoderma edule* in the Ria de Aveiro estuary in Portugal. Parasitology Research **78**:617-618.

Russell-Pinto, F., J. F. Gonçalves, and E. Bowers. 2006. Digenean larvae parasitizing *Cerastoderma edule* (Bivalvia) and *Nassarius reticulatus* (Gastropoda) from Ria de Aveiro, Portugal. Journal of Parasitology **92**:319-332.

25. *Parvatrema minutum*

Bowers, E. A., P. Bartoli, F. Russell-Pinto, and B. L. James. 1996. The metacercariae of sibling species of *Meiogymnophallus*, including *M. rebecqui* comb. nov. (Digenea: Gymnophallidae), and their effects on closely related *Cerastoderma* host species (Mollusca: Bivalvia). Parasitology Research **82**:505-510.

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Fermer, J., S. C. Culloty, T. C. Kelly, and R. O'Riordan. 2009. Intrapopulational distribution of *Meiogymnophallus minutus* (Digenea, Gymnophallidae) infections in its first and second intermediate. Parasitology Research **105**:1231-1238.

Fermer, J., S. C. Culloty, T. C. Kelly, and R. O'Riordan. 2010. Temporal variation of *Meiogymnophallus minutus* infections in the first and second intermediate host. Journal of Helminthology **84**:362-368.

Fermer, J., S. C. Culloty, T. C. Kelly, and R. O'Riordan. 2011. Manipulation of *Cerastoderma edule* burrowing ability by *Meiogymnophallus minutus* metacercariae? Journal of the Marine Biological Association of the United Kingdom **91**:907-911.

Gam, M., H. Bazaïri, K. T. Jensen, and X. de Montaudouin. 2008. Metazoan parasites in an intermediate host population near its southern border: the common cockle (*Cerastoderma edule*) and its trematodes in a Moroccan coastal lagoon (Merja Zerga). Journal of the Marine Biological Association of the United Kingdom **88**:357-364.

Loos-Frank, B. 1971. Zur Kenntis der gymnophalliden Trematoden des Nordseeraumes. IV. Übersicht über die gymnophalliden Larven aus Mollusken der Gezeitenzone. Zeitschrift für Parasitenkunde **36**:206-232.

Russell-Pinto, F. 1990. Differences in infestation intensity and prevalence of hinge and mantle margin *Meiogymnophallus minutus* metacercariae (Gymnophallidae) in *Cerastoderma edule* (Bivalvia): possible species coexistence in Ria de Aveiro. Journal of Parasitology **76**:653-659.

26. *Psilostomum bevicolle*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Loos-Frank, B. 1968. Der Entwicklungszyklus von *Psilostomum brevicolle* (Creplin, 1829) [Syn.: *P. platyurum* (Mühling, 1896)] (Trematoda, Psilostomatidae). Zeitschrift für Parasitenkunde **31**:122-131.

27. *Renicola roscovitus*

de Montaudouin, X., D.X. Thieltges, M. Gam, M. Krakau, S. Pina, H. Bazaïri, L. Dabouineau, F. Russell-Pinto, and K.T. Jensen. 2009. Review - Digenean trematode species in the cockle *Cerastoderma edule*: identification key and distribution along the North-East Atlantic shoreline. Journal of the Marine Biological Association, United Kingdom. **80**:543-556.

Stier, T., J. Drent, and D. W. Thieltges. 2015. Trematode infections reduce clearance rates and condition in blue mussels *Mytilus edulis*. Marine Ecology Progress Series **529**:137-144.

Thieltges, D. W. 2006. Effect of infection by metacercarial trematode *Renicola roscovita* on growth in intertidal blue mussel *Mytilus edulis*. Marine Ecology Progress Series **319**:129-134.

Werding, B. 1969. Morphologie, Entwicklung und Ökologie digener Trematoden-Larven der Strandschnecke *Littorina littorea*. Marine Biology **3**:306-333.

Williams, I. C., and C. Ellis. 1975. Movements of the common periwinkle, *Littorina littorea* (L.), on the Yorkshire coast in winter and the influence of infection with larval digenea. Journal of Experimental Marine Biology and Ecology **17**:47-58.

28. Undetermined cestode

Lauckner, G. 1983. Diseases of Mollusca: Bivalvia. In: Kinne O (ed.) Diseases of Marine Animal, Vol II, Bivalvia to Scaphopoda. Biologische Anstat Helgoland, Hamburg, p. 477-961.

29. *Paravortex cardii*

Atkins, D. 1934. Two parasites of the common cockle *Cardium edule*; a Rhabdocoele *Paravortex cardii* Hallez and a Copepod *Paranthessius rostratus* (Canu). Journal of the Marine Biological Association of the United Kingdom **19**:669-676.

Carballal, M. J., D. Iglesias, J. Santamarina, B. Ferro-Soto, and A. Villalba, A. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**: 87-97. DOI:10.1006/jipa.2001.5049.

Gam, M., H. Bazaïri, K. T. Jensen, and X. de Montaudouin. 2008. Metazoan parasites in an intermediate host population near its southern border: the common cockle (*Cerastoderma edule*) and its trematodes in a Moroccan coastal lagoon (Merja Zerga). Journal of the Marine Biological Association of the United Kingdom **88**:357-364.

Thieltges, D. W., M. Krakau, H. Andresen, S. Fottner, and K. Reise. 2006. Macroparasite community in molluscs of a tidal basin in the Wadden Sea. Helgoland Marine Research **60**:307-316.

30. Unidentified nematode

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom 93:227-247.

Thieltges, D. W., M. Krakau, H. Andresen, S. Fottner, and K. Reise. 2006. Macroparasite community in molluscs of a tidal basin in the Wadden Sea. Helgoland Marine Research 60:307-316.

31. *Malacobdella grossa*

Jones, A. M., Y. M. Jones, and J. L. James. 1979. The incidence of the nemertine *Malacobdella grossa* in the bivalve *Cerastoderma edule* in the Shetland. Journal of the Marine Biological Association of the United Kingdom **59**:373-375.

32. *Herrmannella rostrata*

Atkins, D. 1934. Two parasites of the common cockle *Cardium edule*; a Rhabdocoele *Paravortex cardii* Hallez and a copepod *Paranthessius rostratus* (Canu). Journal of the Marine Biological Association of the United Kingdom. **19**: 669-676.

Díaz, S., I. Madinabeitia, A. Villalba, J. Ho, and M.J. Carballal. 2011. Presencia y efectos histopatológicos del copépodo (*Herrmannella rostrata* Canu, 1891) en berberechos (*Cerastoderma edule* Linnaeus, 1758) de Galicia (NW España). V Foro Iberoam. Rec. Mar. Acui: 435-444.

Fraser, J.H. 1932. Occurrence of the cyclopoid, *Herrmannella rostrata* Canu, in *Cardium edule*. Nature. **130**:279.

Longshaw, M., and S. K. Malham. 2013. A review of the infectious agents, parasites, pathogens and commensals of European cockles (*Cerastoderma edule* and *C. glaucum*). Journal of the Marine Biological Association of the United Kingdom **93**:227-247.

Monod, T., and R. Dollfus. 1932. Les copépodes parasites de mollusques. Annales de Parasitologie. **10** : 129-204.

Stock, J.H. 1993. Copepoda (Crustacea) associated with commercial and non-commercial Bivalvia in the East Scheldt, The Netherlands. Bijdragen tot de Dierkunde. **63**: 61–64.

33. *Mytilicola orientalis*

Bernard, F. R. 1969. Copepod *Mytilicola orientalis* in British Colombia bivalves. Journal of the Fisheries Research Board of Canada **26**:190-191.

Goedknegt, M. A., D. W. Thieltges, J. van der Meer, K. M. Wegner, and P. C. Luttikhuizen. 2018. Cryptic invasion of a parasitic copepod: compromised identification when morphologically similar invaders co-occur in invaded ecosystems. PLOS one 13(3): e0193354.

Goedknegt, M. A., A. K. Schuster, C. Buschbaum, R. Gergs, A. S. Jung, P. C. Luttikhuizen, J. van der Meer, K. Troost, K.M. Wegner, and D.W. Thieltges. 2017. Spillover but no spillback of two invasive parasitic copepods from invasive Pacific oysters (*Crassostrea gigas*) to native bivalve hosts. Biological Invasions **19**:365-379.

Mori T. 1935. *Mytilicola orientalis*, a new species of parasitic Copepoda. Zoological Society of Japan. **47**:687–693.

34. *Afropinnotheres monodi* and *Pinnotheres pisum*

Becker C. 2010. European Pea Crabs – Taxonomy, Morphology, and Host-Ecology (Crustacea: Brachyura: Pinnotheridae). Dissertation, Johann Wolfgang Goethe Universität.

Cuesta J. A., M. Perez-Miguel, E. González-Ortegón, D. Roque, and P. Drake. 2020. The prevalence of the pea crab *Afropinnotheres monodi* in mussels depending on the degree of habitat exposure: implications for mussel culture. Aquaculture **520**: 734772.

Haines, C. M. C., M. Edmunds, and A. R. Pewsey. 1994. The pea crab, *Pinnotheres pisum* (Linnaeus, 1767), and its association with the common mussel, Mytilus edulis (Linnaeus, 1758), in the Solent (UK). Journal of Shellfish Research **13**:5–10.

Perez-Miguel M., J. A. Cuesta, J. I. Navas, J. E. García Raso, and P. Drake. 2018. The prevalence and effects of the African pea crab *Afropinnotheres monodi* on the condition of the mussel *Mytilus galloprovincialis* and the cockle *Cerastoderma edule*. Aquaculture **491**(1): 1-9.

Perez-Miguel M., P. Drake, and J. A. Cuesta. 2020. Temperature effect on the African pea crab *Afropinnotheres monodi*: Embryonic and larval developments, fecundity and adult survival. Journal of Experimental Marine Biology and Ecology **527**: 151380.

Perez-Miguel M., P. Drake, J. E. Garcia Raso, L. Maman Menéndez, J. I. Navas, and J. A. Cuesta. 2019. European Pinnotheridae (Crustacea, Decapoda, Brachyura): Species, Distribution, Host use and DNA barcodes. Marine Biodiversity **49**(1): 57-68.

Triay-Portella R., M. Perez-Miguel, J. A. González, and J. A. Cuesta. 2018. On the presence of *Pinnotheres pisum* (Brachyura, Pinnotheridae) in the Canary Islands (NE Atlantic), its southernmost distribution limit. Crustaceana **91**(11): 1397-1402.

35. Disseminated neoplasia

Carballal, M. J., B. J. Barber, D. Iglesias, A. Villalba. 2015. Neoplastic diseases of marine bivalves. Journal of Invertebrate Pathology **131**: 83-106. DOI:10.1016/j.jip.2015.06.004.

Díaz, S., D. Iglesias, A. Villalba, and M. J. Carballal. 2016. Long term epidemiological study of disseminated neoplasia of cockles in Galicia (NW Spain): temporal patterns at individual and population levels, influence of environmental and cockle-based factors, and lethality. Journal of Fish Diseases DOI:10.1111/jfd.12436.

Díaz, S., A. Villalba,and M. J. Carballal. 2017. Assessment of transmissibility of the disseminated neoplasia affecting cockles *Cerastoderma edule* in Galicia (NW Spain). Bulletin of the European Association of Fish Pathologists **37**: 5-15.

Le Grand, F., E. Kraffe, X. de Montaudouin, A. Villalba, Y. Marty, and P. Soudant. 2010. Prevalence, intensity, and aneuploidy patterns of disseminated neoplasia in cockles (*Cerastoderma edule*) from Archachon Bay: seasonal variation and position in sediment. Journal of Invertebrate Pathology **104**: 110–118. DOI:10.1016/j.jip.2010.01.011.

Metzger, M. J., A. Villalba, M. J. Carballal, D. Iglesias, J. Sherry, C. Reinisch, A. F. Muttray, S. A. Baldwin, and S. P. Goff. 2016. Widespread transmission of independent cancer lineages within multiple bivalve species. Nature **534**: 705-709. DOI:10.1038/nature18599.

Twomey, E., and M. F. Mulcahy. 1984. A proliferative disorder of possible hemic origin in the common cockle *Cerastoderma edule*. Journal of Invertebrate Pathology **44**: 109-111. DOI:10.1016/0022-2011(84)90052-1.

36. Granulomatosis

Carballal, M. J., D. Iglesias, J. Santamarina, B. Ferro-Soto, and A. Villalba, A. 2001. Parasites and pathological conditions of the cockle *Cerastoderma edule* populations of the coast of Galicia (NW Spain). Journal of Invertebrate Pathology **78**: 87-97. DOI:10.1006/jipa.2001.5049.

Carballal M.J., A. Villalba, D. Iglesias, P. M. Hine. 2003. Virus-like particles associated with large foci of heavy hemocytic infiltration in cockles *Cerastoderma edule* from Galicia (NW Spain). Journal of Invertebrate Pathology **84**: 234-237. DOI:10.1016/j.jip.2003.11.002.

Villalba A., M. J. Carballal, and C. López. 2001. Disseminated neoplasia and large foci indicating heavy haemocytic infiltration in cockles *Cerastoderma edule* from Galicia (NW Spain). Diseases of Aquatic Organisms **46**: 213-216.

37. Picornaviral-like infection associated with granulomatosis

Carballal M. J., A. Villalba, D. Iglesias, and P. M. Hine. 2003. Virus-like particles associated with large foci of heavy hemocytic infiltration in cockles *Cerastoderma edule* from Galicia (NW Spain). Journal of Invertebrate Pathology **84**: 234-237. DOI:10.1016/j.jip.2003.11.002.

Interreg
Atlantic Area
European Regional Development Fund

EUROPEAN UNION

Co-Operation for Restoring
CocKle SheLlfisheries
and its Ecosystem Services
in the Atlantic Area (AA)