WORLD ORGANISATION FOR ANIMAL HEALTH
Protecting animals, preserving our future

Original: English
November–December 2020

REPORT OF THE OIE *AD HOC* GROUP ON SUSCEPTIBILITY OF MOLLUCS SPECIES TO INFECTION WITH OIE LISTED DISEASES[1]

November–December 2020

This report covers the work of the OIE *ad hoc* Group on Susceptibility of mollusc species to infection with OIE listed diseases (the *ad hoc* Group) who met electronically between November and December 2020.

The list of participants and the Terms of Reference are presented in Annex I and Annex II, respectively.

Methodology

The *ad hoc* Group applied criteria, as outlined in Article 1.5.3 of the OIE *Aquatic Animal Health Code* (the *Aquatic Code*), to potential host species in order to determine susceptibility and non-susceptibility to infection with *Bonamia exitiosa*. This was done by a three-stage approach, as described below:

1) **Stage 1: Criteria to determine whether the route of transmission is consistent with natural pathways for the infection (as described in Article 1.5.4):**

   Consideration was given to whether experimental procedures mimic natural pathways for disease transmission. Consideration was also given to environmental factors given that these may affect host response, virulence and transmission of infection with *B. exitiosa*.

   The table below describes additional considerations made by the *ad hoc* Group when applying Stage 1 to support susceptibility to infection with *B. exitiosa.*

Source of infection	Considerations
Natural exposure included situations where infection had occurred without experimental intervention (e.g. infection in wild or farmed populations) OR Non-invasive experimental procedures[2]: cohabitation with infected hosts; infection by immersion or feeding.	*In vitro* experimental assays (contact between haemocytes and parasites) were not considered appropriate to answer the question of susceptibility or non-susceptibility.

[1] Note: This *ad hoc* Group report reflects the views of its members and may not necessarily reflect the views of the OIE. This report should be read in conjunction with the February 2021 report of the Aquatic Animal Health Standards Commission because this report provides its considerations and comments. It is available at https://www.oie.int/en/standard-setting/specialists-commissions-working-ad-hoc-groups/aquatic-animals-commission-reports/meeting-reports/

[2] Invasive experimental procedures including injection were only used to demonstrate non-susceptibility.

2) Stage 2: Criteria to determine whether the pathogenic agent has been adequately identified (as described in Article 1.5.5):

The *ad hoc* Group noted that unambiguous pathogenic agent identification might not have been carried out in older publications because molecular techniques were not available at the time. In these circumstances a weight of evidence approach, whereby the combined information from subsequent studies and additional information provided by the authors, was considered and used to conclude sufficiency of pathogen identification.

The table below describes the pathogen identification methods used by the *ad hoc* Group as well as some considerations.

Pathogen Identification	Considerations
Molecular sequence information (species-specific regions of 18S sequence) OR PCR-RFLP (as described in Cochennec *et al*., 2000) OR Species-specific Real-time or conventional PCR (for example Ramilo *et al*., 2013) OR Observed parasite and morphology from histology was later characterised by linked molecular information from other studies	Molecular data should be associated with microscopical examination wherever possible to confirm the presence of the pathogen. ISH is currently not sufficiently specific to resolve species level identifications. For early studies without molecular information, corroborating evidence from later studies was also considered. ITS rDNA sequence has a higher resolution than 18s rDNA and therefore can provide information about the intra-species diversity between populations. Primers and probes from Carnegie *et al.*, 2008, are expected to be specific to *Bonamia exitiosa* but were not considered sufficient singular evidence of pathogen identification as they have not been formally validated to date.

3) Stage 3: Criteria to determine whether the evidence indicates that presence of the pathogenic agent constitutes an infection (as described in Article 1.5.6):

Criteria A to D, as described in Article 1.5.6 and presented below, were used to determine if there was sufficient evidence for infection with *B. exitiosa* in the suspected host species:

A. The pathogenic agent is multiplying in the host, or developing stages of the pathogenic agent are present in or on the host[3];

B. Viable pathogenic agent is isolated from the proposed susceptible species, or infectivity is demonstrated by way of transmission to naïve individuals;

C. Clinical or pathological changes are associated with the infection;

D. The specific location of the pathogen corresponds with the expected target tissues.

Evidence to support criterion A alone was sufficient to determine infection. In the absence of evidence to meet criterion

[3] For the purposes of the assessments for susceptibility to *B. exitiosa*, replication 'on the host' was not considered to apply.

A, satisfying at least two of criteria B, C or D were required to determine infection.

The table below describes the criteria for assessment of Stage 3 to support susceptibility to infection with *B. exitiosa*.

Evidence for infection			
A: Replication	B: Viability / Infectivity	C: Pathology / Clinical signs*	D: Location
1) Presence of multiple intracellular parasites or presence of multinucleated parasites (including plasmodial stage) demonstrated by: a) Histopathology OR b) Cytology (usually gill or heart imprint or haemolymph smears) OR c) *In-situ* hybridization (ISH) OR d) TEM **OR** 2) Demonstration of increasing copy number over time with qPCR (targeting DNA) or reverse transcription qPCR (targeting RNA) in tissues	1) Transmission via co-habitation with uninfected individuals of a known-susceptible (e.g. *Ostrea chilensis*) species **OR** 2) Demonstration of viability of cells isolated from tissues by: a) Flow cytometry OR a) Vital stains OR b) Successful infection of uninfected animals by inoculation	1) Mortality **OR** 2) Macroscopic lesions such as: a. Discolouration of tissue b. Gill ulceration **OR** 3) Rapid loss of condition **OR** 4) Microscopic lesions such as generalized haemocyte infiltration in connective tissues of several organs including gills and mantle	Within haemocytes circulating in the connective tissue in different organs, in particular gills** or heart (rarely extracellular)

* Non-specific signs and inconsistent presentation.

** Inside gills, as opposed to potential external contaminant.

Results

The table below describes the different scores and outcomes of the assessments undertaken by the *ad hoc* Group.

Score	**Outcome**
1.	Species assessed as susceptible (as described in Article 1.5.7) and were proposed for inclusion in Article 11.2.2 of Chapter 11.2, Infection with *B. exitiosa*, of the *Aquatic Code* and Section 2.2.1 of Chapter 2.4.2, Infection with *B. exitiosa*, of the *Manual of Diagnostic Tests for Aquatic Animals* (the *Aquatic Manual*).

2.	Species assessed as having incomplete evidence for susceptibility (as described in Article 1.5.8).
3.	Species that were assessed as not meeting the criteria or for which there was unresolved or conflicting information were not proposed for inclusion in either the *Aquatic Code* or the *Aquatic Manual*. The exceptions were species where there had been reported pathogen-specific positive PCR results, but an active infection had not been demonstrated. These species were proposed for inclusion in a separate paragraph in Section 2.2.2, Species with incomplete evidence for susceptibility, of Chapter 2.4.2 of the *Aquatic Manual.*
4.	Species assessed as non-susceptible.
NS	Not scored due to insufficient or irrelevant information.

Evidence of infection Key Stage 3
Y: Demonstrates criterion is met.
N: Criterion is not met.
ND: Not determined.

Assessments of host susceptibility to infection with *B. exitiosa*

Summary

The *ad hoc* Group agreed that the two species currently included in Article 11.2.2 as susceptible to infection with *B. exitiosa*, the Australian mud oyster *(Ostrea angasi)* and Chilean flat oyster *(Ostrea chilensis)*, meet the criteria for listing as susceptible to infection with *B. exitiosa* in accordance with Chapter 1.5 of the *Aquatic Code*. and were proposed to remain in Article 11.2.2.

Six additional species, the Argentinean flat oyster *(Ostrea puelchana)*, Dwarf oyster *(Ostrea stentina)*, Eastern oyster *(Crassostrea virginica)*, European flat oyster *(Ostrea edulis)*, Olympia oyster *(Ostrea lurida)* and the Suminoe oyster *(Crassostrea ariakensis)* were assessed to meet the criteria for listing as susceptible to infection with *B. exitiosa*, in accordance with Chapter 1.5, and were proposed to be included in Article 11.2.2.

Two species, Pacific cupped oyster *(Crassostrea gigas)* and Sydney rock oyster *(Saccostrea glomerata)*, were assessed as having incomplete evidence of susceptibility and were proposed to be included in Section 2.2.2, of Chapter 2.4.2 of the *Aquatic Manual*.

The assessments for host susceptibility to infection with *B. exitiosa* conducted by the *ad hoc* Group together with the outcomes and relevant references are shown in the table below.

Family	Scientific name	Common name	Stages 1: Route of infection	Stage 2: Pathogen identification	Stage 3: Evidence for infection				Outcome	References
					A	B	C	D		
Score 1										
Ostreidae	*Ostrea edulis*	European flat oyster	YES	YES	YES	ND	YES	YES	1	Abollo *et al*., 2008
			YES	YES	YES	ND	YES	YES	1	Carrasco *et al*., 2012
Ostreidae	*Ostrea chilensis*	Chilean flat oyster	YES	YES	YES	ND	YES	YES	1	Hill *et al*., 2014
			YES	YES	YES	ND	YES	YES	1	Lane *et al*., 2016
Ostreidae	*Ostrea stentina*	Dwarf oyster	YES	YES	YES	ND	YES	YES	1	Hill *et al*., 2014
			YES	YES	YES	ND	ND	YES	1	Hill *et al*., 2010
Ostreidae	*Ostrea puelchana*	Argentinean flat oyster	YES	YES	YES	ND	YES	YES	1	Hill *et al*., 2014
			YES	YES[4]	YES	ND	YES	YES	1	Kroeck, 2010
Ostreidae	*Ostrea angasi*	Australian mud oyster	YES	YES	YES	ND	YES	YES	1	Hill *et al*., 2014
			YES	YES[5]	YES	ND	YES	YES	1	Heasman *et al*., 2004
Ostreidae	*Crassostrea virginica*	Eastern Oyster	YES	YES	YES	ND	YES[6]	YES	1	OIE, 2012 and personal communication (R. Carnegie)
			YES	YES	YES	ND	ND[7]	YES	1	OIE, 2013 and personal communication (R. Carnegie)
			YES	YES	YES	ND	ND	YES	1	Hill *et al*., 2014
			YES	YES	NO	ND	NO	NO	4	Dungan *et al*., 2012

[4] Pathogen identified on histology and was later characterized as *B. exitiosa* through molecular techniques in Hill *et al*., 2014.

[5] Pathogen identified on histology and was later characterized as *B. exitiosa* through molecular techniques in Hill *et al.*, 2014.

[6] No morbidity, mortalities or lesions reported but infiltration of parasites in hemocytes was noted.

[7] No mortality or lesions on histology was documented.

Family	Scientific name	Common name	Stages 1: Route of infection	Stage 2: Pathogen identification	Stage 3: Evidence for infection				Outcome	References
					A	B	C	D		
Ostreidae	*Crassostrea ariakensis*	Suminoe oyster	YES	YES	YES	ND	YES	YES	1	Burreson *et al*., 2004
			YES	YES	YES	ND	YES	YES	1	Dungan *et al*., 2012
Ostreidae	*Ostrea lurida*	Olympia oyster	YES	YES	YES	ND	YES	YES	1	Hill *et al*., 2014
Score 3										
Ostreidae	*Crassostrea gigas*	Pacific cupped oyster	YES	YES	NO	ND	NO	NO	3	Lynch *et al*., 2010
Ostreidae	*Saccostrea glomerata*	Sydney rock oyster	YES	YES	ND	ND	YES	YES[8]	3	Hill *et al*., 2014
			YES	YES	NO	ND	NO	NO	3	Carnegie *et al*., 2014
			YES	YES	NO	ND	NO	NO	3	Spiers *et al*., 2014
Not scored (NS) because pathogen ID was inconclusive										
Mytilidae	*Geukensia demissa*	Ribbed mussel	YES	NO[9]	NO	ND	NO	NO	NS	Laramore *et al*., 2017
Mytilidae	*Brachidontes exustus*	Scorched mussel	YES	NO	NO	ND	NO	NO	NS	Laramore *et al*., 2017
Mytilidae	*Ischadium recurvum*	Hooked mussel	YES	NO	ND	ND	ND	ND	NS	Laramore *et al.*, 2017
Isognomonid	*Isognomon bicolor*	Bicolor purse-oyster	YES	NO	NO	ND	NO	NO	NS	Laramore *et al.*, 2017
Isognomonid	*Isognomon alatus*	Flat tree-oyster	YES	NO	NO	ND	NO	NO	NS	Laramore *et al.*, 2017

[8] Microcells were identified but were not necessarily *B. exitiosa* as ISH was not completed. Pictures of histology were not provided and no specific description of microcells from *Saccostrea glomerata.*

[9] The specificity for the PCR and ISH used in Laramore *et al.*, 2017, has not been formally validated for *B. exitiosa*.

Note:

The scientific names of the species are in line with World Register of Marine Species (WoRMS) https://www.marinespecies.org/index.php (for *Crassostrea gigas* and *Crassostrea ariakensis* see explanatory note below).

The common names of mollusc species are in line with FAOTERM (http://www.fao.org/faoterm/collection/faoterm/en/) and https://www.sealifebase.ca. Where the common mollusc name was not found in FAOTERM, the naming was done in line with sealifebase.

Comments on the *ad hoc* Group's rationale and decision-making:

General comments

The *ad hoc* Group agreed to focus on studies published from 2000 onwards, when molecular testing was available. Papers published in earlier years were referred to when necessary to increase confidence of an assessment or when no recent paper was available for the assessment of a specific host species.

The *ad hoc* Group decided that either two papers with a score of '1', or a single study with corroborative evidence, were enough to conclude susceptibility of a species. Additional studies were still checked and considered for conflicting evidence. When a single publication provided evidence for a score of 1, some form of corroborating evidence was required in addition, specifically:

- Internal corroboration in the published study. Multiple lines of evidence within the same publication. This could result from i) a study that amasses positive molluscs from multiple dates and locations or ii) an experimental study testing several isolates or routes of exposure (e.g. immersion and cohab). In these instances, assuming the research is sound, the species was scored a 1 from a single peer-reviewed publication.

- External corroboration: evidence from other publications or sources. Examples might include data found in a government website, a separate publication that scores a 2 or better, or evidence of expert judgement (e.g. records from a reference lab).

When additional papers were identified but the *ad hoc* Group did not feel that they were necessary to assess as the species had already been determined as susceptible by other studies, these studies were included in the list of references.

Species-specific comments

- *Crassostrea virginica*: The *ad hoc* Group sought additional information from authors regarding infection of *Crassostrea virginica* with *Bonamia exitiosa* to enable an assessment for susceptibility. The *ad hoc* Group scored a '1' for this species but recognise that regression of infection without mortality appeared to occur. This suggests that *C. virginica* displays tolerance/resistance to infection as it supports replication without development of morbidity or mortality. *C. virginica* was proposed to be included in Article 11.2.2 of the *Aquatic Code.*
- *Ostrea lurida*: only one paper was available for assessment but was determined by the *ad hoc* Group as sufficiently having met the criteria for susceptibility to be scored as a '1' as there were multiple collections of oysters from different time periods. *O. lurida* was proposed to be included in Article 11.2.2 of the *Aquatic Code*.

- *Crassostrea gigas* is currently listed as a "possible carrier or reservoir" in the *Aquatic Manual*. The *ad hoc* Group felt that the Lynch *et al.*, 2010, paper reported pathogen specific positive PCR results, but an active infection had not been demonstrated. The *ad hoc* Group determined this met the criteria for susceptibility to be scored as a "3" and included in Section 2.2.2, Species with incomplete evidence for susceptibility, of the *Aquatic Manual*.

- According to WoRMS, the accepted Genus for *Crassostrea* should be *Magallana*. However, Bayne *et al.*, 2017, consider that the report by Salvi & Mariottini, 2017, is not sufficiently robust to support the proposed taxonomic change.

- According to WoRMS, *Ostrea stentina* and *Ostrea equestris* are considered distinct species, however there are some papers (Hill *et al*., 2010; Shilts *et al*., 2007) that consider them synonyms.

Article 1.5.9 Listing of Susceptible species at a taxonomic ranking of Genus or Higher

- The *ad hoc* Group considered Article 1.5.9, Listing of susceptible species at a taxonomic ranking of Genus or higher, in the *Aquatic Code*, but felt that it was not applicable for the hosts of *B. exitiosa* identified at this time.

References:

ABOLLO, E., RAMILO, A., CASAS, S. M., COMESAÑA, P., CAO, A., CARBALLAL, M. J. & VILLALBA, A. (2008). First detection of the protozoan parasite *Bonamia exitiosa* (Haplosporidia) infecting flat oyster Ostrea edulis grown in European waters. *Aquaculture*, **274(2–4)**, 201–207. https://doi.org/10.1016/j.aquaculture.2007.11.037

BURRESON, E. M., STOKES, N. A., CARNEGIE, R. B. & BISHOP, M. J. (2004). *Bonamia* sp. (Haplosporidia) found in nonnative oysters *Crassostrea ariakensis* in Bogue Sound, North Carolina. *Journal of Aquatic Animal Health*, **16(1)**, 1–9. https://doi.org/10.1577/H03-008.1

CARNEGIE, R.B., HILL, K.M., STOKES, N.A. & BURRESON E.M. (2014). The haplosporidian *Bonamia exitiosa* is present in Australia, but the identity of the parasite described as *Bonamia* (formerly *Mikrocytos*) *roughleyi* is uncertain. *Journal of Invertebrate Pathology. **115***, 33-40.

CARRASCO N., VILLALBA A., ANDREE K.B., ENGELSMA M.Y., LACUESTA B., RAMILO A., GAIRIN I. & FURONES M.D. (2012). *Bonamia exitiosa* (Haplosporidia) observed infecting the European flat oyster *Ostrea edulis* cultured on the Spanish Mediterranean coast. *Journal of Invertebrate Pathology*, **110(3)**, 307–313. https://doi.org/10.1016/j.jip.2012.03.015

COCHENNEC, N., LE ROUX, F., BERTHE, F. & GERARD, A. (2000). Detection of *Bonamia ostreae* based on small subunit ribosomal probe. *Journal of Invertebrate Pathology*, **76(1)**, 26–32. https://doi.org/10.1006/jipa.2000.4939

CORBEIL, S., ARZUL, I., ROBERT, M., BERTHE, F. C. J., BESNARD-COCHENNEC, N. & CRANE, M. S. J. (2006). Molecular characterisation of an Australian isolate of *Bonamia exitiosa*. *Diseases in aquatic organisms*, **71**, 81–85.

DUNGAN, C. F., CARNEGIE, R. B., HILL, K. M., MCCOLLOUGH, C. B., LARAMORE, S. E., KELLY, C. J., STOKES, N. A. & SCARPA, J. (2012). Diseases of oysters *Crassostrea ariakensis* and *C. virginica* reared in ambient waters from the Choptank River, Maryland and the Indian River Lagoon, Florida. *Diseases of Aquatic Organisms*, **101(3)**, 173–183. https://doi.org/10.3354/dao02531

HEASMAN, M., DIGGLES, B.K., HURWOOD, D., MATHER, P., PIROZZI, I. & DWORJANYN, S. (2004). Paving the way for continued rapid development of the flat (angasi) oyster (*Ostrea angasi)* farming industry in New South Wales. *NSW Fisheries Final Report Series* **No. 66** ISSN 1440-3544.

HILL, K. M., STOKES, N. A., WEBB, S. C., HINE, P. M., KROECK, M. A., MOORE, J. D., MORLEY, M. S., REECE, K. S., BURRESON, E. M. & CARNEGIE, R. B. (2014). Phylogenetics of *Bonamia* parasites based on small subunit and internal transcribed spacer region ribosomal DNA sequence data. *Diseases of Aquatic Organisms*, **110(1–2)**, 33–54. https://doi.org/10.3354/dao02738

HILL, K. M., CARNEGIE, R. B., ALOUI-BEJAOUI, N., GHARSALLI, R. EL, WHITE, D. M., STOKES, N. A. & BURRESON, E. M. (2010). Observation of a *Bonamia* sp. infecting the oyster *Ostrea stentina* in Tunisia, and a consideration of its phylogenetic affinities. *Journal of Invertebrate Pathology*, **103(3)**, 179–185. https://doi.org/10.1016/j.jip.2009.12.011

KROECK, M. A. (2010). Gross signs and histopathology of *Ostrea puelchana* infected by a *Bonamia exitiosa*-like parasite (Haplosporidia). *Diseases of Aquatic Organisms*, **89(3)**, 229–236. https://doi.org/10.3354/dao02186

LANE, H. S., WEBB, S. C. & DUNCAN, J. (2016). *Bonamia ostreae* in the New Zealand oyster *Ostrea chilensis*: A new host and geographic record for this haplosporidian parasite. *Diseases of Aquatic Organisms*, **118(1),** 55–63. https://doi.org/10.3354/dao02960

LARAMORE, S. E., KREBS, W., LAVE, A. L. & GALLAGHER, K. (2017). Survey of Bivalve Molluscs for *Bonamia* spp. and Other Parasitic Pathogens in Florida East Coast Lagoons. *Journal of Shellfish Research*, **36(2),** 379–390. https://doi.org/10.2983/035.036.0211

LYNCH, S. A., ABOLLO, E., RAMILO, A., CAO, A., CULLOTY, S. C. & VILLALBA, A. (2010). Observations raise the question if the Pacific oyster, *Crassostrea gigas*, can act as either a carrier or a reservoir for *Bonamia ostreae* or *Bonamia exitiosa*. *Parasitology*, **137(10),** 1515–1526. https://doi.org/10.1017/S0031182010000326

OIE World Animal Health Information System (WAHIS), 2012. https://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=12246

OIE World Animal Health Information System (WAHIS), 2013. https://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?page_refer=MapFullEventReport&reportid=14070

SPIERS, Z.B., GABOR, M., FELL, S.A., CARNEGIE, R.B., DOVE, M., O'CONNOR, W., FRANCES, J., GO. J., MARSH, I.B. & JENKINS, C. (2014). Longitudinal study of winter mortality in Sydney rock oysters *Saccostrea glomerata*. *Diseases of Aquatic Organisms.* **110,** 151-164.

Other references reviewed by the *ad hoc* Group but not referred to in the assessment table above:

ARZUL, I. (2018). Situation of European mollusc production regarding diseases. *Bulletin of the European Association of Fish Pathologists*, **38(3)**, 130–139.

ARZUL, I. & CARNEGIE, R. B. (2015). New perspective on the haplosporidian parasites of molluscs. *Journal of Invertebrate Pathology*, **131**, 32–42. https://doi.org/10.1016/j.jip.2015.07.014

AUDEMARD, C., CARNEGIE, R. B., HILL, K. M., PETERSON, C. H. & BURRESON, E. M. (2014). *Bonamia exitiosa* transmission among, and incidence in, Asian oyster *Crassostrea ariakensis* under warm euhaline conditions. *Diseases of Aquatic Organisms*, **110(1–2)**, 143–150. https://doi.org/10.3354/dao02648

BATISTA, F. M., LÓPEZ-SANMARTÍN, M., GRADE, A., NAVAS, J. I. & RUANO, F. (2016). Detection of *Bonamia exitiosa* in the European flat oyster *Ostrea edulis* in southern Portugal. *Journal of Fish Diseases*, **39(5)**, 607–611. https://doi.org/10.1111/jfd.12396

BAYNE, B.L., AHRENS, M., ALLEN, S.K., ANGLES D'AURIAC, M., BACKELJAU, T., BENINGER, P., BOHN, R., BOUDRY, P., DAVIS, J., GREEN, T., GUO, X., HEDGECOCK, D., IBARRA, A., KINGSLEY-SMITH, P., KRAUSE, M., LANGDON, C., LAPEGUE, S., LI, C., MANAHAN, D., MANN, R., PEREZ-PARALLE, L., POWELL, E.N., RAWSON, P.D., SPEISER, D., SANCHEZ, J.L. SHUMWAY, S. & WANG, H. (2017). The proposed dropping of the Genus *Crassostrea* for all Pacific Cupped Oysters and its replacement by a new Genus *Magallana*: A dissenting view. *Journal of Shellfish Research*. **36(3),** 545-547.

BERTHE, F. C. J. & HINE, P. M. (2003). *Bonamia exitiosa* Hine et al., 2001 is proposed instead of *B. exitiosus* as the valid name of *Bonamia* sp. infecting flat oysters *Ostrea chilensis* in New Zealand. *Diseases of Aquatic Organisms*, **57(1–2)**, 181. https://doi.org/10.3354/dao057181

BISHOP, M. J., CARNEGIE, R. B., STOKES, N. A., PETERSON, C. H. & BURRESON, E. M. (2006). Complications of a non-native oyster introduction: Facilitation of a local parasite. *Marine Ecology Progress Series*, **325 (November)**, 145–152. https://doi.org/10.3354/meps325145

BOUGRIER, S., TIGE, G., BACHERE, E. & GRIZEL, H. (1986). *Ostrea angasi* acclimatization to French coasts. *Aquaculture*, **58(1–2)**, 151–154. https://doi.org/10.1016/0044-8486(86)90165-1

BRADLEY, T.L., MERCER, J.A., HUMPHREY, T.L., MOODY, N.J.G. & HUNNAM, J.C. (2004). *Bonamia exitiosa* in farmed native oysters *Ostrea angasi* in Australia: optimal epidemiological qPCR cut-point and clinical disease risks. *Diseases of Aquatic Organisms.* **140,** 151-165.

BUSS, J. J., HARRIS, J. O., ELLIOT TANNER, J., HELEN WILTSHIRE, K. & DEVENEY, M. R. (2020a). Rapid transmission of *Bonamia exitiosa* by cohabitation causes mortality in *Ostrea angasi*. *Journal of Fish Diseases*, **43(2)**, 227–237. https://doi.org/10.1111/jfd.13116

BUSS, J.J., WILTSHIRE, K.H., HARRIS, J.O., TANNER, J.E., & DEVENEY, M.R. (2020b). Infection dynamics of *Bonamia exitiosa* on intertidal *Ostrea angasi* farms. *Journal of Fish Diseases*. **43(3),** 359-369.

BUSS, J.J., WILTSHIRE, K.H., HARRIS, J.O., TANNER, J.E., & DEVENEY, M.R. (2020c). Decontamination of *Bonamia exitiosa*. Aquaculture **523,** 735210.

BUSS, J. J., WILTSHIRE, K. H., PROWSE, T. A. A., HARRIS, J. O. & DEVENEY, M. R. (2019). *Bonamia* in *Ostrea angasi*: Diagnostic performance, field prevalence and intensity. *Journal of Fish Diseases*, **42(1)**, 63–74. https://doi.org/10.1111/jfd.12906

CAMPALANS, M. & LOHRMANN, K. B. (2009). Histological survey of four species of cultivated molluscs in Chile susceptible to OIE notifiable diseases. *Revista de Biología Marina y Oceanografía*, **44(3)**, 561–569. https://doi.org/10.4067/s0718-19572009000300004

CARNEGIE, R.B. AND BUSHEK, D. (2013). *Bonamia exitiosa* and its infection of *Crassostrea virginica* in the eastern USA: An Advisory. 10.13140/RG.2.1.2488.3363.

CARNEGIE, R. B., STOKES, N. A., AUDEMARD, C., BISHOP, M. J., WILBUR, A. E., ALPHIN, T. D., POSEY, M. H., PETERSON, C. H. & BURRESON, E. M. (2008). Strong seasonality of *Bonamia* sp. infection and induced *Crassostrea ariakensis* mortality in Bogue and Masonboro Sounds, North Carolina, USA. *Journal of Invertebrate Pathology*, **98(3)**, 335–343. https://doi.org/10.1016/j.jip.2008.03.009

COCHENNEC-LAUREAU, N., REECE, K. S., BERTHE, F. C. J. & HINE, P. M. (2003b). *Mikrocytos roughleyi* taxonomic affiliation leads to the genus *Bonamia* (Haplosporidia). *Diseases of Aquatic Organisms*, **54(3)**, 209–217. https://doi.org/10.3354/dao054209

CRANFIELD, H. J., DUNN, A., DOONAN, I. J. & MICHAEL, K. P. (2005). *Bonamia exitiosa* epizootic in *Ostrea chilensis* from Foveaux Strait, southern New Zealand between 1986 and 1992. *ICES Journal of Marine Science*, **62(1),** 3–13. https://doi.org/10.1016/j.icesjms.2004.06.021

DE LA BALLINA, N. R., VILLALBA, A. & CAO, A. (2018). Proteomic profile of *Ostrea edulis* haemolymph in response to bonamiosis and identification of candidate proteins as resistance markers. *Diseases of Aquatic Organisms*, **128(2)**, 127–145. https://doi.org/10.3354/dao03220

DIGGLES, B.K, COCHENNEC-LAUREAU, N. & HINE, P.M. (2003). Comparison of diagnostic techniques for *Bonamia exitiosus* from flat oysters *Ostrea chilensis* in New Zealand. *Aquaculture*. **110,** 145-156.

DINAMANI, P., HINE, P. M. & JONES, J. B. (1987). Occurrence and characteristics of the haemocyte parasite *Bonamia* sp. in the New Zealand dredge oyster *Tiostrea lutaria. Diseases of Aquatic Organisms,* **3,** 37-44.

DOLDAN, M. S., MORSAN, E. M., ZAIDMAN, P. C. & KROECK, M. A. (2014). Analysis of large-scale spatio-temporal trends of *Ostrea puelchana* beds in Northern Patagonian Gulfs, Argentina. *Marine Environmental Research*, **101(1)**, 196–207. https://doi.org/10.1016/j.marenvres.2014.07.003

DOONAN, I. J., CRANFIELD, H. J. & MICHAEL, K. P. (1994). Catastrophic reduction of the oyster, *Ostrea chilensis* (Bivalvia: Ostreidae), in Foveaux Strait, New Zealand, due to infestation by the protistan *Bonamia* sp. *New Zealand Journal of Marine and Freshwater Research*, **28(4),** 335–344. https://doi.org/10.1080/00288330.1994.9516623

FARLEY, C. A., WOLF, P. H. & ELSTON, R. A. (1988). A long-term study of "microcell'' disease in oysters with a description of a new genus, Mikrocytos (G.N.), and two new species, *Mikrocytos mackini* (sp.n.) and *Mikrocytos roughleyi* (sp.n.)." *Fishery Bulletin*, **86(3)**, 581–593.

FU, D., DUNN, A., MICHAEL, K. P. & HILLS, J. (2016). The development and performance of a length-based stock assessment of Foveaux Strait oysters (*Ostrea chilensis*, OYU 5) in southern New Zealand, and application to management. *Fisheries Research*, **183(May)**, 506–517. https://doi.org/10.1016/j.fishres.2016.05.003

HILL-SPANIK, K. M., MCDOWELL, J. R., STOKES, N. A., REECE, K. S., BURRESON, E. M. & CARNEGIE, R. B. (2015). Phylogeographic perspective on the distribution and dispersal of a marine pathogen, the oyster parasite *Bonamia exitiosa*. *Marine Ecology Progress Series*, **536**, 65–76. https://doi.org/10.3354/meps11425

HINE, P. M. (1991a). Ultrastructural observations on the annual Infection pattern of *Bonamia* sp. in flat oysters *Tiostrea chilensis*. *Diseases of Aquatic Organisms*, **11**, 163–171. https://doi.org/10.3354/dao011163

HINE, P. M. (1991b). The annual pattern of infection by *Bonamia* sp. in New Zealand flat oysters, *Tiostrea chilensis*. *Aquaculture*, **93(3)**, 241–251. https://doi.org/10.1016/0044-8486(91)90236-Z

HINE, P. M., CARNEGIE, R. B., KROECK, M. A., VILLALBA, A., ENGELSMA, M. Y. & BURRESON, E. M. (2014). Ultrastructural comparison of *Bonamia* spp (Haplosporidia) infecting ostreid oysters. *Diseases of Aquatic Organisms*, **110(1–2)**, 55–63. https://doi.org/10.3354/dao02747

HINE, P. M., COCHENNEC-LAUREAU, N. & BERTHE, F. C. J. (2001). *Bonamia exitiosus* n.sp. (Haplosporidia) infecting flat oysters *Ostrea chilensis* in New Zealand. *Diseases of Aquatic Organisms*, **47(1)**, 63–72. https://doi.org/10.3354/dao047063

HINE, P. M., DIGGLES, B. K., PARSONS, M. J. D., PRINGLE, A. & BULL, B. (2002). The effects of stressors on the dynamics of *Bonamia exitiosus* Hine, Cochennec-Laureau & Berthe, infections in flat oysters *Ostrea chilensis* (Philippi). *Journal of Fish Diseases*, **25(9)**, 545–554. https://doi.org/10.1046/j.1365-2761.2002.00410.x

HINE, P. M. & JONES, J. B. (1994). *Bonamia* and other aquatic parasites of importance to New Zealand. *New Zealand Journal of Zoology*, **21(1)**, 49–56. https://doi.org/10.1080/03014223.1994.9517975

KROECK, M. A., SEMENAS, L. & MORSAN, E. M. (2008). Epidemiological study of *Bonamia* sp. in the native flat oyster, *Ostrea puelchana* from San Matías Gulf (NW Patagonia, Argentina). *Aquaculture*, **276(1–4),** 5–13. https://doi.org/10.1016/j.aquaculture.2008.02.013

KROECK, M. A. & MONTES, J. (2005). Occurrence of the haemocyte parasite *Bonamia* sp. in flat oysters *Ostrea puelchana* farmed in San Antonio Bay (Argentina). *Diseases of Aquatic Organisms*, **63(2–3),** 231–235. https://doi.org/10.3354/dao063231

LANE, H. S., JONES, B. & POULIN, R. (2018). Comparative population genetic study of an important marine parasite from New Zealand flat oysters. *Marine Biology*, **165(1)**, 1–11. https://doi.org/10.1007/s00227-017-3260-4

LOHRMANN, K. B., HINE, P. M. & CAMPALANS, M. (2009). Ultrastructure of *Bonamia* sp. in *Ostrea chilensis* in Chile. *Diseases of Aquatic Organisms*, **85(3),** 199–208. https://doi.org/10.3354/dao02093

LONGSHAW, M., STONE, D. M., WOOD, G., GREEN, M. J. & WHITE, P. (2013). Detection of *Bonamia exitiosa* (Haplosporidia) in European flat oysters *Ostrea edulis* cultivated in mainland Britain. *Diseases of Aquatic Organisms*, **106(2),** 173–179. https://doi.org/10.3354/dao02643

MICHAEL, K. P., DUNN, A. & FORMAN, J. (2006). A survey of *Bonamia exitiosa* infection, and oyster density and recruitment in Foveaux Strait dredge oyster (*Ostrea chilensis*). *New Zealand Fisheries Assessment Report*, **40**.

NARCISI, V., ARZUL, I., CARGINI, D., MOSCA, F., CALZETTA, A., TRAVERSA, D., ROBERT, M., JOLY, P.P. CHOLLET, B., RENAULT, T. & TISCAR, P. G. (2010). Detection of *Bonamia ostreae* and *B. exitiosa* (haplosporidia) in *Ostrea edulis* from the Adriatic Sea (Italy). *Diseases of Aquatic Organisms*, **89(1)**, 79–85. https://doi.org/10.3354/dao02167

NELL, J. A. & PERKINS, B. (2006). Evaluation of the progeny of third-generation Sydney rock oyster *Saccostrea glomerata* (Gould, 1850) breeding lines for resistance to QX disease *Marteilia sydneyi* and winter mortality *Bonamia roughleyi*. *Aquaculture Research*, **37(7)**, 693–700. https://doi.org/10.1111/j.1365-2109.2006.01482.x

OEHRENS KISSNER E.M., DEL SOCORRO DOLDAN, M., ZAIDMAN, P.C., MORSAN E.M. & KROECK M.A. (2014). Bonamiosis status in natural *Ostrea puelchana* beds in San Matias Gulf (Patagonia, Argentina), 14 years after an epizootic. *Disease of Aquatic Organisms*. **110(1-2),** 135-142. https://doi.org/10.3354/dao02707

RAMILO, A., GONZÁLEZ, M., CARBALLAL, M. J., DARRIBA, S., ABOLLO, E. & VILLALBA, A. (2014a). Oyster parasites *Bonamia ostreae* and *B. exitiosa* co-occur in Galicia (NW Spain): Spatial distribution and infection dynamics. *Diseases of Aquatic Organisms*, **110(1–2)**, 123–133. https://doi.org/10.3354/dao02673

RAMILO, A., VILLALBA, A. & ABOLLO, E. (2014b). Species-specific oligonucleotide probe for detection of *Bonamia exitiosa* (Haplosporidia) using in situ hybridisation assay. *Diseases of Aquatic Organisms*, **110(1–2)**, 81–91. https://doi.org/10.3354/dao02646

RAMILO, A., NAVAS, J.I., VILLALBA, A., & ABOLLO, E. 2013. Species-specific diagnostic assays for *Bonamia ostreae* and *B. exitiosa* in European flat oyster *Ostrea edulis*: conventional, real-time and multiplex PCR. *Diseases of Aquatic Organisms* **104(2)**,149-161 https://doi.org/10.3354/dao02597

SALVI, D. & MARIOTTINI, P. (2017). Molecular taxonomy in 2D: a novel ITS 2 rRNA sequence structure approach guides the description of the oysters subfamily *Saccostreinae* and the genus *Magallana* (*Bivalvia: Ostreidae*). *Zoological Journal of the Linnean Society*. **179,** 263-276.

SHILTS, M.H., PASCUAL, M.S. & O'FOIGHIL. (2007). Systematic, taxonomic and biogeographic relationships of Argentine flat oysters. *Molecular Phylogenetics and Evolution*. **44,** 467-473.

VÁZQUEZ, N. & CREMONTE, F. (2017). Review of Parasites and Pathologies of the Main Bivalve Species of Commercial Interest of Argentina and Uruguay, Southwestern Atlantic Coast. *Archives of Parasitology*, **1(2)**, 1–12.

OIE *AD HOC* GROUP ON SUSCEPTIBILITY OF MOLLUCS SPECIES TO INFECTION WITH OIE LISTED DISEASES

November–December 2020

List of participants

MEMBERS OF THE *AD HOC* GROUP

Dr Isabelle Arzul (Chair)
IFREMER
Laboratoire de Génétique et Pathologie de Mollusques Marins
17390 La Tremblade
FRANCE
Tel: +33 5 46 76 26 10
iarzul@ifremer.fr
isabelle.arzul@ifremer.fr

Dr Robert Adlard
Marine Biodiversity at Queensland Museum Network
PO Box 3300, South Brisbane
BC
Queensland 4101
AUSTRALIA
robert.adlard@qm.qld.gov.au

Dr Chang-Ming Bai
Yellow Sea Fisheries Research Institute, CAFS
Division of Maricultural Organism Disease control and Molecular Pathology
No. 106 Nanjing Road
Qingdao, 266071
CHINA
baicm@ysfri.ac.cn

Dr Lori Gustafson
Surveillance Design and Analysis
USDA/APHIS/VS/CEAH
2150 Centre Ave, Bldg B
Mail Stop 2E6
Fort Collins, CO 80526-8117
UNITED STATES
lori.l.gustafson@aphis.usda.gov

Dr Karin B. Lohrmann
Departamento de Biología Marina
Facultad de Ciencias del Mar,
Universidad Católica del Norte,
Larrondo 1281, Coquimbo
CHILE
klohrman@ucn.cl

REPRESENTATIVE OF THE AQUATIC ANIMAL HEALTH STANDARDS COMMISSION

Dr Kevin William Christison
Department of Environment, Forestry and Fisheries
Directorate: Aquaculture Research and Development
Private Bag X 2
Vlaeberg, 8018
SOUTH AFRICA
kchristison@environment.gov.za

OIE HEADQUARTERS

Dr. Bernita Giffin
Scientific Coordinator for Aquatic Animal Health
Standards Department
b.giffin@oie.int

Dr Stian Johnsen
Chargé de mission
Standards Department
s.johnsen@oie.int

OIE AD HOC GROUP ON SUSCEPTIBILITY OF MOLLUSC SPECIES TO INFECTION WITH OIE LISTED DISEASES

November–December 2020

_____

Terms of reference

Background

Chapter 1.5, Criteria for listing species as susceptible to infection with a specific pathogen, was introduced in the 2014 edition of the *Aquatic Code*. The purpose of this chapter is to provide criteria for determining which host species are listed as susceptible in Article X.X.2 of each disease-specific chapter in the *Aquatic Code.* The criteria are to be applied progressively to each disease-specific chapter in the *Aquatic Code*.

These assessments will be undertaken by *ad hoc* Groups and the assessments will be provided to Member Countries for comment prior to any change in the list of susceptible species in Article X.X.2 of the disease-specific chapters in the *Aquatic Code.*

For species where there is some evidence of susceptibility but insufficient evidence to demonstrate susceptibility through the approach described in Article 1.5.3, information will be included in the relevant disease-specific chapter in the *Aquatic Manual*.

Purpose

The *ad hoc* Group on Susceptibility of mollusc species to infection with OIE listed diseases will undertake assessments for the seven OIE listed mollusc diseases.

Terms of Reference

1) Consider evidence required to satisfy the criteria in Chapter 1.5.

2) Review relevant literature documenting susceptibility of species for OIE listed mollusc diseases.

3) Propose susceptible species for OIE listed diseases for molluscs based on Article 1.5.7.

4) Propose susceptible species for OIE listed diseases for molluscs based on Article 1.5.8.

Expected outputs of the *ad hoc* Group

1) Develop a list of susceptible species for inclusion in the relevant Article X.X.2 of mollusc disease-specific chapters in the *Aquatic Code.*

2) Develop a list of species with incomplete evidence for susceptibility for inclusion in Section 2.2.2 of the *Aquatic Manual.*

3) Draft a report for consideration by the Aquatic Animals Commission at their September 2020 meeting.

_____