Strategies to mitigate OsHV-1 in *Crassostrea gigas* hatchery and nursery systems

Dolors Furones, IRTA

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VIVALDI
Preventing and mitigating farmed bivalve diseases

National and international programmes to prevent disease emergence and spread


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Legislative and regulatory aspects of molluscan health management

C.J. Rodgers [a,*], R.B. Carnegie [b], M.C. Chávez-Sánchez [c], C.C. Martínez-Chávez [d], M.D. Furones Nozal [a], P.M. Hine [e]

[a] IRTA-SCR, C/Poble Nou s/n, Sant Carles de la Ràpita, 43540 Tarragona, Spain
[b] Virginia Institute of Marine Science, College of William & Mary, P.O. Box 1346, Gloucester Point, VA, USA
[c] Centro de Investigación en Alimentación y Desarrollo (CIAD), Unidad Mazatlán, Av. Sábalo Cerritos s/n, Mazatlán, 82100 Sinaloa, Mexico
[d] Laboratorio de Acuicultura y Nutrición, Instituto de Investigaciones Agropecuarias y Forestales, UMSNH, Av. San Juanito Itzícuaro s/n, Morelia, 58330 Michoacán, Mexico
[e] 73 rue de la Fée au Bois, 17450 Fouras, France

	Objective	Mechanism	Basis
Australia	Effectively manage aquatic animal health to protect the sustainability of commercial and recreational fisheries, the productivity of aquaculture industries, and access to international markets for Australian seafood industries	National committees responsible for aquatic animal health and development of Australia's National Strategic Plan for Aquatic Animal Health	Management of Australia's aquatic animal disease surveillance and reporting system
Canada	Biosecurity for minimizing the risk of introduction and spread of infectious organisms into or between populations	Protecting wild and farmed aquatic animals against serious infectious diseases through the National Aquatic Animal Health Program	Management of aquatic animal health by regulatory and non-regulatory science programs for both national and international activities
European Union (old)	Protect and raise the health status and condition of aquatic animals in the EU	Permit intra-EU trade and imports of aquatic animals and their products	Appropriate health standards and international obligations
European Union (new)	Reduce the incidence of aquatic animal disease and minimise the impact of outbreaks	Greater focus on precautionary measures, disease surveillance, controls and research	Prevention is better than cure
OIE	Improvement of aquatic animal health and welfare worldwide, including safe international trade	Provide for early detection, reporting and control of agents pathogenic to aquatic animals and to prevent their transfer via international trade	Standards and recommendations for health measures used by importing and exporting countries
New Zealand	Prevent or manage risks from harmful organisms, such as pests and diseases	Stopping pests and diseases before they arrive or dealing with them if they enter the country	Provision of a legal framework for biosecurity through border risk, national pest and dissemination pathway management
USA	Protect the health and improve the quality and productivity of farmed and wild aquatic animals, as well as minimize the impacts of diseases when they occur	Prevention, control and management of aquatic animal diseases in order to protect domestic commerce and support live and processed aquatic animal exports	Implementation of the National Aquatic Animal Health Plan by defining pathogens of national concern, surveillance programs, and health strategies

REVIEWS IN Aquaculture

Reviews in Aquaculture (2019) **11**, 565–585 doi: 10.1111/raq.12246

A literature review as an aid to identify strategies for mitigating ostreid herpesvirus 1 in *Crassostrea gigas* hatchery and nursery systems

Chris Rodgers[1,*], Isabelle Arzul[2], Noèlia Carrasco[1] and Dolores Furones Nozal[1]

1 IRTA-SCR, Sant Carles de la Ràpita, Tarragona, Spain
2 Laboratoire de Genetique et Pathologie des Mollusques Marins, IFREMER, La Tremblade, France

Management control strategies to reduce mortality considering the main compartments affected

Compartment factors	
Animal host	Age of bivalves, size, physiological state and growth rate, immunity to the pathogen, and selective breeding programmes
Husbandry	Production cycle, culture systems used, stocking densities, and presence of co-cultured bivalves
Pathogen	Life cycle, survival in the environment, pathogenicity and virulence
Environment	Temperature, reservoir populations, water pollution, and ecosystem compartments

Management control strategies
Surveillance
Biosecurity
Mitigation
Farm-based decisions
Integrated management
Traceability
Zoning/compartmentalisation

Animal host

Animal host factors
Host range
Wide host range
Bivalve age
Larvae, spat and rapidly growing juveniles are most susceptible
Only juveniles transmit OsHV-1
Adults can act as carriers
Vertical transmission suspected
Antimicrobial response
Genetic basis for survival
Production of probiotic antimicrobial compounds by haemolymph microbiota
Specific phage anti-viral activity
Poly(I:C) induced protective antiviral immune response
Selective breeding programmes
Resistant family lines
Ploidy
Effect of ploidy is not clear
Physiological and nutritional state
Role of the physiological state of *C. gigas* exposed to OsHV-1 is unclear

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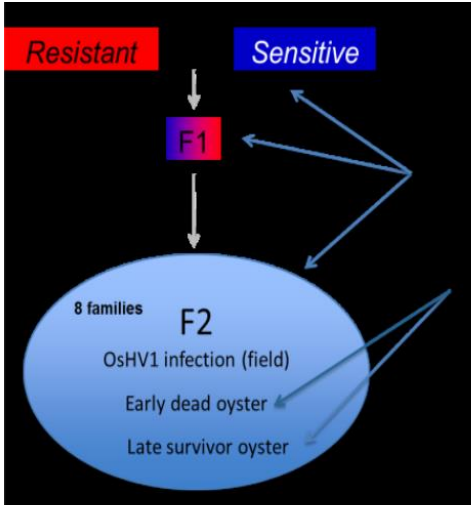
Autophagy in *C. gigas* vs OsHV-1 infection→ different regulation in two tissues, confirming the involvement of the autophagy pathway in the response to the OsHV.-



Warburg effect: link metabolism vs OsHV-1 →survival of oysters was dependent on the shore level during the OsHV-1 infection: no mortality was recorded at the high shore although 60% of oysters were already dead at low shore.

Husbandry

Husbandry factors
Type of culture
Oysters cemented on ropes have less mortality than baskets
Infection prevalence lower in baskets than in trays
Nurseries and semi-enclosed areas are related to spat mortalities
Open sea culture does not show mortality but oysters still susceptible if moved to infected areas
Infection pressure higher in intensive farming areas
Oysters in ponds (e.g. French “claires”) at very low densities are less affected by mortalities
Increased mortality due to numerous smaller farms in close proximity
Higher mortality using on-bottom and low height techniques
Decreased mortality in intertidal trays at a high height
Density and handling
Low host densities can lead to slow pathogen dissemination and unsustainable infection
Handling oysters before an outbreak leads to higher mortality
Oyster mortality decreases with water renewal
Oyster mortality increases with the biomass of neighbouring infected animals
Presence of other species
Host range includes non-susceptible bivalve species
Potential for interspecies transmission from reservoir populations
Non-infected non-susceptible species may act as a “buffer” by removing virus from the water
OsHV-1 cannot be eradicated from stocks of wild self-recruiting oysters

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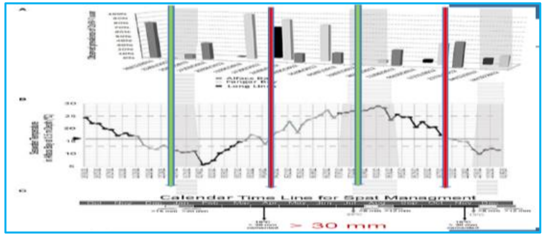

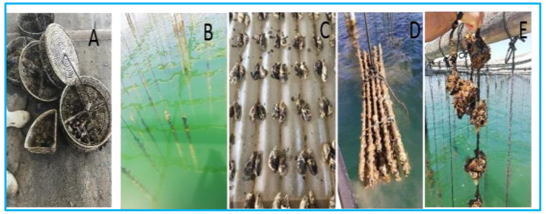

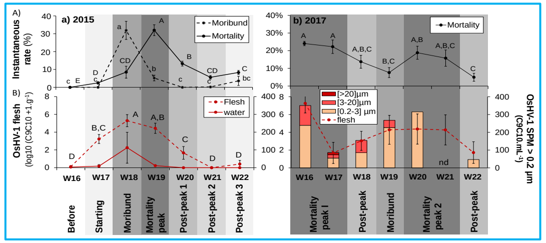

Pathogen

Pathogen factors

Life cycle

- OsHV-1 capable of direct transmission between hosts
- Synchronous exposure to a common environmental source
- Multifactorial induction of mortality events in spat and larvae

Pathogenicity and survival in the environment

- Maximum survival time outside host bivalve species is unknown
- Capable of causing 100% mortality within 6 days after infection
- OsHV-1 can persist and remain infectious in seawater for 54 h at 16 °C and 48 h at 20 °C
- High temperatures reduce infectivity (33 h at 25 °C)
- Pathogenicity varies with the size of the host oyster

Virulence

- Viral load threshold of 8.8×10^{3} OsHV-1 DNA mg tissue^{-1} above which there is a risk of oyster mortality
- Stress or stock transfer can lead to an increase in virulence

Other variants

- Other variants could be widespread in areas with wild stocks

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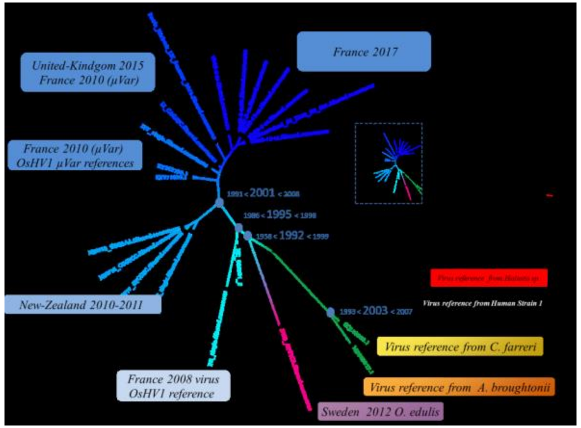

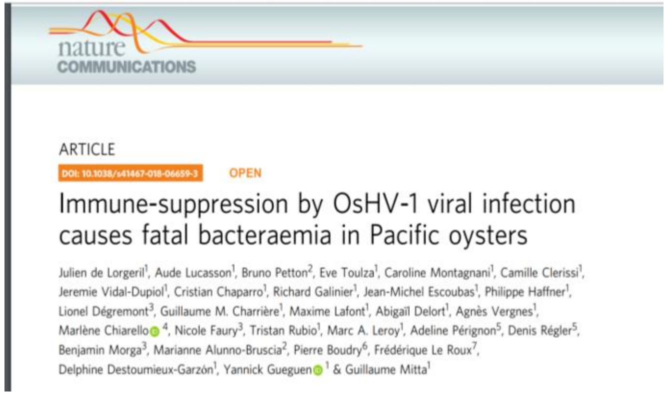
nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-06659-3 OPEN

Immune-suppression by OsHV-1 viral infection causes fatal bacteraemia in Pacific oysters

Julien de Lorgeril[1], Aude Lucasson[1], Bruno Petton[2], Eve Toulza[1], Caroline Montagnani[1], Camille Clerissi[1], Jeremie Vidal-Dupiol[1], Cristian Chaparro[1], Richard Galinier[1], Jean-Michel Escoubas[1], Philippe Haffner[1], Lionel Dégremont[3], Guillaume M. Charrière[1], Maxime Lafont[1], Abigaïl Delort[1], Agnès Vergnes[1], Marlène Chiarello[4], Nicole Faury[3], Tristan Rubio[1], Marc A. Leroy[1], Adeline Pérignon[5], Denis Régler[5], Benjamin Morga[3], Marianne Alunno-Bruscia[2], Pierre Boudry[6], Frédérique Le Roux[7], Delphine Destoumieux-Garzón[1], Yannick Gueguen[1] & Guillaume Mitta[1]

Environment

Environment factors
Temperature
In Europe, a seawater temperature of 16 ºC triggers OsHV-1 infections
Severe mortality where temperature increases rapidly in spring
No significant mortality at lower temperatures
Upper limit for mortalities is 22-25 °C
In Australia, the lower threshold temperature above which mortality occurs is 21-24 °C
Viral particle attachment
Infection from a common environmental source, such as plankton particles
Other bivalves may filter OsHV-1 attached aggregates from the water column
Fouling organisms
Fouling organisms on cage netting may harbour virus and represent a health risk
Water hydrodynamics
Hydrodynamic connectivity represents a driver for disease in culture facilities
Tidal movements can affect mortality
Reservoir populations
OsHV-1 is maintained in wild oysters that can be used as broodstock
Watershed pollution
Pesticides can increase susceptibility to OsHV-1 infection
Global warming/climate change
Climate change can moderate aquaculture production in open systems

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Fish and Shellfish Immunology

journal homepage: www.elsevier.com/locate/fsi

Full length article

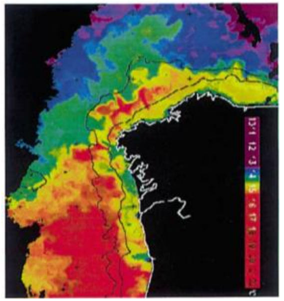
Temperature modulate disease susceptibility of the Pacific oyster *Crassostrea gigas* and virulence of the Ostreid herpesvirus type 1

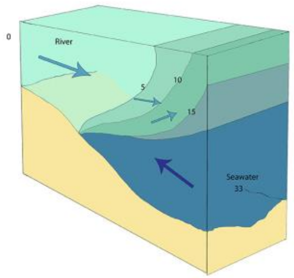
Lizenn Delisle[a], Bruno Petton[b], Jean François Burguin[a], Benjamin Morga[c], Charlotte Corporeau[a], Fabrice Pernet[a,*]

The presence of filter-feeders decreased mortality risk of oysters but the levels of OsHV-1 DNA in the seawater were similar among the tested condition.

Algal community influence disease risk in oyster

Found no effect of water acidification on survival of oysters





Management control strategies to reduce mortality considering the main compartments affected

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Zoning/compartmentalisation

Management control strategies

Surveillance

Management control strategies : Surveillance

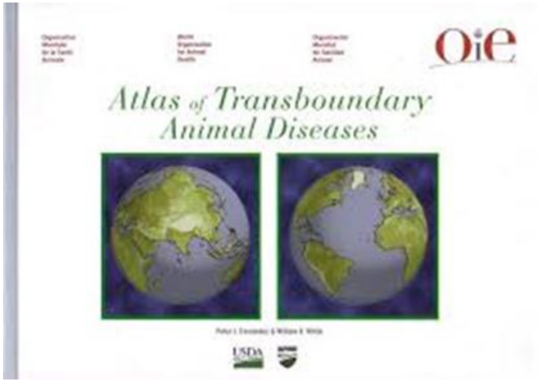
Surveillance factors	Strategy to consider	Recommendations
Early detection of disease trends or drivers	Provide quality data from surveillance programmes supported by linked databases	1A,1B
Improve shellfish aquaculture health management	More broad-based surveillance programmes and application of risk analyses	1C
Develop practical and effective measures to manage OsHV-1	Foster interdisciplinary collaboration between farmers, scientists and policy makers	1D

Management control strategies

Biosecurity

Management control strategies : Biosecurity

Biosecurity factors	Strategy to consider	Recommendations
Prevent or reduce the risk of transmission of OsHV-1	Source stock from certified disease-free locations	2D, 4A
	Hold animals under quarantine conditions until they can be verified as disease-free	
	Regular assessment of bivalve health	3A, 3D, 3E
	Clean and disinfect equipment	
Limit the spread and prevent reinfection after mortality outbreaks	Destruction of infected stock, disinfection of water and equipment, and practice fallowing	7D
	Screening for OsHV-1 prior to transportation between different geographical zones or before transfer of larvae and seed to the field	2C
	Selective breeding programmes for disease resistance	4B
Control the input pathways related to prevention of pathogen entry	Offshore rearing to reduce the probability of disease outbreaks in closed production systems	
Promote the importance of biosecurity for prevention and control of OsHV-1	Communication with and education of the industry and public	3C, 9B, 9C



Management control strategies

Mitigation

Management control strategies : Mitigation

Mitigation factors	Strategy to consider	Recommendations
Movement restrictions		
Unrestricted movement of oysters associated with a high risk of OsHV-1 spread	Source stock from certified disease-free locations	2F (?)
Dissemination is higher for wild oysters collected in infected areas than from hatcheries and nurseries		
Limit the spread and combat disease outbreaks	Restrictions on oyster movements	2C, 2D, 2E
Water treatment		
Discharge of untreated seawater from depuration plants or other bivalve holding facilities	Effective disinfection of effluent water from closed or semi-closed systems	6B, 6C
Risk of transmission of OsHV-1 through inflow water	Effective disinfection and/or filtration of inflow water for closed or semi-closed systems	6A, 6C

Management control strategies : Mitigation (cont.)

Mitigation factors	Strategy to consider	Recommendations
Inactivation of virus		6A, 6B, 6C _ GENERIC
Inactivation of water-borne virus	UV irradiation at 254 nm	6A, 6B, 6C
	Buffodine® iodophor*	
	Impress surfactant*	
	Calcium hypochlorite*	
	Heating seawater (50 °C for 5 min)	
	Virkon-S® (1% v/v for 15 min)	
	Sodium hydroxide (20 g L^{-1} for 10 min)	
	Iodine (0.1% for 5 min)	
	Formalin (10% v/v for 30 min)	
	Chlorine (50 ppm for 15 min)	
Production calendar		8I
Field placement timing	Transfer hatchery-produced spat after the critical high risk period for mortalities	8A, 8I
	Adjust production activities to local water temperature dynamics	8B
	Adjust spat immersion size, culture density and cementing calendar	8C, 8H

Management control strategies : Mitigation (cont.)

Mitigation factors	Strategy to consider	Recommendations
Transmission		
Interspecies viral transmission	Avoid co-culture with different species of unknown health status	
Transmission can lead to poor hatchery production and subsequent survival	Selective breeding programmes for hatchery production	4A
	Source stock from certified disease-free locations	4B (?)
	Improve the knowledge of OsHV-1 transmission	
Epidemiology		
Contribute to effectiveness of disease control scenarios in oyster ecosystems (hatcheries and nurseries)	Develop improved epidemiological models	1B, 1D, 2B
	Provide more data for persistence outside the host and potential for pathogen dispersal	
	Apply the concept of epidemiological units	
	Foster interdisciplinary collaboration between farmers, scientists and policy makers	3A
Support for eradication of OsHV-1 in closed-water systems	Generate more data related to pathogen prevalence and distribution	2C

Management control strategies

Farm-based decisions

Management control strategies : Farm-based decisions

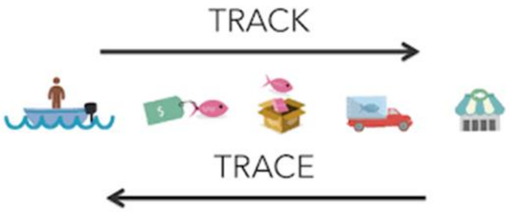
Farm management decision factors	Strategy to consider	Recommendations
Improve shellfish aquaculture health management and control processes	Wider training for better on-farm management decisions	9E
	Foster interdisciplinary collaboration between farmers, scientists and policy makers	3A
	Modify husbandry techniques and operational strategies, such as species diversification, more use of hatchery spat, and new or more versatile infrastructure	8G (?)
	Restrictions on oyster movements between production areas and sites	2A, 2C, 2D
	Prevent movement and transfer of equipment	9D
	Optimise timing of seeding and spatial planning related to seawater temperature and seed origin	8B, 8I
	Density regulation for oyster beds	8H
	Zoning of farming areas by OsHV-1 status	1A, 1B,1C

Management control strategies

Integrated management

Management control strategies : Integrated management

Integrated management factors	Strategy to consider	Recommendations
Consider the ecosystem approach for spatial and temporal distribution controls	Regulate the location of installations and closed areas for shellfisheries	
	Improve decision making through better assessment, monitoring, and scientific research	
	Tiered indicator monitoring with knowledge-based management and an integrative framework (pathogen→introductions→harvesting)	1B
	Foster interdisciplinary collaboration between farmers, scientists and policy makers	1D, 9A, 9C
	Maximise aquaculture stocking biomass (carrying capacity), since lower density equates to less disease pressure	8H

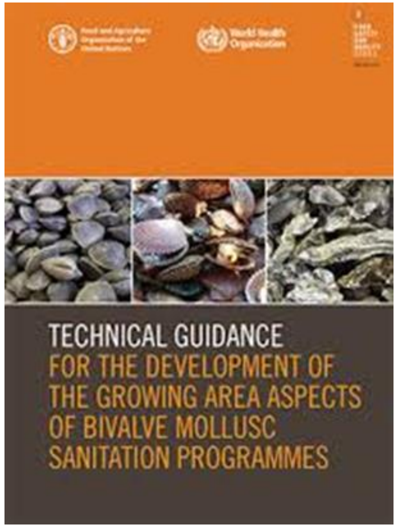


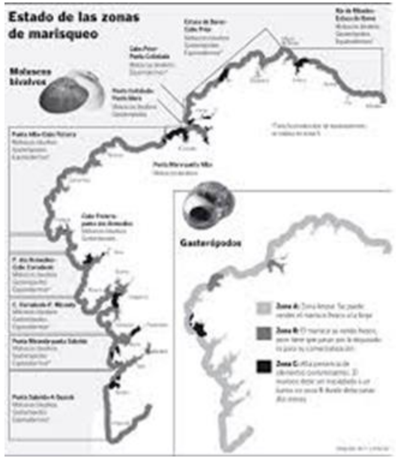
Management control strategies

Traceability

Management control strategies : Traceability

Traceability factors	Strategy to consider	Recommendations
Lack of traceability in oyster farming	Provide more data for identification of epizootic sources, routes of spread and application of control measures	9B, 9C
	Apply traceability at the compartment level	





Management control strategies

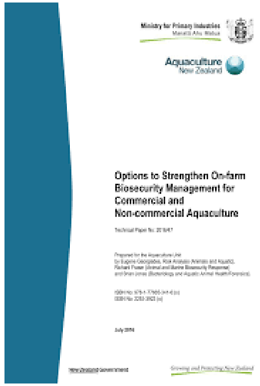
Zoning/compartmentalisation

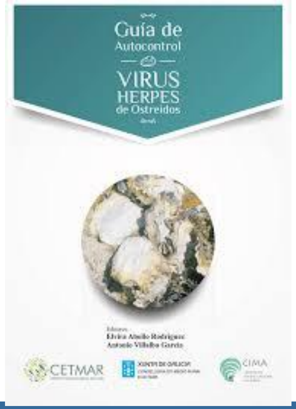
Management control strategies : Zoning/compartmentalisation

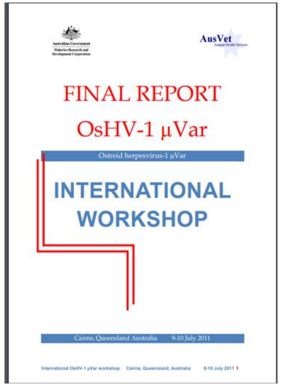
Zoning and compartmentalisation factors	Strategy to consider	Recommendations
Local disease eradication, limitation of disease spread and prevention of pathogen introduction	Compartmentalisation using management practices related to biosecurity, especially closed and semi-closed oyster farming systems	1A, 1B, 1C
	Zoning using geographically aligned spatial considerations	
	Introduce minimum separation distances between farms, “firebreaks” between aquaculture zones and density regulation of susceptible hosts to limit disease spread	7C, 8F
	Epidemiological separation of oysters with different disease status potential	1A, 1B, 1C
	Identify sources of infection and the risk of spread of infection into a compartment	1B
	Recommend a protected water supply, algal feed from a certified source, prohibition of entry of fomites (e.g. transport crates, settlement media, nets), and staff working at other sites	6C

Existing published guidelines for control of OsHV-1

- AQUAVETPLAN Disease Strategy: Infection with ostreid herpesvirus-1 microvariant, Australia (2015).
- Options to strengthen on-farm biosecurity management for commercial and non-commercial aquaculture – Technical Paper No: 2016/47, Ministry for Primary Industries, Aquaculture New Zealand (2016).
- OsHV-1 mortalities in Pacific oysters in Australia and New Zealand: the farmer's story, Cawthron Report No. 2567 (2015).
- Report on the impact of recent *Crassostrea gigas* mortality in France and its consequences to oyster farming in Northern Ireland (2012).
- HERPEMOL Guidelines for autocontrol of Ostreid herpesvirus, Spain (2013).
- International OsHV-1 µVar Workshop, Cairns, Queensland, Australia (2013).







Preventing and mitigating farmed bivalve diseases

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CONTACT

Isabelle ARZUL
Isabelle.Arzul@ifremer.fr

IFREMER - Station de La Tremblade
17390 La Tremblade / FRANCE

Direct line: +33 (0)5 46 76 26 47
Switchboard:+33 (0)5 46 76 26 10

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