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

Supplementary tables

Table S1. Strategies related to ANIMAL HOST factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Animal host factors	**Strategy to consider**
Host range	
Wide host range	Avoid co-culture with different species of unknown health status
Bivalve age	
Larvae, spat and rapidly growing juveniles are most susceptible	Acclimatise small oysters
Adults can act as carriers	Use genetically resistant broodstock
Vertical transmission suspected	
Antimicrobial response	
Genetic basis for survival	Natural selection for resistance
Production of probiotic antimicrobial compounds by haemolymph microbiota	Probiotic treatment programmes
Specific phage anti-viral activity	Phage treatment programmes
Specific viral pathogen interference	Therapeutic virus treatment programmes
Poly(I:C) induced protective antiviral immune response	Induction of antiviral response with early treatment of juvenile bivalves and parental strains
Selective breeding programmes	
Resistant family lines	Selective breeding programmes for hatchery production
Ploidy	
Effect of ploidy is not clear	Production of tetraploid lines from selected diploid broodstocks
	Hatcheries should use the best breeders with the greatest resistance to OsHV-1
Physiological and nutritional state	
Role of the physiological state of *C. gigas* exposed to OsHV-1 is unclear	Avoid the likelihood that high metabolic requirements, exhausted energetic reserves and scarce natural food resources lead to higher mortalities in oysters growing at high densities

Table S2. Strategies related to HUSBANDRY factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Husbandry factors	**Strategy to consider**
Type of culture	
Oysters cemented on ropes can have less mortality than baskets	Use most adequate culture method: cemented ropes→baskets→trays
Infection prevalence lower in baskets than in trays	
Nurseries and semi-enclosed areas can be related to spat mortalities	Consider less enclosed open areas
Open sea culture does not show mortality but oysters still susceptible if moved to infected areas	Offshore operations should use *C. gigas* from areas where infection is not present
Infection pressure higher in intensive farming areas	Low intensity culture
Oysters in ponds (e.g. French “claires”) at very low densities can be less affected by mortalities	Low density short production cycles for acclimatisation
Increased mortality due to numerous smaller farms in close proximity	Adequate spatial separation for culture sites
Higher mortality using on-bottom and low height techniques	Use off-bottom culture in tidal areas
Decreased mortality in intertidal trays at a high height	Use high height culture in tidal areas
Density and handling	
Low host densities can lead to slow pathogen dissemination and unsustainable infection	Low density culture
Handling oysters before an outbreak leads to higher mortality	Avoid handling before and during high risk periods
Oyster mortality decreases with water renewal	Position open system facilities for optimised water flow
Oyster mortality increases with the biomass of neighbouring infected animals	Adequate spatial separation and stocking density for culture sites
Presence of other species	
Host range includes non-susceptible bivalve species	Avoid co-culture with different species of unknown health status
Potential for interspecies transmission from reservoir populations	
Non-infected non-susceptible species may act as a “buffer” by removing virus from the water	Consider close cultivation of non-infected non-susceptible bivalves
OsHV-1 cannot be eradicated from stocks of wild self-recruiting oysters	Avoid restocking in areas where there is no natural recruitment

Table S3. Strategies related to PATHOGEN factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Pathogen factors	**Strategy to consider**
Life cycle	
OsHV-1 capable of direct transmission between hosts	Reduce the infection and transmission pressure
Suggested 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	Reduce the infection and transmission pressure
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	Modulate the water temperature
High temperatures reduce infectivity (33 h at 25 °C)	
Pathogenicity varies with the size of the host oyster	Optimise the size of cultivated oysters
Virulence	
Viral load threshold of 8.8×10^{3} OsHV-1 DNA mg $tissue^{-1}$ above which there is a risk of oyster mortality	Reduce exposure to OsHV-1
Stress or stock transfer can lead to an increase in virulence	Avoid handling before and during high risk periods
Other variants	
Other variants could be widespread in areas with wild stocks	Avoid co-culture with different species of unknown health status

Table S4. Strategies related to ENVIRONMENT factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Environment factors	**Strategy to consider**
Temperature	
In Europe, a seawater temperature of 16 ºC triggers OsHV-1 infections	Maintain daily average seawater temperature <14 °C or >24 °C
Severe mortality where temperature increases rapidly in spring	
No significant mortality at lower temperatures	
Upper limit for mortalities may be 22-25 °C	
In Australia, the lower threshold temperature above which mortality occurs is 21-24 °C	
Viral particle attachment	
Suggested infection from a common environmental source, such as plankton particles	Inflow water filtration to 5 µm, where feasible
Other bivalves may filter OsHV-1 attached aggregates from the water column	Consider close cultivation of non-infected non-susceptible bivalves
Fouling organisms	
Fouling organisms on cage netting may harbour virus and represent a health risk	Clean and disinfect equipment
Water hydrodynamics	
Hydrodynamic connectivity represents a driver for disease in culture facilities	Careful siting of hatchery and nursery areas
Tidal movements can affect mortality	
Reservoir populations	
OsHV-1 is maintained in wild oysters that can be used as broodstock	Avoid collection of wild species with unknown health status
Other bivalve species could represent potential reservoirs	
Watershed pollution	
Pesticides can increase susceptibility to OsHV-1 infection	Position open system facilities to optimise land run-off reduction
Global warming/climate change	
Climate change can moderate aquaculture production in open systems	Use of recirculation aquaculture systems

Table S5. Strategies related to SURVEILLANCE factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

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

Table S6. Strategies related to BIOSECURITY factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Biosecurity factors	Strategy to consider
Prevent or reduce the risk of transmission of OsHV-1	Source stock from certified disease-free locations
	Hold animals under quarantine conditions until they can be verified as disease-free
	Regular assessment of bivalve health
	Clean and disinfect equipment
	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
Limit the spread and prevent reinfection after mortality outbreaks	Destruction of infected stock, disinfection of water and equipment, and practice fallowing
	Screening for OsHV-1 prior to transportation between different geographical zones or before transfer of larvae and seed to the field
	Selective breeding programmes for disease resistance
Control the input pathways related to prevention of pathogen entry	Onshore 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

Table S7. Strategies related to MITIGATION factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Mitigation factors	Strategy to consider
Movement restrictions	
Unrestricted movement of oysters associated with a high risk of OsHV-1 spread	Source stock from certified disease-free locations
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
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
Risk of transmission of OsHV-1 through inflow water	Effective disinfection and/or filtration of inflow water for closed or semi-closed systems
Inactivation of virus	
Inactivation of water-borne virus	UV irradiation at 254 nm
	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	
Field placement timing	Transfer hatchery-produced spat after the critical high risk period for mortalities
	Adjust production activities to local water temperature dynamics
	Adjust spat immersion size, culture density and cementing calendar
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
	Source stock from certified disease-free locations
	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
	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
Support for eradication of OsHV-1 in closed-water systems	Generate more data related to pathogen prevalence and distribution

*Herpesvirus (AbHV) of abalone

Table S8. Strategies related to FARM MANAGEMENT DECISION factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

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

Table S9. Strategies related to INTEGRATED MANAGEMENT factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Integrated management factors	Strategy to consider
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)
	Foster interdisciplinary collaboration between farmers, scientists and policy makers
	Maximise aquaculture stocking biomass (carrying capacity), since lower density equates to less disease pressure

Table S10. Strategies related to TRACEABILITY factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

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

Table S11. Strategies related to ZONING AND COMPARTMENTALISATION factors for potentially avoiding the entrance and survival of OsHV-1 in hatchery and nursery systems.

Zoning and compartmentalisation factors	Strategy to consider
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
	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
	Epidemiological separation of oysters with different disease status potential
	Identify sources of infection and the risk of spread of infection into a compartment
	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