Aquaculture 495 (2018) 179–186

Contents lists available at ScienceDirect

Aquaculture

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

Review

Analysis of farm management strategies following herpesvirus (OsHV-1) disease outbreaks in Pacific oysters in Tasmania, Australia

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A R T I C L E I N F O

Keywords:
Magallana gigas
Disease
Husbandry
Ostreid herpesvirus-1
Pacific oyster mortality syndrome

A B S T R A C T

The microvariant genotype of *Ostreid herpesvirus 1* (OsHV-1 μVar) has severely disrupted oyster production in Europe, New Zealand, and Australia by causing repeated and seasonal outbreaks of mass mortality in Pacific oysters (*Magallana gigas*). The virus was first detected in Tasmania, Australia, in January 2016, and mortalities of up to 87% were reported (de Kantzow et al., 2017). This study surveyed 95% of Tasmanian oyster farmers in OsHV-1 infected growing areas one year following initial detection, and recorded mortalities and associated farm management strategies in the 2016/2017 season, compared with the initial outbreak and before OsHV-1 occurrence. The survey was comprised of 37 open- and closed-ended questions, with data collected on background information, mortalities, environmental, genetic, and husbandry information. Perceived business viability was overall strong (75%), with changes to farm management occurring on 88% of leases in response to the virus. Commercial oyster farming businesses ranked handling regimes and stocking densities as the most important husbandry factors for influencing mortalities. Water temperature was ranked as the most important environmental factor, with 60% of businesses considering mean water temperature of 18– < 20 °C sufficient to activate disease. Mortalities for oyster size classes across multiple years are also reported. This survey has provided an expedient and cost-effective method to obtain information on the impact of a highly virulent disease and associated environmental conditions across an industry. These results will inform future management strategies and associated research.

1. Introduction

Ostreid herpesvirus-1 microvariant (OsHV-1 μVar, hereafter 'OsHV-1'), also referred to as Pacific Oyster Mortality Syndrome (POMS) in Australia, is a highly contagious and lethal virus to Pacific oysters (*Magallana gigas, previously known as Crassostrea gigas*) (Salvi et al., 2014). First detection occurred in France 2008, and the virus is now seasonally active during warmer months throughout several countries in Europe, New Zealand, and Australia (Friedman et al., 2005; Renault and Novoa, 2004; Segarra et al., 2010; Jenkins et al., 2013; Keeling et al., 2014). The high mortality rate and seasonal reoccurrence of OsHV-1 in oyster growing regions causes significant economic and production loss, and considerable effort is being invested into establishing best farm management strategies to reduce OsHV-1-associated mortalities and overall impact, in conjunction with selective breeding programs for disease resistance.

OsHV-1 was first detected in Tasmania, Australia, in January 2016 and rapidly spread to four major growing areas (Pipeclay Lagoon, Little Swanport, Blackman Bay and Pitt Water). Mortalities in all infected growing areas of up to 87% on commercial *M. gigas* leases were reported (de Kantzow et al., 2017). At the time of detection 100 oyster leaseholders were active in Tasmania producing 3029 tons, almost entirely *M. gigas*, with an estimated value in 2014–15 of $23 million (Australian Bureau of Agriculture and Resources Economics and Sciences; Mobsby and Koduak, 2017). Almost one third of active leases were affected by OsHV-1 which is the only known disease affecting *M. gigas* production in Tasmania. This joins with marine biotoxins produced by harmful algal blooms as the major challenges now facing the industry.

Farmer environmental observations during potential OsHV-1 seasons could contribute to an understanding of complex lease and growing area dynamics, and this information could be utilised to develop predictive tools and improved farm management. Seasonal OsHV-1 outbreaks occur during warmer months, and historically, water temperature has been the primary predictive tool. Water temperature thresholds for disease activation varies. Studies in France report temperatures between 16 and 20 °C, which are considered to be the risk threshold for disease activation (Petton et al., 2013; Pernet et al., 2014;

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https://doi.org/10.1016/j.aquaculture.2018.05.019
Received 9 March 2018; Received in revised form 7 May 2018; Accepted 11 May 2018
Available online 24 May 2018
0044-8486/

Dégremont, 2013). In Australia, mortalities have been observed between 21 and 27 °C (Paul-Pont et al., 2014), with an estimated increased risk between 18 and 26 °C (de Kantzow et al., 2016). However, water temperature patterns are complex, and are characterised by large temperature swings driven by sharp peaks and troughs. These are influenced by broad- and fine-scale hydrology (e.g. tides and currents) and atmospheric/climatic drivers (e.g. atmospheric heat, rainfall and wind), making predictions based on temperature particularly challenging. In addition, OsHV-1 dynamics could also be influenced by the surrounding biodiversity, including natural populations and over-catch on farming infrastructure by a variety of bivalves (Pernet et al., 2014). Lease-specific observations in conjunction with growing area data provided by oyster farmers who have a consistent daily presence at these farms will likely assist in the development of environmental predictive tools and identification of risk thresholds.

Farm management strategies, along with genetic breeding for increased resistance (Dégremont et al., 2016), are considered to be crucial to reduce OsHV-1-associated mortalities (de Kantzow et al., 2017; Paul-Pont et al., 2013a). Various management strategies to mitigate the effect of OsHV-1 outbreaks have been investigated in other regions infected with the virus, including handling regimes (Peeler et al., 2012), lease infrastructure (Pernet et al., 2012), oyster age and size (Dégremont, 2013; Paul-Pont et al., 2014), and stock growing height in the water column (Paul-Pont et al., 2013a; Whittington et al., 2015a; Azéma et al., 2017). Individually, as well as combinations of, these management strategies impose varying levels of physiological stress, altering the vulnerability of oysters to disease. However, best management practices have been difficult to elucidate, particularly due to high seasonal and spatial variability, inconsistencies and contradictions in observations, difficulties in detecting and quantifying disease, differences in farm management strategies and infrastructure, and limited data sources (Pernet et al., 2016). By collecting information through a well-designed survey, some of these difficulties can be strategically minimalised by utilising the first-hand experiences of farmers in a structured and systematic approach.

In this study, we surveyed oyster farmers in OsHV-1 infected areas in Tasmania to increase knowledge of OsHV-1 disease events, in particular (i) drivers of outbreaks to support the development of a predictive framework that forecasts risk of OsHV-1 disease activation, and (ii) farm management practices that reduce OsHV-1 mortalities and overall impact.

2. Methods

2.1. Farm survey

Human ethics was attained through a Minimal Risk Application from the Tasmanian Social Sciences Human Research Ethics Committee, University of Tasmania. All leaseholders in OsHV-1 infected bays in south-eastern Tasmania (Fig. 1) were invited to participate in the survey conducted in May 2017, approximately one year following initial detection and after the second summer of disease events. Leaseholders were initially contacted through industry newsletters and communications, and directly through phone and email. Participation in the survey was voluntary and confidential, and each farmer and lease was issued a unique identifier code to comply with ethical requirements. Subsequently, 30 leases across 21 commercial businesses from all four infected bays participated, representing 95% of eligible respondents. As part of standard monitoring procedures, initial mortalities observed by leaseholders were tested by Biosecurity Tasmania to confirm the presence of OsHV-1 by use of qPCR analysis (data not shown).

2.2. Survey questions

Survey questions were developed based on similar surveys conducted elsewhere (Carlier et al., 2013; Castinel et al., 2015; Peeler et al., 2012) and discussions with various industry representatives. The survey consisted of 37 open- and closed-ended questions in 5 sections; background information, lease mortalities, and environmental, genetic, and husbandry information. Surveys were completed on-farm during visitation by one or two researchers, with the exception of one survey that was completed over the phone. Survey respondents were small-scale company owners or managers of larger companies. In addition to the structured questions, respondents were also encouraged to provide information on specific observations, trials, and future research direction. Researchers conducting the interview scribed responses to all questions, and undertook a scribe standardisation process to reduce biases.

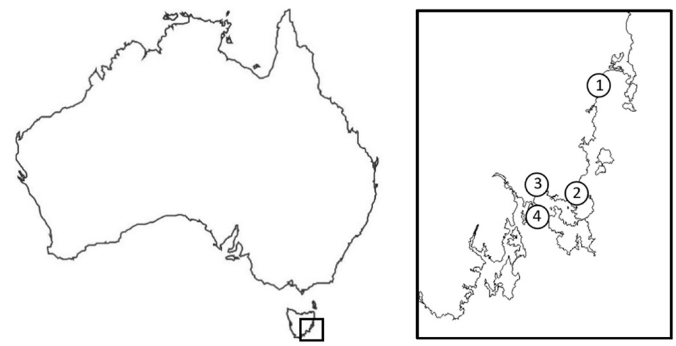

Fig. 1. OsHV-1 infected areas in Tasmania – Little Swanport (1; −42.340497, 147.937958), Blackman Bay (2; −42.854509, 147.831351), Pitt Water (3; −42.80806, 147.494742), and Pipeclay Lagoon (4; −42.969895, 147.524052).

2.3. Data analysis

Data was investigated on one of two levels; lease-level and business-level. Lease-level data looked at differences between all leases, regardless of some business owning or managing multiple leases, where specific business decisions did not skew results (e.g. '*How much stock do you have on this lease of each type and size class?*'). Business-level data looked at differences from a company perspective (e.g. '*What temperature regimes to do you consider to be required for an outbreak?*') (see supplementary material). Both levels were compared between growing areas. Statistics were performed in SPSS (IBM, Statistics 24) using ANOVAs where sample size met assumptions.

One open-ended question relating to future research priorities required semi-quantitative content analysis using descriptive statistics, in which responses were categorised into topic codes and expressed as a percentage of total suggested topic priorities at a company-level.

3. Results

3.1. Characteristics of lease sites and farm operations

The mean developed lease size was 7.8 ± 1.1 (standard error, SE) ha, range: 0.3 to 20.0 ha (Table 1). Most leases employed intertidal racks (20 in total), with 15 leases employing both intertidal racks and injection moulded plastic baskets attached to adjustable lines (SEPA-type) baskets (Fig. 2). Two leases involved shallow sub-tidal farming.

The type and size of oysters deployed on leases as of 1 November 2016 (pre-season) are summarised in Table 2. These included a combination of genetically selected (i.e. Australian Seafood Industries Pty Ltd. family lines), pre-exposed (i.e. oysters exposed to OsHV-1 in the previous year), and naïve stock (i.e. oysters not exposed to OsHV-1 previously).

Records of oyster farm operations were updated daily for 72.2% of leases, compared with 25.0% and 2.7% updating weekly or 'other' (e.g. only when farm is managed), respectively. These records were mostly managed through detailed white board notes (42.6%), notebooks