Survey for WSSV vectors in the Moreton Bay White Spot Biosecurity Area

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Abbreviations, acronyms and definitions

Abbreviations and Acronyms

AFDL	Australian Centre for Disease Preparedness Fish Diseases Laboratory (Geelong, Victoria)
ALOP	Appropriate level of protection
APFA	Australian Prawn Farmers Association
APVMA	Australian Pesticide and Veterinary Medicines Authority
BQ	Biosecurity Queensland
BSL	Biosecurity Sciences Laboratory
c.	circa/approximately
Ct value	Cycle threshold value (for qPCR) (see definitions).
DAF	Department of Agriculture and Fisheries
DIV1	Decapod Iridescent Virus 1
FRDC	Fisheries Research and Development Corporation
IRA	Import risk analysis
kGy	kilogray, a quantitative measure of gamma irradiation dose
OIE	Office International des Epizooties, the world organisation for animal health
PL	Post larvae
QLD	Queensland
PCR	Polymerase Chain Reaction (a genetic diagnostic test)
QSIA	Queensland Seafood Industry Association
qPCR	Quantitative PCR (also known as real time PCR)
RA	Risk analysis
WSD	White spot disease
WSSV	White spot syndrome virus

Definitions

Ct value: Cycle threshold value for quantitative PCR. A positive reaction using quantitative PCR (also known as real time PCR) is detected by accumulation of a fluorescent signal. The Ct (cycle threshold) is defined as the number of PCR reaction cycles required for the fluorescent signal to cross a threshold that exceeds background levels of fluorescence. The Ct value is inversely related to the level of target genetic material in the sample. A high level of WSSV means fewer cycles are required to cross the threshold target, resulting in a lower Ct value (typically <20 for a strong positive). A low level of target genetic material in the sample requires more cycles to generate a positive test result (in this study considered to be a Ct value of up to 36.00) that exceeds the predetermined fluorescence threshold. Samples where the threshold value for fluorescence is reached between 36.00 and 45.00 cycles (Ct >36.00, <45.00) are considered suspect, while test results are classified as negative in this study if the fluorescence threshold is not reached by 45 cycles.

Prevalence: Prevalence of a disease agent within a host population is defined by Bush et al. (1997) as the number of infected hosts divided by the number of hosts examined for that disease agent (i.e. population prevalence). However, as the sampling of host populations described in the present report was not undertaken randomly, and results obtained for many host species were from pooled samples, the results given as prevalence in the present study reflect the “sample prevalence”, which for many reasons (including small sample sizes and limited temporal and spatial sampling effort) may not necessarily reflect the true population prevalence of WSSV in the host populations examined.

Executive Summary

This report presents the results of investigations conducted by DigsFish Services who examined a range of species of wild caught decapod crustaceans and other potential vectors for white spot syndrome virus (WSSV) in northern Moreton Bay and near prawn farms along the Logan River in April and May 2020. WSSV is exotic to Australia and its presence in the Moreton Bay White Spot Disease Biosecurity Control Zone can be explained by at least one successful recent (post-2006 and pre-December 2016) WSSV incursion, most likely via imported prawns used as bait or burley, followed by a modest founder effect as that strain adapted to local conditions and hosts.

The objective of this project was to undertake opportunistic plankton sampling (n = 31 samples) and collect small non-commercial species of decapod crustaceans (n = 2462) in northern Moreton Bay and near the intakes of the three prawn farms which remained operating on the Logan River during April and May 2020, at a time when it was known that WSSV was active in the environment. These samples were tested by qPCR for WSSV (n = 454 pooled and individual tests) in order to determine if these taxa were acting as WSSV vectors and/or reservoirs and to inform the design of more detailed epidemiological studies of WSSV in the environment of South East Queensland (SE QLD) that may be undertaken in the future. Interviews with prawn farmers operating on the Logan River were also conducted to document the biosecurity protocols used on affected prawn farms during the two growing seasons since they restarted following fallowing after the 2016-17 WSD incursion. The interviews revealed that overall production at the three prawn farms dropped 65% (range -52 to -69%) in the first (2018-19) growing season following the enforced fallow period (2017-18), increasing only slightly to -44% (range -33% to -49%) in the most recent 2019-20 growing season compared to the baseline (pre WSD) 2015-16 growing season. Reduction in production since 2018-19 was attributed to rearrangement of ponds, and adoption of lower stocking densities and reduced water exchange to minimise risk of disease introduction.

A range of wild taxa sampled near or on prawn farms on the Logan River were found to be qPCR positive (Ct <36.00) for WSSV, including plankton samples, jelly prawns (*Acetes sibogae australis*), estuarine shrimp (*Palaemon serrifer*), rock pool shrimp (*Palaemon serenus*), *Palaemonella* spp., Family Pandalidae, freshwater prawns (*Macrobrachium novaehollandiae*), school prawns (*Metapenaeus macleayi*), banana prawns (*Penaeus merguiensis*), red-fingered marsh crabs (*Parasesarma erythodactyla*), mangrove crabs (*Metapograspus frontalis*), smooth handed crabs (*Pilumnopeus serratifrons*), mangrove swimming crabs (*Thalamita crenata*), blue swimmer crabs (*Portunus armatus*), and mud crabs (*Scylla serrata*). Non-decapod hosts returning suspect (Ct >36.00,<45.00) test results for WSSV included amphipods (Suborder Gammaridea and Family Caprellidae). All three operating prawn farms had improved their biosecurity arrangements since the 2016 WSD incursion. However, qPCR testing demonstrated that the biosecurity approaches employed were not able to exclude WSSV vectors during the 2019-20 growing season. A notable finding was discovery of wild school prawns, banana prawns and a mud crab which had died from WSD in water distribution canals at Farm C, with their carcasses remaining evident due to the absence of scavenging fish excluded by drum filters. A significant risk factor for all farms appeared to be intake of water from the Logan River after a large rainfall event in February 2020.

As WSSV was found at low levels in a broad range of taxa, and at high levels in some wild prawns and crabs near prawn farms, this suggests that WSSV has become embedded in the lower trophic levels of aquatic food chains in northern Moreton Bay and on the Logan River. The virus is therefore likely to remain in this region for the foreseeable future, signalling an urgent need for prawn farmers to further increase biosecurity as they farm in the presence of the virus. As long as the White Spot Biosecurity Area remains in place, the economic impact on the commercial bait prawn and baitworm fisheries in Moreton Bay will continue to accumulate over time, potentially exceeding that experienced by the prawn farming industry.

Keywords

White Spot Disease, WSSV, Vectors, Logan River, Moreton Bay, *Metapenaeus*, *Penaeus*, *Scylla, Acetes, Portunus*

1. Introduction

White spot disease (WSD) is an internationally notifiable disease of crustaceans caused by White Spot Syndrome Virus (WSSV), a double-stranded DNA virus of the genus *Whispovirus* within the Family *Nimaviridae* that emerged from China in the early 1990's (Lightner 2003). WSD causes devastating epizootics (up to 100% mortality within 3-10 days) on prawn farms throughout Asia, the Americas, and the Middle East, with many affected prawns displaying characteristic white spots on the carapace (Lightner 2003; OIE 2019). WSSV infects a wide range of decapod crustaceans (Bateman et al. 2012) and is considered exotic to Australia, but international trade in crustacean commodities has resulted in several incursions. The first WSSV incursion into Australia involved its detection in broodstock prawns (*Penaeus monodon*) and mud crabs (*Scylla serrata*) at an aquaculture hatchery in Darwin Harbour in December 2000 after they were fed frozen prawns imported from Indonesia (East et al. 2004, Scott-Orr et al. 2017). In that case, wild mud crabs and prawns adjacent to the hatchery outlet were also infected with WSSV, but over time this infection fizzled out and subsequent testing indicated that the virus did not become established (East et al. 2004, 2005, DAWE 2020).

A second WSSV incursion was reported in black tiger prawns (*Penaeus monodon*) cultured on a prawn farm taking water from the Logan River, in Moreton Bay, SE QLD on 22rd November 2016. Biosecurity Queensland (BQ) was alerted, obtained diagnostic samples, and a confirmed diagnosis of White Spot Disease (WSD) was obtained from the (now) Australian Centre for Disease Preparedness, Australian Fish Diseases Laboratory (AFDL) on 1 December 2016 (Diggles 2017; Scott-Orr et al. 2017). The exotic virus proved to be highly contagious for cultured *P. monodon* and despite attempts at containment and eradication, over the next 3 months the disease subsequently spread downriver to infect all operational prawn farms in the area by February 2017 (Diggles 2017, 2020). Delimiting surveillance undertaken by Biosecurity Queensland in March 2017 also detected WSSV in wild commercially caught prawns (greasyback prawns *Metapenaeus bennettae*, brown tiger prawns *Penaeus esculentus*, banana prawns *Penaeus merguiensis*) and crabs (mud crabs *Scylla serrata*, mangrove crab *Thalamita crenata*) in the Logan River and/or north-western parts of Moreton Bay (over 70 km north of the Logan River), but only in the late summer months of 2017 and 2018. Most recently, WSSV was detected in 112 out of 125 (89.6%) *T. crenata* from Deception Bay, and 230 of 438 (52.5%) *M. bennettae*, 75 of 196 (38.3%) *P. esculentus* and 77 of 141 (54.6%) sand crabs (*Portunus armatus*) sampled across 11 sites in northern Moreton Bay in March 2020 (Biosecurity Queensland 2020).

Due to the seasonal detection of WSSV in wild populations of commercial crustaceans, a White Spot biosecurity control zone established restrictions on movements of uncooked crustacean products out of Moreton Bay (Biosecurity Queensland 2017, Figure 1), resulting in significant impacts on the commercial fishing industries supplying bait prawns and bloodworms which account for over 80% of Australia's supply for these products (Ridge Partners 2017; Diggles 2020). Furthermore, in an attempt at eradication of the incursion, all prawn farms on the Logan River were required to cease production for the 2017-18 growing season, effectively fallowing their ponds for up to 18 months, during which time improvements to on-farm biosecurity protocols were made (Diggles 2020; Mann et al. 2020). Three of the prawn farms recommenced farming under improved biosecurity protocols during the 2018-19 growing season (Farms A, B and C, with Farm A being furthest upstream, Farm C furthest downstream), without any evidence of WSSV returning during the 2018-19 production cycle. However, during the 2019-20 growing season, a few weeks after WSSV was detected again in wild crustaceans in northern Moreton Bay in March 2020, two of the three farms (Farms A and B) also recorded WSD outbreaks in April 2020, during harvesting at the end of the 2019-20 production cycle (Diggles 2020).

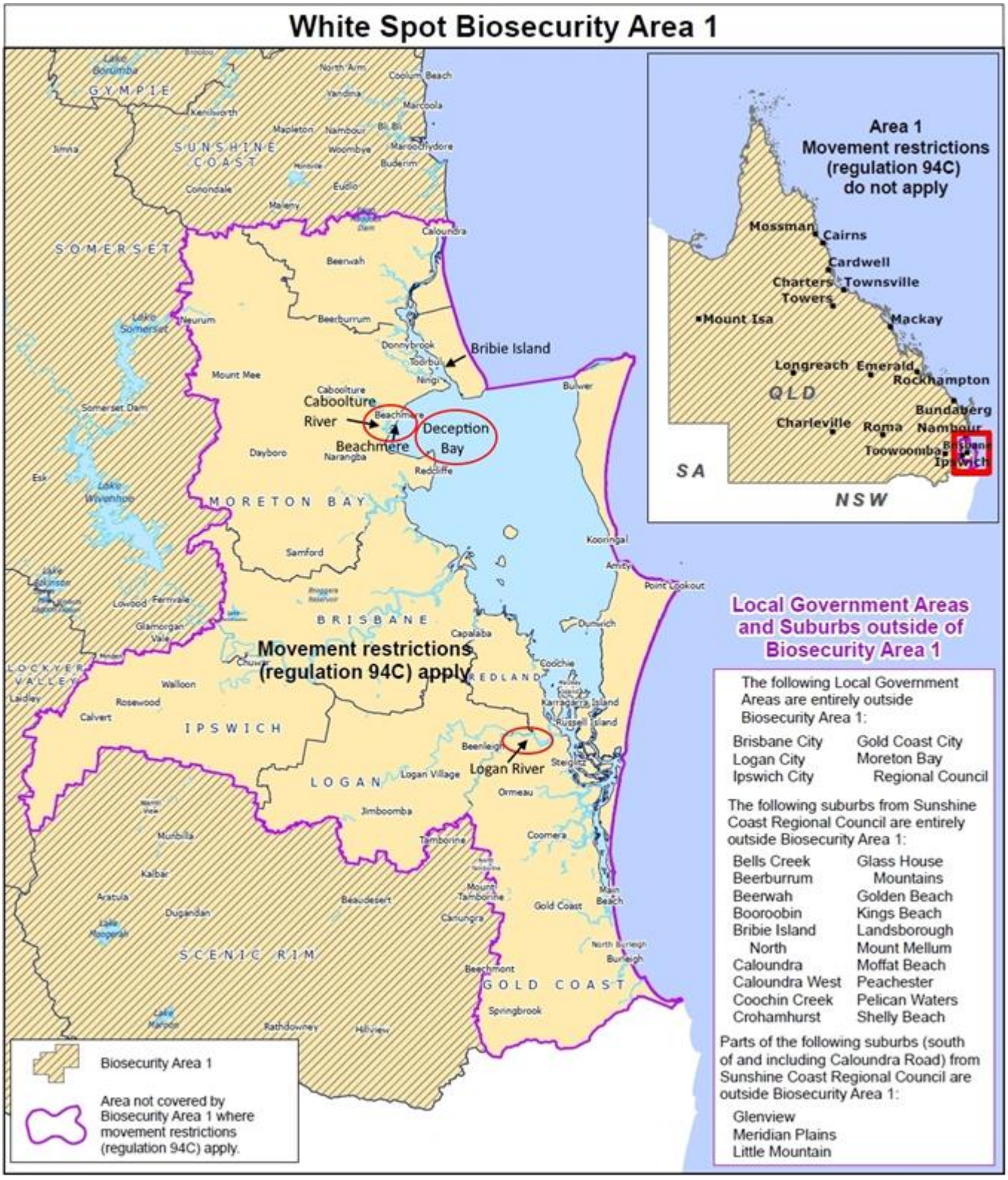

Figure 1: Map of the White Spot Biosecurity Area in Moreton Bay, SE Queensland, showing sampling locations mentioned in the text (Deception Bay, Beachmere, Caboolture River, Bribie Island, Logan River).

Genetic analysis done after the 2016-17 outbreak suggests that the WSSV strains found in the Logan River and northern Moreton Bay differed slightly from each other (Oakey et al. 2019), but both have relatively small genomes with several deletions typical of more recent WSSV strains isolated from parts of Asia and the Middle East, particularly China (Oakey and Smith 2018; Oakey et al. 2019). The Australian strains of WSSV have a "shrunken genome" compared to ancestral WSSV strains isolated from the original panzootic in Asia (Kawato et al. 2019; Oakey et al. 2019). This, together with the historical absence of WSD on prawn farms along the Logan River which have been established there for decades, and failure to detect WSSV in various species of prawns sampled from Moreton Bay for surveillance and the University of Queensland Marine Parasitology field course (PA305) from the 1980's till 2006 (Paynter et al. 1985; Spann and Lester 1996; Owens 1997), suggest a recent introduction of WSSV into the Moreton Bay region sometime after 2006 and prior to November 2016 (Diggles 2017, 2020; Oakey et al. 2019). The most likely pathway for introduction of WSSV into Moreton Bay is widely considered to be through substantial usage of imported frozen uncooked WSSV positive prawns that were used as bait or burley by recreational fishers (Diggles 2017, 2020; Scott-Orr et al. 2017). Indeed, recent surveys in Queensland have shown 27% of recreational fishers still specifically purchase raw (uncooked) imported prawns from supermarkets for use as bait (Kantar Public 2019). These data indicate that many hundreds of tonnes of frozen imported prawns are entering Australian waterways each year as bait or burley (DAWE 2020), demonstrating the high risks involved with this pathway of direct introduction of imported raw seafood products (together with their viable microbial disease agents) into the environment (Durand et al. 2000, 2003; Hasson et al. 2006; Jones 2012; Oidtmann and Stentiford 2011; Oidtmann et al. 2018).

The sequence differences between the Moreton Bay/Logan River WSSV strains and other WSSV isolates available from imported prawns in supermarkets in SE QLD since late 2016 make the precise timing and pathway of the introduction cryptic (Oakey et al. 2019). However, the present incursion can be explained by at least one successful recent (post-2006 and pre-December 2016) WSSV introduction via imported prawns used as bait or burley, followed by a modest founder effect as that strain adapted to local conditions and local hosts. Other potential pathways for recent introduction of WSSV, such as via ballast water from international shipping at the Port of Brisbane, also cannot be entirely ruled out, although they appear far less likely as the ballast water pathway has never been previously recorded to disseminate WSSV anywhere in the world. This author considers that spontaneous recent emergence of a local "endemic strain" of WSSV can be ruled out with high confidence, due to the fact that both the Logan River and Moreton Bay strains of WSSV are of the more recent "shrunken genome" type, which differs significantly from the larger genomes of the ancestral WSSV strains that were collected from their original sites of emergence (Kawato et al. 2019; Oakey et al. 2019). Epidemiology of the 2016-17 outbreak strongly suggests that prawn farming activities on the Logan River were not responsible for the incursion, as it was clear that WSSV entered all of the affected farms via intake water (Diggles 2017, 2020).

WSSV can infect all decapod crustaceans, including not only penaeid prawns but also crabs, freshwater crayfish, and lobsters (Wang et al. 1998; Stentiford et al. 2009; Oidtmann and Stentiford 2011; OIE 2019). It is also known that WSSV can infect or be carried by many smaller crustaceans including copepods and various types of zooplankton (Zhang et al. 2008; Esparza-Leal et al. 2009; Mendoza Cano et al. 2014; OIE 2019). Transmission of WSSV can occur horizontally through contact with viral particles in the water, however the most effective method of transmission is via the *per-os* route when infected tissue is ingested (Soto and Lotz 2001; Wu et al. 2001; Raja et al. 2015), while the existence of "true" vertical transmission has not been demonstrated (OIE 2019). This suggests that a major pre-requisite for establishment of WSSV in a new environment is whether the virus can become embedded in populations of crustacean hosts that occur in the lower trophic levels of food chains which, via predation, leads to their eventual ingestion by commercially important wild caught or cultured crustaceans, resulting in WSSV infections that are detectable in fisheries and aquaculture industries.

The persistence (albeit seasonal) of WSSV in northern Moreton Bay since March 2017 (Biosecurity Queensland 2020), together with the high prevalence (89.6%) of WSSV recorded in mangrove crabs and other species in northern Moreton Bay in March 2020, and the recent positive test results in cultured prawns during late harvest on two of the three operating Logan River farms in April 2020 (Diggles 2020), suggests that WSSV may have become established in wild crustaceans in the White Spot Biosecurity Area in SE QLD between Caloundra and the NSW border. If this is the case, experience overseas suggest that the virus will remain in this region for the foreseeable future, signalling a need for prawn farmers in SE QLD to further increase their biosecurity protocols and learn how to farm in the presence of the virus.

2. Objectives

This project was initiated to undertake opportunistic sampling of a range of potential WSSV vectors including plankton and non-commercial crustacean species in northern Moreton Bay and the Logan River during April and May 2020, at a time when it was known that WSSV was active in the environment.

The three main project objectives were as follows:

1. Interview prawn farmers and collect and archive field samples of potential WSSV vectors (microcrustaceans, small crabs, plankton) at several locations along the Logan River and in northern Moreton Bay (Figures 1-3);

2. Testing of vector samples at BSL by qPCR to determine their WSSV status. Examine sub-samples of populations of any WSSV positive vector species using histopathology to determine if the presence of the virus is accompanied by pathological lesions or WSD disease; and

3. Development of a report which combines the results of the vector testing with the outcomes of the on-farm biosecurity assessment to arrive at better understanding of how WSSV may be persisting in the environment of SE QLD, how the virus may be gaining entry into prawn farms on the Logan River, and how to improve prawn farm biosecurity to reduce risk of WSD outbreaks on prawn farms and WSSV spillback into wild fisheries.

3. Methods

Upon request from the APFA and FRDC, and after obtaining permissions from BQ, in April and May 2020 DigsFish Services undertook field collections of potential WSSV vector organisms at several locations in northern Moreton Bay (Figures 1-3) in waterways adjacent to Deception Bay where the various WSSV positive crustacean species were collected by BQ in March 2020. Collections were also undertaken on the Logan River in and around the inlets and inlet canals of Farms A, B and C (Figure 4). Prawn farmers were interviewed when sampling was undertaken. Using Davie (1998) and Chan (1998) for identifications, species collected were mostly non-commercially targeted small decapod crustaceans, mainly jelly prawns (*Acetes sibogae australis*), and estuarine shrimp (*Palaemon serrifer*), but also rock pool shrimp (*Palaemon serenus*), other shrimp (*Palaemonella* spp. and Family *Pandalidae*), school prawns (*Metapenaeus macleayi*), banana prawns (*Penaeus merguiensis*), freshwater prawns (*Macrobrachium novaehollandiae*), red-fingered marsh crabs (*Parasesarma erythodactyla*), round shore crabs (*Cyclograpsus audouinii*), stout rock crabs (*Ozius truncatus*), mangrove crabs (*Metapograspus frontalis*), smooth handed crabs (*Pilumnopeus serratifrons*), mangrove swimming crabs (*Thalamita crenata*), blue swimmer crabs (*Portunus armatus*), and mud crabs (*Scylla serrata*). Non-decapods which were also sampled included amphipods and water striders (identified as *Limnogonus windi* using the key of Møller Andersen and Weir (1997)). Photographs of the various potential vector species are shown in Appendix 1.

At the same locations where potential WSSV vectors were collected, 31 samples of zooplankton and phytoplankton were also collected either by David Mann (Department of Agriculture and Fisheries, DAF) using an 80 µm mesh net (Farms A, C, Beachmere Lake/South and Caboolture River) or by the author using a 100 µm mesh (Farm B, Bribie Island). Water quality (temperature, salinity, DO) was measured using a YSI 85 probe and refractive salinometer. Labelling codes were developed to identify the samples taken from each location to ensure that each collection site for potential vector hosts or plankton was given a unique identification code number (Table 1). Details of the final numbers of specimens (n = 2462 potential vectors and 31 plankton samples fixed into 70% ethanol) obtained during the various collections are shown in Table 2. Pooling of samples (maximum of 5 individuals per pool, see Laurin et al. 2019) prior to qPCR was undertaken for some target species (see Table 3).

Table 1. Labelling codes used to describe the location characteristics of each sample.

Sampling location code	**Characteristics of sampling location**	
Farm A = A	1 = Intake (unfiltered)	7 = settlement pond (followed by pond #)
Farm B = B	2 = Intake (drum filter backwash)	8 = outlet back to river
Farm C = C	3 = Intake (post treatment)	9 = Upstream Logan River
Northern Moreton Bay = D	4 = Distribution canal (followed by #)	10 = Deception Bay
	5 = culture pond (followed by pond #)	11 = Caboolture River
	6 = pond drain pipe	12 = Bribie Island

Samples of jelly prawns (Family *Sergestidae*), small palaemonid shrimp (Families *Palaemonidae*, *Pandalidae*), amphipods (Family *Caprellidae*, Suborder Gammaridea) and water striders (Family Gerridae) were collected by dipnet (3 mm mesh) or a lift net (80 cm diameter, 5 mm mesh) baited with small pieces of bread or muesli bar. The crabs (Families Grapsidae, Portunidae) were collected by hand or dip net (3 mm mesh), while freshwater and marine prawns (Family *Penaeidae*, *Macrobrachium* spp.) were collected using a cast net (14 ft diameter, 12.5 mm mesh). Immediately at the site of collection jelly prawns and small palaemonid shrimp were fixed whole directly either into 70% ethanol or Davidsons fixative (Table 2). Amphipods and insects were also fixed whole directly into 70% ethanol, as were penaeids smaller than around 50 mm total length (TL).

Figure 2. Sampling locations for specimen collections in northern Moreton Bay from Beachmere and Caboolture River.

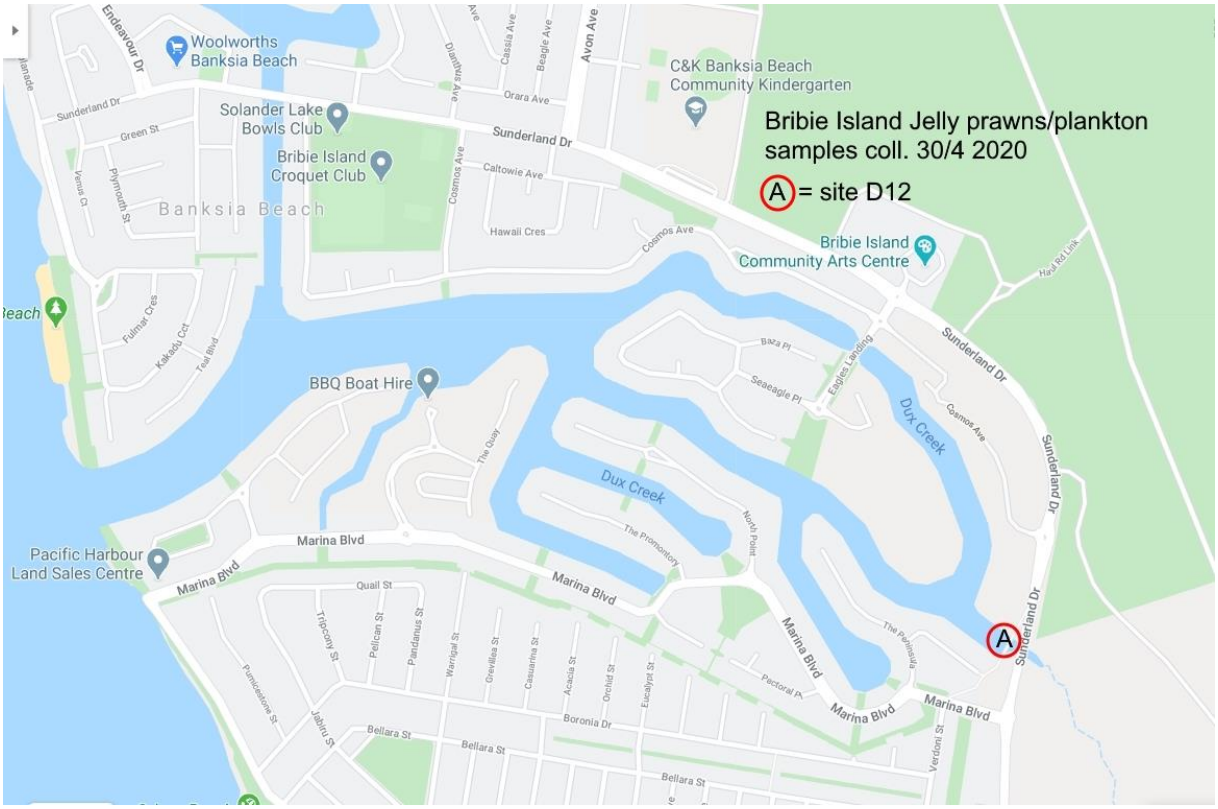

Figure 3. Sampling locations for specimen collections in northern Moreton Bay at Bribie Island.

Table 2. Details of the potential vector organisms sampled from several locations in northern Moreton Bay and near prawn farms on the Logan River. Numbers in parentheses indicate number of specimens fixed in Davidsons fixative for histopathology. n/a = not available.

	Location	**Logan River**			**Northern Moreton Bay**			**TOTAL**	
Host group	Sub location (2016-17 outbreak designation)	Farm A* (3IP)	Farm B (4IP)	Farm C (5IP)	Beachmere Lake/South	Caboolture River	Bribie Island	70% ethanol	Davidsons fixative
	Collection Dates	27/04/2020 8/5/2020	25/4/2020	5/05/2020	29/4/2020	30/4/2020	30/4/2020 2/5/2020		
	Water quality during collection	23.8°C, 23.5‰, DO 7.7 mg/L	n/a	n/a	26.2°C, 26‰, DO 7.7 mg/L	24.8°C, 30‰, DO 6.8 mg/L	27.1°C, 32 ‰, DO 6.1 mg/L		
Sergestids	Jelly prawns (*Acetes sibogae australis*)	355 (65)		346 (124)	300 (60)	259	200 (35)	1460	284
Palaemonids	Estuarine shrimp (*Palaemon serrifer*)	77	296	80	210 (22)	53		716	22
	Rock pool shrimp (*Palaemon serenus*)			2				2	
	Palaemonella spp.			4				4	
	Family Pandalidae			17				17	
	FW prawns (*Macrobrachium novaehollandiae*)	1	1					2	
Penaeids	School prawns (*Metapenaeus macleayi*)	31		45	7 (1)	46		129	1
	Banana prawns (*Penaeus merguiensis*)			8				8	
Grapsids	Red-fingered marsh crab (*Parasesarma erythodactyla*)	39 (29)	8 (8)					47	37
	Round shore crab (*Cyclograpsus audouinii*)				6 (1)			6	1
	Stout rock crab (*Ozius truncatus*)				1 (1)			1	1
	Mangrove crab (*Metapograspus frontalis*)			1 (1)	7 (7)			8	8
	Smooth handed crab (*Pilumnopeus serratifrons*)			2 (2)	1 (1)			3	3
Portunids	Mud crab (*Scylla serrata*)			1 (1)				1	1
	Blue swimmer crab (*Portunus armatus*)			1 (1)				1	1
	Mangrove swimming crab (*Thalamita crenata*)			1 (1)				1	1
Amphipods	Amphipods (Family Caprellidae)			5				5	
	Amphipods (Suborder Gammaridea)			29				29	
Insects	Water striders (*Limnogonus windi*)	8				14		22	
Total hosts		511	305	539	531	372	200	2462	365
Zooplankton	Various	8	2	6	4	2	1	23	
Phytoplankton	Various	3	0	3	1	1	0	8	
Total plankton		11	2	9	5	3	1	31	

* Denotes including 10 red fingered marsh crabs and 55 jelly prawns that were collected and frozen by farmers on 12/4/2020.

Table 3. Details of the pooling of potential vector organisms sampled from northern Moreton Bay and near prawn farms on the Logan River.

Ethanol fixed samples (max pool = 5)		Logan River Area		Northern Moreton Bay			
Host	Farm A	Farm B	Farm C	Beachmere Lake/South	Caboolture River	Bribie Island	TOTAL TESTS
Grapsid crabs	A7/2 - 1 = 1 crab, A5/17 - 2-4 = 3 pools, A5/3 - 5-7 = 3 pools, A6/35 - 8 = 1 pool, A4/36- 9 = 1 pool, total = 9 pools	B1/3 - 1-2 = 2 pools, B5/S4 - 3 = 1 pool, total = 3 pools	C3/13 = 1 crab, C3/16 = 1 crab, C3/17 = 1 crab, total = 3 crabs	D1/10E -1-3 = 3 pools, total = 3 pools			18
Commercial crab species			C3/10 = 1 crab, C3/11 = 1 crab, total = 2 crabs				2
Mangrove swimming crab			C3/12 = 1 crab				1
Amphipods			C4/34/6E 1-5 = 5 pools, C7/5Ed 1 = 1 pool, C7/5Ee 1 = 1 pool, total = 7 pools				7
Jelly Prawns	A4/34E 1-11 = 11 pools, A2/1/3 12-30 = 19 pools, total = 30 pools		C4/3 1-20 = 20 pools, C4/8 21-30 = 10 pools, C4/34/6Ec1 = 1 pool, total = 31 pools	D1/2E 1-30 = 30 pools	D11/1E 1-30 = 30 pools	D12/1E 1-30 = 30 pools	151
Palaemonids	A0/1E 1-2 = 2 pools, A2/1/1E 3-15 =13 pools, total = 15 pools	B4/11 1-30 = 30 pools	C7/5E 1-16 = 16 pools, C7/5E b = 1 pool, C7/5E c1-c3 = 3 pools, C7/5E f = 1 pool, C4/34/6EB = 1 pool, total = 22 pools	D1/1E 1-30 = 30 pools	D11/2E 1-11 = 11 pools		108
Macrobrachium novaehollandiae	A2/1/5E = 1 prawn	B1/2-1 = 1 prawn					2
Metapenaeus macleayi	A0/2E 1-3 = 3 prawns, A2/1/2E 4-31 = 28 prawns, total = 31 prawns		C4/1E 1-40 = 40 prawns, C4/2E 41-43 = 3 prawns, C4/1E 43-44 = 2 pools, total = 45 prawns	D1/0 - 1-6 = 6 prawns, D1/3E - 1 = 1 prawn, Total = 7 prawns	D11/4E 1-46 = 46 prawns		129
Banana prawns			C4/4E 1-8 = 8 prawns				8
Water striders	A0/4E - 1-2 = 2 pools				D11/5E - 1-3, = 3 pools		5
TOTAL							431
Plankton samples (80µm net, ethanol)		Logan River Area			Northern Moreton Bay		
Location	Farm A	Farm B	Farm C	Beachmere Lake/South	Caboolture River	Bribie Island	TOTAL
Zooplankton	8	2	6	4	2	1	
Phytoplankton							
Total	8	2	6	4	2	1	23
							Total qPCR pools
Total number of qPCR samples	96	36	125	74	92	31	454

Figure 4. Sampling of potential WSSV vectors was undertaken at various locations (including pre and post drum filter) around the inlet canals of the three operational prawn farms on the Logan River in late April and early May 2020. A range of biosecurity measures had been implemented since 2016-17, including installation of drum filters, which at this farm (Farm C) can filter 1200 L of intake water per second (4320 m³/hr) to a nominal 50 microns.

Penaeids and *Macrobrachium* spp. larger than 50 mm TL were cut laterally at the base of the cephalothorax using scissors and the entire cephalothorax was fixed in 70% ethanol at the site of collection. Grapsid crabs were bisected medially using scissors with one half fixed in 70% ethanol, and the other fixed in Davidsons fixative at the site of collection. Large commercial (Portunid) crab species were killed by removing the carapace and samples of whole gill filaments from each crab were excised and fixed in 70% ethanol and Davidsons fixative at the site of collection. For all potential vector species where dissection was required in the field (penaeid prawns, grapsid crabs), between the processing of each animal scissors were wiped down with a disposable paper towel soaked in a 1:4 solution of domestic bleach (c. 1% solution of sodium hypochlorite).

Pooling of some of the WSSV vector species fixed in 70% ethanol was undertaken prior to qPCR analysis at BSL (Table 3) in an attempt to reduce processing and analysis costs, whilst retaining surveillance objectives (Lane et al. 2017; Laurin et al. 2019). Pools were limited to a maximum of 5 individuals of a given host within each sampling site and sampling location as recommended by Laurin et al. (2019). However, due to substantial size variations between animals within and between potential vector species, pool to pool variation in the quantity of initial host tissue inocula extracted for qPCR means that caution should be applied to any quantitative interpretations of viral load data from Ct results from pooled samples. Instead, for those potential vector species subjected to pooling, the qPCR results collected in the present study should be interpreted as initial screening results for the presence/absence of the virus within the vector hosts' population at that site and location at a time of collection when WSSV was likely to be active in the environment.

Pooling of jelly prawns and palaemonids was undertaken by excising a thin (1-2 mm) section through the cephalothorax (which would contain gills, hepatopancreas and walking legs, but not (usually) eyes or antennae) from up to 5 individual prawns fixed in 70% ethanol and placing the sections into a single 1.5 ml eppendorf tube containing fresh 70% ethanol. Pooling of crabs was undertaken by excising a couple of whole gill filaments (smaller crabs) from up to 5 individual crabs into a single 1.5 ml eppendorf tube containing fresh 70% ethanol. Pooling of amphipods and insects was undertaken by bisecting (medially in the case of water striders, and laterally for amphipods) and placing one half of up to 5 individuals into a single 1.5 ml eppendorf tube containing fresh 70% ethanol. Penaeid prawns (*Macrobrachium* spp., *Penaeus* spp., *Metapenaeus* spp.) and commercial crab species were not pooled. Instead, the distal tip of a single gill filament was excised from each commercial crab and placed into a single 1.5 ml eppendorf tube containing fresh 70% ethanol. Penaeids were sampled by providing a single pereiopod and gill from each side of the cephalothorax (large prawns >50 mm long for which only the cephalothorax was fixed), or a pair of pleopods and gills from each side of the cephalothorax (for small *Metapenaeus* spp. <50 mm long which were fixed whole) from each individual into a single 1.5 ml eppendorf tube containing fresh 70% ethanol. To avoid cross-contamination between each pool (jelly prawns, palaemonids, grapsid crabs, water striders or amphipods) or individual (*Macrobrachium* spp., *Penaeus* spp., *Metapenaeus* spp., commercial crabs) sampled for qPCR, five sets of forceps and scissors were used. Each scissor/forceps set was decontaminated in a 1:4 solution of domestic bleach (c. 1% solution of sodium hypochlorite) for at least 5 minutes then rinsed twice in freshwater and air dried before that particular scissor/forceps set was used on the next pool or individual.

Plankton samples taken by the author from Bribie Island and Farm B were collected using a 100 µm mesh plankton net (250 mm diameter, rigged on a 2.5 meter long pole) that was towed obliquely through the water column from the bottom to the surface for a standardised distance (c. 10 meters). Upon completion of the tow, the contents of the net were rinsed with clean seawater into c. 500 ml containers which were allowed to settle before being decanted so that 70% ethanol could be introduced to kill motile plankton. Further decanting then allowed the sample to be concentrated into 70 ml containers in which all supernatant water was replaced with 70% ethanol. Zooplankton samples were also collected by David Mann from Farm A, Farm C, Beachmere and Caboolture River using an 80 µm mesh plankton tow net (30 cm diameter, 90 cm long) attached to a pole extendable to 3.9 m. From

the pond bank or jetty the operator applied an oblique tow, directing the net through the water column from near the bottom to the surface as it passed through a circular arc of up to 180° (Mann et al. 2020). At sampling locations where the operator was positioned on the bank of a channel, the tow net was obliquely towed through a 130° arc. The volume of water passing through the tow net, was calculated from the length of the total tow. Additionally, where the sampled water was flowing, an estimate of flow direction and velocity at the sampling point was included in calculation of the filtered volume (Mann et al. 2020). Zooplankton collected in the tow net was washed down into the net's collection jar using clean, town-supply fresh water supplied from a pressurised manual-pump spray. This concentrate was then transferred to a small 20 µm sieve to drain the water and the dewatered plankton residue was transferred into a 70 ml sample jar using an ethanol hand spray before the sample was preserved in 80% ethanol (Mann et al. 2020). The tow net and dewatering sieve were then thoroughly flushed down with fresh water using a pressurised pump spray and the sieve was also rinsed with 80% ethanol. A high dose chlorination step, or similar decontamination process, was not undertaken between samplings performed at a single location. The sampling apparatus was disinfected using Virkon® S bath and extended dry period between samplings at different locations (Mann et al. 2020). The zooplankton samples were tested for WSSV by qPCR and were provided to the diagnostic laboratory in the 70 ml jars (Table 3). To ensure complete chain of custody, all 454 samples for qPCR were personally delivered by the author to BSL on 11 September 2020. Results from qPCR testing were presented as sample prevalence (see definition of prevalence on page vi), and thus may not necessarily reflect true prevalence within the host population (Bush et al. 1997).

Diagnostic screening of ethanol-fixed tissue was undertaken at BSL using their real-time PCR assay to assess the presence or absence of WSSV DNA. The Taqman real-time PCR assay is based on the original method of Sritunyalucksana et al. (2006) optimised for gill and pleopod tissue at BSL. Briefly, the tissue was homogenised for 1 min and 40 s at the highest frequency in 2 mL Lysing Matrix D tubes containing ceramic beads (MP Biomedicals) using a Tissuelyser (Qiagen). DNA from the homogenised tissue sample was then extracted using a KingFisher 96 Magnetic Particle Processor with the MagMAX-96 Viral RNA Isolation Kit (ThermoFisher Scientific), as per the manufacturer's protocol. Extracted nucleic acid was added to Quantifast multiplex PCR master mix (QIAGEN) with Rox and containing the previously published primers, probe and BSA. Forward and reverse primers were used at a final concentration of 0.8 µM and 2.4µM respectively, the 6FAM labelled probe at a final concentration of 0.1 µM and BSA at a final concentration of 0.4 mg/mL. The assay was multiplexed with an in-house real-time PCR targeting Decapod 18S as an internal control used to assess DNA extraction and PCR competency (presence/absence of inhibitors). Real-time PCR was performed on an ABI7500 (Applied Biosystems) or a RotorGene real-time PCR cycler (QIAGEN) using the following cycling conditions: 95°C for 5 min, followed by 45 cycles of 95°C for 15 sec and 60°C for 1 min. For non-decapod samples the DNA extraction and PCR competency were assessed using a reverse transcription 18S real-time PCR assay using the described cycling conditions with an initial reverse-transcription step of 50°C for 10 minutes. Any sample that resulted in a Ct value ≥30 or 0.00 in either internal control real-time PCR was retested at a 1:10 dilution. A cut-off of ≤36.00 was established for a positive detection of WSSV DNA. Samples with Ct values >36 and ≤45 were reported as suspect for WSSV DNA detection. Samples with Ct values of 0.00 were reported as negative.

Selected vector samples from Farms A, B and C which had tested positive for WSSV by qPCR were also processed for histopathology to examine if the presence of WSSV was associated with viral inclusions or other pathological lesions. The species examined included red fingered marsh crabs (*Parasesarma erythodactyla*) from Farms A (n = 6, qPCR Ct range 32.47 – 34.97) and B (n = 3, Ct 32.79), estuarine shrimp (*Palaemon serrifer*) from Farm B (n = 12, Ct range 28.56 – 42.38), jelly prawns (*Acetes sibogae australis*) from Farm C (n = 30, Ct range 22.87 – 34.04), smooth handed crabs (*Pilumnopeus serratifrons*) from Farm C (n = 2, Ct range 23.53 – 24.71), school prawns (*Metapenaeus macleayi*) from Farm C (n = 3, Ct range 14.28 – 14.69), banana prawns (*Penaeus merguiensis*) from Farm C (n = 5, Ct range 14.48 – 15.94), a mangrove swimming crab (*Thalamita crenata*) from Farm C (n = 1, Ct = 22.76),

a blue swimmer crab (*Portunus armatus*) from Farm C (n = 1, Ct = 28.11), and a deceased mud crab (*Scylla serrata*) from Farm C (n = 1, Ct = 16.45). All samples processed for histopathology were fixed in Davidsons fixative, except for the school prawns and banana prawns which had been fixed in 70% ethanol. All of these samples were delivered to BSL on 10 November 2020 after which they were embedded and processed for routine wax histopathology, after which sections 4 µm thick were cut and stained with haematoxylin and eosin for examination by light microscope.

4. Results

4.1 Prawn farms on the Logan River – production losses since 2016-17 WSD outbreak

Interviews with Logan River prawn farmers were undertaken during sampling visits between 25 April and 8 May 2020. Farmers were asked about any additional biosecurity measures that had been implemented following the 2016-17 WSD outbreaks and 2017-18 enforced fallow period for the 2018-19 and 2019-20 growing seasons that have been completed since they restarted farming. Farmers were also asked to what extent their farm production has recovered since the zero production year represented by the 2017-18 fallow period, and whether the detection of WSSV on their farms had affected production during the 2019-20 growout season. These production data are summarised in Table 4.

Table 4. Percentage loss of production (parentheses) compared to production achieved during the pre-WSD 2015-16 growing season for the three farms (A, B, C) that have resumed operation on the Logan River. Production data are not available from the other three farms which have not recommenced operation since the WSD outbreak.

Growing season	Farm A	Farm B	Farm C	% loss (all farms combined)
2016-17 (WSD outbreak)	-100%	-100%	-94%	**96% loss**
2017-18 (fallow period)	-100%	-100%	-100%	**100% loss**
2018-19	-52%	-69%	-52%	**65% loss**
2019-20	-33%	-36%	-49%	**44% loss**
Target for 2020-21	-33%	-36%	-43%	**40% loss**

4.2 Prawn farms on the Logan River – biosecurity upgrades, sequelae to 2020 WSD outbreaks

The farmers at Farm A (which was designated 3IP during the 2016-17 WSD outbreaks, see Diggles 2017) were interviewed on 27 April 2020, which was 16 days after an incursion of WSD was recorded there on 11 April 2020 in two of the three ponds remaining to be harvested for the 2019-20 growing season. The farmers reported that, as there was no minimum biosecurity standards required of them under QLD aquaculture legislation, for the 2018-19 growing season they determined to apply a combination of increased operational biosecurity, reduced water exchange, enhanced treatment of intake water, and reduced stocking density in order to reduce the risk of WSSV incursions onto their farm. The pond layout was revised to allow treatment of intake water using Chinese manufactured drum filters arranged in 3 x 3 filter arrays (1 x 150 µm screen prefilter flowing 300 m^3/hr into 2 x 50 µm screen filters) for a total of 9 filters with a practical capacity of c. 900 m^3/hr whilst filtering water down to a nominal 50 µm. The filtered water was then ozonated to a target oxidation/reduction potential (ORP) of >700 mV (maximum 1100mV, c. 3.2 mg/L/min ozone) and pumped into a holding pond for several days before being used to fill the distribution canals and dried earthen grow out ponds that were prepared in the normal manner except for addition of shade cloth screens on the pond outlets (to prevent crab incursions) and particular attention to elimination of leaks. A reduction of total pond area from 13 ha to 12 ha (-8%) was required to accommodate the drum filters, ozonation system and holding pond. Enhanced record keeping including tight control of visitor access via the electronic front gate and sign in/out tracking of all farm visitors was also being undertaken to further improve biosecurity. Given the reduced supply of intake water compared to the 2015-16 baseline season, the reduced water exchange necessitated a reduced *Penaeus monodon* PL stocking density compared to the baseline. This resulted in an absence of WSD, but was accompanied by a reduction of total farm

gate production of 52% for the 2018-19 growing season compared to the 2015-16 baseline season (Table 4). Stocking densities were identical between 2018-19 and 2019-20 growing seasons, with the only difference being that for 2019-20 shade cloth for crab exclusion was removed from the pond outlets, and the 50 µm screens became unserviceable on some of the drum filter arrays in mid/late March 2020 after a rainfall event in mid-February (see Appendix 2) reduced water quality from the Logan River and induced a minor flow event (intake water salinity dropped to 6 ‰ and water temperature dropped briefly from 28°C to c. 20°C).

The circumstances surrounding the 2019-20 WSD outbreak at Farm A were as follows: Harvesting started on 7 February 2020 and was being undertaken as per normal through the rainfall event in mid-February and into March. The 50 µm screens on some of the drum filters were observed to be damaged in mid/late March but this was not considered important enough to stop pumping intake water given the advanced stage of the harvest and the fact that water requirements were relatively low, given only a few remaining ponds required topping up prior to harvesting. Water requirements were achieved by pumping for 4 hours on the top of the tide every 3 or 4 days. By early April two of the remaining unharvested ponds (#3 and #6) furthest from the river were being topped up most frequently due to them having leaks, and it was in these two ponds that signs of WSD were noticed as they were being drain harvested on 11 and 12th of April, respectively (Figure 5). After around 1000 kg of dead *P. monodon* were observed during drain harvesting of pond 3 (the same index pond as occurred during the WSD outbreak on 3IP in 2016-17, see Diggles 2017), the farmers notified BQ and a diagnosis of WSD was confirmed by a positive qPCR result with CT value of < 13 from samples collected on 11 April 2020. Only around 10 kg of dead prawns were observed when pond 6 was harvested on 12 April, giving a total farm production for the 2019-20 growing season a 20% improvement on the 2018-19 season but still a 33% reduction from the 2015-16 baseline (Table 4). After diagnosis of WSD in both ponds 3 and 6, BQ required these and the remaining pond on Farm A to be harvested into cooking, with all remaining water on the farm drained into a suitable empty pond where it could be treated with trichlorfon (Lepidex®, Nufarm) using a dose of 0.5 g/1000L, (or 0.5 mg/L, see APVMA permit # PER84088) and held for >12 days prior to discharge to the environment once trichlorfon levels were below the level of detection (< 0.01 ug/L) (APVMA 2017). At the time of the farmer interviews and first sampling for this project (27 April 2020), all production ponds on Farm A were dry (Figure 5), with all remaining water in settlement ponds and intake canals having been treated with 0.5 mg/L trichlorfon. A second sampling visit was undertaken at Farm A on 8 May 2020 to collect additional samples of vector species (mainly palaemonids, jelly prawns, and grapsid crabs) adjacent to where intake water was taken from the Logan River (prior to filtration) (Figure 6).

The farmers at Farm B (which was designated 4IP during the 2016-17 WSD outbreaks, see Diggles 2017) were interviewed on 25 April 2020, which was 11 days after BQ had taken samples of cultured P. monodon from production ponds that were being drain harvested near the end of their 2019-20 growing season. These samples collected by BQ on 14 April 2020 were found to be positive for WSSV by qPCR, however some unexplained mortalities were observed in pond #19 earlier in the harvest. The farmers reported that, as there was no minimum biosecurity standards required of them under QLD aquaculture legislation, in order to try to reduce the risk of WSSV incursions onto their farm for the 2018-19 growing season they controlled farm visitors with an electronic gate (Figure 7), filtered all intake water through a 150-200 µm nylon "sock" filter to initially fill the dried earthen grow out ponds, which was followed by use of a significantly reduced (1/3 normal) stocking density together with near static water exchange. The reduced stocking rate compared to the 2015-16 baseline season, combined with the much reduced water exchange and basically static pond production, resulted in a 69% reduction of total farm gate production for the 2018-19 growing season compared to the 2015-16 baseline, with minimal to no profitability but with an absence of WSD (Table 4). Then for the 2019-20 growing season, water treatment remained identical for initial pond filling (filtration through a 150-200 µm sock filter), however an increased (compared to 2018-19) stocking density of 2/3 of normal was utilised, resulting in a requirement for increased water exchange through the production ponds.

As these prawns approached market size the rainfall event in mid-February (see Appendix 2) reduced water quality from the Logan River and induced a minor flow event (intake water salinity dropped to a measured 0‰ for a short period and water temperature dropped briefly from 28°C to 24°C). However, reduced pond water quality due to the increased stocking densities necessitated regular "top up" intakes of water from the Logan River, which from March 2020 onwards (and possibly earlier) consisted of pumping of raw (unfiltered) water on the top 3 hours of the high tide at a frequency of around twice a week. Despite the disease problems in pond 19 and at least 2 other ponds, total farm production for the 2019-20 growing season increased by 105% compared to the 2018-19 season (in line with the doubled stocking density), but total farm production was still around 36% less than the 2015-16 baseline (Table 4).

After the diagnosis of WSD on Farm B was confirmed by BQ on 14 April 2020, the farmers were required to cease discharge and move all harvest water into the discharge channels for treatment with trichlorfon (Lepidex® 0.5 g/1000L, or 0.5 mg/L, see APVMA permit # PER84088) for at least 12 days prior to discharge to the environment once trichlorfon levels were below the level of detection (< 0.01 ug/L) (APVMA 2017). At the time of the farmer interview and sampling for this project (25 April 2020), all production ponds on Farm B were dry, however the water remaining in the intake canals was still untreated so samples of palaemonids (*Palaemon serrifier*) and freshwater prawns (*Macrobrachium novaehollandiae*) were obtained from the unfiltered and untreated water remaining in the intake canals, and grapsid crabs (red fingered marsh crabs *Parasesarma erythodactyla*) were collected from some of the dried production ponds.

The farmers at Farm C (designated 5IP during the 2016-17 WSD outbreaks, see Diggles 2017) were interviewed on 5 May 2020, upon completion of harvesting at that farm. No unusual mortality events had been recorded on Farm C during the 2019-20 growing season, and BQ had taken samples of *P. monodon* from Farm C around 2 weeks earlier, and all of these tested negative for infection by WSSV by qPCR. The farmers reported that, because there was no minimum biosecurity standards required of them under QLD aquaculture legislation, they applied a combination of increased operational biosecurity, reduced water exchange, enhanced treatment of intake water, and reduced stocking density in order to try to reduce the risk of WSSV incursions onto their farm. The pond layout near the intakes was revised to allow treatment of intake water using large drum filters (Hex brand) with a total capacity of 4320 m^3/hr whilst filtering water down to a nominal 50 µm (Figure 4). The filtered water was then pumped into the large storage capacity water reservoirs and inlet channels for several days before being used to fill both partially lined and unlined dried earthen grow out ponds that were prepared in the normal manner with particular attention to elimination of leaks. Farm C also engaged a consultant veterinarian to develop and implement a comprehensive farm biosecurity and emergency response plan beginning in the 2018-19 growing season which detailed various standard operating procedures (SOPs) allowing the farm to meet the requirements of Australia's National Aquaculture Farm Biosecurity Plan Guidelines (Sub-Committee on Aquatic Animal Health (SCAAH) 2017). Enhanced record keeping including many SOPs for operational activities, tight control of the electronic front gate and sign in/out tracking of all farm visitors. Given a somewhat reduced supply of intake water compared to the 2015-16 baseline, this necessitated a 36% reduction in the *P. monodon* PL stocking density for the 2018-19 season compared to the baseline, resulting in an absence of WSD accompanied by a reduction of total farm gate production of 52% compared to the 2015-16 baseline (Table 4). For the 2019-20 growing season a slight increase (+15%) in stocking density compared to the 2017-18 season was counteracted somewhat by slightly reduced survival rates, resulting in a modest 6% increase in production for 2019-20 growing season compared to 2018-19, which still represents a reduction of total farm gate production of 49% compared to the 2015-16 baseline season (Table 4).

Figure 5. Dead P. monodon in the dried bottom sediment (pond 3, Farm A) 16 days after a WSD outbreak.

Figure 6. Sampling of potential WSSV vectors was undertaken at several locations along the Logan River near and on the 3 operational prawn farms. Several wild crustacean taxa were found to be WSSV positive in this river tributary (pre filtration at Farm A). Intake pipes for Farm A are to the right of the photo.

Figure 7. All 3 farms on the Logan River had increased their operational biosecurity since the 2016-17 season, including much tighter control of farm visitors with fencing and electronic gates.

Figure 8. Water intakes at Farm C, which ceased pumping water after the WSD outbreaks were reported upriver. Sampling for this project occurred after harvest before the water remaining in intakes was drained.

As the prawns from the 2019-20 growing season approached market size on Farm C, the rainfall event in mid-February (see Appendix 2) reduced water quality from the Logan River and induced a minor flow event. Salinity measurements were not routinely taken at Farm C, however pond water quality records showed that the cooler weather that accompanies rainfall events at this time of year resulted in substantial (6 to 8°C) drops in the morning water temperatures measured in production ponds (from 28-29°C to around 21-22°C in early/mid February, and again from 26-27°C to 22-23°C for a period of over a week during the second week of March 2020). Given the large water reservoir capacity at this farm, water intakes were not required during the February 2020 river flow event, and regular "top up" intakes of water from the Logan River began again in early March 2020, with pumping of 50 µm filtered water occurring on the top 2-3 hours of the high tide at a frequency of around twice a week. However, after the diagnosis of WSD on Farms A and B upriver were confirmed by BQ in the second week of April 2020, the farmers at Farm C switched off the intake pumps to ensure that no more water was taken in from the Logan River, and ensured that water that was already in storage reservoirs and intakes on the farm was not introduced into any of the remaining unharvested production ponds. At the time of the farmer interview and sampling for this project (5 May 2020), all production ponds on Farm C were dry, however the filtered water remaining in the intake canals (Figure 8) had not been discharged back into the Logan River. Table 5 contains a summary of the range of different biosecurity arrangements employed on the three farms, however qPCR testing demonstrated that none of these farms were able to exclude WSSV (see Section 4.3 below).

Table 5. Summary of the range of biosecurity protocols employed since the 2018-19 growout season on the three remaining prawn farms operating on the Logan River, and the resultant WSSV outcomes. ✓ = yes, ✗ = No.

Biosecurity protocol	Farm A	Farm B	Farm C
Intake water pre treatment – sock filter (200 µm)	✗	✓	✗
Intake water treatment – drum filters (50 µm)	✓	✗	✓
Intake water treatment - Ozone	✓	✗	✗
Electronic access gate	✓	✓	✓
Upgraded record keeping, reduced visitor access	✓	✓	✓
Full biosecurity plan implemented	✗	✗	✓
2019-20 production loss compared to baseline	-33%	-36%	-49%
Intake of unfiltered water during late 2019-20 season	✗	✓	✗
50 µm filters damaged during late 2019-20 season	✓	not applic.	✗
WSSV + pre-intake for 2019-20 season	✓	✓ (assumed)	✓ (assumed)
WSSV + in intakes (post filters) for 2019-20 season	✓	✓	✓
WSSV + in growout ponds for 2019-20 season	✓	✓	✗

4.3 Prawn farms on the Logan River – WSSV vector testing results

Results from the qPCR testing for potential vector organisms sampled from the Logan River are presented in Table 6. A wide range of taxa were found to be positive for WSSV using a qPCR Ct cutoff of <36.00. These included jelly prawns (*Acetes sibogae australis*) collected from the inlet canals of Farm A (pre-filtration) and Farm C (post-filtration, Figure 9), estuarine shrimp (*Palaemon serrifer*) collected from the inlet canals of Farm A (pre-filtration), B (unfiltered) and C (post-filtration), rock pool shrimp

*Table 6. Results of WSSV qPCR testing of potential vector organisms sampled from several locations in northern Moreton Bay and near prawn farms on the Logan River. Sample prevalence of positive (P = qPCR Ct result <36.00) and suspect (S = Ct between 36.00 and 45.00) qPCR results and mean Ct (Ct range in parentheses) are presented. * denotes samples pooled for this species (max 5 individuals per pool), ns = no samples available from that site.*

	Location	**Logan River**			**Northern Moreton Bay**			**Summary of all sites**	
Species group	Sub location (incl. 2016-17 outbreak designation)	Farm A (3IP)	Farm B (4IP)	Farm C (5IP)	Beachmere Lake/South	Caboolture River	Bribie Island	Sample prevalence	Mean Ct (range)
Sergestids	Jelly prawns* (*Acetes sibogae australis*)	50% P* 16.6% S* Ct 35.02 (32.67-40.12)	ns	100% P* Ct 27.98 (22.87-34.04)	0%*	0%*	0%*	30.5% P* 3.3% S*	30.74 (22.87-40.12)
Palaemonids	Estuarine shrimp* (*Palaemon serrifer*)	83.3% P* 3.3% S* Ct 34.15 (32.48-38.88)	13.3% P* 30% S* Ct 37.77 (28.56-42.38)	93.7% P* Ct 33.89 (31.31-36.34)	0%*	45.5% S* Ct 37.70 (36.84 - 38.54)	ns	30.4% P* 14.7% S*	35.47 (28.56-42.38)
	Rock pool shrimp* (*Palaemon serenus*)	ns	ns	100% P* Ct 34.72	ns	ns	ns	100% P*	34.72
	Palaemonella spp.*	ns	ns	100% P* Ct 35.71	ns	ns	ns	100% P*	35.71
	Family Pandalidae*	ns	ns	100% P* Ct 32.69 (31.62-33.58)	ns	ns	ns	100% P*	32.69 (31.62-33.58)
	Freshwater prawns (*Macrobrachium novaehollandiae*)	100% P Ct 32.72	0%	ns	ns	ns	ns	50% P	32.72
Penaeids	School prawns (*Metapenaeus macleayi*)	48.4% P 41.9% S Ct 35.63 (29.65-41.58)	ns	100% P Ct 17.40 (11.06-30.02)	0%	2.2% P Ct 30.32	ns	47.3% P 10.1% S	24.47 (11.06-41.58)
	Banana prawns (*Penaeus merguiensis*)	ns	ns	100% P Ct 14.49 (12.00-16.44)	ns	ns	ns	100% P	14.49 (12.00-16.44)
Grapsids	Red-fingered marsh crab* (*Parasesarma erythodactyla*)	33.3% P* 22.2% S* Ct 35.64 (32.47-38.31)	33.3% P* Ct 32.79	ns	ns	ns	ns	33.3% P* 16.7% S*	35.17 (32.47-38.31)

Table 6 (con't)

	Location	**Logan River**			**Northern Moreton Bay**			**Summary of all sites**	
Species group	Sub location (incl. 2016-17 outbreak designation)	Farm A (3IP)	Farm B (4IP)	Farm C (5IP)	Beachmere Lake/South	Caboolture River	Bribie Island	Sample prevalence	Mean Ct (range)
Grapsids (con't)	Round shore crab* (*Cyclograpsus audouinii*)	ns	ns	ns	0%*	ns	ns	0%*	-
	Stout rock crab* (*Ozius truncatus*)	ns	ns	ns	0%*	ns	ns	0%*	-
	Mangrove crab* (*Metapograspus frontalis*)	ns	ns	100% P Ct 22.76	33.3% P* Ct 25.34	ns	ns	50% P*	24.05 (22.76-25.34)
	Smooth handed crab* (*Pilumnopeus serratifrons*)	ns	ns	100% P Ct 24.12 (23.53-24.71)	100% P* Ct 25.34	ns	ns	100% P*	24.52 (23.53-25.34)
Portunids	Mud crab (*Scylla serrata*)	ns	ns	100% P Ct 16.45	ns	ns	ns	100% P	16.45
	Blue swimmer crab (*Portunus armatus*)	ns	ns	100% P Ct 28.11	ns	ns	ns	100% P	28.11
	Mangrove swimming crab (*Thalamita crenata*)	ns	ns	100% P Ct 23.56	ns	ns	ns	100% P	23.56
Amphipods	Amphipods* (Family Caprellidae)	ns	ns	100% S* Ct 36.95	ns	ns	ns	100% S*	36.95
	Amphipods* (Suborder Gammaridea)	ns	ns	33.3% P* 50% S* Ct 35.52 (31.35-37.56)	ns	ns	ns	33.3% P* 50% S*	35.52 (31.35-37.56)
Insects	Water striders* (*Limnogonus windi*)	0%*	ns	ns	ns	0%*	ns	0%*	-
Zooplankton	Various species	12.5% P Ct 32.39	50% P Ct 33.97	100% P Ct 31.99 (27.01-35.72)	0%	0%	0%	34.78% P	32.29 (27.01-35.72)

Figure 9. Sampling a water distribution canal at Farm C (post-filter). All pools of jelly prawns (sampled by lift net), school and banana prawns (sampled by castnet), and plankton from this spot were WSSV positive.

Figure 10. Several moribund and dead school and banana prawns collected by castnet from a water distribution canal at Farm C. High WSSV loads (lowest Ct 11.06) and pathological lesions in these moribund prawns (see figures 11-16) indicated they were dying or had died of WSD, their carcasses remaining evident due to a lack of scavenging finfish (excluded by drum filtration).

(*Palaemon serenus*) and other shrimp (*Palaemonella* spp. and Family *Pandalidae*) collected from water reservoirs on Farm C (post-filtration), freshwater prawns (*Macrobrachium novaehollandiae*) collected from the inlet canal of Farm A (pre filtration), school prawns (*Metapenaeus macleayi*) collected from the inlet canals of Farm A (pre filtration) and Farm C (post-filtration, Figure 10), banana prawns (*Penaeus merguiensis*) collected from the inlet canal of Farm C (post-filtration, Figure 10), red-fingered marsh crabs (*Parasesarma erythodactyla*) collected from the inlet canals and dried ponds of Farm A (post-filtration) and Farm B (unfiltered), as well as mangrove crabs (*Metapograspus frontalis*), smooth handed crabs (*Pilumnopeus serratifrons*), a mangrove swimming crab (*Thalamita crenata*), a blue swimmer crab (*Portunus armatus*), and a deceased mud crab (*Scylla serrata*) collected from the inlet canal of Farm C (post-filtration). Plankton samples taken from inlet canals of all 3 farms were also WSSV positive (Table 6). Non-decapod hosts which were found to be positive or suspect (qPCR Ct cutoff between 36.00 and 45.00) for WSSV included amphipods (Suborder Gammaridea and Family *Caprellidae*) collected from water reservoirs on Farm C (post-filtration) (Table 6).

Besides the wide range of naturally occurring WSSV positive and WSSV suspect vector taxa, the most notable finding recorded along the Logan River was the discovery of moribund and dead wild school prawns and banana prawns which were collected by castnet from a water distribution canal located after the drum filters at Farm C (Figure 10). While water quality information was not available for this sampling location at the time of collection (Table 2) due to concerns about cross contamination of the water quality sampling equipment, the large number of live jelly prawns, school prawns and banana prawns sampled at this particular distribution canal suggests water quality was acceptable for prawn survival and was likely to be similar to that measured in nearby tributaries of the Logan River at that time (21-24°C, 23-25‰, DO 90-100% 6-7 mg/L, B.K. Diggles personal observations). Nevertheless, a total of 4 dead school prawns were recorded together with the 42 live school prawns that were sampled from this location (8.7% mortality). Many of the live school prawns appeared moribund as they exhibited loose carapaces and lethargy. All of the live and moribund school prawns individually tested from this location by qPCR were WSSV positive with a mean Ct of 17.40 (range 11.06 – 30.02), see Table 6). Similarly, a total of 3 dead banana prawns (Figure 10) were recorded together with 8 live but moribund banana prawns from this same location (27.3% mortality). Moribund banana prawns also exhibited loose carapaces and lethargy. When the moribund banana prawns were individually tested for WSSV by qPCR, all were found to be infected with high WSSV loads (mean Ct 14.49 (range 12.00 – 16.44), see Table 6). These results suggest that these wild school prawns and banana prawns were dying from WSD, an observation that was backed up by the presence of extensive pathological lesions in these animals as demonstrated using histopathology (see Section 4.5 below). A low number (n = 3) of dead jelly prawns were also noted from the large number of live jelly prawns (n = 470) collected from this same sampling location (0.2% mortality). All 30 pools of jelly prawns tested for WSSV from this location were WSSV positive (mean Ct 27.98, range 22.87-34.04), suggesting that mortality of wild jelly prawns due to WSD also cannot be ruled out at this time.

4.4 Northern Moreton Bay – WSSV vector testing results

Results from the qPCR testing for potential vector organisms sampled from northern Moreton Bay are presented in Table 6. Compared to the Logan River no plankton samples and relatively few wild taxa were found to be positive for WSSV using a qPCR Ct cutoff of <36.00. The species found to be WSSV positive in northern Moreton Bay included mangrove crabs (*M. frontalis*) (pooled sample prevalence 33.3%, Ct 25.34) and smooth handed crabs (*P. serratifrons*) (sample prevalence 100%, Ct 25.34) collected from under rocks at Beachmere South, and a single school prawn (*M. macleayi*) collected by castnet from the Caboolture River (sample prevalence 2.2%, Ct 30.32) (Table 6). Furthermore, some pools of estuarine shrimp (*P. serrifer*) collected by liftnet from the Caboolture River were found to be suspect for WSSV using a qPCR Ct cutoff between 36.00 and 39.00 (pool prevalence 45.5%, mean Ct 37.70, range 36.84-38.54) (Table 6). All other taxa and plankton samples collected from northern Moreton Bay were negative for WSSV by qPCR (Table 6).

4.5 Histopathology of WSSV positive vectors

Examination of histopathology slides taken from WSSV positive vectors found little evidence of pathological lesions or WSD in sections taken from red fingered marsh crabs (n = 9, qPCR Ct range 32.47 – 34.97), estuarine shrimp (n = 12, Ct range 28.56 – 42.38), jelly prawns (n = 30, Ct range 22.87 – 34.04), smooth handed crabs (n = 2, Ct range 23.53 – 24.71), mangrove swimming crab (n = 1, Ct = 22.76), or blue swimmer crab (n = 1, Ct = 28.11).

However, the wild school prawns (n = 3, Ct range 14.28 – 14.69), and banana prawns (n = 5, Ct range 14.48 – 15.94) examined by histopathology from Farm C exhibited moderate to high numbers of hypertrophic, basophilic nuclei containing intranuclear WSSV inclusion bodies throughout a range of tissues of ectodermal and mesodermal origin, including connective tissues and subcuticular epithelium of the carapace, gills, appendages, foregut, antennal gland and the cuticle of the gill cover (Figures 11-16). A section through the lymphoid organ of one school prawn showed necrosis of the tubule wall with abundant amorphous eosinophilic material and pyknotic nuclear debris scattered throughout the necrotic material (Figure 14).

The deceased mud crab from Farm C (Ct = 16.45) exhibited a large number of WSSV inclusions in the filament epithelium and a large number of inclusions in the cuticular epithelium of the gill axis, as well as signs of post mortem degeneration and necrosis (Figure 17).

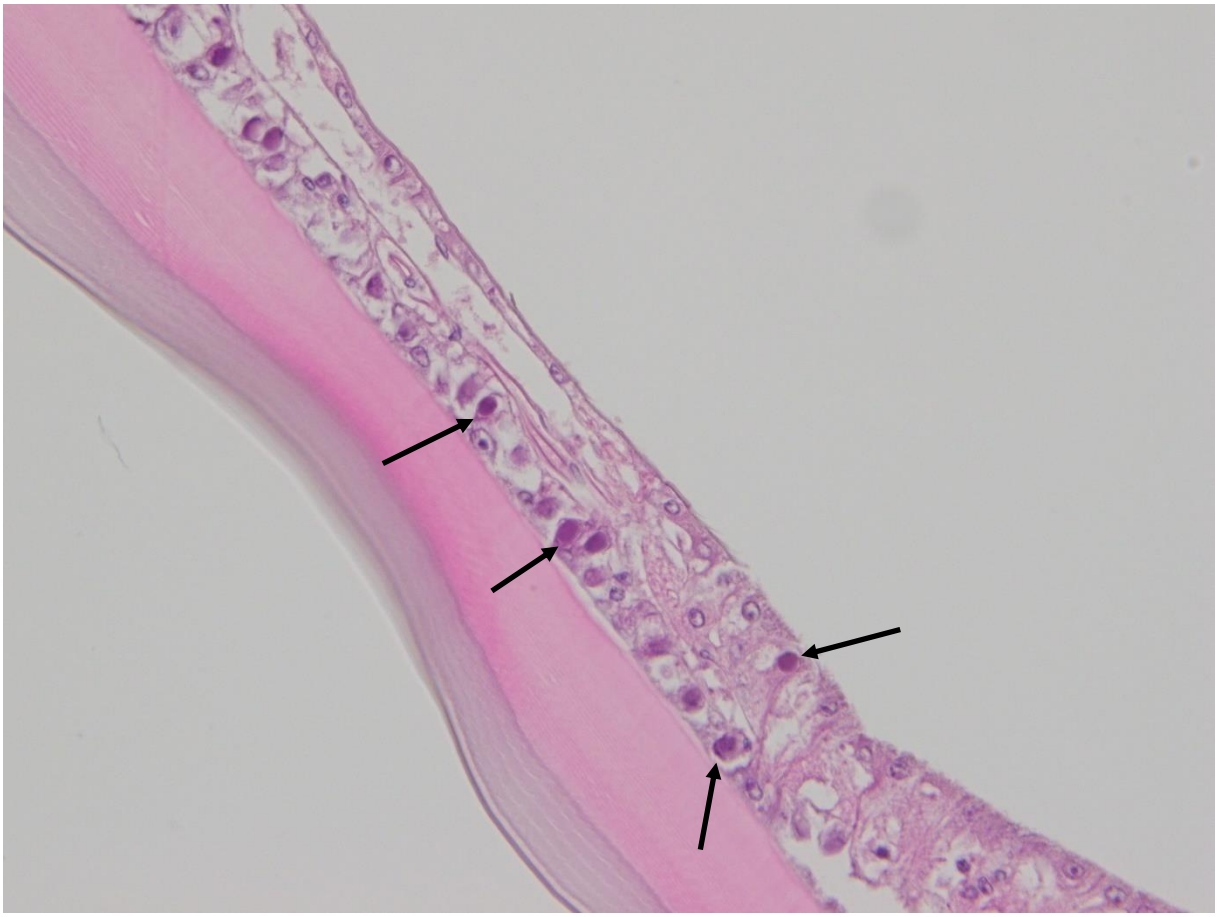

Figure 11. Histopathology of the subcuticular epithelium of the carapace of a moribund wild school prawn (Metapenaeus macleayi) from the intake canal of Farm C. Numerous hypertrophied, basophilic intranuclear WSSV inclusions are evident (arrows). 40x magnification. Photo by I. Anderson.

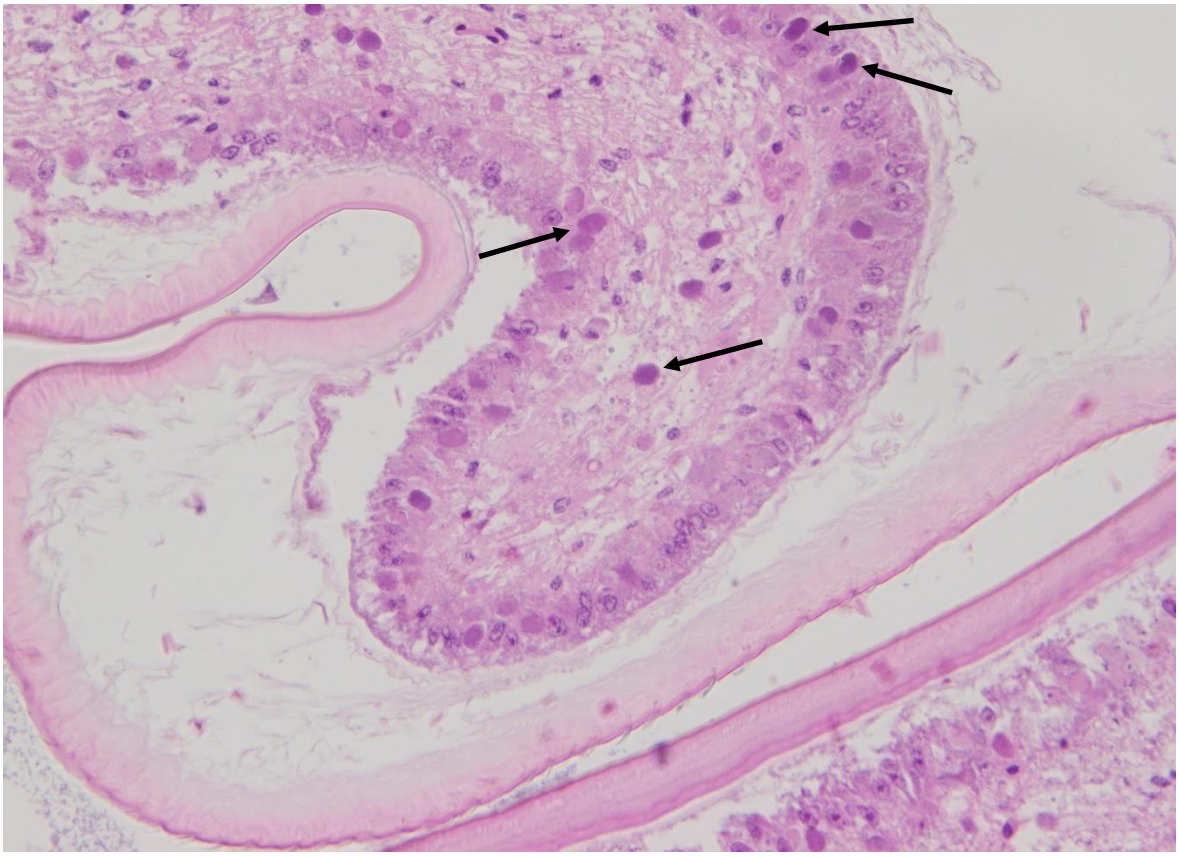

Figure 12. Subcuticular epithelium and connective tissue of the foregut of a school prawn from farm C. Numerous WSSV inclusions are evident (arrows). 40x magnification. Photo by I. Anderson.

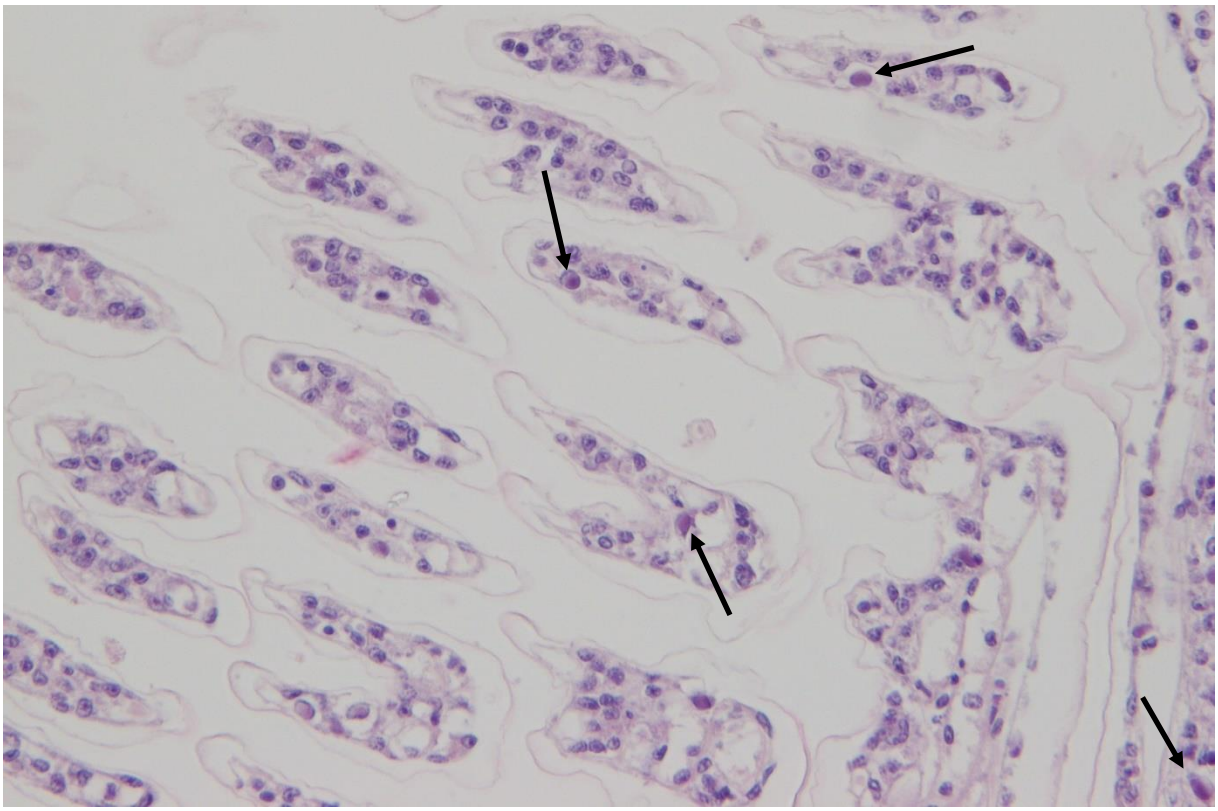

Figure 13. Section through the gills of a school prawn from Farm C, showing scattered WSSV inclusions in nuclei of the subcuticular epithelium (arrows). 40x magnification. Photo by I. Anderson.

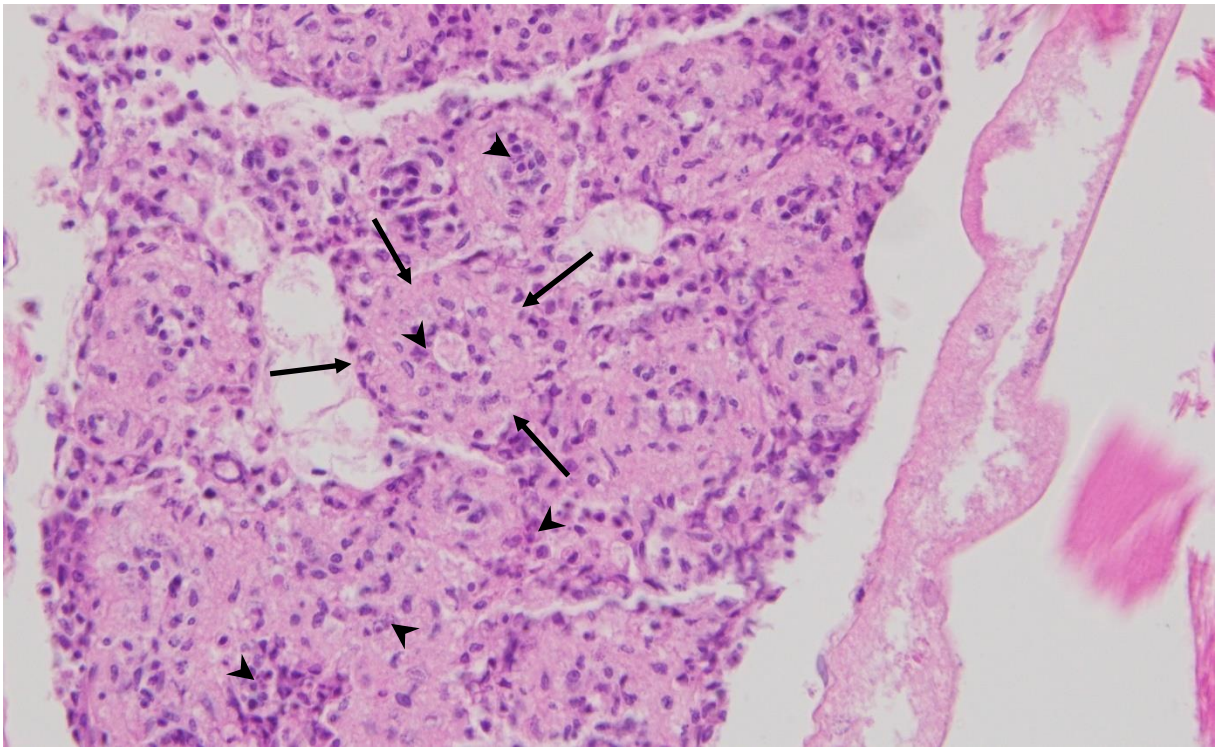

Figure 14. Section of the lymphoid organ of a school prawn showing necrosis of the tubule wall (arrows) with amorphous eosinophilic material and pyknotic nuclear debris (arrowheads) scattered throughout the necrotic material. 40x magnification. Photo by I. Anderson.

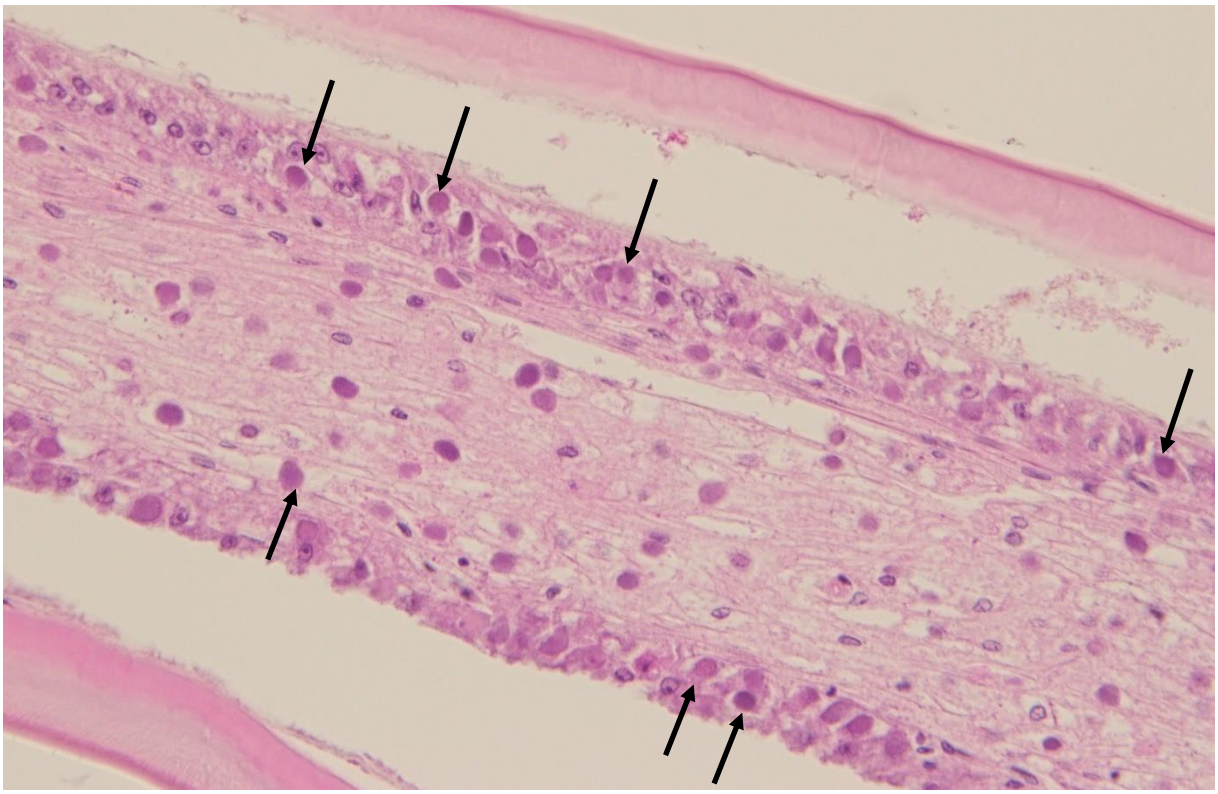

Figure 15. Section through the foregut of a moribund wild banana prawn (Penaeus merguiensis) from the intake canal of farm C. Numerous WSSV inclusions are evident in the subcuticular epithelium and connective tissue (arrows). 40x magnification. Photo by I. Anderson.

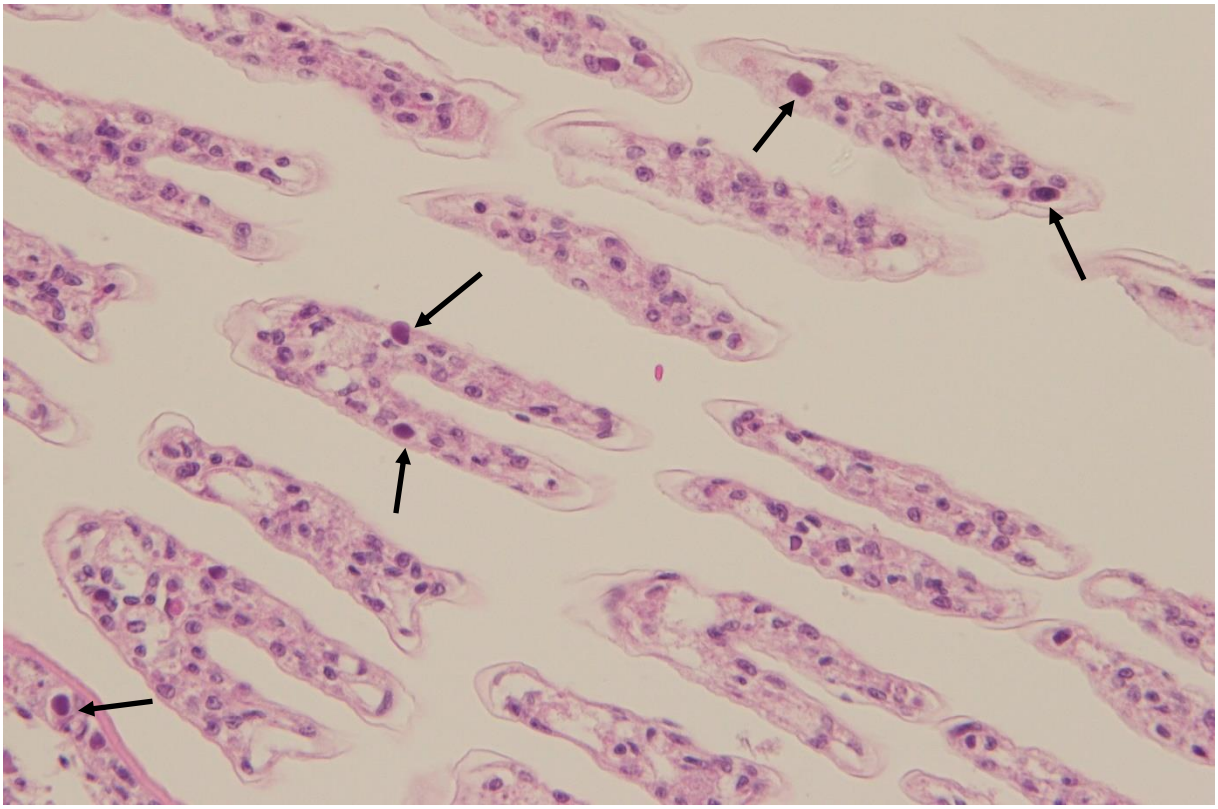

Figure 16. Section through the gills of a banana prawn from Farm C, showing numerous WSSV inclusions in nuclei of the subcuticular epithelium (arrows). 40x magnification. Photo by I. Anderson.

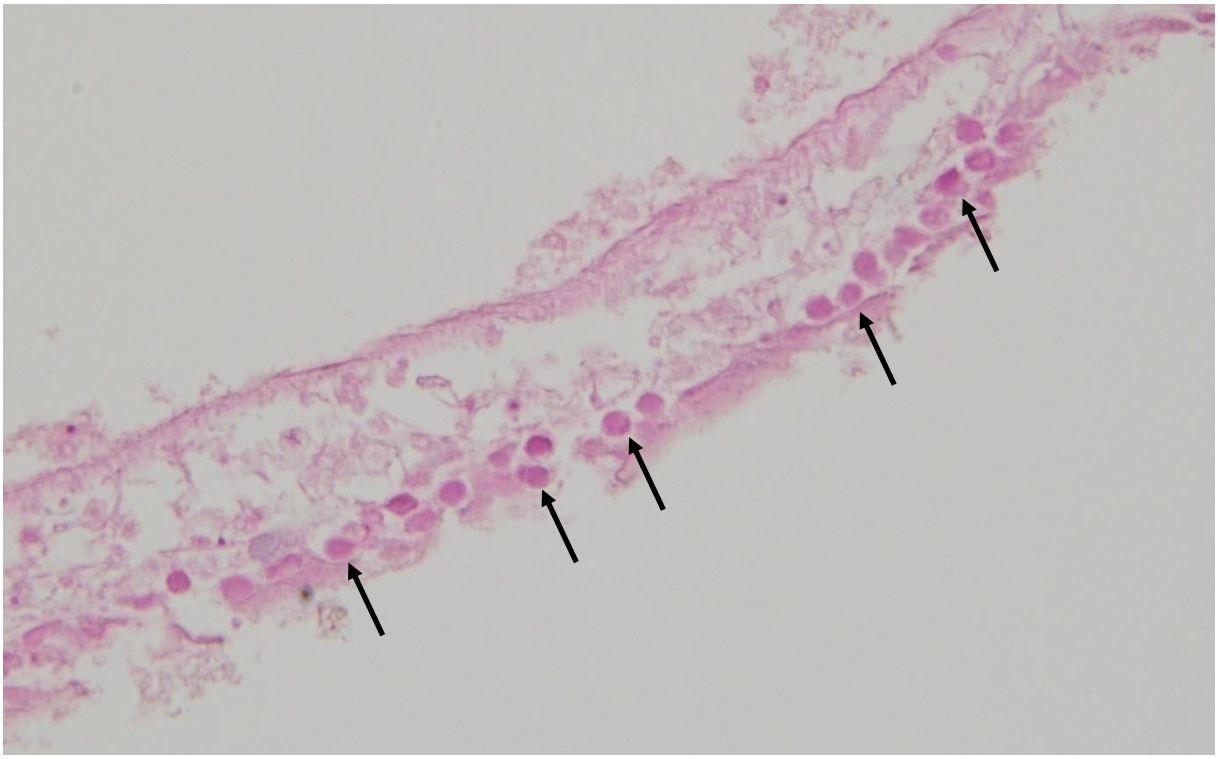

Figure 17. Section of gill axis subcuticular epithelium of a deceased mudcrab (Scylla serrata) from the intake canal of farm C. Large numbers of WSSV inclusions are evident in the subcuticular epithelium (arrows). Significant post-mortem tissue degradation is also evident. 40x magnification. Photo by I. Anderson.

5. Discussion

5.1 WSSV vector testing results

The high prevalence (89.6%, or 112 out of 125 crabs) of WSSV found by Biosecurity Queensland (2020) in wild caught mangrove crabs (*Thalamita crenata*) as well as other crustacean species in the north-western parts of Moreton Bay (Deception Bay) in March 2020 suggested that WSSV may have become established in populations of wild crustaceans in some parts of the White Spot Biosecurity Area in SE QLD between Caloundra and the NSW border. The data collected in the present study reinforce that conclusion. WSSV was found at low levels but in moderate to high sample prevalences in a broad range of decapod taxa, and at high levels in some wild prawns (apparently causing WSD and mortalities in moribund banana prawns (*Penaeus merguiensis*) and school prawns (*Metapenaeus macleayi*) which were sampled with qPCR Cts as low as 11.06-12.00). It also appeared that WSSV was also being sequestered and accumulated in several non-commercially important crab species (e.g. not only in *T. crenata*, but also *Metapograspus frontalis* (pooled sample prevalence 33.3%, Ct 25.34) and in 100% (n = 3) of smooth handed crabs (*Pilumnopeus serratifrons*) sampled from Beachmere and the Logan River with qPCR Cts between 23.53 and 25.34). These data suggest that WSSV has become embedded within various lower trophic levels of aquatic food chains in both northern Moreton Bay (Deception Bay, Beachmere, Caboolture River) as well as along the Logan River. The results from this study confirm that WSSV is likely to be persisting in the environment of SE QLD in populations of various species of small non-commercial decapod crustaceans, while the detection of positive WSSV test results in some species of amphipods suggest that some non-decapod invertebrate taxa in this region also may have the potential to act as WSSV vectors. Given previous experience from overseas, these findings suggest that WSSV has established within the White Spot Biosecurity Area in Moreton Bay, and is likely to remain in this region for the foreseeable future. These results signal an urgent need for prawn farmers in the region to further increase on-farm biosecurity and learn how to farm in the presence of the virus, so they can continue to farm profitably whilst avoiding WSD outbreaks and the potential for WSSV spillback into adjacent wild fisheries.

The WSSV real-time PCR used at BSL has already been validated for use on samples from prawns and crabs (Biosecurity QLD 2020), but not other taxa, so the positive test results obtained in the present study from zooplankton and jelly prawns (taxa not typically tested for WSSV by BSL) were examined in more detail by sequencing of amplicons. These sequencing data (not shown) confirmed that the amplicons were consistent with the two WSSV strains detected previously in the Moreton Bay White Spot Biosecurity Area, with genetic analysis again confirming that the WSSV strains found in the Logan River and northern Moreton Bay have relatively small genomes that differ slightly from each other as found by Oakey et al. (2019) (Ian Anderson, personal communication, 30 October 2020). In contrast, sequencing was not possible for the WSSV positive and suspect tests obtained from palaemonids or amphipods, hence technically the results from these taxa cannot be confirmed without further analyses.

Diggles (2020) noted that some wild prawns sampled by BQ from northern Moreton Bay since March 2017 had WSSV Ct values as low as 13.8, which was similar to the Ct values recorded in moribund *P. monodon* dying from WSD in ponds on the Logan River during the 2016-17 WSD outbreak, and again for moribund *P. monodon* sampled from pond 3 on Farm A during the most recent WSD outbreak on 11-12 April 2020 (see Section 4.2, Figure 5). These low Ct values from some wild prawns strongly suggested that the WSSV disease incursion was causing mortalities in some species of wild crustaceans in Moreton Bay (Diggles 2020). These suspicions were confirmed in the present study when it was found that c. 8.7% of wild school prawns and c. 27.3% of wild banana prawns sampled by cast net from a distribution canal on Farm C had recently died and that the remaining live but moribund prawns sampled and tested individually from the same populations exhibited 100% prevalence of WSSV

infection, often with very high WSSV loads (lowest Ct 11.06 and 12.00 for moribund school prawns and banana prawns, respectively, see Table 6). Histopathology of the affected banana and school prawns confirmed the presence of extensive lesions typical of WSD in various tissues of ectodermal and mesodermal origin (Figures 11-16). The gill tissues of the deceased mud crab (*Scylla serrata*) sampled from the intake of Farm C with a WSSV Ct of 16.45 also exhibited large numbers of WSD inclusions when they were examined by histopathology (Figure 17). WSSV inclusions or other lesions typical of WSD were not observed by histopathology in WSSV positive crustaceans with qPCR Cts above 20. From the limited histopathology materials examined here, it appeared increasing numbers of WSSV inclusions, suggestive of clinical disease, became evident in various tissues only once Ct values were below 18-20, while death due to WSD appeared to be occurring in infected wild crustaceans with qPCR Cts in the 11-16 range.

The Ct values found in wild prawns and crabs in farm intakes in the present study were similar to, if not slightly lower (signalling an even higher WSSV viral load) than previously observed for wild prawns and crabs sampled by BQ from northern Moreton Bay and in moribund *P. monodon* dying from WSD in ponds on the Logan River during the 2016-17 and 2019-20 WSD outbreaks. These data, together with the histological evidence, confirm that these wild school and banana prawns were indeed dying from WSD, and also suggest that wild mud crabs may also experience WSD under certain conditions. While mortality of wild crustaceans due to WSD is rarely reported in the scientific literature (Bateman and Stentiford 2017), as pointed out by Diggles (2020), the fact that WSSV is causing mortality of wild crustaceans in SE QLD is not necessarily unexpected, given that WSSV is a highly pathogenic exotic disease agent that was introduced into a naïve population of crustaceans which have no natural resistance to this disease.

The results from the present study therefore suggest that the lack of reporting in the scientific literature of mortalities in naïve wild penaeids during WSSV incursions may be due to a lack of detailed surveillance combined with effective scavenging of the carcasses of dead and moribund wild prawns by predatory fish (i.e. it is likely that mortalities due to WSSV in penaeid wildlife are usually cryptic "silent mortalities", see Behringer 2012; Stentiford et al. 2012; Shields 2012). Indeed, mortalities of wild crustaceans infected with serious pathogens can be expected wherever host-pathogen associations are altered by exotic incursions or adverse environmental conditions (Shields 2019), as has been previously reported for some other viral pathogens of prawns (Couch and Courtney 1977). Given that persistence of the carcasses of dead wild prawns and crabs would occur for any significant length of time only in water bodies where scavenging fish are excluded, only data from such water bodies can be expected to reveal the true impact of this incursion of an exotic virus. Indeed, scavenging finfish appeared to be excluded from the water supply channels at Farm C (where drum filtration to a nominal 50 µm is used) due to their absence during cast net sampling, but this level of filtration is apparently insufficient to exclude eggs or nauplii of many species of decapod crustaceans (Mann et al. 2020), including *Penaeus*, *Metapenaeus*, *Acetes*, *Scylla*, *Portunus* and *Thalamita*, as demonstrated by their presence in the water supply channels at Farm C. It therefore appears that conditions in the water supply channels of Farm C during this study were ideal for revealing the detrimental impacts of exotic WSSV incursions on naïve wild populations of susceptible penaeids and other crustaceans. Such effects can thus also be expected to occur in isolated water bodies or smaller watercourses and tributaries, if not larger river and bay fisheries where such disease impacts would become harder to detect, given the normally high rates of natural mortality exerted on prawn and crab populations by predatory fishes (Salini et al. 1990; Brewer et al. 1991).

The qPCR results from the plankton samples in the present study indicated an apparent absence of WSSV in plankton samples from northern Moreton Bay, but a significant number of WSSV positive plankton samples were detected from areas in and around the prawn farms along the Logan River. The single WSSV positive plankton sample from Farm A was obtained from a pond discharge channel which had received water from a production pond that had experienced a WSD outbreak. The single WSSV

positive plankton sample from Farm B came from a water intake canal, which is consistent with the intake of WSSV positive vectors from the Logan River via the unfiltered, untreated water on that farm. The fact that 100% of the plankton samples from Farm C were WSSV positive, including samples taken from intake storage ponds, intake channels and settlement ponds, suggests that WSSV positive vectors or free virus had been pumped onto Farm C only in recent weeks, given that no WSSV positive plankton samples had been collected from Farm C during regular plankton surveillance undertaken in the previous 2 years up until and including early March 2020 (Mann et al. 2020). The 100% WSSV prevalence in the plankton testing results from Farm C in May 2020 suggests a significant amount of WSSV entered the farm after early March 2020, however there is also a possibility of some cross-contamination between samples taken with the same plankton net from different locations on the farm without high dose chlorination between collections. Nevertheless, the fact that no WSSV positive *P. monodon* or WSD outbreaks were recorded in their production ponds during 2019-20, despite the widespread presence of WSSV positive vectors in their intake channels, suggests that the decision by staff at Farm C to immediately cease pumping water into their production ponds upon being informed of the WSD diagnosis on the farms upriver around 12 April 2020 probably saved them from a severe WSD outbreak in their cultured *P. monodon*.

The other important ramification arising from the fact that WSSV has become embedded within various lower trophic levels of aquatic food chains in certain areas of the White Spot Biosecurity Area in SE QLD, is the persistence of the virus in populations of commercial bait prawns. Previous surveillance by BQ has found WSSV in greasyback prawns (*Metapenaeus bennettae*) trawled from various locations in Moreton Bay as well as the Logan River (Biosecurity Queensland 2020). The present study has confirmed that WSSV is also present in school prawns (*M. macleayi*) which is the other of the two species of *Metapenaeus* targeted by the bait prawn fishery in Moreton Bay, as well as banana prawns *P. merguiensis* which are also important to the bait fishery (Hyland 1985). *Metapenaeus bennettae* tends to dominate the bait prawn catches from the Brisbane and Pine Rivers (95 and 99.6% respectively), however around one third of the commercial bait prawn catch from the Logan River is *M. macleayi*, while this species makes up around a quarter of the commercial catch from the Caboolture River with *M. bennettae* and *P. merguiensis* comprising the remainder of the catch (Hyland 1985). Disruption of the bait prawn supply from Moreton Bay due to the WSSV incursion continues to affect recreational fisheries Australia-wide, due to reduced availability and increased cost of domestic bait prawns, which are now required to be either cooked, or gamma irradiated to a dose of no less than 50 kilogray (kGy) prior to being allowed out of the White Spot Biosecurity Area (Department of Agriculture 2014; Wesche 2017). The increased costs of the treatment of these bait prawns must be passed onto consumers, while the additional handling time and potential for partial thawing of frozen prawns during the prolonged irradiation treatment required to achieve the mandated dose rate of 50 kGy is problematic for industry, as it has the potential to reduce their freshness and quality (Wesche 2017; BK Diggles, personal observations). Together, these changes to the supply and increased cost of bait prawns from Moreton Bay due to the WSSV incursion has led to a perverse economic incentive for recreational fishers throughout Australia to use more imported uncooked prawns from supermarkets as bait (Kantar Public 2019; Diggles 2020), which represents a further increase to the already high biosecurity risk of incursions of exotic diseases of crustaceans via the bait and burley pathway (Biosecurity Australia 2009; DAWE (2020). Furthermore, as long as the White Spot Biosecurity Area remains in place, the ongoing economic impact on the commercial bait prawn and baitworm fisheries in Moreton Bay will continue to accumulate over time, eventually exceeding that experienced by the aquaculture industry. This is because aquaculturists can improve biosecurity (given enough financial investment) to try to prevent the virus from entering their farm, but commercial fishers cannot do this and thus face permanent biosecurity restrictions which will affect their profitability and ability to sell their products into their usual markets (Diggles 2020).

5.2 Risk factors relating to the on-farm WSSV incursions in the 2019-2020 growing season

Interviews with prawn farmers on the Logan River revealed the significant rainfall events that occurred between 6 and 14 February 2020 resulted in large drops in the temperature and salinity of intake water. The water temperature in the lower reaches of the Logan River dropped from around 28 to 20-22°C, while salinity in the top meter or two of the water column dropped to 0 ppt for a short period of time. It is known that reductions in water temperature are stressful for prawns and that reduced water temperature is a risk factor for initiation of WSD in populations of prawns exposed to WSSV (Corsin et al. 2005). Furthermore, a low salinity river flow event causes a transient reduction in water quality, and would also be expected to promote downstream movements ("flushing out") of known WSSV vectors such as estuarine shrimp (*P. serrifer*) which inhabit the middle and upper reaches of local estuaries (Davie 1998). WSSV was highly prevalent in *P. serrifer* in the present study, with 67.2% pooled sample prevalence for WSSV positive and suspect samples taken from 3 sites on the Logan River, and 45.1% mean pooled WSSV sample prevalence across all sampling sites throughout Moreton Bay. For these reasons, it is concluded that intake of unfiltered, untreated water from the Logan River following the 6-14 February 2020 rainfall event was an important risk factor likely to be responsible for precipitating the outbreak of WSD detected in subsequent weeks in *P. monodon* on Farm B.

Once harvesting of affected ponds on Farm B commenced in March 2020, it is likely that water containing WSSV vectors and possibly also free WSSV was discharged into the Logan River. An increase in WSSV load in the river may explain the subsequent emergence of WSD near the end of the harvest on Farm A, around 2.7 km upriver, in early April 2020, despite the treatment of the intake water on Farm A using 50 µm drum filters and ozonation. This is because the 50 µm screens on some of the drum filters were observed to be damaged in mid/late March (Table 5), degrading their effectiveness and allowing more vector organisms through (Mann et al. 2020), but given the advanced stage of the harvest and the fact that water requirements were relatively low, at the time pumping continued with the damaged screens and, after March 2020, without ozonation. Obviously, intake of water containing WSSV vectors or free virus is a significant risk factor in the emergence of WSD (Corsin et al. 2001; Cullinan et al. 2013), which would explain the emergence of WSD in pond 3 near the end of the harvest at Farm A. As mentioned previously, the decision by Farm C to immediately cease pumping water into their production ponds upon being informed of the WSD diagnosis on the farms upriver around 12 April 2020 appears, in hindsight, to have saved Farm C from a severe WSD outbreak in their cultured *P. monodon*, given the large number of vector taxa that were subsequently found to be infected with WSSV at high prevalence within their water supply channels in early May 2020 (Table 6). Instead, the *P. monodon* harvest at Farm C proceeded normally and the only detrimental outcomes recorded appeared to be the mortalities of wild penaeids (school and banana prawns) and the mud crab observed in their water supply channels during the present study. The failure to detect WSSV in plankton samples taken from the inlet canals of Farm C for the previous 2 years up until early March 2020 (Mann et al. 2020), confirms that the WSSV load in the Logan River environment must have increased markedly sometime between March and April 2020. It is notable that once WSD was detected at Farms A and B, for all farms on the Logan River, treatment of all farm effluent water with trichlorfon was a mandatory requirement from BQ to kill all crustacean vectors, followed by a minimum 12 day post-treatment water holding period prior to release of the sanitised water into the river (S. Wesche, personal communication). Furthermore, thorough pond sediment treatment, drying out and preparation followed by careful filling of the farms with properly treated intake water free of WSSV vectors appears necessary in order to reduce the risk of WSSV persisting in and around Farms A, B and C during the start of the 2020-21 growing season and beyond.

One other risk factor worthy of mention is seasonal effects due to time of year. Pond water quality records from Farm C showed that in late summer and early autumn in SE QLD, rainfall events at this time of year are accompanied by cooler weather (southerly fronts) which results in substantial (6 to 8°C) drops in the morning water temperatures measured in production ponds (from 28-29°C to around 21-22°C). Given that these reductions in water temperature are stressors that represent a significant

risk factor for initiation of WSD disease in populations of prawns exposed to WSSV (Corsin et al. 2005), and acknowledging the fact that it appears very difficult to completely exclude all WSSV and/or WSSV infected vectors from intake water using existing economically feasible technology (Mann et al. 2020), it becomes clear that the risks of a WSD outbreak in prawn farms along the Logan River accumulate over the course of each production cycle and are directly linked to water use from the Logan River and the duration of the growout cycle.

6. Conclusion and implications

The results from the present study indicate that the enhanced biosecurity protocols employed by all three prawn farms which remained operational on the Logan River during the 2019-20 growing season failed to completely exclude WSSV from their facilities. The presence of several taxa that are now known to be WSSV vectors under Australian conditions in river tributaries and supply channels both pre and post-intake water treatment suggests that, in practice, it may be impossible to completely exclude WSSV from these farms using existing affordable and logistically/practically suitable technologies.

The recipe for successfully farming prawns in SE QLD (now that WSSV appears to be firmly embedded within aquatic food chains in this region) therefore now appears to hinge around a combination of being able to completely eliminate all potential sources and reservoirs of the virus from intakes and production ponds during dry out between production cycles, then starting with zero virus in the culture water and robust, domesticated, disease free PL. Stress due to water quality fluctuations will need to be minimised throughout the entire growout period, keeping cumulative WSSV loads (and vector populations) as low as possible during water exchanges, with the aim of getting the farmed prawns growing as fast as possible so they can be harvested as soon as possible, preferably before water temperatures begin to decline from their summer peaks with particular attention paid following periods of high rainfall when water temperature and salinity may change quickly.

As far as commercial fisheries for wild crustaceans in the Logan River and Moreton Bay are concerned, disruption of the bait prawn (and baitworm) supplies from Moreton Bay due to the WSSV incursion is likely to affect these fisheries, and recreational fisheries Australia-wide, for the foreseeable future. This is due to reduced availability and/or increased cost of domestic bait prawns, which must be either cooked, or gamma irradiated to a dose of no less than 50 kilogray (kGy) prior to being allowed out of the White Spot Biosecurity Area. The increased cost of bait prawns from Moreton Bay due to the WSSV incursion has led to a perverse economic incentive for recreational fishers throughout Australia to use more imported uncooked prawns from supermarkets as bait, which represents a further increase to the already high biosecurity risk of incursions of exotic diseases of crustaceans via the bait and burley pathway. As long as the White Spot Biosecurity Area remains in place, the ongoing economic impact on the commercial bait prawn and baitworm fisheries in Moreton Bay will continue to accumulate over time, potentially exceeding that experienced by the prawn farming industry.

8. Recommendations

To further improve prawn farm biosecurity to reduce risk of WSD outbreaks on the Logan River and potential spillback into wild fisheries, some additional considerations are as follows:

- Intake of untreated (raw) water from the Logan River into prawn ponds is now an extremely high risk activity that should no longer be undertaken under any circumstances, but especially after rain events which reduce water temperature and salinity.

- Intake water for farms and ponds should be extracted from moving water bodies (e.g. "ring mains approach"), and not be taken from the "dead ends" of water supply channels, as those locations appear to concentrate WSSV vector organisms (Diggles 2017, present study).

- The risk of WSSV incursion into prawn ponds will be reduced the more stringent treatment of intake water becomes. Filtration of intake water to a nominal 50 µm will exclude many vectors and will thus reduce WSSV risk compared to unfiltered water (and hence delay the onset of disease), but will not prevent ingress of free virus or the planktonic larval stages of some WSSV vectors (Esparza-Leal et al. 2009, Mann et al. 2020, present study). Nevertheless, filtration of all intake water to the lowest nominal particle size possible for the required flow rate is recommended, as is ozonation to provide additional assurance for more effective vector removal (Mann et al. 2020).

- Compartmentalisation of water distribution canals may be useful to allow for secondary filtration with smaller nominal sized mesh (20 µm or less) at lower flow rates in certain parts of each farm prior to entry of water into production ponds, and/or to allow regular drying out of parts of the water distribution system for vector control.

- Ponds and water supply channels need to be thoroughly dried and treated to remove all potential WSSV vectors between each growing season.

- Ponds should be filled with WSSV free water and stocked with pathogen free PL as early as possible in the season, so that WSSV loads start at zero and remain as low as possible for as long as possible during growout (Corsin et al. 2003).

- Consider introducing cultured finfish into water distribution canals to keep populations of potential vectors in check and quickly remove any crustacean carcasses which may transmit WSSV. Alternatively, water distribution canals could be drained and dried one or more times each growing season to prevent accumulation/propagation of WSSV vectors over the course of the growout period.

- Regular testing of stock for WSSV throughout the growing season and/or prior to drain harvesting ponds

- Routine treatment of effluent water prior to its discharge is recommended.

- Rapid removal/harvest of any WSSV positive ponds, cooking of this product followed by treatment of all water from affected ponds and raceways prior to its release into the environment, noting that such an approach is already a mandatory requirement enforced by BQ.

- The proposed risk mitigation methods suggested in the current draft prawn Import Risk Analysis (IRA) (DAWE 2020) represent little change compared to those that are currently implemented at the international border following the failed 2009 IRA (Biosecurity Australia 2009). The proposed risk mitigation methods detailed in DAWE (2020) are thus inconsistent with Australia's domestic Appropriate Level of Protection (ALOP), and therefore do not meet Queenslands ALOP (which has been

demonstrated to be a requirement for either cooking or gamma irradiation of prawns originating from regions where WSSV is endemic). The proposed risk mitigation measures for the international border thus cannot be relied upon to protect Australia's environment against not only WSSV, but also other known emerging diseases (e.g. decapod iridescent virus (DIV1)), as well as future (currently unknown) emerging diseases to a level of risk that meets the domestic ALOP. For these reasons, a highly precautionary approach to on-farm biosecurity is recommended on prawn farms not only along the Logan River, but elsewhere throughout Australia.

9. Extension and Adoption

This report has been made available to the FRDC, QSIA, the APFA as well as all prawn farmers operating along the Logan River. It has also been made available to the Government of Queensland (through Biosecurity Queensland) and the Australian Federal Government (through the Department of Agriculture and Water Resources) for their consideration and for inclusion in submissions to the revised draft prawn IRA (DAWE 2020).

It is also planned that the results from this study will eventually be included with other surveillance data compiled by Biosecurity Queensland and developed into a scientific paper which will be drafted and then submitted to a peer reviewed journal in the not too distant future.

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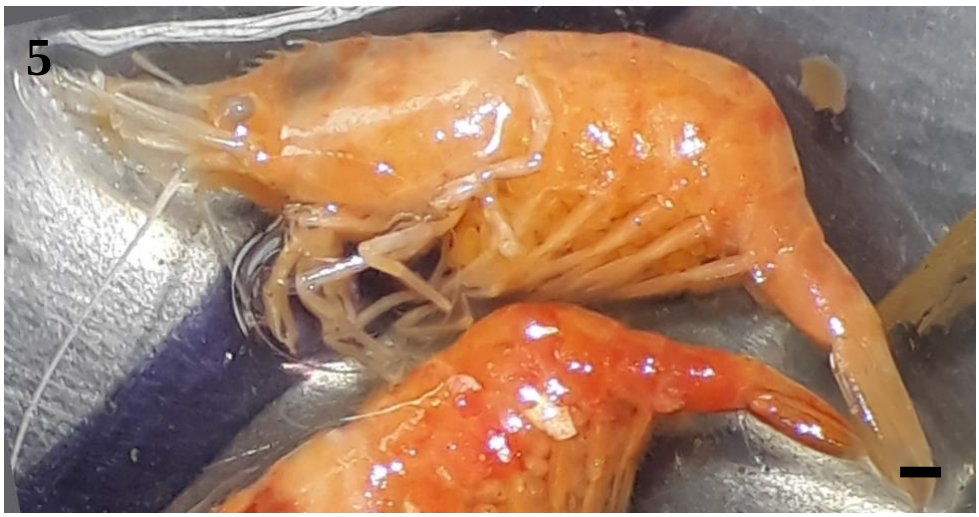
Appendix 1. Vector host identification photos

1. Jelly prawn (*Acetes sibogae australis*) (live) scale bar = 1 mm.

2. Estuarine shrimp (*Palaemon serrifer*) (ethanol fixed) scale bar = 1 mm.

3. Rock pool shrimp (*Palaemon serenus*) (live) scale bar = 1 mm.

4. *Palaemonella* spp. (live) scale bar = 1 mm.



5. Family Pandalidae (ethanol fixed) scale bar = 1 mm.

6. School prawn (*Metapenaeus macleayi*) (live) and fixed (inset), scale bar = 10 mm.

7. Banana prawn (*Penaeus* (*Fenneropenaeus*) *merguiensis*) (dead) scale bar = 10 mm.

8. Freshwater prawn (*Macrobrachium novaehollandiae*) (live) scale bar = 10 mm.

9. Red-fingered marsh crab (*Parasesarma erythodactyla*) (live) scale bar = 1 mm.

10. Round shore crab (*Cyclograpsus audouinii*) (live) scale bar = 1 mm.

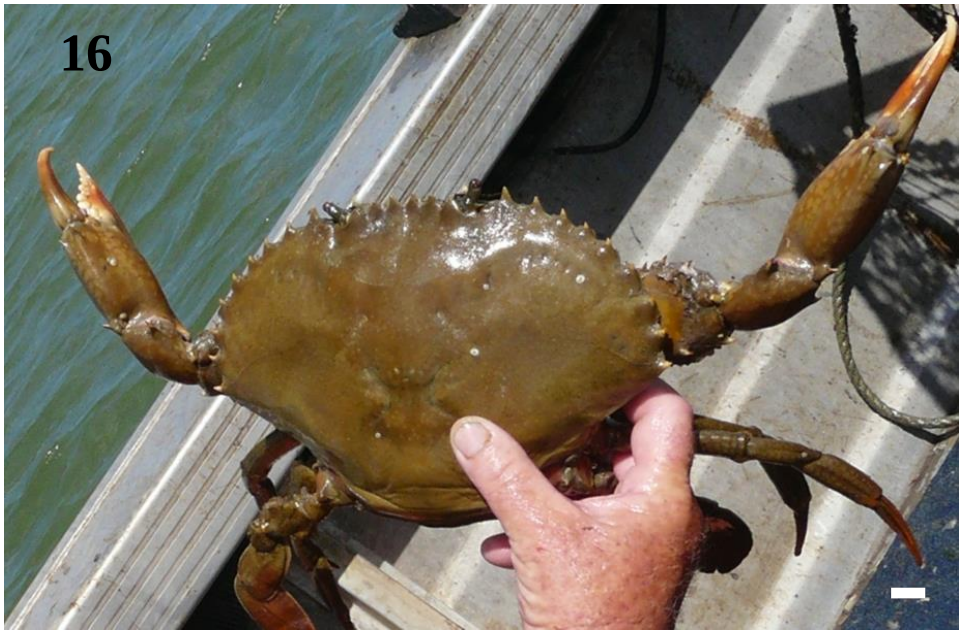
11. Stout rock crab (*Ozius truncatus*) (live) scale bar = 1 mm.

12. Mangrove crab (*Metapograspus frontalis*) (live) scale bar = 1 mm.

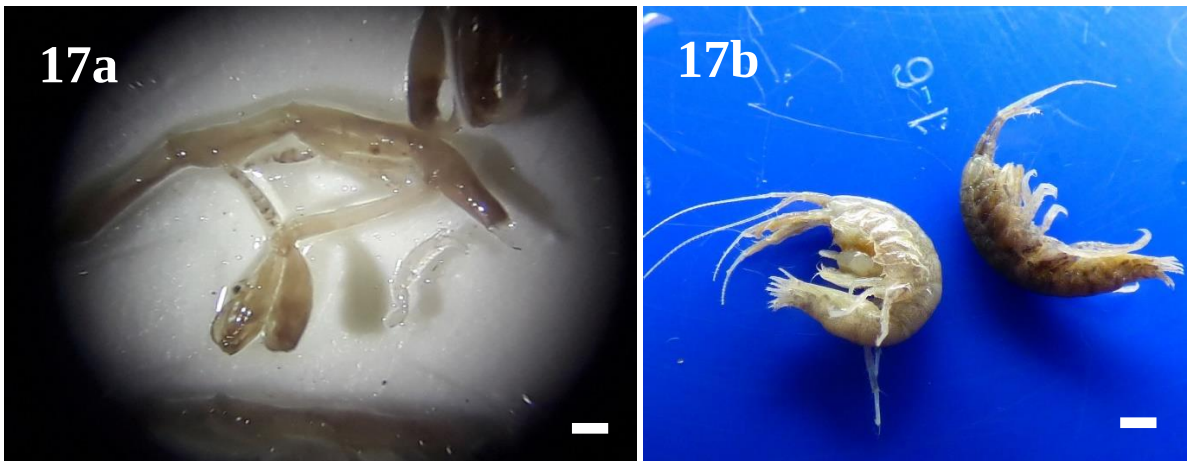
13. Smooth handed crab (*Pilumnopeus serratifrons*) (live) scale bar = 1 mm.

14. Mangrove swimming crab (*Thalamita crenata*) (live) scale bar = 10 mm.

15. Blue swimmer crab (*Portunus armatus*) (live) scale bar = 10 mm.



16. Mud crab (*Scylla serrata*) (live) scale bar = 10 mm.



17.Amphipods, Family *Caprellidae* (17a), Suborder Gammaridea (17b) (ethanol fixed) scale bar = 1 mm.

18. Water strider (*Limnogonus windi*) (live) scale bar = 1 mm.

Appendix 2. Weather data for Gold Coast and Beaudesert for Jan-Apr 2020

Gold Coast Seaway January 2020

Gold Coast, Queensland
January 2020 Daily Weather Observations

Observations from the Gold Coast Seaway, at the northern end of Southport Spit.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	We	22.6	29.4	0			NNE	33	14:24	28.4	69		NNE	17	1016.1	28.5	69		NNE	26	1014.1
2	Th	21.0	29.8	0			NE	30	11:32	28.2	80		NNE	19	1017.3	28.7	74		NE	24	1015.4
3	Fr	20.8	28.6	0			ENE	28	13:20	27.5	78		SE	9	1017.7	27.5	75		ENE	24	1014.8
4	Sa	21.0	29.6	0			NNE	39	13:15	28.2	75		NNE	17	1016.9	28.3	74		NNE	33	1013.5
5	Su	21.1	30.3	0			NNE	39	13:20	26.4	75		NW	24	1016.3	27.6	76		NNE	31	1013.5
6	Mo	20.3	29.3	0			NE	26	14:16	25.6	95		SE	11	1018.2	27.3	82		NE	22	1014.6
7	Tu	22.2	29.0	0			SE	31	07:13	23.8	100		ENE	20	1016.9	27.7	86		NE	15	1013.8
8	We	21.0	30.2	0			NNE	31	13:38	26.9	88		NE	13	1016.4	29.1	79		NNE	28	1012.8
9	Th	20.9	29.8	0			NNE	31	14:31	27.2	89		NE	13	1015.8	29.1	78		NNE	28	1013.7
10	Fr	22.3		0						29.4	84		NNE	17	1015.9	29.2	59		NE	28	1013.1
11	Sa	24.3	30.7				NNE	39	11:29	29.1	54		N	24	1011.1	26.6	72		NNE	30	1007.6
12	Su	21.0	25.8	23.6			S	61	08:39	21.3	88		S	37	1012.9	23.7	70		S	37	1012.2
13	Mo	20.9	27.3	2.6			SSE	52	14:45	24.1	65		SSE	37	1015.5	26.0	63		SSE	39	1013.8
14	Tu	22.0	28.9	0			SE	50	14:17	24.9	69		SSE	31	1014.7	27.2	66		SE	35	1012.3
15	We	22.0	28.9	4.2			SSE	33	01:49	26.8	72		E	15	1013.3	28.0	66		ENE	20	1010.8
16	Th	23.9	29.2	0			ENE	33	18:01	27.3	67		ENE	15	1010.1	26.1	71		NE	20	1007.1
17	Fr	23.4	29.6	1.2			E	48	22:28	27.8	68		NE	24	1006.4	27.1	65		ENE	28	1004.7
18	Sa	20.6	27.5	254.8			NNE	54	02:22	21.6	91		S	19	1005.1	25.2	81		SSE	15	1003.5
19	Su	21.5	29.2	0.8			N	48	23:49	27.1	76		NE	9	1005.6	27.7	75		NE	28	1004.1
20	Mo	23.3	30.8	60.6			NNE	65	03:08	28.9	72		N	28	1008.2	25.8	80		N	31	1005.1
21	Tu	23.0	31.0	1.2			N	41	17:20	28.9	63		N	19	1009.6	27.5	74		N	28	1006.4
22	We	22.3	29.6	0.2			NNE	35	14:37	25.3	74		NE	15	1012.4	28.7	72		NNE	30	1009.2
23	Th	23.3	30.1	0			NNE	39	17:24	25.3	82		N	17	1013.3	28.0	75		NNE	30	1009.9
24	Fr	23.2	29.9	0			NNE	35	13:09	29.8	68		N	24	1012.6	27.0	74		N	24	1009.2
25	Sa	22.7	28.5	0			NNE	30	09:18	26.8	74		NNE	22	1013.0	25.6	78		NNE	17	1012.5
26	Su	20.8	28.7	0			NE	26	05:53	25.9	71			Calm	1015.1	26.9	68		ENE	17	1013.2
27	Mo	22.1	29.4	0			ENE	28	19:20	28.1	71		ESE	7	1014.9	27.3	68		ENE	17	1013.2
28	Tu	22.7	29.1	24.8			NE	31	03:30	25.3	85		S	11	1015.1	26.4	77		E	15	1013.2
29	We	23.0	32.2	1.0			NNE	33	13:17	28.9	61		NW	19	1013.9	29.6	66		NNE	28	1012.5
30	Th	23.1	30.9	0			E	19	15:29	27.6	76		SE	11	1016.6	28.9	67		ENE	15	1014.9
31	Fr	22.6	29.4	0			ENE	26	20:00	27.7	73		SSE	11	1018.7	28.9	64		E	19	1016.6
Statistics for January 2020																					
Mean		22.1	29.4							26.8	75			17	1013.7	27.5	72			25	1011.3
Lowest		20.3	25.8							21.3	54			Calm	1005.1	23.7	59		#	15	1003.5
Highest		24.3	32.2	254.8			NNE	65		29.8	100		#	37	1018.7	29.6	86		SSE	39	1016.6
Total				375.0																	

Observations were drawn from Gold Coast Seaway (station 040764)

The Gold Coast Seaway site is an Automatic Weather Station (AWS) at the northern end of Southport Spit. If you are interested in the southern end of the Gold Coast, see the observations from Coolangatta.

Gold Coast, Queensland
February 2020 Daily Weather Observations

Observations from the Gold Coast Seaway, at the northern end of Southport Spit.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Sa	22.9	30.2	0			NNE	35	17:07	28.0	63		SSE	2	1018.4	29.8	60		NE	28	1014.6
2	Su	23.0	31.9	0			NNE	43	14:16	28.8	53		NW	19	1013.6	30.1	59		NNE	33	1009.5
3	Mo	24.8	33.4	0			S	54	23:03	29.6	57		NW	24	1009.0	27.5	68		N	30	1004.8
4	Tu	21.9	25.0	10.8			S	61	09:42	24.1	77		S	46	1014.3	22.1	86		S	41	1015.5
5	We	20.4	24.4	0.8			SE	52	16:05	22.8	74		SSE	37	1017.9	24.1	71		SSE	33	1015.8
6	Th	20.9	23.7	27.6			S	41	02:15	21.4	90		S	17	1016.2	22.4	89		S	17	1013.9
7	Fr	21.1	26.8	105.0			NE	41	01:12	22.6	91		S	11	1015.1	26.0	77		SE	22	1012.7
8	Sa	22.5	26.9	29.4			WNW	44	23:08	24.1	91		SE	7	1012.1	23.8	88		SSE	20	1008.3
9	Su	22.1	26.6	103.6			NNE	35	11:52	24.5	88		S	7	1007.5	24.7	85		SSE	19	1005.6
10	Mo	21.5	28.5	23.6			N	37	01:22	25.9	79		N	11	1010.1	28.2	73		ENE	13	1007.5
11	Tu	22.4	28.3	7.4			NNE	41	20:52	25.6	81		SE	9	1009.5	26.1	84		ESE	13	1006.3
12	We	23.3	25.5	30.2			E	48	15:50	23.4	91		SSW	7	1007.4	24.9	86		S	11	1005.8
13	Th	22.0	26.8	177.8			SE	39	13:24	22.8	92		S	17	1005.6	24.8	85		S	11	1003.3
14	Fr	21.7	28.8	50.0			SE	39	12:35	26.8	75		ESE	11	1006.0	27.0	67		SE	30	1003.5
15	Sa	23.2	30.5	0			NNE	33	14:33	26.2	77		NW	13	1007.7	29.5	69		NNE	28	1005.1
16	Su	23.4	30.3	0			ESE	30	16:57	27.9	75		SE	13	1011.5	29.6	70		ESE	20	1010.6
17	Mo	25.4	30.8	0			ESE	28	19:49	29.7	66		SSE	15	1013.7	29.4	64		ESE	19	1012.0
18	Tu	23.0	30.3	0			E	28	13:42	28.5	68			Calm	1012.1	29.2	66		ENE	22	1009.0
19	We	25.3	33.1	0			NNE	41	14:38	29.0	65		NNW	20	1007.6	30.4	66		NNE	35	1003.5
20	Th	24.8	31.0	0			SSE	39	06:01	29.2	61		SSE	24	1008.2	29.8	55		SE	28	1007.3
21	Fr	22.5	29.6	0			ESE	35	17:25	26.2	70		SE	15	1015.0	28.2	57		ESE	26	1013.3
22	Sa	24.0	28.1	0.4			SSE	52	20:02	28.1	62		SE	30	1019.9	26.3	60		SSE	35	1019.0
23	Su	20.7	25.5	7.4			ESE	57	02:34	22.8	86		SE	39	1021.0	24.7	66		SSE	31	1018.4
24	Mo	21.4	26.1	20.2			ESE	41	16:06	22.3	90		S	11	1018.6	23.6	86		SSE	17	1015.9
25	Tu	21.1	28.5	10.8			SSE	43	08:43	25.3	76		S	35	1016.1	26.3	74		ESE	26	1013.2
26	We	21.3	29.3	22.0			NNE	31	15:59	26.9	77		SSE	11	1011.7	28.4	71		NE	19	1007.7
27	Th	23.2	29.4	0			SE	44	11:43	26.8	79		NNE	17	1008.2	25.1	84		E	30	1007.2
28	Fr	21.2	29.3	3.6			SE	37	20:04	26.2	72		ESE	6	1008.6	27.3	71		SE	17	1007.3
29	Sa	23.6	29.9	0			SE	39	16:34	27.0	67		SSW	17	1014.3	27.4	64		SE	28	1012.1
Statistics for February 2020																					
Mean		22.6	28.6							25.9	75			16	1012.3	26.8	72			24	1010.0
Lowest		20.4	23.7							21.4	53			Calm	1005.6	22.1	55		S	11	1003.3
Highest		25.4	33.4	177.8			S	61		29.7	92		S	46	1021.0	30.4	89		S	41	1019.0
Total				630.6																	

Observations were drawn from Gold Coast Seaway (station 040764)

The Gold Coast Seaway site is an Automatic Weather Station (AWS) at the northern end of Southport Spit. If you are interested in the southern end of the Gold Coast, see the observations from Coolangatta.

Gold Coast, Queensland
March 2020 Daily Weather Observations

Observations from the Gold Coast Seaway, at the northern end of Southport Spit.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Su	21.4	29.8	0			S	30	08:13	28.0	62		S	24	1015.0	28.7	64		ESE	24	1012.6
2	Mo	21.9	31.6	0			N	35	18:28	27.2	63		NW	9	1014.0	30.7	61		NNE	28	1010.9
3	Tu	22.5	30.8	0			S	50	20:48	28.8	72		N	11	1015.1	29.4	64		ESE	22	1013.5
4	We	25.5	29.2	0			SE	52	01:44	27.1	69		SE	35	1016.0	27.9	65		ESE	22	1013.0
5	Th	24.6	31.0	0.4			ENE	37	00:03	27.3	69		NE	24	1013.3	29.9	53		NNE	24	1010.1
6	Fr	24.9	31.6	0			N	35	17:27	27.4	71		NW	11	1011.5	30.0	59		NNE	26	1007.8
7	Sa	24.5	31.5	0			S	69	15:43	28.8	65		SSE	33	1013.0	28.0	64		SSE	46	1012.5
8	Su	22.5	29.0	0			SSE	61	01:29	26.0	58		S	39	1016.4	27.0	59		SSE	39	1014.2
9	Mo	20.8	23.0	5.0			SE	63	18:01	21.7	90		SSE	33	1015.8	21.4	89		SE	43	1014.0
10	Tu	18.8	24.2	52.4			SSE	63	01:41	21.7	82		SSW	20	1016.4	21.7	88		SE	2	1014.4
11	We	19.7	27.2	14.0			S	61	17:15	23.6	68		S	35	1018.5	25.3	56		SSE	46	1017.6
12	Th	19.0	24.6	1.8			SSE	69	12:56	23.2	69		S	37	1019.6	22.1	84		SE	48	1018.0
13	Fr	18.9	26.1	28.8			SE	56	15:24	24.4	65		S	30	1016.6	24.5	63		SSE	41	1013.2
14	Sa	20.0	28.2	0.2			SSE	59	13:37	25.0	55		SSE	43	1011.0	24.8	65		SE	44	1008.8
15	Su	19.7	27.9	0			S	78	18:04	23.5	62		S	33	1012.5	25.8	57		S	46	1011.2
16	Mo	19.4	27.5	2.0			SSE	76	17:45	23.6	51		S	39	1017.8	24.7	57		SSE	35	1017.6
17	Tu	18.9	27.1	0.6			SSE	74	10:57	23.9	59		S	41	1022.5	25.2	56		SSE	48	1020.8
18	We	19.6	27.6	0			S	52	09:08	24.6	50		S	31	1024.6	25.4	60		SE	41	1022.0
19	Th	17.9	27.6	0			SSE	28	08:28	25.8	51		S	19	1024.0	26.3	57		ESE	19	1020.9
20	Fr	18.1	29.7	0			NNE	35	14:59	25.5	56		NW	13	1021.2	28.0	57		NNE	31	1017.2
21	Sa	20.6	31.3	0			SE	50	15:44	26.1	60		NW	17	1017.4	28.0	67		SE	35	1016.2
22	Su	21.3	28.9	0			N	30	17:32	27.3	62		SSE	9	1019.9	27.6	68		NE	17	1016.0
23	Mo	21.3	28.2	0			S	59	16:32	26.7	66		S	39	1019.8	26.8	69		SE	37	1019.0
24	Tu	20.4	25.7	5.8			SE	52	12:32	22.9	75		SSE	31	1022.5	22.6	75		SW	11	1020.3
25	We	19.6	26.6	5.8			SE	31	00:01	24.2	71		SSE	9	1021.4	25.8	55		E	15	1018.1
26	Th	19.2	28.4	0			S	52	22:52	26.2	59		SSE	15	1020.2	26.3	56		ESE	22	1018.7
27	Fr	19.8	25.8	0			S	61	15:45	22.2	73		S	28	1021.7	22.4	76		S	30	1020.0
28	Sa	20.2	27.7	0.6			ESE	48	16:06	25.8	63		SSE	28	1020.4	26.0	61		SE	19	1017.6
29	Su	19.7	27.6	4.2			SSE	35	09:12	25.2	70		SSE	26	1019.6	25.4	70		ESE	19	1016.8
30	Mo	19.4	27.8	0			NNE	31	15:00	25.2	68		ESE	7	1017.1	27.1	63		NNE	26	1014.1
31	Tu	21.2	29.8	0			SE	37	18:12	24.3	70		NW	20	1015.7	26.5	66		SE	28	1013.6
Statistics for March 2020																					
Mean		20.7	28.2							25.3	65			25	1017.8	26.2	64			30	1015.5
Lowest		17.9	23.0							21.7	50		ESE	7	1011.0	21.4	53		SE	2	1007.8
Highest		25.5	31.6	52.4			S	78		28.8	90		SSE	43	1024.6	30.7	89		#	48	1022.0
Total				121.6																	

Observations were drawn from Gold Coast Seaway (station 040764)

The Gold Coast Seaway site is an Automatic Weather Station (AWS) at the northern end of Southport Spit. If you are interested in the southern end of the Gold Coast, see the observations from Coolangatta.

IDCJDW4050.202003 Prepared at 16:01 UTC on 7 Oct 2020

Gold Coast, Queensland
April 2020 Daily Weather Observations

Observations from the Gold Coast Seaway, at the northern end of Southport Spit.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	We	20.5	28.9	0			SE	41	15:11	25.7	68		S	26	1017.9	27.1	65		SE	31	1015.4
2	Th	20.5	28.4	0			ESE	33	11:19	26.7	64		SSE	19	1016.7	26.2	68		ESE	22	1013.5
3	Fr	21.0	29.9	0			N	37	18:31	26.3	68		NW	13	1012.7	28.2	63		NNE	28	1009.3
4	Sa	23.5	30.1	0.2			NW	44	13:37	26.4	65		NW	24	1010.0	28.3	55		NW	28	1006.6
5	Su	18.9	27.8	0.2			SE	39	13:02	25.2	54		SSE	20	1015.1	25.9	54		SE	31	1012.8
6	Mo	18.1	26.8	0			SE	35	16:44	24.4	54			Calm	1017.1	25.8	60		SE	28	1014.5
7	Tu	19.2	28.4	0			SSE	54	15:41	25.0	53		S	30	1018.0	26.8	47		SSE	31	1014.9
8	We	19.5	27.3	0.6			SSE	50	15:57	24.5	63		SSE	33	1019.1	24.3	66		SSE	31	1017.4
9	Th	20.5	26.9	0			SSE	52	10:40	24.3	59		S	31	1023.4	25.2	61		SE	31	1021.5
10	Fr	19.7	23.9	8.2			E	33	00:08	21.1	88		S	13	1021.8	21.7	88		SE	13	1017.1
11	Sa	19.9	30.7	4.4			NNE	41	13:05	23.7	75		NNW	20	1012.5	30.6	27		NW	24	1006.4
12	Su	17.1	26.5	0.2			SE	57	14:24	25.7	37		SSE	30	1013.1	23.5	53		SE	39	1014.2
13	Mo	15.4	25.9	0			ESE	28	15:46	23.2	52		SSE	15	1021.2	24.2	57		ESE	20	1019.0
14	Tu	17.1	27.0	0			SE	30	14:32	24.7	56		S	17	1024.7	24.8	57		ESE	24	1022.2
15	We	17.8	27.1	0			ESE	30	13:39	24.4	59		S	13	1024.5	24.8	64		ESE	24	1020.8
16	Th	17.2	28.6	0			NNE	37	16:10	24.0	61		NW	13	1020.0	27.7	52		NNE	22	1015.4
17	Fr	19.6	32.6	0			NW	31	08:06	24.1	65		NW	20	1014.7	32.0	33		NW	17	1009.4
18	Sa	21.1	25.8	0			WNW	39	13:20	24.2	69		NNE	7	1012.0	21.7	74		NNE	13	1010.5
19	Su	16.0	25.1	1.2			N	22	12:39	21.8	57		NW	13	1012.9	23.6	64		ENE	9	1010.4
20	Mo	13.1	25.2	0			NE	24	13:29	21.9	56			Calm	1016.4	24.3	54		ENE	17	1013.9
21	Tu	16.9	26.3	0			SW	20	04:02	24.6	54		SSE	9	1019.4	25.1	62		E	9	1016.6
22	We	18.6	27.8	0			SE	31	15:13	24.6	62		NW	15	1018.3	26.2	61		SE	26	1015.5
23	Th	17.8	26.9	0			SE	24	13:14	24.8	58		SSE	13	1021.6	25.3	58		ESE	15	1017.9
24	Fr	17.9	28.0	0			NNE	30	13:30	24.3	61		NW	13	1019.2	25.5	63		NNE	26	1016.6
25	Sa	16.4	27.5	0			SE	28	16:00	24.5	61		S	15	1022.2	25.4	58		SE	20	1020.0
26	Su	17.5	27.5	0			NNE	35	14:32	23.8	62		NW	9	1020.5	26.4	58		NNE	30	1016.5
27	Mo	15.7	26.1	0			E	33	20:23	23.2	67		NW	9	1020.0	25.8	60		NE	11	1018.7
28	Tu	19.5	24.3	2.8			ESE	43	14:11	23.5	73		S	15	1022.4	21.9	76		SSE	19	1020.1
29	We	18.6	25.9	9.2			SE	19	02:42	22.6	75		SSE	13	1020.1	25.2	65		SE	9	1016.9
30	Th	18.0	28.6	0			WNW	52	00:00	22.3	78		NW	13	1015.3	26.1	70		NNE	35	1009.3
Statistics for April 2020																					
Mean		18.4	27.4							24.2	62			16	1018.1	25.7	59			22	1015.1
Lowest		13.1	23.9							21.1	37			Calm	1010.0	21.7	27		#	9	1006.4
Highest		23.5	32.6	9.2			SE	57		26.7	88		SSE	33	1024.7	32.0	88		SE	39	1022.2
Total				27.0																	

Observations were drawn from Gold Coast Seaway {station 040764}

The Gold Coast Seaway site is an Automatic Weather Station (AWS) at the northern end of Southport Spit. If you are interested in the southern end of the Gold Coast, see the observations from Coolangatta.

Beaudesert (Logan River catchment) January 2020

Beaudesert, Queensland
January 2020 Daily Weather Observations

Observations from a site in Drumley Street, about 1.5 km northwest of the town centre.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	We	18.8	34.5	0.2			NNE	28	17:48				NNW	7	1015.9	32.6	41		NNE	15	1012.6
2	Th		34.3	0			ENE	30	16:08	27.5	68		WNW	7	1017.0	33.3	43		N	9	1013.6
3	Fr	18.7	34.4	0			NE	30	14:46	26.6	65		WSW	6	1017.5	32.5	42		NE	17	1013.3
4	Sa	16.2	35.7	0			N	28	15:42	26.5	60		N	6	1017.2	34.0	30		NNE	15	1011.9
5	Su	17.5	36.1	0			NNE	31	16:13	27.1	59		NNW	6	1016.6	35.3	33		N	11	1011.9
6	Mo	19.2	34.1	0			NNE	30	14:49	29.7	51		E	6	1017.6	32.3	46		NNE	15	1013.2
7	Tu	20.6	32.4	0			NE	31	13:32	26.7	70		SW	2	1016.4	30.9	52		NE	13	1012.4
8	We	19.0	35.2	0			NNE	30	15:13	28.2	58		NW	6	1016.4	33.8	40		NNE	13	1010.9
9	Th	19.3	35.5	0			N	35	14:04	27.2	64		S	4	1015.8	34.3	41		NE	13	1011.8
10	Fr	21.1	34.2	0			NNE	31	12:32	26.7	70		NNW	6	1015.6	33.2	37		NE	15	1011.8
11	Sa	21.4	36.1	0			SE	39	18:15	28.7	64		NW	6	1011.8	33.6	49		NNE	13	1006.4
12	Su	23.2	29.1	0.4			SW	41	13:23	25.7	71		S	19	1012.6	26.2	59		SSW	19	1011.5
13	Mo	20.9	29.9	0			WSW	33	09:58	26.2	57		SW	20	1015.3	26.7	57		ESE	11	1013.2
14	Tu	17.9	31.5	0			SSW	35	15:02	25.1	69		SW	15	1014.7	31.3	52		SSW	20	1011.4
15	We	20.0	30.0	10.4			ENE	26	16:41	24.2	89		SSW	4	1013.6	27.6	75		WNW	4	1009.7
16	Th	19.5	29.0	10.2			NE	24	15:00	26.9	71		WSW	6	1009.8	26.9	73		NE	11	1006.7
17	Fr	21.3	29.8	27.8			E	31	13:34	27.0	69		NNW	6	1005.9	29.1	59		ENE	20	1003.6
18	Sa	19.9	29.0	83.4			ENE	30	17:53	22.2	96			Calm	1005.1	28.3	69		ESE	9	1002.8
19	Su	21.4	32.0	2.2			NNE	44	13:12	26.7	81		NW	2	1005.6	29.4	78		E	9	1003.2
20	Mo	23.5	35.2	2.0			W	54	15:15	29.2	76		NNW	6	1008.2	26.4	75		N	24	1004.6
21	Tu	22.0		25.0			S	65	16:11	28.9	66		NNW	7	1009.6	36.5	47		ENE	7	1004.9
22	We	21.4	36.4	22.2			NE	30	22:18	28.9	65		W	4	1012.2	34.8	54		ENE	15	1007.6
23	Th	26.3	33.4	0			NNE	35	12:50	29.1	80		NNW	6	1013.2	32.0	68		NNE	13	1008.9
24	Fr	25.6	35.4	0			N	26	16:31	29.1	76		NW	7	1012.6	34.1	56		NW	6	1008.2
25	Sa	25.1	32.3	0			ESE	26	11:31	28.6	82		NNW	6	1012.8	27.4	89		ENE	2	1012.0
26	Su	21.0	31.0	0.2			NE	30	15:42	27.8	73		E	7	1014.9	29.3	66		ENE	11	1012.2
27	Mo	21.4	32.1	0.2			NE	26	17:34	28.1	64		NNE	7	1014.8	31.0	47		ENE	13	1011.8
28	Tu	20.5	31.5	0.6			N	28	10:37	25.7	86		SW	6	1015.2	30.5	63		NE	11	1012.3
29	We	21.4	35.5	0.8			NE	24	17:05	28.7	74		WNW	2	1014.4	35.0	52		ESE	6	1011.1
30	Th	22.4	32.9	0			ENE	26	17:45	28.6	72		E	6	1016.4	31.2	60		NE	9	1013.6
31	Fr	20.0	32.6	0			ENE	26	14:56	27.5	67		SW	4	1018.6	31.3	56		E	13	1015.5
Statistics for January 2020																					
Mean		20.9	33.0							27.3	70			6	1013.7	31.3	55			12	1010.1
Lowest		16.2	29.0							22.2	51			Calm	1005.1	26.2	30		ENE	2	1002.8
Highest		26.3	36.4	83.4			S	65		29.7	96		SW	20	1018.6	36.5	89		N	24	1015.5
Total				185.6																	

Observations were drawn from Beaudesert Drumley Street (station 040983)

Beaudesert, Queensland
February 2020 Daily Weather Observations

Observations from a site in Drumley Street, about 1.5 km northwest of the town centre.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Sa	19.9	34.6	0			ENE	31	16:10	28.3	61		NE	7	1018.4	33.1	50		ENE	13	1013.3
2	Su	20.0	35.7	0			NNE	28	17:17	27.8	70		NW	6	1014.1	34.6	41		WSW	4	1008.5
3	Mo	21.9	38.3	0			N	35	15:57	28.6	68		W	4	1009.3	37.6	38		NNE	11	1003.4
4	Tu	23.0	27.0	2.2			SSE	31	07:14	25.8	76		S	9	1014.3	23.5	84		S	7	1015.1
5	We	20.1	25.2				E	33	11:40	24.2	72		SSW	7	1017.6	24.8	66		ESE	11	1015.5
6	Th	19.7	23.9	17.2			SW	17	08:30	20.9	97		SSW	7	1016.2	23.3	98		SE	7	1013.6
7	Fr	20.6	29.5	30.6			E	28	16:24	23.9	94		ESE	7	1015.2	29.0	67		ENE	11	1011.7
8	Sa	21.3	29.3	7.4			NE	24	14:12	22.9	100			Calm	1012.3	25.8	88		NE	9	1007.7
9	Su	22.1	27.9	27.4			ENE	15	15:36	25.3	93			Calm	1007.4	27.4	78		E	7	1005.2
10	Mo	22.1	30.6	16.4			ENE	33	12:52	26.6	81		WNW	6	1009.7	28.4	75		E	11	1006.4
11	Tu	21.9	31.2				ENE	20	15:55	26.0	89		SW	2	1009.6	30.9	67		N	7	1005.6
12	We	21.6	28.3	0.2			E	24	16:50	25.2	92		SSW	2	1007.3	24.3	96		NE	6	1005.7
13	Th	21.7	26.6	63.8			SSE	17	08:49	22.0	100		SSE	9	1006.2	22.4	100		SW	6	1004.4
14	Fr	20.3	31.9	92.4			N	26	15:49	26.6	78		SSW	9	1006.0	30.6	63		WNW	7	1002.8
15	Sa	22.3	34.0	0			ENE	22	18:02	27.0	78		NW	2	1007.6	33.5	56		NW	6	1004.5
16	Su	22.8	33.8	0			E	28	15:32	28.9	77		SSW	4	1011.3	31.9	60		E	15	1009.3
17	Mo	22.8	32.5	0			ENE	24	16:50	28.2	74		NE	4	1013.6	31.9	52		NE	11	1010.8
18	Tu	21.1	33.5	0			ENE	22	17:52	26.3	81		SSW	2	1012.4	33.0	51		NE	4	1008.1
19	We	23.4	35.4	0			W	41	18:56	27.9	79		NNW	6	1007.9	34.2	55		NW	9	1003.1
20	Th	20.9	32.7	5.4			ENE	26	15:57	27.1	63		SW	6	1008.2	32.5	42		E	4	1006.2
21	Fr	20.6	31.0	0.2			ENE	31	16:47	27.1	71		E	6	1014.7	28.1	61		E	19	1012.2
22	Sa	21.3	29.0	0			SE	33	10:52	26.6	66		SE	11	1019.9	26.5	59		SE	13	1018.2
23	Su	20.3	25.9	0			SE	24	11:13	25.3	71		S	9	1020.9	24.5	80		SSW	4	1018.6
24	Mo	19.6	28.5	3.0			SSE	28	13:38	22.4	90			Calm	1018.8	27.2	70		ESE	9	1015.5
25	Tu	20.0	29.8	4.8			ESE	30	15:40	25.6	79		SW	11	1016.0	27.0	70		E	11	1013.1
26	We	19.1	32.3	0			NE	20	17:29	26.2	76		SSW	4	1011.8	30.9	59		NNW	7	1006.8
27	Th	21.9	31.4	0			ENE	30	15:40	24.7	100		W	6	1008.4	29.8	66		ENE	11	1006.1
28	Fr	19.4	32.8	1.0			ESE	37	13:33	26.3	83		WSW	2	1008.5				NE	6	1006.6
29	Sa	19.7	30.9	0			SSW	24	07:35	24.3	81		SSW	9	1014.8	28.4	64		ENE	7	1011.4
Statistics for February 2020																					
Mean		21.1	30.8							25.8	80			5	1012.4	29.1	66			8	1009.3
Lowest		19.1	23.9							20.9	61			Calm	1006.0	22.4	38		#	4	1002.8
Highest		23.4	38.3	92.4			W	41		28.9	100		#	11	1020.9	37.6	100		E	19	1018.6
Total				272.0																	

Observations were drawn from Beaudesert Drumley Street {station 040983}

IDCJDW4141.202002 Prepared at 16:02 UTC on 16 Apr 2020

Beaudesert, Queensland
March 2020 Daily Weather Observations

Observations from a site in Drumley Street, about 1.5 km northwest of the town centre.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Su	17.3	32.8	0			NE	22	17:05	25.5	74		SW	7	1015.4	31.9	44		WNW	7	1011.6
2	Mo	19.1		0			NE	17	17:55	26.1	80		W	4	1014.5	34.5	39		W	4	1010.6
3	Tu	19.4	33.7	0			ENE	28	15:34	26.3	80		SW	4	1015.0	32.2	54		E	13	1012.4
4	We	22.3	27.9	0			ESE	28	11:28	26.5	82			Calm	1015.8	26.1	86		ENE	2	1013.2
5	Th	19.7	31.0	2.4			NE	30	11:40	25.7	87			Calm	1013.2	29.1	59		ENE	9	1009.4
6	Fr	23.8	32.8	0			NNE	20	14:26	26.9	84		NE	4	1011.7	31.0	62		N	9	1007.9
7	Sa	23.1	30.1	3.4			S	37	15:45	27.7	77		S	9	1013.1	29.1	65		SSE	20	1011.9
8	Su	19.2	29.5	0			ESE	30	10:30	25.0	67		SSW	7	1016.7	26.9	61		E	11	1013.4
9	Mo	20.1	22.3	0			SE	19	01:37	21.7	88		S	7	1016.2	20.9	97		S	4	1013.8
10	Tu	18.1	25.7	31.4			SSE	24	13:02	22.1	86			Calm	1017.1	24.4	71		ESE	7	1014.5
11	We	17.0	26.5	0.4			SE	33	12:32	23.0	77		S	13	1018.9	24.6	59		S	7	1017.5
12	Th	15.8	25.1	0			ESE	30	13:50	22.8	75		S	13	1020.2	24.2	66		SE	20	1017.8
13	Fr	16.0	27.8	0			SE	33	10:57	23.3	74		SSW	13	1017.1	26.2	59		ESE	13	1012.6
14	Sa	14.1	28.5	0			SW	26	10:42	23.9	66		SSW	11	1011.0	27.1	52		ESE	11	1008.3
15	Su	17.4	26.1	0			SW	44	07:22	22.4	71		S	22	1013.0	24.6	59		S	22	1011.9
16	Mo	17.5	26.7	0			SSE	43	13:03	22.4	60		SSW	19	1018.2	24.9	50		SSE	13	1017.5
17	Tu	16.4	26.7	0			S	33	13:28	22.0	66		SSW	19	1022.7	26.3	44		S	19	1020.6
18	We	13.9	28.4	0			SW	31	10:18	22.8	63		SSW	13	1024.8	27.6	43			Calm	1021.1
19	Th	11.3	30.1	0			NE	20	17:19	21.6	75		SSE	4	1024.3	29.1	36		SW	4	1020.2
20	Fr	12.9	30.8	0			NNE	19	18:02	22.3	78		SW	2	1021.6	30.1	46		W	6	1016.8
21	Sa	14.8	33.6	0			NNE	20	16:06	23.1	81			Calm	1018.5	32.4	46		NNE	7	1015.2
22	Su	16.2	33.6	0			NE	20	17:06	25.6	78		SW	4	1020.1	32.0	52		W	4	1015.3
23	Mo	18.8	28.4	0			ESE	28	15:48	27.2	68		S	11	1019.6	28.0	60		ESE	9	1018.4
24	Tu	19.1	26.1	0			E	26	14:56	23.9	68		S	4	1022.5	22.4	75		E	15	1020.1
25	We	18.4	28.4	0			ENE	19	17:09	23.7	78		S	2	1021.6	27.1	56		NE	6	1017.4
26	Th	15.2	29.5	0			ENE	30	15:20	22.8	78		S	7	1020.5	28.1	54		ENE	15	1017.9
27	Fr	16.6	25.2	0			SSW	31	12:57	23.3	72		S	13	1021.6	24.2	60		SSE	17	1019.8
28	Sa	16.9	28.8	0			SE	31	14:42	23.6	67		S	13	1020.6	21.9	95		NE	9	1017.5
29	Su	15.8	29.9	11.6			E	24	15:51	22.6	84		SSE	2	1019.6	27.5	58		E	7	1015.7
30	Mo	15.6		0			NE	20	16:38	23.4	80		SSE	4	1017.5	30.6	49		ENE	6	1013.4
31	Tu	18.2		0			E	28	15:57	25.4	79		SW	2	1016.1	30.7	49		S	6	1012.5
Statistics for March 2020																					
	Mean	17.4	28.8							24.0	75			7	1018.0	27.6	58			9	1015.0
	Lowest	11.3	22.3							21.6	60			Calm	1011.0	20.9	36			Calm	1007.9
	Highest	23.8	33.7	31.4			SW	44		27.7	88		S	22	1024.8	34.5	97		S	22	1021.1
	Total			49.2																	

Observations were drawn from Beaudesert Drumley Street (station 040983)

IDCJDW4141.202003 Prepared at 13:02 UTC on 21 Apr 2020

Beaudesert, Queensland
April 2020 Daily Weather Observations

Observations from a site in Drumley Street, about 1.5 km northwest of the town centre.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	We	15.1	30.9	0			ENE	26	14:42	24.8	79		W	2	1018.2	29.0	52		ENE	15	1014.7
2	Th	16.6		0			ESE	22	15:07	24.2	75		WSW	4	1016.9				E	13	1012.7
3	Fr	17.4		0			NNE	26	15:01	24.6	79		E	4	1012.7	31.1	51		NNE	9	1008.7
4	Sa	21.2	28.9	0			NW	33	10:38	26.3	72		NW	11	1010.4	25.7	75		N	13	1006.9
5	Su	15.4	29.4	0.2			ENE	24	17:06	22.6	63		SW	7	1015.4	28.5	26		S	7	1012.3
6	Mo	11.7	29.4	0.2			E	26	17:24	20.7	74		SW	2	1017.5	28.4	32		S	6	1013.7
7	Tu	15.1	27.9	0			SW	30	11:20	23.1	66		SW	11	1018.5	27.1	45		SSW	17	1015.0
8	We	18.5	26.8	0			SW	26	10:47	22.6	73		SSW	7	1019.4	24.4	67		ENE	7	1017.1
9	Th	16.4	28.4	0			ESE	31	14:22	22.0	78		SSW	7	1023.8	24.2	64		ESE	11	1021.2
10	Fr	17.3	25.5	2.0			NE	26	14:02	20.6	98		SW	7	1021.7	23.2	83		ENE	9	1016.8
11	Sa	17.6	31.6	0			WNW	37	12:47	24.4	77		NNW	7	1012.5	31.0	24		WSW	19	1006.9
12	Su		28.2	0			ENE	30	14:40				S	2	1013.1	26.2	44		ENE	15	1012.9
13	Mo	8.9	27.9	0			ENE	20	15:45	18.0	73		SSW	4	1021.7	26.8	35		N	7	1018.2
14	Tu	12.0	29.3	0			ENE	20	15:48	20.2	80		SSE	4	1025.0	28.5	40		ENE	7	1021.4
15	We	12.1	29.8	0			ENE	20	15:16	20.5	79		SW	2	1024.9	26.9	46		NNE	6	1020.1
16	Th	11.5	30.6	0			NNE	26	16:51	20.6	84			Calm	1020.6	30.4	39		NNW	4	1014.9
17	Fr	12.7	33.9	0			W	19	13:19	22.0	84			Calm	1015.8	33.5	34		NW	6	1009.4
18	Sa	17.7	25.9	0			W	26	12:42	21.8	83			Calm	1012.3	21.5	78			Calm	1010.8
19	Su	11.0	28.0	1.0			N	13	12:52	17.3	91			Calm	1013.5	27.4	37		WSW	6	1010.1
20	Mo	7.5	29.5	0			W	20	14:09				SW	4	1017.2	28.3	27		SW	9	1013.7
21	Tu	10.4	30.9	0			E	20	15:42	21.4	57			Calm	1019.5	29.5	34		N	11	1015.8
22	We	13.6	33.0	0			ENE	26	16:18	22.4	73		WSW	2	1019.0	31.2	30		S	4	1014.3
23	Th	11.7	29.8	0			NE	20	15:34	21.7	77			Calm	1021.8	28.0	46		NNE	9	1017.1
24	Fr	12.5	30.2	0			WSW	22	12:06	22.7	74			Calm	1019.6	29.4	46			Calm	1016.3
25	Sa	12.0	29.6	0			NE	26	13:43	20.3	77		SE	2	1022.6	28.1	41		NE	11	1019.3
26	Su	10.7	30.0	0			N	20	14:49	19.8	82		SSE	2	1021.2	29.7	34		NW	6	1016.0
27	Mo	12.4	29.0	0			ESE	20	17:03	20.6	82		SE	2	1020.6	26.5	54		ENE	9	1018.2
28	Tu	17.0	26.2	3.0			ESE	26	15:52	21.4	86		S	6	1022.7	23.3	76		S	11	1019.8
29	We	17.4	28.1	6.4			NE	22	13:49	22.1	85		SW	2	1020.2	26.3	54		ENE	11	1016.4
30	Th	12.6	30.7	0			NNE	30	16:01	20.1	90			Calm	1016.1	30.0	49		N	11	1008.6
Statistics for April 2020																					
Mean		14.0	29.3							21.7	78			3	1018.5	27.7	47			8	1014.6
Lowest		7.5	25.5							17.3	57			Calm	1010.4	21.5	24			Calm	1006.9
Highest		21.2	33.9	6.4			WNW	37		26.3	98		#	11	1025.0	33.5	83		WSW	19	1021.4
Total				12.8																	

Observations were drawn from Beaudesert Drumley Street (station 040983)