Rusaini (2013) *Suppression subtractive hybridization to investigate viruses in the lymphoid organ of Penaeus merguiensis and the gills of Cherax quadricarinatus.* PhD Thesis, James Cook University.

SUPPRESSION SUBTRACTIVE HYBRIDIZATION TO INVESTIGATE VIRUSES IN THE LYMPHOID ORGAN OF *Penaeus merguiensis* AND THE GILLS OF *Cherax quadricarinatus*

VOLUME 2: APPENDICES

Thesis submitted by

R U S A I N I

in August 2013

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN MICROBIOLOGY AND IMMUNOLOGY
SCHOOL OF VETERINARY AND BIOMEDICAL SCIENCES
JAMES COOK UNIVERSITY
TOWNSVILLE 4811
AUSTRALIA

APPENDICES

Appendix 1. Genes/molecules that may have immune function identified within the lymphoid organ of penaeid prawns.

Genes/molecules	Inducer	Species	Authors
Immune related factor and homeostatis			
Alpha2-macroglobulin	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
	WSSV	*P. vannamei*	(Rodríguez *et al.*, 2012)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Alpha2-macroglobulin 1 (A2M-1)	-	*P. chinensis*	(Ma *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Ma *et al.*, 2010)
	WSSV	*P. chinensis*	(Ma *et al.*, 2010)
Alpha2-macroglobulin 2 (A2M-2)	-	*P. chinensis*	(Ma *et al.*, 2010)
Clotting protein (CP)	YHV	*P. monodon*	(Bourchookarn *et al.*, 2008)
	CP-dsRNA	*P. japonicus*	(Maningas *et al.*, 2008a)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Copper homeostatis protein	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cyclophilin-5	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cyclophilin-18	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cyclophilin A	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Ferritin	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Haemocyanin	-	*P. chinensis*	(Zhang *et al.*, 2010)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Haemocyanin subunit Y	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Haem peroxidase	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Heat shock protein 1, beta isoform 1	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Heat shock protein-70	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Peroxiredoxin	Peptidoglycan (*Bifidobacterium thermophilum*)	*P. japonicus*	(Maningas *et al.*, 2008b)
Prophenoloxidase (proPO)	-	*P. vannamei*	(Yeh *et al.*, 2009a)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Prophenoloxidase I (proPOI)	-	*P. vannamei*	(Yeh *et al.*, 2009a)
Prophenoloxidase II (proPO2)	-	*P. vannamei*	(Yeh *et al.*, 2009a)
	-	*P. vannamei*	(Ai *et al.*, 2009)
ProPO activating factor III	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Transglutaminase (TGase)	-	*P. chinensis*	(Zhang *et al.*, 2010)
	-	*P. vannamei*	(Yeh *et al.*, 2009b)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)

Genes/molecules	Inducer	Species	Authors
Transglutaminase (TGase)	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
	YHV	*P. monodon*	(Bourchookarn *et al.*, 2008)
	TGase-dsRNA	*P. japonicus*	(Maningas *et al.*, 2008a)
Antimicrobial peptides (AMP)			
11.5 kDa antibacterial protein	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Anti-lipopolysaccharide factors (ALFs)	-	*P. monodon*	(Supungul *et al.*, 2004)
	-	*P. vannamei*	(O'Leary *et al.*, 2006; de la Vega *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008; Somboonwiwat *et al.*, 2008)
ALF6	-	*P. monodon*	(Ponprateep *et al.*, 2012)
Crustins	-	*P. monodon*	(Supungul *et al.*, 2004)
	-	*P. monodon*	(Soonthornchai *et al.*, 2010)
	V. nigripulchritudo	*P .japonicus*	(Fall *et al.*, 2010)
	Nucleotide-rich baker's yeast extract, Vertex IG20	*P .japonicus*	(Biswas *et al.*, 2012)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
Crustin 5	Heat-shock	*P. monodon*	(Vatanavicharn *et al.*, 2009)
C-type lysozyme	-	*P. monodon*	(Supungul *et al.*, 2010)
Lysozyme	*V. campbellii*	*P. vannamei*	(Burge *et al.*, 2007)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. nigripulchritudo	*P .japonicus*	(Fall *et al.*, 2010)
	Nucleotide-rich baker's yeast extract, Vertex IG20	*P .japonicus*	(Biswas *et al.*, 2012)
Lysozyme C	-	*P. stylirostris*	(Mai and Hu, 2009b)
	V. alginolyticus (heat-killed)	*P. stylirostris*	(Mai and Hu, 2009b)
Penaeidins	-	*P. monodon*	(Supungul *et al.*, 2004)
	-	*P. monodon*	(Soonthornchai *et al.*, 2010)
	V. nigripulchritudo	*P .japonicus*	(Fall *et al.*, 2010)
	Nucleotide-rich baker's yeast extract, Vertex IG20	*P .japonicus*	(Biswas *et al.*, 2012)
	WSSV	*P. vannamei*	(Rodríguez *et al.*, 2012)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
Penaeidin-5	-	*P. monodon*	(Hu *et al.*, 2006)
Penaeidin-2 precursor	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Penaeidin-3c precursor	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Techylectin-5B precursor	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)

Genes/molecules	Inducer	Species	Authors
Antioxidants and antitoxicities			
Cytosolic manganese superoxide dismutase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Glutathione peroxidase	-	*P. chinensis*	(Zhang *et al.*, 2010)
	-	*P. monodon*	(Liu *et al.*, 2010b)
NADPH oxidase	-	*P. japonicus*	(Inada *et al.*, 2012)
Nitric oxide	*V. penaeicida*	*P. japonicus*	(Inada *et al.*, 2010)
Selenium-dependent glutathione peroxidase	-	*P. monodon*	(Liu *et al.*, 2010b)
Selenophosphate synthetase (SPS)	-	*P. monodon*	(Yeh *et al.*, 2012)
Thioredoxin 1	-	*P. chinensis*	(Zhang *et al.*, 2010)
Thioredoxin peroxidase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteinases and inhibitors			
Argonaute (Ago)	*V. harveyi*	*P. monodon*	(Unajak *et al.*, 2006)
	YHV	*P. monodon*	(Unajak *et al.*, 2006)
	WSSV	*P. monodon*	(Unajak *et al.*, 2006)
Cathepsin A	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cathepsin B	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cathepsin C	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cathepsin D	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cathepsin L	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	-	*P. vannamei*	(O'Leary *et al.*, 2006)
	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
C-type lectin	-	*P. monodon*	(Soonthornchai *et al.*, 2010)
	-	*P. vannamei*	(Junkunlo *et al.*, 2012)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Cysteine aspartate protease-2 (caspase-2)	-	*P. vannamei*	(Chang *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cytosolic non-specific dipeptidase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Double whey acidic protein (WAP) domain (DWD)	WSSV	*P. monodon*	(Suthianthong *et al.*, 2011)
Inhibitor of apoptosis protein 1 (IAP1)	-	*P. vannamei*	(Leu *et al.*, 2012)
Inhibitor of apoptosis protein 2 (IAP2)	-	*P. vannamei*	(Leu *et al.*, 2012)
Kazal type 2	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Leucine-rich repeat (LRR)	YHV	*P. monodon*	(Sriphaijit and Senapin, 2007)

Genes/molecules	Inducer	Species	Authors
Leucine-rich repeat (LRR)	WSSV	*P. monodon*	(Sriphaijit and Senapin, 2007)
Melanization inhibition protein	-	*P. monodon*	(Angthong *et al.*, 2010)
Protein inhibitor-signal crayfish	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Protein kinase c inhibitor	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Saposin	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Serine protease	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Serine protease-14D	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Serine protease inhibitor (serpin)	-	*P. chinensis*	(Liu *et al.*, 2009b)
Serpin 6	-	*P. monodon*	(Homvises *et al.*, 2010)
Serpin 8	-	*P. monodon*	(Somnuk *et al.*, 2012)
Survivin	-	*P. vannamei*	(Leu *et al.*, 2012)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
	Leg-amputated	*P. monodon*	(Suthianthong *et al.*, 2011)
Tudor staphylococcal nuclease (TSN)	-	*P. monodon*	(Phetrungnapha *et al.*, 2011)
Whey acidic protein (WAP)	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Synthesis, processing, regulation and apoptotic related proteins			
26S proteasome regulatory subunit	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
*A*poptosis-*l*inked-gene-2-*i*nteracting protein *X* (*Alix)*	-	*P. monodon*	(Sangsuriya *et al.*, 2007)
Calreticulin	-	*P. monodon*	(Visudtiphole *et al.*, 2010)
Calreticulin precursor	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Carboxypeptidase B	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Caspase	pH-stress	*P. chinensis*	(Wang *et al.*, 2011)
Chaperonin	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Chaperonin containing T-complex	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Chaperonin containing TCP-1β	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Croquemort scavenging receptor (SCRBQ)	WSSV	*P. japonicus*	(Mekata *et al.*, 2011)
Defender against cell death	-	*P. vannamei*	(O'Leary *et al.*, 2006)
Drosha	-	*P. japonicus*	(Huang *et al.*, 2012)
	WSSV	*P. japonicus*	(Huang *et al.*, 2012)
	Drosha-siRNA	*P. japonicus*	(Huang *et al.*, 2012)
Elongation factor-1α	-	*P. chinensis*	(Zhang *et al.*, 2010)
	-	*P. monodon*	(Pongsomboon *et al.*, 2008)

Genes/molecules	Inducer	Species	Authors
Elongation factor-1α	-	*P. monodon*	(Soonthornchai *et al.*, 2010)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Elongation factor 2	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Nucleosome remodelling factor e 38kD, isoformA	-	*P. chinensis*	(Zhang *et al.*, 2010)
Protein disulfide isomerase	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Proteasome 25 kDa subunit	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteasome 26S ATPase subunit 4 isoform 1	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteasome alpha 4 subunit	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteasome subunit alpha type 5	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteasome subunit beta type 6 precursor	-	*P. chinensis*	(Zhang *et al.*, 2010)
Proteasome delta	-	*P. chinensis*	(Zhang *et al.*, 2010)
QM protein	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
snRNA-activating protein complex subunit	-	*P. chinensis*	(Zhang *et al.*, 2010)
Translation initiation factor 3 47 kDa subunit	-	*P. chinensis*	(Zhang *et al.*, 2010)
Translationally controlled tumor protein (TCTP)	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Tumor necrosis factor (TNF)	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	-	*P. japonicus*	(Mekata *et al.*, 2010)
	V. nigripulchritudo	*P .japonicus*	(Fall *et al.*, 2010)
	Lipopolysaccharide (LPS)	*P. japonicus*	(Mekata *et al.*, 2010)
	Peptidoglycan (PG)	*P. japonicus*	(Mekata *et al.*, 2010)
	Poly I:C (polyinosinic-polycytidylic acid)	*P. japonicus*	(Mekata *et al.*, 2010)
Tumor necrosis factor induced protein	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
T-complex Chaperonin 5, isoform A	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Ubiquitin c (Ubc)	-	*P. monodon*	(Sangsuriya *et al.*, 2010)
Voltage-dependent anion channel (VDAC)	-	*P .japonicus*	(Han-Ching Wang *et al.*, 2010)
	VDAC-dsRNA	*P .japonicus*	(Han-Ching Wang *et al.*, 2010)
Replication, transcription, translation and repair related proteins			
Tat-binding protein-1	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Rad23	-	*P. japonicus*	(Wang *et al.*, 2011)
Really interesting new gene (RING)-box protein	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)

Genes/molecules	Inducer	Species	Authors
Really interesting new gene (RING)-box protein	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Cell adhesion molecules			
Down syndrome cell adhesion molecule (Dscam)	-	*P. monodon*	(Chou *et al.*, 2011)
	-	*P. vannamei*	(Chou *et al.*, 2009)
Peroxinectin	-	*P. vannamei*	(Burge *et al.*, 2009)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
Tetraspanin-3	-	*P. chinensis*	(Gui *et al.*, 2012)
Signal transduction factors			
14-3-3 like protein	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
14-3-3A like protein	-	*P. monodon*	(Kaeodee *et al.*, 2011)
Astakine	-	*P. monodon*	(Hsiao and Song, 2010)
	WSSV	*P. monodon* (LOCC)	(Jose *et al.*, 2012)
Clip domain serine proteinases (clip-SPs)	-	*P. monodon*	(Amparyup *et al.*, 2010)
Cyclic AMP-regulated protein like protein	-	*P. chinensis*	(Zhang *et al.*, 2010)
Cytokine	-	*P. vannamei*	(O'Leary *et al.*, 2006)
Dorsal	-	*P. chinensis*	(Li *et al.*, 2010a)
	V. anguillarum	*P. chinensis*	(Li *et al.*, 2010a)
	WSSV	*P. chinensis*	(Li *et al.*, 2010a)
Guanylyl cyclase (GC)	-	*P. monodon*	(Sangsuriya *et al.*, 2010)
Interferon-c-inducible lysosomal thiol reductase enzymes (GILT)	LPS	*P. monodon*	(Kongton *et al.*, 2011)
	WSSV	*P. monodon*	(Kongton *et al.*, 2011)
Interleukin-1 receptor associated kinase-4 (IRAK-4)	-	*P. monodon*	(Watthanasurorot *et al.*, 2012)
Receptor for activated protein kinase C1 (RACK1)	-	*P. monodon*	(Tonganunt *et al.*, 2009)
	WSSV	*P. monodon*	(Tonganunt *et al.*, 2009)
Receptor kinase CG6033-PA, isoform A	-	*P. chinensis*	(Zhang *et al.*, 2010)
GDI-1 GDP dissociation inhibitor	-	*P. chinensis*	(Zhang *et al.*, 2010)
Immune deficiency (*imd*) gene	-	*P. vannamei*	(O'Leary *et al.*, 2006)
Intracellular fatty acid binding protein	-	*P. chinensis*	(Zhang *et al.*, 2010)
Protein kinase c protein 2, isoform d	*V. anguillarum*	*P. chinensis*	(Zhang *et al.*, 2010)
RAS protein	-	*P. chinensis*	(Zhang *et al.*, 2010)
Relish	-	*P. chinensis*	(Li *et al.*, 2009a)
	Micrococcus lysodeikticus	*P. chinensis*	(Li *et al.*, 2009a)
	V. anguillarum (heat-inactivated)	*P. chinensis*	(Li *et al.*, 2009a)
	dsRNA-Relish	*P. chinensis*	(Li *et al.*, 2009a)

Genes/molecules	Inducer	Species	Authors
Rho guanine dissociation factor isoform 1	-	*P. chinensis*	(Zhang *et al.*, 2010)
Signal transducer and activators of transcription (STAT)	Peptidoglycan (*staphylococcus aureus*)	*P. japonicus*	(Okugawa *et al.*, 2012)
	Polycytidylic acid	*P. japonicus*	(Okugawa *et al.*, 2012)
	Spawning stress	*P. monodon*	(Lin *et al.*, 2012)
Suppressors of cytokine signaling (SOCS)	Peptidoglycan (*staphylococcus aureus*)	*P. japonicus*	(Okugawa *et al.*, 2012)
	Polycytidylic acid	*P. japonicus*	(Okugawa *et al.*, 2012)
Toll-like receptor (TLR)	-	*P. monodon*	(Assavalapsakul and Panyim, 2012)
	V. anguillarum	*P. chinensis*	(Yang *et al.*, 2008)
	V. nigripulchritudo	*P .japonicus*	(Fall *et al.*, 2010)
	WSSV	*P. chinensis*	(Yang *et al.*, 2008)
Energy and metabolisms			
Arginine kinase	-	*P. chinensis*	(Zhang *et al.*, 2010)
ATP synthase beta subunit	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
ATP synthase F0 sub 6	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Cytochrome *c* oxidase sub I	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Cytochrome *c* oxidase sub II	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
Esterase D/formylglutathione hydrolase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Farnesoic acid O-methyltransferase	-	*P. chinensis*	(Zhang *et al.*, 2010)
H^+ transporting ATP synthase O sub	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Malate dehydrogenase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Nad dependent epimerase/dehydratase	-	*P. chinensis*	(Zhang *et al.*, 2010)
NADH dehydrogenase sub 1	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Phosphopyruvate hydratase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Phosphogluconate dehydrogenas	-	*P. chinensis*	(Zhang *et al.*, 2010)
S-adenosylhomocysteine hydrolase, putative	-	*P. chinensis*	(Zhang *et al.*, 2010)
Spermatogonial stem-cell renewal factor	-	*P. chinensis*	(Zhang *et al.*, 2010)
Transketolase	-	*P. chinensis*	(Zhang *et al.*, 2010)
Triosephosphate isomerase	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Vacuolar ATP synthase subunit B K form	-	*P. chinensis*	(Zhang *et al.*, 2010)

Genes/molecules	Inducer	Species	Authors
Active transporter			
Plasmolipin 1 (PLP1)	-	*P. monodon*	(Vatanavicharn *et al.*, 2012)
Plasmolipin 2 (PLP2)	-	*P. monodon*	(Vatanavicharn *et al.*, 2012)
Structural and cytoskeletal related proteins			
Actin	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Actin 1	-	*P. chinensis*	(Zhang *et al.*, 2010)
Actin 2	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Alpha tubulin	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Alpha-III tubulin	-	*P. chinensis*	(Zhang *et al.*, 2010)
Beta-actin	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Beta-thymosin	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Cytoplasmic actin Cy II	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
Cytoplasmic type actin 3	-	*P. chinensis*	(Zhang *et al.*, 2010)
Beta tubulin	*V. harveyi*	*P. monodon*	(Chaikeeratisak *et al.*, 2012)
	V. anguillarum	*P. chinensis*	(Zhang *et al.*, 2010)
Myosin II essential light chain	-	*P. chinensis*	(Zhang *et al.*, 2010)
Profilin	-	*P. chinensis*	(Zhang *et al.*, 2010)
	V. harveyi	*P. monodon*	(Pongsomboon *et al.*, 2008)
	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Thymosin-1	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Thymosin beta-9	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Thymosin beta-11	Oxytetracyclin	*P. monodon*	(Fagutao *et al.*, 2009)
	Oxolinic acid	*P. monodon*	(Fagutao *et al.*, 2009)
Extracellular matrix components			
Laminin receptor (Lamr)	-	*P. monodon*	(Senapin *et al.*, 2010)
	-	*P. vannamei*	(Senapin *et al.*, 2010)
Peritrophin	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Thrombospondin	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Pigments			
Crustacyanin	-	*P. vannamei*	(O'Leary *et al.*, 2006)
Ribosomal proteins			
40S ribosomal protein S12	-	*P. chinensis*	(Zhang *et al.*, 2010)
Ribosomal protein L21	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Ribosomal protein L26 (Phagocytosis activating protein)	-	*P. vannamei*	(Khimmakthong *et al.*, 2011)
Ribosomal protein p1	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)

Genes/molecules	Inducer	Species	Authors
Ribosomal protein S10	-	*P. monodon*	(Pongsomboon *et al.*, 2008)
Ribosomal protein S17	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Ribosomal protein S27	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)
Miscellaneous			
Macrophage migration inhibitory factor	-	*P. vannamei*	(O'Leary *et al.*, 2006)
Cytidylate kinase	*V. harveyi*	*P. monodon*	(Pongsomboon *et al.*, 2008)

Appendix 2. Differentially expressed genes of penaeid prawns from various tissues SSH cDNA libraries.

Differentially expressed genes	Challenges	Tissues	Species	References
Up-regulated Genes				
Immune-related factors and homeostatis				
1,3-β-D-glucan-binding protein	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
70 kD heat shock-like protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Adenosin deaminase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Alpha2-macroglobulin	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Alpha-2-macroglobulin isoform 3	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Alpha-aspartyl dipeptidase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Amyloid precursor protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Annexin II	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
ARP-like protein	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Cell-surface antigen	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Chitinase	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	V. harveyii	PL	*P. indicus*	(Nayak *et al.*, 2011)
Clotable protein	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Coagulation factor Xa	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Coagulation factor XIII, A1 subunit	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Complement factor B precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Corticol granule protein with LDL-receptor	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Cryptdin-related protein 4C	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Cyclophylin-5	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Cyclophylin-5	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Death domain protein	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Dipeptidyl peptidase III	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Ecdysteroid regulated protein 16 kDa	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Epoxide hydrolase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ferritin	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Ferritin peptide	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Ferritin subunit I	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Ferritin subunit II	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Haemocyanin	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a; de la Vega *et al.*, 2007b)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
Haemocyanin subunit L	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Heat shock protein 70	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Heat shock protein 90	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Heat shock protein gp96	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)

Differentially expressed genes	Challenges	Tissues	Species	References
Hemolectin	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Heparan sulphate	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Hyaluronoglucosamidase	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Interferon receptor 1-bound protein 4	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Interferon α-I-B	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Laccase	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Leuchine-rich repeat LGI family	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Lipase precursor	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Monocyte/neutrophil elastase inhibitor	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Ninjurin I	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
NUCB1 CG32190-PA	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Phospholipid-hydroperoxide glutathione peroxide	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Prostaglandin E synthase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Procollagen-proline, 2-oxoglutarate 4-dioxygenase (proteindisulfide isomerase-associated 1)	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Protein-disulfide isomerase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Prothymosin alpha	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Sarco/endoplasmic reticulum Ca^{2+}-ATPase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Stress-70 protein, mitochondrial precursor (75 kDa glucose-regulated protein)	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Synthenin-like protein (TE8)	WSSV	H	*P. monodon*	(Bangrak *et al.*, 2002)
TAR-binding protein	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
T-complex protein 11	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	V. penaeicida	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)

Differentially expressed genes	Challenges	Tissues	Species	References
TM2 domain containing 1	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Transglutaminase (TGase)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. penaeicida	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Tyrosine-rich heat shock protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Zinc proteinase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Zinc proteinase Mpc1	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Zinc proteinase Mpc2	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Antimicrobial peptides (AMP)				
Anti-lipopolysaccharide factor (ALF)	dsRNA	H	*P. vannamei*	(Robalino *et al.*, 2007a)
	FAV	G, H	*P. vannamei*	(Robalino *et al.*, 2007a)
Anti-lipopolysaccharide factor 6	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Antimicrobial peptides	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Crustin voucher PvHm116	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Crustin-1	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Crustin-4	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
C-type lectin	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)

Differentially expressed genes	Challenges	Tissues	Species	References
C-type lectin	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
C-type lectin-like domain-containing protein PtLP	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
HEPATIC lectin	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Lysozyme	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a; Zhao *et al.*, 2007)
	V. penaeicida	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Mitochondrial C type lectin containingdomain protein	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Penaeidin	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Penaeidin 2	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Penaeidin 3	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Penaeidin 3	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Tachylectin-5A	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Antioxidants and antitoxicities				
2-Cys thioredoxin peroxidase	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Alcohol dehydrogenase	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Catalase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
Cytosolic manganese superoxide dismutase (MnSOD)	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
DNA gyrase A subunit	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Glutathione peroxidase	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Manganese superoxide dismutase (MnSOD)	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Monomeric sarcosine oxidase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Selenoprotein M precursor	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Thioredoxin reductase	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
	FAV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Zinc-binding dehydrogenases	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Proteases and inhibitors				
Aminopeptidase	FAV	G, H	*P. vannamei*	(Robalino *et al.*, 2007a)
Basic proteinase inhibitor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Cathepsin A serine carboxypeptidase	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Cathepsin B	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Cathepsin B cysteine protease	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Cathepsin L	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Cathepsin L cysteine protease	dsRNA	G, H	*P. vannamei*	(Robalino *et al.*, 2007a)
	WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Inhibitor of Bruton agammaglobulinemai tyrosine kinase	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Kunitz-type proteinase inhibitor	PEB	H	*P. japonicus*	(He *et al.*, 2004)
Kazal-type proteinase inhibitor 2	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Kazal-type proteinase inhibitor 5	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Lysosomal carboxypeptidase	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Matrix metalloproteinase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Nuclease diphosphate kinase B	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
PfP1 family	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Preamylase	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Protein phosphatase 2c gamma				
Secretory leucocyte protease inhibitor	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Serine carboxypeptidase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Serine protease inhibitors	dsRNA, FAV, WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Similar to protease inhibitor WSSV-infected	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Suppressor of profilin 2	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Transposase IS630	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Trypsin	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Zinc carboxypeptidase	dsRNA, WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Zinc metalloproteinase nas-10	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Haematopoiesis-differentiation				
CBF1 interacting corepressor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
dMi protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Granulocyte-macrophage coloni-stimulating factor precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Helicase DOMINO A	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Innexin	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Laminin gamma-1	WSSV	H	*P. japonicus*	(He *et al.*, 2005)

Differentially expressed genes	Challenges	Tissues	Species	References
Lsc protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Macrophage colony-stimulating factor 1 receptor precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Mi protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
	V. penaeicida	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Ra1-A exchange factor Ra1GPS2	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Stress-associated endoplasmic reticulum protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Transforming growth factor (TGF) β precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
TGF beta inducible nuclear protein 1	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Synthesis, processing, regulation and apoptotic-related proteins				
26S proteasome (prosome, macropain) non-ATPase subunit 13	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
26S proteasome (prosome, macropain) ATPase subunit 5 isoform CRA_a	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
26S proteasome ATPase subunit 4 CG5289-PA	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
26S proteasome non-ATPase regulatory subunit	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
26S proteasome non-ATPase subunit 12	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
26S proteasome regulatory subunit rpn2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
26S proteasome regulatory complex ATPase RPT4	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Abrupt	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Activated protein kinase C receptor	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Activator of S phase kinase	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)

Differentially expressed genes	Challenges	Tissues	Species	References
Acyl-CoA synthase	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Allatotropin neuropeptide precursor	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Anaphase-promoting complex subunit 4	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Apoptosis 1 inhibitor	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Ataxin1 ubiquitin-like interacting protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Ataxin 2-binding protein 1 (A2BP1)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Authophagy protein 9	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
C-1-tetrahydrofolate synthase, cytoplasmic (C1-THF synthase)	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Calcitonin gene-related peptide-receptor component protein isoform a	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Calreticulin	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Calreticulin precursor (CRP55) (Calregulin)	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Carboxypeptidase B	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Caspase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Caspase 3	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
CCR4-NOT transcription complex, subunit 10	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
CDK5 regulatory subunit associated protein 1-like 1	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Cellular apoptosis susceptible gene	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Cement precursor protein 3B variant 2	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Cement precursor protein 3B variant 3	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Chaperonin containing T-complex polypeptide 1 (TCP1)	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Chaperonin containing TCP1(CCT)	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)

Differentially expressed genes	Challenges	Tissues	Species	References
Chaperonin containing TCP1, subunit 3 (gamma)	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Chitin binding domain RE24790p	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Complete mitochondrial genome (16S ribosomal)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Cyclin A	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Cyclin B3, CG5814-PA	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
DEAD (Asp-Glu-Ala-Asp) box polypeptide 5	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
DEAD (Asp-Glu-Ala-Asp) box polypeptide 54 iso-3	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
DEAD box ATP-dependent RNA helicase	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
DNA-directed RNA polymerase, I, II, and III subunit RPABC2	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Dolichyl-diphosphooligosaccharide-protein-glycotransferase	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Elongation factor-1α	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Elongation factor-1δ (eEF1delta)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Elongation factor-1 γ	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Elongation factor 2	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
Elongation factor 2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
EF hand-containing protein 1, isoform CRA-a	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Endoplasmin	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Eukaryotic translation initiation factor	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Eukaryotic translation initiation factor 2, subunit 2	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Eukaryotic translation initiation factor 2, subunit 2 beta	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Eukaryotic translation initiation factor 2B, subunit 5 epsilon,isoform 3	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Eukaryotic translation initiation factor 3, subunit 4	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Eukaryotic translation initiation factor 3, subunit B	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Eukaryotic initiation factor 3e (eIF3e)	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Eukaryotic initiation factor 4A	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
F-box protein	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Fizzy-related protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Gelsolin, cytoplasmic (actin-depolymerizing factor, ADF)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Guanylate kinase-1	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Guanyl-nucleotide exchange factor:Schizo CG32434_PB, isoform B	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Histidine triad nucleotide-binding protein 2	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Histone H1	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Histone H2A variant Z	FAV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Histone H3.3B	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Histone H4	*FAV*	H	*P. vannamei*	(Robalino *et al.*, 2007a)
HIT protein	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
HLA-B-associated transcript 3	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Malate dehydrogenase 1, isoform CRA_d	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)

Differentially expressed genes	Challenges	Tissues	Species	References
Meiotic recombination protein DMC1/LIM15 homolog isoform 1	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Metabolism haloacid dehalogenase-like hydrolase:AGAP003372-PA	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Methylenetetrahydrofolate dehydrogenase	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Mitochondrial 16S rRNA	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Mitochondrial precursor protein import receptor	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Mitochondrial protein NADH dehydrogenase subunit 2	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Nucleolar RNA helicase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Nucleolin	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Oncoprotein nm23	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Peanut gene product	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Peptidylprolyl isomerase D	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Phosphoglucomutase	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Programmed cell death 6 interacting protein	*V. penaeicida*	H	*P. japonicus*	(de Lorgeril *et al.*, 2005)
Programmed cell death-involved protein	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Proteasome alpha 4 subunit	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Proteasome subunit alpha type 2 (proteasome component C3, macropain subunit C3)	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Proteasome subunit alpha type 5	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
QM protein	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
RAD1 protein	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Radixin	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)

Differentially expressed genes	Challenges	Tissues	Species	References
Receptor for activated protein kinase C (RACK) 1 isoform 1	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Receptor for activated protein kinase C (RACK) 1 isoform 2	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Ribonuclease P 40kDa subunit isoform 3	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
RING finger protein 2, CG15814-PA, isoform A	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
S-phase kinase-protein 1A	*V. harveyii*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Selenophosphate synthetase (selenium donor protein)	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Signal peptidase complex 18 kD (SPC18)	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Signal peptidase complex subunit 2	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Signal sequence receptor	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Small optic lobes CG1391-PB, isoform B (calpain)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Translation elongation factor eEF-1	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Translation elongation factor EF-1a	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Translation initiation factor 3 subunit 6	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Translation initiation factor IF-3	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Translation initiation factor IIB-1	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Translation initiation factor eIF4A	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Translationally controlled tumour protein (TCTP)	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Transposase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Transposase IS630	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Tu translation elongation factor,mitochondrial (tufm)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Ubiquitin	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Ubiquitin-like 1 activating enzyme E1B (SUMO-1 activatingenzyme subunit 2)	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Ubiquitin specific protease 30	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Ubiquitin/ribosomal 27a	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Ubiquitin/ribosomal L40 fusion protein	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Vitronectin precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Replication, transcription, translation and repair related factors				
ATP-dependent chromatin assembly factor	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
ATP-dependent RNA helicase	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Basic leucine zipper and W2 domain-containing protein 2	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Brahma associated protein 60 kDa, chromatin remodelling	*FAV*	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Bucentaur: endonuclease/exonuclease/phophatase family	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Centromere/kinetochore protein zw10 homolog	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Check point kinase	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
CWF19-like 2, cell cycle control	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
DNA gyrase subunit B	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
DNA replication licensing factor	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
dsDNA-binding, chromatin organization, transcriptional regulation	*FAV*	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Gastrula zinc finger protein	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
General transcription factor IIH subunit 3	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Helicase, lymphoid-specific isoform 2	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Helicase/SNF2 family	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Heterogeneous nuclear ribonucleoprotein	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Heterogeneous nuclear ribonucleoprotein L	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
High mobility group 20A, isoform CRA-b	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
KIN, antigenic determinant of recA protein homolog	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Mcm-3 prov protein (minichromosome maintanance protein)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Muskelin 1	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
NSFL1 cofactor p47	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Nop56CG13849-PA, isoform A (nucleolar KKE/D repeat protein; DmNOP56)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
PolyA binding protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Proliferating cell nuclear antigen	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Replication factor C/activator 1 subunit	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Rhombotin-like transcription factor	WSSV/32°C	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Ribosomal RNA methyltransferase	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
RNA polymerase	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
RNA polymerase I associated factor 53 isoform 1	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
RNA polymerase II ctd phosphatase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Similar to cAMP responsive element binding protein-like 2, transcriptional regulation	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
SMAD transcription factor	WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Small nuclear ribonucleoprotein D2 polypeptide 16.5 kDa, isoform CRA_b	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Small nuclear ribonucleoprotein E (snRNP-E)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
SPARC	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Splicing factor, arginine/serine-rich 7	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
ssRNA/DNA binding protein, chromatin regulation	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Thyroid hormone receptor-associated protein TRAP240	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Transcription factor AP-1 precursor	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Transcription factor E3	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Transcription factor pdm2	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Transcription initiation factor TFIID subunit 12	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
U2 small nuclear ribonucleoprotein auxiliary	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Zinc finger protein	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Zinc finger protein 146	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Zinc finger protein 84 (HPF2) isoform 1	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Reverse transcriptases/retrotransposons				
Endonuclease-reverse transcriptase	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Gag (I factor)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Pol-like protein (*MosquI-Aa2* non-LTR retrotransposon)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Pol-like protein (non-LTR retrotransposon from *D. melanogaster*)	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Pol-like protein (non-LTR retrotransposon from *D. melanogaster*)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Polymerase polyprotein (Gypsy type retrotransposon)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Protease, reverse transcriptase, ribonuclease H, integrase (osvaldo-like retrotransposon)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Putative ORF non-LTR retrotransposon	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Putative reverse transcriptase (Bilbo-like non-LTR)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Reverse transcriptase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Reverse transcriptase (Jockey type retrotransposon)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Reverse transcriptase (R2Bm non-LTR retrotransposon)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Reverse transcriptase like (non-LTR retrotransposon)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Reverse transcriptase-like	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
RTE-like non-LTR retrotransposon	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
RTE-like non-LTR retrotransposon	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Cell adhesion molecules				
Deleted in malignant brain tumors 1	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Immunoglobulin domain	FAV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Integrin α	dsRNA	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Integrin β	dsRNA	H	*P. vannamei*	(Robalino *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Integrin β-1	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Integrin β-1 precursor	PEB	H	*P. japonicus*	(He *et al.*, 2004)
Integrin β-4 protein binding	PEB	H	*P. japonicus*	(He *et al.*, 2004)
Interleukin enhancer binding factor 2	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
MHC class I RT.Aa alpha chain (Rt1.aa)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Receptor type tyrosine phosphatise beta	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
RNA binding motif protein 4	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
RNA binding protein 5	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Transmembrane 4 superfamily member 8 isoform 1/ Tetraspanin 3	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Tetraspanin	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
	FAV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Tetraspanin 3, isoform CRA-a	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Tetraspanin 96F CG6120-PA	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Tetraspanin D107	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Tetraspanin, cell surface glycoprotein	FAV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Unc-112-related, pleckstrin homology domain	*WSSV*	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Signal transduction factors				
14-3-3 zeta protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Acyl-CoA-binding protein	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Amyloid beta (A4) precursorprotein-binding (APBB2)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Arginine methyltransferase	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Armadillo repeat	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)

Differentially expressed genes	**Challenges**	**Tissues**	**Species**	**References**
CAP, adenylate cyclase-associate d protein(yeast)(CAP2)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Casein kinase 2	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Casein kinase 2, alpha subunit	WSSV, FAV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
CD53 antigen	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
cGMP-dependent protein kinase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Coatomer delta subunit	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
COP9 signalosome complex subunit I	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
	FAV, WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
CRK protein	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Cyclophilin A	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Cyclophilin-like protein	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Cyclophylin-5 precursor	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Fatty acid binding protein	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Ficolin	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Growth factor receptor bound protein 2	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
GTP-binding protein	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
I κB Kinase	WSSV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Inositol 1,4,5-triphosphate 3-kinase	FAV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Kelch domain containing 3	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
N-Myristoylation	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Ovarian lipoprotein receptor	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Peptidylprolyl isomerase A	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)

Differentially expressed genes	Challenges	Tissues	Species	References
Phospholipase C gamma	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Platelet derived growth factor-like	*FAV*	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Protein kinase C phosphorylase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Protein kinase raf	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Protein phosphatase 1 catalytic subunit gamma	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Putative regulator of MAPK pathway	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Rab11	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Rac GTPase-activating protein 1, isoform CRA-a	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ran-binding protein	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Ras oncogene family member RAP1B	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Ras small monomeric GTPase Rab6	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Ras-like GTP-binding protein Rho	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Ras-related nuclear protein	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Ras-related nuclear protein RAN	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Ras-related protein Rab-6A	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
RhoGap protein	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
RSR 1 protein (GTPase)	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Serine/threonine checkpoint kinase 1 (Chk1),	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Serine/threonine protein kinase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Serine/threonine protein kinase checkpoint	FAV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine/threonine protein kinase Misshapen	FAV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine/threonine protein kinase TAO2	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Serine/threonine protein phosphatise PP1	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Tetratricopeptide repeat domain 3	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
TGF-β receptor interacting protein 1	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Trio protein, spectrin repeat, nucleotide exchange factor, serine/threonine kinase	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
WD40 domain	*FAV*	H, Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Energy and metabolism				
2-amino-3-ketobutyrate coenzyme a ligase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Arginine kinase	*V. harveyii*	PL	*P. indicus*	(Nayak *et al.*, 2011)
ADP-ATP translocator	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Alcohol dehydrogenase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Amidase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Arginine kinase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
ATP binding protein associated with cell differentiation	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
ATP lipid-binding protein like protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
ATP synthase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
ATP synthase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
ATP synthase, CG11154-PA isoform A	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
ATP synthase beta subunit	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
ATP synthase delta chain	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
ATP synthase F0 subunit 6	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
ATP synthase g chain	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
ATP synthase oligomycin sensitivity conferral protein	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
ATPase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
ATPase subunit 6	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Carbamoyl-phosphate synthetase 2, aspartate transcarbamylase, and dihydroorotase	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Carbonyl reductase	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Carboxypeptidase B	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Chitin deacetylase-like 9, CG15918-PA	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Citrate synthase	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Cytochrome *b*	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Cytochrome *b5*	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Cytochrome Bc1 complex	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Cytochrome *c*	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Cytochrome *c*-1	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Cytochrome *c* oxidase	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Cytochrome c oxidase polypeptide IV	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Cytochrome *c* oxidase subunit 6a polypetide 1	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Cytochrome *c* oxidase subunit I	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Cytochrome *c* oxidase subunit I	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Cytochrome *c* oxidase subunit I	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Cytochrome *c* oxidase subunit II	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Cytochrome *c* oxidase subunit III	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
Cytochrome *c* oxidase subunit III	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Delta-aminolevulinate dehydratase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Dihydrolipoamide acetyltransferase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Dihydrolipoamide dehydropgenase precursor	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
F1-ATP synthase beta subunit	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
F1F0 ATP synthase subunit G	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
F1F0 ATP synthase subunit G	*V. harveyii*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Farnesoic acid O-methyltransferase	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Fatty acid elongation protein 3	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Glycosyl-phosphatidylinositol-linked carbonic anhydrase	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
H^+-transporting ATP synthase protein	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
Histidyl-tRNA synthetase	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Intracellular fatty acid binding protein	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Isocitrate dehydrogenase 2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Leucyl aminopeptidase	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Mitochondrion	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Mitochondrial ATP synthase e chain	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Na^+-K^+-ATPase α- subunit	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
	V. penaeicida	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
NADH dehydrogenase	PEB	H	*P. japonicus*	(He *et al.*, 2004)
	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
NADH dehydrogenase subunit 1	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)
	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
NADH dehydrogenase subunit 1	*V. harveyii*	PL	*P. indicus*	(Nayak *et al.*, 2011)
NADH dehydrogenase subunit 2	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
	V. harveyii	PL	*P. indicus*	(Nayak *et al.*, 2011)
NADH dehydrogenase subunit 4	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	V. harveyii	PL	*P. indicus*	(Nayak *et al.*, 2011)
NADH dehydrogenase subunit 5	*V. harveyii*	PL	*P. indicus*	(Nayak *et al.*, 2011)
NADH dehydrogenase subunit 6	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
NADH ubiquinone dehydrogenase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Neutral alpha-glucosidase AB precursor (Glucosidase II subunit alpha)	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Phosphoglycerate kinase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Pyruvate kinase	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Short chain dehydrogenase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Succinate-CoA ligase, alpha subunit	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Transaldolase	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Ubiquinol-cytochrome *c* reductase	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Ubiquinol-cytochrome *c* reductase binding protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
	Osmotic stress	G	*P. monodon*	(Gonçalves-Soares *et al.*, 2012)
V-ATPase subunit A	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Xylose isomerise	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Active transporters				
ADP-ribosylation factor related family member (arf-3)	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
ATPase, H+ transporting, lysosomal accessory protein2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
ATP/ADP translocase	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Calcium-dependent chloride channel-1	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Calsium ATPase	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Carbonic anhydrase I	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
CG10527-like methyltransferase	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Coatomer protein	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Ecxdysteroid regulated 16kDa	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Ferric reductase-like protein	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Glutathione S-transferase	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Glycosyltransferase	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Intracellular fatty acid binding protein	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Karyopherin (importin) alpha 4	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Kinesin heavy chain	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Kinesin heavy chain	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Kinesin-like protein 2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Lysine rich bipartite NLS	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Membrane-associated protein gex-3	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Niemann-Pick disease type C2	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
NTF2-related export protein	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Sec23 protein	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Signal sequence receptor	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Sodium dependent phosphate transporter	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Sodium glutamate symporter	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Sterol carrier protein	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Stored-operated calcium entry	WSSV	Hp	*P. indicus*	(James *et al.*, 2010)
Synaptosome-associated protein of 25 kDa	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Transmembrane protein	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Structural and cytoskeletal related molecules				
Alpha actin	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Actin	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Actin 1	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Actin 2	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Actin D	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Actin T2	WSSV/33°C	Cep	*P. Vannamei*	(Reyes *et al.*, 2007)
Actin, alpha, cardiac muscle	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Actin-depolymerizing factor 1	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Adducin-like protein R1	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Allergen Pen m2	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Allergen Pen m2	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Alpha-1-tubulin	*WSSV*	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Alpha-4-tubulin	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Arp2/3 complex 21 KDa subunit	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Beta-actin	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Beta-actin	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Beta-1-tubulin	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Beta-tubulin	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Beta-tubulin	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Cardiac muscle actin	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Cell wall hydroxyproline-rich glycoprotein	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Ciboulot	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
Cofilin	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Cuticle protein CUT5	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Fast myotomal muscle actin 2	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Four and a half LIM domain	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Four and a half LIM domains 1	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Keratinocyte-associated protein 2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Myosin	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Myosin 1A	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Myosin heavy chain	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Myosin II essential light chain	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Myosin II essential light chain	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Myosin light chain	WSSV	Hp	*P. japonicus*	(Pan *et al.*, 2005)
	V. harveyi	PL	*P. monodon*	(Nayak *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Non muscle myosin-II heavy chain	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Profilin	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Sarcoplasmic Ca^{+} binding protein	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Shroom family member	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Thymosin β	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Troponin I	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Troponin I, fast skeletal muscle	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Tubulin folding cofactor C	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Vinculin	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Extracellular matrix components				
Cyteine-rich with epidermal growth factor (EGF)-like domain 2, CG11377-PA	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Peritrophin	-	Ov	*P. merguiensis*	(Loongyai *et al.*, 2007a; Wonglapsuwan *et al.*, 2009)
	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Peritrophin 1	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Peritrophin 2	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Secreted nidogen domain protein	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Secreted nidogen domain protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Thrombospondin	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Thrombospondin	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Pigments				
Crustacyanin-A2 subunit	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Crustacyanin-C1 subunit	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Crustacyanin-C1 subunit	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Crustacyanin-like lipocalin	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Rhodopsin	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Microsatelites				
Microsatellite	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Microsatellite (PM2334)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Microsatellite (TUZX4-6:32)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Microsatellite t1609	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Microsatellite t403	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Ribosomal protein				
40S ribosomal protein S4	-	OvTP	*P. chinensis*	[33](Xie *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
40S ribosomal protein S7	-	OvTP	*P. chinensis*	[33](Xie *et al.*, 2010)
40S ribosomal protein S23	-	OvTP	*P. chinensis*	[33](Xie *et al.*, 2010)
	YHV	H	*P. monodon*	[39](Prapavorarat *et al.*, 2010)
60S ribosomal protein L3	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
60S ribosomal protein L5	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
60S ribosomal protein L6e	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
60S ribosomal protein L7a	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
60S ribosomal protein L8	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
60S ribosomal protein L11	-	OvTP	*P. chinensis*	[33](Xie *et al.*, 2010)
60S ribosomal protein L13	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
60S ribosomal protein L13a	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
60S ribosomal protein L27	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Acidic ribosomal protein	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Mitochondrial ribosomal protein L43	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Ribosomal protein fibrillarin	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Ribosomal protein L6	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
Ribosomal protein L7	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Ribosomal protein L7A	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Ribosomal protein L8	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
Ribosomal protein L10A	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
Ribosomal protein L10Ae	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Ribosomal protein L11	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ribosomal protein L18	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ribosomal protein L26	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Ribosomal protein L30	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ribosomal protein S5	-	OvDP	*P. chinensis*	(Xie *et al.*, 2010)
Ribosomal protein S6 serine/threonine kinase	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Ribosomal protein S8	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Ribosomal protein S11	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Ribosomal protein S13	-	OLLF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Ribosomal protein S23e	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Ribosomal protein S24	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ribosome biogenesis protein NSA2 homolog	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Ribosome S6 protein kinase	*V. penaeicida*	H	*P. stylirostris*	(de Lorgeril *et al.*, 2005)
Miscellaneous				
(2’-5’) Oligo(A) synthetase-like protein	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Accessory gland protein (putative)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Arsenite-resistance protein	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
Beta-alanyl conjugating enzyme	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Bmsqd-2	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
C2 domain containing protein	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Collagen α-1	WSSV	H	*P. japonicus*	(He *et al.*, 2005)
Chromosome-associated protein, CG9802-PA, iso A	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Domino isoform D, CG9696-PD	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Egalitarian	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Endothelial chloride channel	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
GRN protein	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
H-L(3)MBT-like protein	-	Ov	*P. merguiensis*	(Wonglapsuwan *et al.*, 2009)
Methionyl-tRNA formyltransferase, mitochondrial precursor (MtFMT)	-	OvIII	*P. monodon*	(Preechaphol *et al.*, 2010)
Myelodysplasia/myeloid leukimia factor CG8295-PD, isoform D	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Myeloid leukimia factor 2 (myelodysplasia-myeloid leukimia factor 2)	-	Tjuv	*P. monodon*	(Leelatanawit *et al.*, 2008)
Neuralized protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Nuclear autoantigenic sperm protein	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
PC2-like protein	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Puroinodoline B protein	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
	V. harveyi	PL	*P. indicus*	(Nayak *et al.*, 2011)
Sensitized chromosome inheritance modifier 19 CG9241-PA	-	Tbs	*P. monodon*	(Leelatanawit *et al.*, 2008)
Similar to astacin-like protein	*V. harveyi*	PL	*P. monodon*	(Nayak *et al.*, 2010)
SpAN-like protein	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Spermatogonial stem-cell renewal factor	-	OvTP	*P. chinensis*	(Xie *et al.*, 2010)
Synapse-associated protein- SAP90/PSD95	*PEB*	H	*P. japonicus*	(He *et al.*, 2004)
T-complex protein	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)
Thioesterase superfamily member 2	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
TRI1, CG7338-PA	-	OvI	*P. monodon*	(Preechaphol *et al.*, 2010)
Tudor staphylococcal nuclease	FAV	H	*P. vannamei*	(Robalino *et al.*, 2007a)
WW domain binding protein	-	OLSF	*P. monodon*	(Tangprasittipap *et al.*, 2010)

Differentially expressed genes	Challenges	Tissues	Species	References
Viral protein and coding genes				
3C-like protein	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Glycoprotein 116	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Glycoprotein 64	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Hemagglutinin esterase	*V. harveyi*	PL	*P. indicus*	(Nayak *et al.*, 2011)
Helicase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
Nucleocapsid protein	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
ORF44	WSSV/26ºC	Cep	*P. vannamei*	(Reyes *et al.*, 2007)
ORF70	WSSV/26ºC	Cep	*P. vannamei*	(Reyes *et al.*, 2007)
Replicase polyprotein	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
RNA polymerase	YHV	H	*P. monodon*	(Prapavorarat *et al.*, 2010)
VP15	WSSV/26ºC	Cep	*P. vannamei*	(Reyes *et al.*, 2007)
VP28	WSSV/26ºC	Cep	*P. vannamei*	(Reyes *et al.*, 2007)
WSSV P22	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
WSSV protein VP28 gene	WSSV	H	*P. vannamei*	(García *et al.*, 2009)
Down-regulated genes				
Immune-related factors and homeostatis				
Peptidylprolyl isomerase B(cyclophilin B)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Ferritin	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Haemocyanin	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
Haemocyanin	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Prophenoloxidase (proPO)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Transglutaminase (TGase)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
Antimicrobial peptides				
Anti-lipopolysaccharide factor (ALF)	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Crustin-like	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
C-type lectin	YHV	G	*P. vannamei*	(Junkunlo *et al.*, 2010; Junkunlo *et al.*, 2012)
	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Lysozyme	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Lysozyme	dsRNA	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Lysozyme	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
Tachylectin-5A	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Antioxidants and antitoxicities				
Zinc binding alcoholdehydrogenase, domaincontaining 2 (zadh2)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Proteases and inhibitors				
Astacin protease	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Cathepsin D aspartic protease	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Cathepsin L cysteine protease	WSSV/32°C	H, Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Cubilin protease	WSSV	H, Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Neprilysin metalloproteinase	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Palmitoyl-proteinthioesterase 2	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)

Differentially expressed genes	Challenges	Tissues	Species	References
PAPI I protein, kazal protease inhibitor	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Protease inhibitor	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Serine carboxypeptidase	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine protease inhibitors	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
WAP domain protease inhibitor	dsRNA	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Synthesis, processing, regulation and apoptotic related protein				
Acidic ribosomal phosphor-protein (PO)	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Disulfide isomerase	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
EF2Mc2 elongation factor 2 (Ef-2)	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Elongation factor 1α	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
FinTRIM family protein(ftr02 gene)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Histone H3.3B	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Non-SMCcondensin IIcomplex, subunit D3(NCAPD3)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Nucleosida diphosphate kinase	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Tripartit motif containing37 (TRIM37)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Replication, transcription, translation and repair related factors				
CHK1 checkpoint homolog	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Endo/excinuclease domainprotein	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Interleukin enhancer binding factor 2	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Similar to cAMP responsive element binding protein-like 2, transcriptional regulation	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Zn finger protein, associated with PKC-related kinase	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Reverse transcriptase/retrotransposons				
BCNT LINE insert	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Gag, pol and env.protein (Gypsy/Ty retrotransposon)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Lreo 3	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Pol-like protein (*MosquI-Aa2* non LTR retrotransposon)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a; de la Vega *et al.*, 2007b)
	hypoxia	H	*P. monodon*	(de la Vega *et al.*, 2007a)
	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a; de la Vega *et al.*, 2007b)
Pol-like protein (non LTR retrotransposons)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a; de la Vega *et al.*, 2007b)
	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Pol-like protein (non LTR retrotransposons)	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a; de la Vega *et al.*, 2007b)
Cell adhesion molecules				
Cadherin 23	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Leuchine-rich repeat and PDZ domain protein	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Peroxinectin	WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Tetraspanin	WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Signal transduction factors				
cAMP dependent protein kinase	WSSV	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Casein kinase II, alpha subunit	*FAV*	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Platelet derived growth factor-like	WSSV/32°C	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Rho small GTPase	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)

Differentially expressed genes	Challenges	Tissues	Species	References
Serine/theronine protein kinase 2A	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine/theronine protein kinase, polo	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine/theronine protein kinase, transduction of mitogenic signal	WSSV/32°C	H	*P. vannamei*	(Robalino *et al.*, 2007a)
Serine/threonine protein kinase 25	dsRNA	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Src-family tyrosine protein kinase	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
WD40 domain	*FAV*	G	*P. vannamei*	(Robalino *et al.*, 2007a)
Energy and metabolism				
Alanyl (membrane)aminopeptidase	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Arginin kinase	WSSV	Cep.	*P. chinensis*	(Wang *et al.*, 2006)
ATP synthase subunit 9mitochondrial precursor	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
ATP synthase subunit alpha precursor	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Complete mitochondrial genome (16S ribosomal)	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Cytochrome c oxidasesubunit II	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Cytochrome *c* oxidase subunit IIIv b v	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Malate dehydrogenase 2–2,NAD (mitochondrial)	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Mitochondria	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Mitochondrial ATPsynthase F chain	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
NADH dehydrogenase[ubiquinone] 1 alphasubcomplex subunit 5	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Phosphopyruvate hydratase	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Vacuolar ATPase G subunitlikeprotein	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
V-H-ATPase subunit A	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Active transporters				
H+transporting ATPsynthase O subunit	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)

Differentially expressed genes	Challenges	Tissues	Species	References
Glutathione S-transferase	WSSV	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Nucleoside diphosphate kinase	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Structural and cytoskeletal molecules				
Actin	WSSV	Cep	*P. chinensis*	(Wang *et al.*, 2006)
Actin D	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Calcified cuticle proteinCP14.1	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Early cuticle protein 1	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Nuclear β-tubulin	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Smooth muscle myosin	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Extracellular matrix components				
Peritrophin	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Pigments				
Crustacyanin-A2 subunit	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Microsatelites				
Microsatellites	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007b)
Ribosomal proteins				
16S ribosomal RNA gene	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
40S ribosomal protein S8	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
40S ribosomal protein S23	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
40S ribosomal protein S24	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
60S ribosomal	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
60S ribosomal L35a	Osmotic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
60S ribosomal L8	Hyperthermic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Ribosomal protein L23	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)

Differentially expressed genes	Challenges	Tissues	Species	References
Ribosomal protein L3	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Ribosomal protein L35A	WSSV	Hp	*P. vannamei*	(Zhao *et al.*, 2007)
Ribosomal protein large PO	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Ribosomal protein S24	Hypoxic	H	*P. monodon*	(de la Vega *et al.*, 2007a)
Miscelloneous				
CCCH-type zinc finger antiviral protein	WSSV/32°C	Hp	*P. vannamei*	(Robalino *et al.*, 2007a)
Proline-rich protein BstNIsubfamily 1	Osmotic stress	G	*P. vannamei*	(Gonçalves-Soares *et al.*, 2012)
Putative helicase from Moloney leukemia virus, SDE-3/armitage	WSSV/32°C	G	*P. vannamei*	(Robalino *et al.*, 2007a)

Cep., cephalotorax; G, gills; H, haemocyte; Hp, hepatopancreas; OLLF, optic lobes of large female prawn; OLSF, optic lobes of small female prawn; Ov, ovary; OvI, previttelogenic (stage I) ovary; OvIII, cortical rod (stage III) ovary; OvDP, ovary of diploid prawn; OvTP, ovary of triploid prawn; Tbs, testis of broodstock; Tjuv, testis of juvenile; Sub, subcuticular epithelium of cephalotorax; *FAV*, a mixture of heat-inactivated microorganism (*Fusarium oxysporum, Aerococcus viridans, Vibrio parahaemolyticus*); *PEB*, a mixed suspension of heat-killed microorganisms (*Pichia pastoris*, *Escherichia coli*, *Bacillus subtilis*); WSSV/32°C, WSSV infected at 32°C.

Appendix 3. Differentially expressed gene identified in the lymphoid organ cDNA SHH libraries that may have immune function in *Penaeus merguiensis*.

Appendix 3.1. Proteases and inhibitors

Cathepsin B not only has endopeptidase activity but also dipeptidyl-carboxypeptidase activity. Cathepsin B is mainly involved in degradation of cellular protein and turnover (Mort and Buttle, 1997; Turk *et al.*, 2012). In mammals, this enzyme is implicated in physiological process such as thyroid hormone generation by proteolytic processing of thyroglobulin and mechanism of calcium homeostatis. In pathological mechanism, the type B cathepsin is associated with inflammatory airways diseases, rheumatoid arthritis and acute pancreatitis. It is also involved in the invasion, metastasis and proliferation of cancer cells (Mort and Buttle, 1997; Nomura and Katunuma, 2005; Turk *et al.*, 2012).

Appendix 3.2. Structural and cytoskeletal related molecules

Actins are highly conserved proteins and universally expressed in all living organisms (Schoenenberger *et al.*, 2011). The functional variability of actins was determined by regulation or expression of their isoforms in different tissues (Schoenenberger *et al.*, 2011). In vertebrates, three isoforms of actin were identified. The α-actins were identified in cardiac, skeletal and smooth muscles, while β and γ-actins were expressed in most cell types (Dominguez and Holmes, 2011). Actin isoforms may only have a few differences in amino acids; but they may not substitute each other in the tissue specific functions (Dominguez and Holmes, 2011; Schoenenberger *et al.*, 2011). This protein may also undergo posttranslational modifications (Hild *et al.*, 2010; Schoenenberger *et al.*, 2011). In the muscle, actin participated in contraction. Actin in the cytoskeleton is involved in cellular polarity, cellular trafficking, cell motility, cell shape, adhesion, cytokenesis, and endocytosis. Nuclear actin plays an important role in signal transduction, transcription and chromatin remodelling (Hild *et al.*, 2010).

Numerous viruses such as adenovirus, baculovirus, herpesvirus, iridovirus, orthomyxovirus, paramyxovirus, poxvirus, retrovirus, rhabdovirus and togavirus have been documented to interact with actin at various stages throughout their life cycles, either disrupting or rearranging the actin cytoskeleton to their own advantage (Cudmore *et al.*, 1997). Vaccinia virus for instance, not only disrupts the actin cytoskeleton at the early stage of infection, but also utilises polymerization of actin to enhance viral spread into the neighbouring cells at the later stage (Cudmore *et al.*, 1997; Ploubidou and Way, 2001). Actin facilitates viral entry into the host cells (Ploubidou and Way, 2001; Smith and Helenius, 2004; Liu *et al.*, 2009a; Pongsomboon *et al.*, 2011) and promotes vesicle budding at the cell surface and to propel virus-containing endocytic vesicle through the cytoplasm (Smith and Helenius, 2004). Actin is also indicated to be involved in intracellular transport mechanism for many viruses. Most viral genomes should be transported to nucleus or specific cytosolic membranes after penetration (Smith and Helenius, 2004). For example, baculovirus take advantage of actin microfilament in cytoplasmic transport of nucleocapsid to the nucleus (van Loo *et al.*, 2001).

Appendix 3.3.Synthesis, processing and regulation proteins

Translation of mRNA by ribosomes consists of initiation, elongation, termination and recycling (Passmore *et al.*, 2007). Moreover, eIF6 is rate-limiting for translation, growth and oncogene-driven transformation (Gandin *et al.*, 2008; Miluzio *et al.*, 2009). The eIF6 have been found to be up regulated in colon cancer and aggressive leukaemia (Miluzio *et al.*, 2009). Furthermore, the initiation factor eIF6 has been shown to have a crucial role in regulating miRNA-dependent gene silencing. Reduction of eIF6 in human cells and the unsegmented nematode, *Caenorhabditis elegans* perturbed miRNA-mediated regulation of target protein and mRNA levels (Chendrimada *et al.*, 2007).

Ubiquitin is a ubiquitously expressed protein family that has a variety of sequences, but has a highly similar structure and conjugates mainly to isopeptide bond between its C-terminal glycine and a lysine residue within the target protein. Ubiquitination of proteins is achieved through an enzymatic cascade involving ubiquitin-activating

(E1), ubiquitin-conjugating (E2), and ubiquitin-ligating (E3) enzymes (Pickart and Eddins, 2004; Deshaise and Joazeiro, 2009; Schaefer *et al.*, 2012).

Appendix 3.4. Energy and metabolism factors

Mitochondria, double-membrane organelles regulate many critical cellular processes and homeostasis that are closely related to the cellular metabolic networks including intermediary metabolism, metabolism of amino acids, lipids, cholesterol, steroids and nucleotides, generation and detoxification of reactive oxygen species (ROS), apoptosis and intracellular signalling. Possibly, mitochondria play a crucial role in cellular energy metabolism including fatty acid β oxidation, the urea cycle and the final common pathway of ATP production (Chinnery and Schon, 2003; Picard *et al.*, 2011; Cloonan and Choi, 2012). Mitochondrial proteins are encoded by two distinct gene sets: nuclear DNA (nDNA) and mitochondrial DNA (mtDNA). Mitochondrial DNA is located within the mitochondria and maternally inherited (Chinnery and Schon, 2003; Máximo *et al.*, 2009).

More than 150 different pathogenic point mutations and a number of partial deletions and duplication of mtDNA are related to diseases. Nuclear genes are fundamental for mitochondrial homeostasis and if these genes are disrupted, autosomally inherited mitochondrial diseases occur. Several nuclear genetic disorders including Friedreich´s ataxia, Wilson´s diseases, hereditary spastic paraplegia and dominant optic atrophy are associated with mitochondrial dysfunction (Chinnery and Schon, 2003). Mitochondria also associated with neurodegenerative diseases such as Parkinson's disease, Alzheimer's disease and amyotrophic lateral sclerosis (Cassarino and Bennett Jr, 1999). Mutations of mtDNA are frequent events in tumorigenesis such as lung, liver, prostate, kidney, and breast cancers (Máximo *et al.*, 2009).

NADH dehydrogenase is the most complex proton translocating enzyme, consists of 45 different subunits that are mostly encoded by nDNA and imported from cytoplasm. However, like cytochrome reductase, cytochrome oxidase and the H^+-ATPase, some NADH dehydrogenases are encoded by mtDNA and synthesised in mitochondria. The ND4 and ND5 subunits which are involved in proton translocation are located in the distal end of the membrane arm of the NADH dehydrogenease (Weiss *et al.*, 1991; Kerscher *et al.*, 2008). A variety of human diseases have been reported to be associated with impaired NADH dehydrogenease activities. These diseases predominantly affect organs with high demand of ATP such as muscle and brain and therefore called mitochondrial enchephalomyopathies (Weiss *et al.*, 1991). The NADH dehydrogenase was also implicated in neurodegenerative diseases such as Parkinson's and suggested to be the primary sources for reactive oxygen species (ROS) derived from respiratory chain (Kerscher *et al.*, 2008). Expression of NADH dehydrogenase could be induced by infectious pathogens.

Cytochrome oxidase is a transmembrane protein that localises in the inner membrane of mitochondria and expressed ubiquitously in all aerobic cells (Brunori and Wilson, 1982; Capaldi *et al.*, 1983; Denis, 1986). Cytochrome oxidase composes of 11-13 subunits depending on the organism. Three main subunits of cytochrome oxidase, COI, COII and COIII are encoded by mtDNA, while the other subunits are encoded by nDNA and synthesised in cytoplasm (Denis, 1986; Robinson, 2000; Khalimonchuk and Rödel, 2005). Various clinical phenotypes of cytochrome oxidase deficiency in humans have been documented including Leigh's syndrome, a progressive neurologic deterioration of basal ganglia and brain stem, lactic acidemia, fatal infantile form and a benign reversible form (Robinson, 2000). Others include sideroplastic anemia, motor neuro-like degeneration, multisystemic disorder, myoglobinuria, encephalopathy encephalomyopathy, cardioencephalomyopathy and hepatic failure (Barrientos *et al.*, 2002).

Appendix 3.5. Ribosomal proteins

Ribosomes are built up from ribosomal proteins and ribosomal RNA (rRNA). Most ribosomal proteins localise at the surface of the particle, whilst rRNA is in the central core (Brodersen and Nissen, 2005; Wilson and Nierhaus, 2005). Even though rRNA is involved in a certain aspects of ribosomal functions including decoding and peptidyl-transferase centre (PTC) of the ribosomes, the ribosomal proteins play a crucial role in assembly and optimal function of ribosomes (Wilson and Nierhaus, 2005).

It is difficult to assign the specific function of individual ribosomal proteins because the complexity and diversity of interaction between rRNA and ribosomal proteins and between the ribosomal proteins themselves, but functional roles of some distinct ribosomal proteins can be determined (Wilson and Nierhaus, 2005). In prokaryotes for instance, small subunit ribosomal protein S1 plays an essential role in transporting the mRNA as well as tmRNA mediated trans-translation. Ribosomal protein S3, S4 and S5 are involved in the formation of the entry pore of the mRNA and exerting helicase activity. Ribosomal proteins S4 and S5 with S12 also have critical function in decoding and fidelity of translation. Large subunit ribosomal proteins L1 and L16/L27 may be important in releasing and binding of tRNA to ribosomes. Ribosomal protein L9 may affect the stability of tRNA at the P site and mRNA movement. The efficiency of translational bypassing was affected by mutation in L9 (Wilson and Nierhaus, 2005). Ribosomal protein L5 may also interact with the P site tRNA (Brodersen and Nissen, 2005).

The receptor of activated C kinase (RACK1) a ribosomal protein in eukaryotes, plays a role as a scaffolding protein, binding to kinases such protein kinase C, Rsc kinase, mRNA-binding proteins and signalling pathways (Brodersen and Nissen, 2005). Ribosomal proteins also act as a docking site for chaperons (Wilson and Nierhaus, 2005). Mutation in ribosomal protein genes or interruption in their gene expressions are related to inherited genetic disorder including Tuner syndrome, Bardet-Bield syndrome, Noonan syndrome, Diamond-Blackfan anemia syndrome, and Camuraty-Engelmann disease (Lai and Xu, 2007).

Appendix 4. Publishedmanuscripts from research project of PhD candidature.

Appendix 4.1.Rusaini and Owens, L. (2010) Insight into the lymphoid organ of penaeid prawn: A review. *Fish Shellfish Immunol***29**: 367-377.

THIS ARTICLE HAS BEEN REMOVED DUE
TO COPYRIGHT RESTRICTIONS

Appendix 4.2.Rusaini, Ariel, E., Burgess, G.W. and Owens, L. (2013) Investigation of an idiopathic lesion in redclaw crayfish *Cherax quadricarinatus* using suppression subtractive hybridization. *J Virol Microbiol* **2013, Article ID 569032**: 15 pages.

IBIMA Publishing
Journal of Virology & Microbiology
http://www.ibimapublishing.com/journals/JVM/jvm.html
Vol. 2013 (2013), Article ID 569032, 15 pages
DOI: 10.5171/2013.569032

Research Article

Investigation of an Idiopathic Lesion in Redclaw Crayfish *Cherax Quadricarinatus* Using Suppression Subtractive Hybridization

Rusaini[1,2], Ellen Ariel[2], Graham W. Burgess[2] and Leigh Owens[2]

[1]Aquaculture, Faculty of Agriculture, University of Tadulako, Bumi Tadulako Tondo, Palu, Indonesia

[2]Microbiology and Immunology, School of Veterinary and Biomedical Sciences, James Cook University, Townsville, Australia

Received 18 January 2013; Accepted 27 February 2013; Published 24 April 2013

Academic Editor: Parin Chaivisuthangkura

Abstract

Lesions indicative of putative parvovirus infection were detected in a population of freshwater redclaw crayfish (*Cherax quadricarinatus*) displaying hypertrophied nuclei, while these changes were undetected in another population. These changes were characterised by hypertrophic nuclei with marginated chromatin but without Cowdry type A (CA) intranuclear inclusion bodies. Suppression subtractive hybridization (SSH) was performed to generate a cDNA forward library between the two populations of crayfish. A total of 323 sequences were analysed from SSH libraries. These sequences were grouped into 76 consensus sequences and clustered into 8 categories based on sequence homology from the NCBI GenBank database. Even though histopathological observations consistently revealed lesions presumptive of putative parvovirus in *C. quadricarinatus* as previously reported, the molecular method failed to confirm a viral aetiology. Despite the absence of viral gene detection and therefore a conclusion of an idiopathic aetiology, the health status of these two populations of redclaw crayfish was different, resulting in differentially expressed immune-related genes in the two populations, with some genes being up-regulated in the hypertrophied nuclei population. Furthermore, the absence of parvovirus from the SSH libraries indicates that perhaps the viral messenger RNA was in too low a concentration to be detected or does not have any poly(A) tail which the SSH methodology needs to function correctly.

Keywords: Redclaw crayfish, Parvovirus, Suppression subtractive hybridization, Idiopathic aetiology.

Introduction

Like their marine crustacean counterparts, freshwater redclaw crayfish (*Cherax quadricarinatus*) can be affected detrimentally by viral infections. In Australia alone, several viruses have been found to cause infection in redclaw crayfish. *Cherax quadricarinatus* bacilliform virus was reported to be widespread in wild and cultured redclaw crayfish in northern Queensland between 1992 and 1996 (Anderson and Prior, 1992; Edgerton, 1996; Edgerton and Owens, 1999). *Cherax Giardiavirus*-like virus was also commonly found in cultured redclaw crayfish and thought to be a significant pathogen of juveniles (Edgerton and Owens, 1997; Edgerton et al., 1994; Edgerton and Owens, 1999). In addition, a presumptive

---

Cite this Article as: Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), "Investigation of an Idiopathic Lesion in Redclaw Crayfish Cherax Quadricarinatus Using Suppression Subtractive Hybridization," Journal of Virology & Microbiology, Vol. 2013 (2013), Article ID 569032, DOI: 10.5171/2013.569032

JAMES COOK UNIVERSITY AUSTRALIA

hepatopancreatic reovirus has been reported to decrease stress resistance in farmed *C. quadricarinatus* (Edgerton et al., 2000; Hayakijkosol and Owens, 2011). Even though these viruses are not very virulent to redclaw crayfish, they have been shown to cause low level mortalities and growth retardation and are thought to suppress the immunoresponse of animals (Edgerton and Owens, 1999; Hayakijkosol and Owens, 2011). These orphan viruses (viruses which infect a host, but are not considered to cause any diseases) have been ignored as causes of economic losses in cultured crayfish. However, when eggs specific-pathogen-free for these viruses were produced as hatchery technology developed, the culture period shortened by approximately 15% and production doubled, thereby reducing the production cost and increasing the profit margin (Owens, 2011).

Another disease caused by spawner-isolated mortality virus (SMV) was previously detected in penaeid prawns, but has since caused significant mortality in captured and transported redclaw crayfish in 1997 – 1998 (Owens and McElnea, 2000). Therefore, these authors predicted that viral diseases of penaeid prawns may have potential effects on the health status of crayfish. Moreover, white spot syndrome virus (WSSV), the main cause of catastrophic losses within the penaeid prawn industry, can also infect crayfish both experimentally and naturally in wild and farmed animals (Baumgartner et al., 2009; Edgerton, 2004; Edgerton et al., 2002; Jiravanichpaisal et al., 2001).

Putative parvovirus infection has been documented to be associated with chronic and mass mortalities in freshwater crayfish. Tissue changes and viral morphology have been described using light microscopy and transmission electron microscopy (TEM) (Bowater et al., 2002; Edgerton et al., 1997; Edgerton et al., 2000). However, genetic characterisation of the viruses has not been carried out and studies on immune-related genes of redclaw crayfish are sparse. Lesions characterised by hypertrophied nuclei with rarefied chromatin but without Cowdry type A (CA) intranuclear inclusion bodies that resemble those associated with putative parvovirus infection previously reported in *C. quadricarinatus* (Edgerton et al., 2000) were observed in a population, while these changes were not observed in another population of redclaw crayfish in the aquaculture facilities of the School of Veterinary and Biomedical Sciences, James Cook University. Therefore, this study was conducted to profile possible viral genomes and differentially expressed genes from gills of the two populations of crayfish using suppression subtractive hybridization (SSH).

Materials and Methods

Experimental Animals

Redclaw crayfish (*Cherax quadricarinatus*) were sampled from the aquaculture facilities at the School of Veterinary and Biomedical Sciences, James Cook University. One population which comprised about 200 animals was maintained in an outdoor facility (hypertrophied nuclei population) while the other population which consist of about 500 animals was in an indoor facility (non-hypertrophied nuclei population). Both populations were reared in 1,000 l plastic bins with a recirculating system. Experimental animals were anaesthetised by placing them in iced water for a few minutes prior to gill excision and histological preparation.

Histology

The cephalothorax was fixed in Davidson's fixative (formaldehyde 220 ml, acetic acid 115 ml, absolute ethanol 313 ml and tap water 352 ml) at a ratio of tissue to fixative 1:10 for 24 hours. The cephalothorax was cut longitudinally, placed in a histocassette, stored in 70% ethanol and then processed for routine histological examination using standard paraffin embedded procedure (Bell and Lightner, 1988). Sections were cut at 5 µm using a rotary microtome, mounted on glass slides, stained with haematoxylin and eosin (H & E) examined under a light microscopy.

RNA Extraction

Total RNA was extracted separately from the gills of hypertrophied nuclei (6 crayfish) and non-hypertrophied nuclei (6 crayfish) *C. quadricarinatus* using SV Total RNA Isolation System (Promega, USA) according to the manufacturer's instructions. The

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), *Journal of Virology & Microbiology*, DOI: 10.5171/2013. 569032

concentration and purity of total RNA was determined using spectrophotometry (NanoPhotometerTM, Implen, Germany) and stored at -80°C until required. Polyadenylated (Poly(A)+) RNA was isolated from pooled total RNA using Poly A Tract mRNA Isolation System III (Promega, USA) following the manufacturer's protocol. Before use, 750 µl Poly(A)+ RNA was concentrated by freeze drying (Telstar 23750 - Cryodos -50/230 V 50 Hz, United Kingdom) and re-dissolved in 25 µl RNase-free water. Concentration and purity of Poly (A) + RNA was examined using spectrophotometry.

Suppression Subtractive Hybridization

Suppression subtractive hybridization was performed using the PCR-Select cDNA Subtraction Kit (Clontech, USA) following the manufacturer's instructions to generate a cDNA forward library between hypertrophied nuclei population (tester) and non-hypertrophied nuclei population (driver). Briefly, the tester cDNA was prepared from 1.24 µg of poly(A)+ RNA and the driver cDNA was synthesised from 1.16 µg of poly(A)+ RNA. Both tester and driver cDNAs were digested with a four-base cutting restriction enzyme (Rsa I) to obtain blunt-ended molecules. Following this, tester cDNA was equally divided into two samples and ligated with one of the two different adaptors (adaptor 1 and adaptor 2R) to the 5' end of cDNA. The ligation efficiency was evaluated on a 1.2% agarose-TAE gel containing ethidium bromide (EtBr) at a concentration of 0.5 µg/ml. Next, tester cDNAs were hybridized with an excess of driver cDNA at 68°C for 8 hours following denaturation at 98°C for 1.5 minutes. Two samples from the first hybridization were mixed and hybridized with an excess of freshly denatured driver cDNA overnight at 68°C to enrich the differentially expressed gene fraction. Finally, the mixture was subjected to two rounds of PCR using specific primers to both adaptors to amplify exponentially the target differentially expressed genes and suppress the common sequence of the two cDNA populations. These PCR products were examined on a 1.2% agarose/ethidium bromide gel.

Cloning and Sequencing

Subtracted PCR products were cloned into T & A cloning vectors (RBC, Taiwan) or pGEM-T easy vectors (Promega, USA) and transformed into HIT-DH5α or JM109 competent cells which were plated onto agar containing ampicillin, X-gal (5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside) and IPTG (isopropyl-β-D-thiogalactopyranoside). Plasmid DNA was extracted using Wizard® Plus SV Minipreps DNA Purification System (Promega, USA) from randomly selected white colonies and sent to Macrogen, Korea for sequencing. Nucleotide sequences were analysed with BLASTx and BLASTn against known amino acid/nucleotide sequences on GenBank databases (NCBI). Sequences with E-values $<1e^{-05}$ were considered significant.

Results

Histology

Lesions typical of putative parvovirus infection, consisting of hypertrophic nuclei with rarefied chromatin but without Cowdry type A inclusion body in the gill tissues (Fig. 1a) were found in the population displaying hypertrophied nuclei (10 out of 10 crayfish), while these lesions were not observed in the non-hypertrophied nuclei population (7/7) of crayfish (Fig. 1b). In the gills of the hypertrophied nuclei population, pyknotic and karyorrectic nuclei were also detected. Aggregation of haemocytes and granulomatous reactions in the gill tissues were seen in both populations suggesting the probability of subclinical bacterial infections.

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

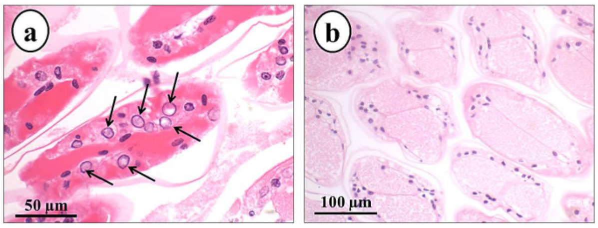

Fig. 1. Longitudinal Section of the Gills of *Cherax Quadricarinatus* from Hypertrophied Nuclei Population (a) and Non-hypertrophied Nuclei Population (b). Note Hypertrophy of Nuclei with arefied Chromatin (Arrow) in the Gills from the Hypertrophied Nuclei Population (a) Compared to Normal Gill Tissue from the Non-hypertrophied Nuclei Population (b)

Haematoxylin and Eosin Stain

Suppression Subtractive Hybridization

Suppression subtractive hybridization was conducted three times resulting in several libraries (Table 1). A total of 339 clones were sequenced. After removing vector sequences and the poor quality sequences of these three attempts, a total of 323 sequences were grouped into 76 consensus sequences (contigs) with a range of insert sizes between 61 bp and 484 bp. The homology search revealed that around 61.6% of the total clones (199 out of 323 clones) shared significant similarities to known proteins in the GenBank database (Table 2).

Table 1. Gill cDNA Libraries Obtained from Approximate PCR Product Amplicons of Suppression Subtractive Hybridization (SSH) Trials

Trial	Libraries	PCR products
1	1a	270 bp
	1b	200 bp
2	2a	200 bp
3	3a	450 bp
	3b	350 bp
	3c	300 bp

These transcripts were clustered into 8 categories based on sequence homology from the public database (Fig. 2). Significantly matching transcripts were clustered to immune-related genes (15.2%), energy and metabolism factor genes (3.1%) and muscle and cytoskeletal-related proteins (0.6%). Transcripts that had significant similarity to amino acids of unknown functionalities in the public database were grouped into ribosomal (2.8%) and hypothetical protein sequences (39.9%). These were the most abundant transcripts found in the SHH libraries. Transcripts that did not match any protein sequences but had significant matches with nucleotides in GenBank were clustered into redclaw crayfish mRNA (13.0%) and other sequences (0.6%). Sequences that had no significant matches either with amino acids or nucleotides in the public database were grouped into unknown sequences (24.8%).

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), *Journal of Virology & Microbiology,* DOI: 10.5171/2013. 569032

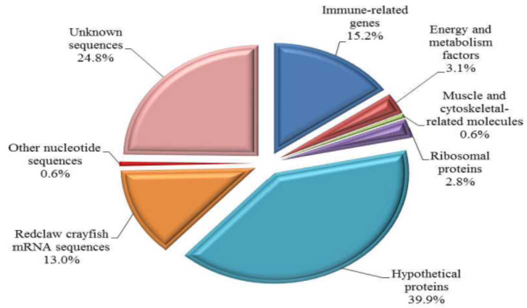

Fig. 2. Functional Categories of Differentially Expressed Genes From The Gill Cdna Suppression Subtractive Hybridization (SSH) Libraries Of Redclaw Crayfish *Cherax Quadricarinatus*

Table 2. Differentially Expressed Genes from Suppression Subtractive Hybridization (SSH) Libraries of the Gills of Freshwater Redclaw Crayfish, *Cherax Quadricarinatus* with Amino Acids/Sequences Similarity to Amino Acids/Sequences in the GenBank Database (NCBI)

Contig	Number of clones	Library	Fragment size (bp)	BLAST type	Accession number	Closest homology	Species	E-value	Identity (%) - (q/s)
						Immune-related genes			
CqG003	1	3	302	X	ABC59529.1	Cytosolic manganese superoxide dismutase	*Penaeus vannamei*	2.00E-09	93 (26/28)
CqG008	6	3a	360	X	ACD76641.1	C-type lysozyme	*Penaeus stylirostris*	3.00E-08	63 (24/38)
CqG015	17	3, 3a, 3b, 3c	235	X	P19857.2	Serum amyloid A protein	*Equus cabalus*	9.00E-06	76 (22/29)
CqG018	1	3c	243	X	ACL79888.1	Putative elastin a	*Rimicaris exoculata*	1.00E-22	75 (41/55)
CqG025	1	3c	240	X	ACY66442.1	Eukaryotic initiation factor 4A	*Scylla paramamosain*	7.00E-39	99 (79/80)
CqG026	1	3c	150	X	ACY66461.1	Translationally-controlled tumour protein	*Scylla paramamosain*	1.00E-18	78 (38/49)
CqG027	1	3c	161	X	ACY66388.1	Chaperonin 10	*Scylla paramamosain*	3.00E-14	85 (45/53)
CqG029	1	3c	237	X	ABZ90154.1	Translationally-controlled tumor protein	*Penaeus japonicus*	1.00E-29	86 (49/57)
CqG030	2	3a, 3c	368	X	ACY64752.1	Crustin 2	*Procambarus clarkii*	4.00E-49	74 (64/87)
CqG047	1	3	388	X	AEL23029.1	Insulin-like growth factor binding protein 7-like protein	*Cherax quadricarinatus*	2.00E-37	96 (54/56)
CqG048	14	2a, 3, 3a, 3c	343	X	ADI96221.1	Kazal-type serine proteinase inhibitor I	*Procambarus clarkii*	2.00E-17	76 (34/45)
CqG050	2	3, 3b	269	X	ABH10628.1	Laminin receptor	*Penaeus vannamei*	1.00E-38	92 (79/86)
CqG075	1	3a	388	X	ADM21460.1	Anti-lipopolysaccharide factor (ALF) isoform 6	*Penaeus monodon*	1.00E-43	71 (62/87)
						Energy and metabolism factors			
CqG007	1	3	189	X	YP_022769.1	NADH dehydrogenase subunit 3	*Cherax destructor*	2.00E-05	67 (33/49)
CqG021	1	3c	215	X	AAM11778.1	Cytochrome oxidase subunit I	*Engaeus strictifrons*	1.00E-36	89 (63/71)

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

CqG024	4	2a, 3, 3c	254	X	YP_022768.1	Cytochrome c oxidase subunit III (COIII)	*Cherax destructor*	2.00E-35	78 (62/79)
CqG035	1	3	350	X	CBW54880.1	Putative DEAD box ATP-dependent RNA helicase	*Cancer pagurus*	1.00E-17	95 (37/39)
CqG041	1	3	225	X	ACR54103.1	ATP synthase subunit g	*Palaemonetes varians*	2.00E-20	79 (37/47)
CqG056	1	1a	81	X	YP_004563978.1	NADH dehydrogenase subunit 4	*Homarus americanus*	1.00E-06	81 (21/26)
CqG076	1	3a	175	X	YP_022765.1	Cytochrome c oxidase subunit II (COII)	*Cherax destructor*	5.00E-15	89 (32/36)
Contig	**Number of clones**	**Library**	**Fragment size (bp)**	**BLAST type**	**Accession number**	**Closest homology**	**Species**	**E-value**	**Identity (%) - (q/s)**
						Muscle/cytoskeletal related-molecules			
CqG037	1	2	76	X	AAS98886.1	Allergen Pen m2	*Penaeus chinensis*	2.00E-10	100 (25/25)
CqG060	1	3a	405	X	BAJ14323.1	Alpha tubulin	*Pinctada fucata*	1.00E-66	96 (96/100)
						Ribosomal proteins			
CqG014	1	3c	240	X	AEB54647.1	Ribosomal protein S18	*Procambarus clarkii*	2.00E-33	100 (76/76)
CqG022	1	3c	265	X	ADY39535.1	Putative 60S ribosomal protein L7-like	*Hottentotta judaicus*	1.00E-41	75 (61/81)
CqG058	2	2, 2a	62	X	ACY66551.1	Ribosomal protein L10	*Scylla paramamosain*	2.00E-05	95 (19/20)
CqG062	2	3b	191	X	XP_002733250.1	PREDICTED: Ribosomal protein L38-like	*Saccoglossus kowalevskii*	6.00E-20	95 (40/42)
CqG064	2	3b, 3c	275	X	ADW95789.1	Ribosomal protein S30-like protein	*Pectinaria gouldii*	3.00E-11	51 (31/61)
CqG070	1	3c	138	X	ACN44179.1	Ribosomal protein S16	*Cavia porcellus*	2.00E-17	89 (50/56)
						Hypothetical proteins			
CqG023	4	3b, 3c	229	X	DAA34691.1	TPA_inf: hypothetical secreted protein 323	*Amblyomma variegatum*	2.00E-11	39 (30/77)
CqG028	121	1, 1a, 1b, 2, 2a, 3, 3a, 3b, 3c	437	X	CAM36311.1	Hypothetical protein	*Thermobia domestica*	8.00E-07	71 (23/32)
CqG065	1	3b	305	X	EFZ23151.1	Hypothetical protein SINV_03072	*Solenopsis invicta*	3.00E-20	62 (61/98)
CqG066	1	3b	155	X	XP_002739723.1	PREDICTED: Protein-like	*Saccoglossus kowalevskii*	1.00E-15	87 (34/39)
CqG068	1	3b	240	X	EFX85348.1	Hypothetical protein DAPPUDRAFT_230545	*Daphnia pulex*	5.00E-22	68 (54/79)
CqG073	1	3c	166	X	XP_780871.2	PREDICTED: Hypothetical protein	*Strongylocentratus purpuratus*	1.00E-06	43 (23/53)
						Redclaw crayfish mRNA sequences			
CqG002	21	1, 1a, 1b, 2, 2a	61	n (h)	EF692627.1	Clone y9_B8 mRNA sequences	*Cherax quadricarinatus*	3.00E-21	98 (60/61)
CqG005	3	1b, 2a, 3c	86	n (h)	GQ286092.1	Clone GB_1A mRNA sequences	*Cherax quadricarinatus*	1.00E-27	93 (82/88)
CqG012	1	3b	233	n (h)	DQ847728.1	Clone cherax_207 mRNA sequences	*Cherax quadricarinatus*	1.00E-67	100 (143/143)
CqG016	1	3c	170	n (h)	DQ847803.1	Clone y1_a2 mRNA sequences	*Cherax quadricarinatus*	7.00E-78	99 (163/164)
CqG020	2	3, 3c	242	n (h)	DQ847728.1	Clone cherax_207 mRNA sequences	*Cherax quadricarinatus*	3.00E-98	99 (203/205)
Contig	**Number of clones**	**Library**	**Fragment size (bp)**	**BLAST type**	**Accession number**	**Closest homology**	**Species**	**E-value**	**Identity (%) - (q/s)**
CqG031	2	3, 3c	221	n (h)	DQ847679.1	Clone cherax_157 mRNA sequences	*Cherax quadricarinatus*	1.00E-106	99 (220/223)
CqG034	3	1, 3	374	n (h)	DQ847684.1	Clone cherax_163 mRNA sequences	*Cherax quadricarinatus*	7.00E-171	99 (333/335)
CqG036	2	1, 1b	73	n (h)	DQ847743.1	Clone cherax_223	*Cherax*	9.00E-28	99 (72/73)

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), *Journal of Virology & Microbiology*, DOI: 10.5171/2013. 569032

						mRNA sequences	*quadricarinatus*		
CqG045	2	3	233	n (h)	DQ847664.1	Clone cherax_141 mRNA sequences	*Cherax quadricarinatus*	6.00E-90	96 (200/208)
CqG046	1	3	135	n (h)	DQ847565.1	Clone epi2_G11 mRNA sequences	*Cherax quadricarinatus*	2.00E-38	98 (94/96)
CqG049	1	3	260	n (h)	EF692615.1	Clone y17_B11 mRNA sequences	*Cherax quadricarinatus*	1.00E-132	100 (260/260)
CqG051	1	3	484	n (h)	DQ847548.1	Clone epi1_B3 mRNA sequences	*Cherax quadricarinatus*	0.00E+00	99 (464/467)
CqG053	2	1a, 1b	66	n (h)	GQ286117.1	Clone GI_2D mRNA sequences	*Cherax quadricarinatus*	4.00E-21	97 (63/65)
						Other nucleotides sequences			
CqG040	1	3c	229	n (s)	AM439566.1	Whole genome shotgun sequence contig VV78X26936.8	*Vitis vinifera*	4.00E-05	83 (48/58)
CqG059	1	3a	255	n (s)	HM020387.1	Secretory eggshell protein precursor (SEP18.7) mRNA	*Clonorchis sinensis*	3.00E-20	79 (93/117)

When no homology was found with a BLASTx **[x]** against non-redundant sequences in the public database, BLASTn optimised for highly similar sequences (megablast) **[n (h)]** was conducted against sequences in database. If no similarity obtained from n (h), then BLASTn optimised for somewhat similar sequences (blastn) **[n (s)]** was performed. If multiple significant similarities matched with a single cDNA (sequence consensus), only the highest scoring hit was included in the table. Library 1a and 1b were produced from the first SHH trial with amplicon size of 270 bp and 200 bp, respectively. Library 2a was constructed from the second SSH trial with amplicon size of 200 bp. Library 3a, 3b and 3c were constructed from the third SSH trial with amplicon size of 450 bp, 350 bp, and 300 bp respectively. All these bands (amplicons) were cut, purified and cloned to construct the libraries. Library 1, 2 and 3 were constructed from the first, second and third SSH trial respectively, directly purified and inserted to the cloning vector without cutting the bands. q/s: number of identical amino acids (nucleotides) between query and subjects sequences/number of amino acids (nucleotides) for alignment. A similarity was considered significant at E-value < $1e^{-05}$.

Discussion

In the present study gills were selected as a target tissue because of its distinct histopathological features between the hypertrophied nuclei and non-hypertrophied nuclei populations. The affected crayfish had hypertrophic nuclei with rarefied chromatin but without CA intranuclear inclusion bodies in the gill epithelium which resembled histological changes consistent with a putative gill parvovirus reported by Edgerton et al. (2000) in this species from northern Queensland. On this basis, it was assumed that these animals were infected with putative gill parvovirus. In addition, as a multifunctional organ, gills not only play an important role in respiration, osmotic and ionic regulation, and detoxification (Clavero-Salas et al., 2007; Freire et al., 2008), but are also considered to be involved in the immune response to invading pathogens (Clavero-Salas et al., 2007; Somboonwiwat et al., 2008; Yeh et al., 2007) and were therefore ideal for detecting up-regulation of immune-related genes using suppression subtractive hybridization.

Many transcripts were identified in the SSH libraries, but for the purpose of this study, only immune-related transcripts will be discussed. Among a variety of transcripts related to immune response, three antimicrobial peptides belonging to lysozyme, crustin and the anti-lipopolysaccharide (ALF) families were detected. Lysozymes have the ability to lyse bacteria by splitting the glycosidic linkage between N-acetylglucosamine and N-acetylmuramic acid of peptidoglycan in the bacterial cell wall (Bachali et al., 2002; Jolles and Jolles, 1984). Bacteriolytic activity of these enzymes in crustacea has been reported against both Gram-positive and negative bacteria including pathogenic *Vibrio* species (Burge et al., 2007; Fenouil and Roch, 1991; Hikima et al., 2003; Yao et al., 2008). Lysozymes are also thought to play a role in

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

an antiviral response in crustacea (He et al., 2005; Mai and Wang, 2010; Pan et al., 2005). Senapin and Phongdara (2006) found that lysozymes could bind to viral capsid proteins (VP1 and VP2) of Taura syndrome virus (TSV). Similarly, crustin, a cystein-rich peptide that contains a whey acidic protein (WAP) domain also has antibacterial activity against Gram-positive bacteria, but some type II and III crustins have the ability to respond to both Gram-positive and negative bacteria (Donpudsa et al., 2010b). Type III crustins may also have proteinase inhibitory activities (Amparyup et al., 2008).

Like lysozymes, anti-lipopolysaccharide factor can be found across a variety of organisms and has multiple biological activities. This molecule inhibits both Gram-positive and negative bacteria and fungus (de la Vega et al., 2008; Sun et al., 2011; Yedery and Reddy, 2009). This antimicrobial peptide is also predicted to have an opsonising function for haemocytes in phagocytosing bacteria (Sun et al., 2011). The ALF may have an immunological function against viral infections in crustacea (Antony et al., 2011; de la Vega et al., 2008; Liu et al., 2011; Liu et al., 2006). It was found that the ALF was up-regulated in the WSSV-experimentally infected crayfish and silencing this protein enhanced viral propagation (Liu et al., 2011; Liu et al., 2006). Furthermore, this peptide is considered a potential therapeutic agent for prophylactic treatment of viral and bacterial infectious diseases and septic shock (Somboonwiwat et al., 2008)

Kazal-type serine proteinase inhibitor of *Procambarus clarkii* and serum amyloid A of *Equus caballus* transcripts dominated the immune-related genes from the SHH library. The Kazal-type serine proteinase inhibitors are believed to have a role in regulation of immune reactions of crustacea, inhibition of proteinase from microorganisms, bacteriostatic activities against both Gram-positive and negative bacteria (Donpudsa et al., 2009; Li et al., 2009) and are probably involved in an antiviral response as well (Donpudsa et al., 2010a; Liu et al., 2011). Serum amyloid A (SAA) is an acute phase protein (APP) that has a role in inflammatory processes in vertebrates. This acute phase protein increased in viral and bacterial infected animals (Cray et al., 2009). Its role in invertebrates, in particular crustaceans, has hardly been investigated. However, in the sea cucumber *Holothuria glaberrima*, the serum amyloid A was predicted to be involved in intestinal morphogenesis (Santiago-Cardona et al., 2003).

Two transcripts representing translationally controlled tumour proteins (TCPT), also called fortilins, were identified in the SSH libararies. Translationally controlled tumour proteins have been implicated in cell cycle progression, malignant transformation, anti-apoptotic activity and cell stress (Bommer and Thiele, 2004). In the banana prawn, *Penaeus merguiensis*, fortilin was suggested to be involved in early oocyte maturation and may be related to cell proliferation and differentiation (Loongyai et al., 2007). This protein also has binding ability to calcium, tubulin, myeloid cell leukaemia (MCL)-1 protein, elongation factor (EF)-1α (Bangrak et al., 2004; Bommer and Thiele, 2004; Loongyai et al., 2007) and some transcription factors (Chen et al., 2009). In *P. monodon*, TCTP was suggested to protect virally infected cells from dying, thus keeping the prawns healthy (Bangrak et al., 2004; Graidist et al., 2006). TCTP could also inhibit viral replication, thus decreasing the amount of viral infection (Tonganunt et al., 2008).

Additional transcripts related to immune factors found in the gill cDNA SSH libraries were chaperonin 10 and eukaryotic initiation factor (eIF) 4A. Chaperonin is a protein that plays an essential role in mediating folding of unfolded polypeptides such as newly translated, imported and stress-denatured proteins. The type of chaperonin determines the process of protein-folding activity. The protein-folding activity of chaperonin I is related to the interaction of chaperonin 60 and chaperonin 10 activities. The type I chaperonin can be found in the chloroplast, eubacteria and mitochondria. Type II chaperonin has only chaperonin 60 and can be found in *Archaebacteria* and eukaryotic cytosol (Levy-Rimler et al., 2002; Valpuesta et al., 2002). Chaperonin also plays an important role in cellular functions. For example, deletion of mitochondrial yeast and bacterial chaperonins can be lethal to both organisms. It is suggested that in humans hereditary spastic paraplegia spg 13 occurs due to mutation of mitochondrial chaperonin

60 (Levy-Rimler et al., 2002). Accumulation of toxic protein aggregating in systemic and neurological diseases of humans such as Parkinson's and Huntington's may be related to protein misfolding (Spiess et al., 2004). Chaperonin 10 was also implicated as growth and differentiation factors and may have immunosuppressive activity such as an anti-inflammatory activity (Dobocan et al., 2009).

A transcript similar to a matrix cellular protein, putative elastin A of *Rimicaris exoculata* was also identified in the gill cDNA library. In vertebrates, the presence of elastic fibres in the extracellular space of the connective tissue determines their resilience and maintains pressure related to liquid and air flow. This protein can be found abundantly in the skin, ligament, cartilage, lungs and vascular tissue (Duca et al., 2004; Foster, 2004; Muiznieks et al., 2010). Accordingly, the extracellular matrix content of various organs also determines the susceptibility of the organs to tumour progression. In an experimental tumour model, elastin has been implicated as a factor involved in inhibition of the metastatic processes (Lapis and Tímár, 2002). This protein also has the ability to induce motility signals in cancer cells (Lapis and Tímár, 2002). Despite their biological activities related to cancer, elastin peptides are also suggested to be involved in vasorelaxation, stimulation of leukocytes' oxidative burst, release of lysosomal enzyme, synthesis of endogenous cholesterol, modification of ion fluxes and inducing apoptosis (Duca et al., 2004).

In addition, a gene representing laminin receptor was also expressed in the SSH libraries. Laminin receptor is a protein with a molecular mass about 67kDa that has high affinity and specificity for laminin (Nelson et al., 2008). The binding of laminin protein to laminin receptor have been implicated in many biological activities such as cell adhesion, proliferation, differentiation and migration. This receptor has also binding ability to elastin and its degradation products (Fülöp and Larbi, 2002). Elastin-laminin receptor plays an important role in aging, atherosclerosis, extravasations, tumour invasion and metastasis (Fülöp and Larbi, 2002; Kunecki and Nawrocka, 2001). In addition, laminin receptor may contribute in bacterial and viral infection (Fülöp and Larbi, 2002; Senapin and Phongdara, 2006). In penaeid prawns, laminin receptor was observed to bind to viral protein (VP) of Taura syndrome virus (TSV), yellow head virus (YHV) and infectious myonecrosis virus (IMNV) (Busayarat et al., 2011; Senapin and Phongdara, 2006). Up-regulation of laminin receptor was found in WSSV-infected redclaw crayfish (Liu et al., 2011), suggesting this receptor has protective function against viral infections in decapod crustacea through binding to viral enveloped proteins that prevents viruses binding to target host cells (Busayarat et al., 2011; Liu et al., 2011).

An antioxidant enzyme, cytosolic manganese superoxide dismutase was detected in the library. This enzyme has been implicated in the immune response of crustacea. The principal function of SOD is to protect host cells against the cytotoxic effect of reactive oxygen species (ROS) produced during the activation of host NADPH-oxidase in the phagocytosis process (Li et al., 2010; Lin et al., 2010). Marchand et al. (2009) found that cMnSOD mRNA expression in hydrothermal crab species, *Bythograea thermydron* and *Segonzacia mesantlantica* was significantly higher than in coastal crab species, *Necora puber* and *Cancer pagurus*. These authors suggested that the environmental conditions of the hydrothermal vent might induce the cMnSOD expression in the crabs as an adaptive response to the higher exposure to oxidative stress compared to less exposure of littoral crabs.

Finally, within the group of genes related to immune factors, insulin growth factor binding protein (IGFBP) 7 was detected in the SSH library. The IGFBP is a family of secreted proteins that bind to insulin-like growth factor (IGF)-I and –II with high affinity and determines their biological activities (Clemmons, 1997). This protein is involved in IGFs transport, protects them from degradation, limits their binding to receptors and maintains a reservoir of biologically inactive IGFs (Castellanos et al., 2008). Insulin-like growth factor plays an important role in growth and differentiation of normal and malignant cells (Hwa et al., 1999; Navarro et al., 1999). The up regulation of IGFBP 7 in WSSV-infected crayfish suggests its involvement in anti-viral defence mechanism (Liu et al., 2011).

In spite of the SSH transcripts that were identified in this study, there was no sequence with homology to parvovirus genes or any other viral genes. Similar results were also found in previous studies when penaeid prawns and crayfish were experimentally infected with WSSV (James et al., 2010; Liu et al., 2011; Wang et al., 2006; Zeng and Lu, 2009; Zhao et al., 2007). In these studies WSSV genomes could not be profiled in the SHH libraries but differentially expressed genes were. However, in the other studies on penaeids experimentally infected with WSSV (García et al., 2009; Reyes et al., 2007) and YHV (Junkunlo et al., 2010; Prapavorarat et al., 2010) both host genes and viral genes were identified in the SSH libraries. These discrepancies may indicate the variability of the suppression subtractive hybridization method in profiling viral genomes in given samples. This is the first study attempting to profile the viral genome in presumptive naturally infected crustacea using the PCR-based cDNA subtraction method.

The absence of parvovirus genes from SSH libraries may be explained by the following reasons. Firstly, the concentration of viral genes in the tester cDNAs may have been too low to be expressed using the SSH technique. Secondly, the poly (A) tail on the mRNA of the parvovirus may be too short for this SSH technology to be successful. The complementary DNA synthetic primer of this protocol contains four poly (T) at the first 5′ end. Thus, the target gene should also have at least four or more poly (A)s in the tail in order to be amplified using this method. However, studies on parvovirus indicate that this may not be the case (Tattersall et al., 2008). Finally, the virus causing these lesions may not have any poly (A) tail, therefore it could not be expressed in the cDNA SSH libraries. Further studies are necessary to determine which hypothesis is more likely and uncover the cause of the hypertrophied nuclei with marginated chromatin in the gills of *C. quadricarinatus* from the hypertrophied nuclei population.

Despite the absence of viral gene detection and therefore a conclusion of an idiopathic aetiology, one should keep in mind that the health status of these two populations of redclaw crayfish was different; resulting in differentially expressed immune-related genes in the two populations, with some genes being up regulated in hypertrophied nuclei animals. These genes represented antimicrobial peptides, proteinase inhibitors, acute phase protein, insulin growth factor binding protein, protein folding, eukaryotic initiation factor and matrix cellular protein, which are all known to be involved in immune reactions. This study has provided an insight into the host-viral interaction at molecular level. It may contribute to the future research on crustacean immunity into establishing immune-intervention strategy to combat the devastating impact of viral diseases in order to maintain production of crustacean aquaculture.

Acknowledgment

The authors would like to thank Dr. Jennifer Elliman for reading the manuscript and offering valuable suggestions on bench work and Dr. Kathy La Fauce for technical suggestions. This work was partly supported by the Graduate Research Scheme (GRS) Grant 2011 Faculty of Medicine, Health and Biomolecular Sciences, James Cook University. Rusaini is an awardee of Australian Development Scholarship (ADS) Program from Australian Agency for International Development (AusAID).

References

Amparyup, P., Donpudsa, S. & Tassanakajon, A. (2008). "Shrimp Single WAP Domain (SWD)-Containing Protein Exhibits Proteinase Inhibitory and Antimicrobial Activities," *Developmental & Comparative Immunology*, 32 (12) 1497-1509.

Anderson, I. G. & Prior, H. C. (1992). "Baculovirus Infections in the Mud Crab, Scylla Serrata, and a Freshwater Crayfish, Cherax Quadricarinatus, from Australia," *Journal of Invertebrate Pathology*, 60 (3) 265-273.

Antony, S. P., Philip, R., Joseph, V. & Singh, I. S. B. (2011). "Anti-Lipopolysaccharide Factor and Crustin-III, the Anti-White Spot Virus Peptides in Penaeus Monodon: Control of

Viral Infection by Up-Regulation," *Aquaculture*, 319 (1-2) 11-17.

Bachali, S., Jager, M., Hassanin, A., Schoentgen, F., Jolles, P., Fiala-Medioni, A. & Deutsch, J. S. (2002). "Phylogenetic Analysis of Invertebrate Lysozyme and the Evolution of Lysozyme Activity," *Journal of Molecular Evolution*, 54 (5) 652-664.

Bangrak, P., Graidist, P., Chotigeat, W. & Phongdara, A. (2004). "Molecular Cloning and Expression of a Mammalian Homologue of a Translationally Controlled Tumor Protein (TCTP) Gene from Penaeus Monodon Shrimp," *Journal of Biotechnology*, 108 (3) 219-226.

Baumgartner, W. A., Hawke, J. P., Bowles, K., Varner, P. W. & Hasson, K. W. (2009). "Primary Diagnosis and Surveillance of White Spot Syndrome Virus in Wild and Farmed Crawfish (Procambarus Clarkii, P. Zonangulus) in Louisiana, USA," *Diseases of Aquatic Organisms*, 85 (1) 15-22.

Belevich, I., Gorbikova, E., Belevich, N. P., Rauhamäki, V., Wikström, M. & Verkhovsky, M. I. (2010). "Initiation of the Proton Pump of Cytochrome C Oxidase," *Proceeding of National Academy of Sciences*, 107 (43) 18469-18474.

Bell, T. A. & Lightner, D. V. (1988). A Handbook of Normal Penaeid Shrimp Histology, *World Aquaculture Society*, Baton Rouge, Louisiana, USA.

Bommer, U.- A. & Thiele, B.- J. (2004). "The Translationally Controlled Tumour Protein (TCTP)," *The International Journal of Biochemistry & Cell Biology*, 36 (3) 379-385.

Bowater, R. O., Wingfield, M., Fisk, A., Condon, K. M., Reid, A., Prior, H. & Kulpa, E. C. (2002). "A Parvo-Like Virus in Cultured Redclaw Crayfish Cherax Quadricarinatus from Queensland, Australia," *Diseases of Aquatic Organisms*, 50 (2) 79-86.

Burge, E. J., Madigan, D. J., Burnett, L. E. & Burnett, K. G. (2007). "Lysozyme Gene Expression by Hemocytes of Pacific White Shrimp, Litopenaeus Vannamei, after Injection with Vibrio," *Fish and Shellfish Immunology*, 22 (4) 327-339.

Busayarat, N., Senapin, S., Tonganunt, M., Phiwsaiya, K., Meemetta, W., Unajak, S., Jitrapakdee, S., Lo, C.- F. & Phongdara, A. (2011). "Shrimp Laminin Receptor Binds with Capsid Proteins of Two Additional Shrimp RNA Viruses YHV and IMNV," *Fish and Shellfish Immunology*, 31 (1) 66-72.

Castellanos, M., Jiménez-Vega, F. & Vargas-Albores, F. (2008). "Single IB Domain (SIBD) Protein from Litopenaeus Vannamei, a Novel Member for the IGFBP Family," *Comparative Biochemistry and Physiology* D, 3 (4) 270-274.

Chen, D., He, N., Lei, K. & Xu, X. (2009). "Genomic Organization of the Translationally Controlled Tumor Protein (TCTP) Gene from Shrimp Marsupenaeus Japonicus," *Molecular Biology Reports*, 36 (5) 1135-1140.

Clavero-Salas, A., Sotelo-Mundo, R. R., Gollas-Galván, T., Hernández-López, J., Peregrino-Uriarte, A. B., Muhlia-Almazán, A. & Yepiz-Plascencia, G. (2007). "Transcriptome Analysis of Gills from the White Shrimp Litopenaeus Vannamei Infected with White Spot Syndrome Virus," *Fish and Shellfish Immunology*, 23 (2) 459-472.

Clemmons, D. R. (1997). "Insulin-Like Growth Factor Binding Proteins and Their Role in Controlling IGF Actions," *Cytokine & Growth Factor Reviews*, 8 (1) 45-62.

Cray, C., Zaias, J. & Altman, N. H. (2009). "Acute Phase Response in Animals: A Review," *Comparative Medicine*, 59 (6) 517-526.

De la Vega, E., O'Leary, N. A., Shockey, J. E., Robalino, J., Payne, C., Browdy, C. L., Warr, G. W. & Gross, P. S. (2008). "Anti-Lipopolysaccharide Factor in Litopenaeus Vannamei (LvALF): A Broad Spectrum Antimicrobial Peptide Essential for Shrimp Immunity against Bacterial and Fungal Infection," *Molecular Immunology*, 45 (7) 1916-1925.

Dobocan, M. C., Sadvakassova, G. & Congote, L. F. (2009). "Chaperonin 10 as an Endothelial-Derived Differentiation Factor: Role of Glycogen Synthase Kinase-3," *Journal of Cellular Physiology*, 219 (2) 470-476.

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

Donpudsa, S., Ponprateep, S., Prapavorarat, A., Visetnan, S., Tassanakajon, A. & Rimphanitchayakit, V. (2010a). "A Kazal-Type Serine Proteinase Inhibitor SPIPm2 from the Black Tiger Shrimp Penaeus Monodon is Involved in Antiviral Responses," *Developmental & Comparative Immunology*, 34 (10) 1101-1108.

Donpudsa, S., Rimphanitchayakit, V., Tassanakajon, A., Söderhäll, I. & Söderhäll, K. (2010b). "Characterization of Two Crustin Antimicrobial Peptides from the Freshwater Crayfish Pacifastacus Leniusculus," *Journal of Invertebrate Pathology*, 104 (3) 234-238.

Donpudsa, S., Tassanakajon, A. & Rimphanitchayakit, V. (2009). "Domain Inhibitory and Bacteriostatic Activities of the Five-Domain Kazal-Type Serine Proteinase Inhibitor from Black Tiger Shrimp Penaeus Monodon," *Developmental & Comparative Immunology*, 33 (4) 481-488.

Duca, L., Floquet, N., Alix, A. J. P., Haye, B. & Debelle, L. (2004) "Elastin as a Matrikine," *Critical Reviews in Oncology/Hematology*, 49 (3) 235-244.

Edgerton, B. (1996). "A New Bacilliform Virus in Australian Cherax Destructor (Decapoda: Parastacidae) with Notes on Cherax Quadricarinatus Bacilliform Virus (= Cherax Baculovirus)," *Diseases of Aquatic Organisms*, 27 (1) 43-52.

Edgerton, B. F. (2004). "Susceptibility of the Australian Freshwater Crayfish Cherax Destructor Albidus to White Spot Syndrome Virus (WSSV)," *Diseases of Aquatic Organisms*, 59 (3) 187-193.

Edgerton, B. F., Evans, L. H., Stephens, F. J. & Overstreet, R. M. (2002). "Synopsis of Freshwater Crayfish Diseases and Commensal Organisms," *Aquaculture*, 206 (1-2) 57-135.

Edgerton, B. F. & Owens, L. (1999). "Histopathological Surveys of the Redclaw Freshwater Crayfish, Cherax Quadricarinatus, in Australia," *Aquaculture*, 180 (1-2) 23-40.

Edgerton, B. F., Webb, R., Anderson, I. G. & Kulpa, E. C. (2000). "Description of a Presumptive Hepatopancreatic Reovirus, and a Putative Gill Parvovirus, in the Freshwater Crayfish Cherax Quadricarinatus," *Diseases of Aquatic Organisms*, 41 (2) 83-90.

Edgerton, B. & Owens, L. (1997). "Age at First Infection of Cherax Quadricarinatus by Cherax Quadricarinatus Bacilliform Virus and Cherax Giardiavirus-Like Virus, and Production of Putative Virus-Free Crayfish," *Aquaculture*, 152 (1-4) 1-12.

Edgerton, B., Owens, L., Glasson, B. & De Beer, S. (1994). "Description of a Small dsRNA Virus from Freshwater Crayfish Cherax Quadricarinatus," *Diseases of Aquatic Organisms*, 18 63-69.

Edgerton, B., Webb, R. & Wingfield, M. (1997). "A Systemic Parvo-Like Virus in the Freshwater Crayfish Cherax Destructor," *Diseases of Aquatic Organisms*, 29 (1) 73-78.

Fenouil, E. & Roch, P. (1991). "Evidence and Characterization of Lysozyme in Six Species of Freshwater Crayfish from Astacidae and Cambaridae Families," *Comparative Biochemistry and Physiology* B, 99 (1) 43-49.

Foster, J. A. (2004). "Elastin," In J. L. William and M. D. Lane (Eds.), Encyclopedia of Biological Chemistry, *Elsevier*, New York, USA, pp. 10-12.

Freire, C. A., Onken, H. & McNamara, J. C. (2008). "A Structure-Function Analysis of Ion Transport in Crustacean Gills and Excretory Organs," *Comparative Biochemistry and Physiology* A, 151 (3) 272-304.

Fülöp, T. & Larbi, A. (2002). "Putative Role of 67 kDa Elastin-Laminin Receptor in Tumor Invasion," *Seminars in Cancer Biology*, 12 (3) 219-229.

García, J. C., Reyes, A., Salazar, M. & Granja, C. B. (2009). "Differential Gene Expression in White Spot Syndrome Virus (WSSV)-Infected Naïve and Previously Challenged Pacific White Shrimp Penaeus (Litopenaeus) Vannamei," *Aquaculture*, 289 (3-4) 253-258.

Graidist, P., Fujise, K., Wanna, W., Sritunyalucksana, K. & Phongdara, A. (2006). "Establishing a Role for Shrimp Fortilin in Preventing Cell Death," *Aquaculture*, 255 (1-4) 157-164.

Hayakijkosol, O. & Owens, L. (2011). "Investigation into the Pathogenicity of Reovirus to Juvenile Cherax Quadricarinatus," *Aquaculture*, 316 (1–4) 1-5.

He, N., Qin, Q. & Xu, X. (2005). "Differential Profile of Genes Expressed in Hemocytes of White Spot Syndrome Virus-Resistant Shrimp (Penaeus Japonicus) by Combining Suppression Subtractive Hybridization and Differential Hybridization," *Antiviral Research*, 66 (1) 39-45.

Hernández, G., Lalioti, V., Vandekerckhove, J., Sierra, J. M. & Santarén, J. F. (2004). "Identification and Characterization of the Expression of the Translation Initiation Factor 4A (eIF4A) from Drosophila Melanogaster," *Proteamics*, 4 (2) 316-326.

Hernández, G. & Vazquez-Pianzola, P. (2005). "Functional Diversity of the Eukaryotic Translation Initiation Factors Belonging to eIF4 Families," *Mechanisms of Development*, 122 (7-8) 865-876.

Hikima, S., Hikima, J.- I., Rojtinnakorn, J., Hirono, I. & Aoki, T. (2003). "Characterization and Function of Kuruma Shrimp Lysozyme Possessing Lytic Activity against Vibrio Species," *Gene*, 316, 187-195.

Hwa, V., Oh, Y. & Rosenfeld, R. G. (1999). "The Insulin-Like Growth Factor-Binding Protein (IGFBP) Superfamily," *Endocrine Reviews*, 20 (6) 761-787.

James, R., Thampuran, N., Lalitha, K. V., Rajan, L. A. & Joseph, T. C. (2010). "Differential Gene Expression Profile of the Hepatopancreas of White Spot Syndrome Virus Infected Fenneropenaeus Indicus by Suppression Subtractive Hybridization," *Fish and Shellfish Immunology*, 29 (5) 884-889.

Jankowsky, E. (2011). "RNA Helicases at Work: Binding and Rearranging," *Trends in Biochemical Sciences*, 36 (1) 19-29.

Jiravanichpaisal, P., Bangyeekhun, E., Soderhall, K. & Soderhall, I. (2001). "Experimental Infection of White Spot Syndrome Virus in Freshwater Crayfish Pacifastacus Leniusculus," *Diseases of Aquatic Organisms*, 47 (2) 151-157.

Jolles, P. & Jolles, J. (1984). "What's New in Lysozyme Research? Always a Model System, Today as Yesterday," *Molecular and Cellular Biochemistry*, 63 (2) 165-189.

Junkunlo, K., Barvornpinyo, S., Flegel, T. W. & Sritunyalucksana, K. (2010). "Characterization of Putative Immune Genes in Yellow Head Virus (YHV) Infected Shrimp (Penaeus Vannamei) by Suppression Subtractive Hybridization (SSH) Technique," *Proceeding of the 48th Kasetsart University Annual Conference, 3-5 March, 2010. Kasetsart University, Bangkok, Thailand*, p. unpaginated.

Kunecki, M. & Nawrocka, A. (2001). "Elastin–Laminin Receptor and Abdominal Aortic Aneurysms. New Subject to Study? A Review," *Pathologie Biologie*, 49(4), 333-338.

Lapis, K. & Tímár, J. (2002). "Role of Elastin-Matrix Interactions in Tumor Progression," *Seminars in Cancer Biology*, 12 (3) 209-217.

Levy-Rimler, G., Bell, R. E., Ben-Tal, N. & Azem, A. (2002). "Type I Chaperonins: Not All are Created Equal," *FEBS Letters*, 529 (1) 1-5.

Li, J., Chen, P., Liu, P., Gao, B., Wang, Q. & Li, J. (2010). "The Cytosolic Manganese Superoxide Dismutase cDNA in Swimming Crab Portunus Trituberculatus: Molecular Cloning, Characterization and Expression," *Aquaculture*, 309 (1-4) 31-37.

Lin, Y.- C., Lee, F.- F., Wu, C.- L. & Chen, J.- C. (2010). "Molecular Cloning and Characterization of a Cytosolic Manganese Superoxide Dismutase (cytMnSOD) and Mitochondrial Manganese Superoxide Dismutase (mtMnSOD) from the Kuruma Shrimp Marsupenaeus Japonicus," *Fish and Shellfish Immunology*, 28 (1) 143-150.

Liu, H., Jiravanichpaisal, P., Söderhäll, I., Cerenius, L. & Söderhäll, K. (2006). "Antilipopolysaccharide Factor Interferes with White Spot Syndrome Virus Replication in Vitro and in Vivo in the Crayfish Pacifastacus Leniusculus," *Journal of Virology*, 80 (21) 10365-10371.

Liu, H.- P., Chen, R.- Y., Zhang, Q.- X., Peng, H. & Wang, K.- J. (2011). "Differential Gene Expression Profile from Haematopoietic

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

Tissue Stem Cells of Red Claw Crayfish, Cherax Quadricarinatus, in Response to WSSV Infection," *Developmental & Comparative Immunology*, 35 (7) 716-724.

Li, X.- C., Wang, X.- W., Wang, Z.- H., Zhao, X.- F. & Wang, J.- X. (2009). "A Three-Domain Kazal-Type Serine Proteinase Inhibitor Exhibiting Domain Inhibitory and Bacteriostatic Activities from Freshwater Crayfish Procambarus Clarkii," *Developmental & Comparative Immunology*, 33 (12) 1229-1238.

Loongyai, W., Phongdara, A. & Chotigeat, W. (2007). "Cloning and Expression of a TCTP Homolog from the Ovaries of Banana Prawn," *Marine Biology*, 150 (3) 455-462.

Low, W.- K., Dang, Y., Bhat, S., Romo, D. & Liu, J. O. (2007). "Substrate-Dependent Targeting of Eukaryotic Translation Initiation Factor 4A by Pateamine A: Negation of Domain-Linker Regulation of Activity," *Chemistry & Biology*, 14 (6) 715-727.

Mai, W.- J. & Wang, W.- N. (2010). "Protection of Blue Shrimp (Litopenaeus Stylirostris) against the White Spot Syndrome Virus (WSSV) When Injected with Shrimp Lysozyme," *Fish and Shellfish Immunology*, 28 (4) 727-733.

Marchand, J., Leignel, V., Moreau, B. & Chénais, B. (2009). "Characterization and Sequence Analysis of Manganese Superoxide Dismutases from Brachyura (Crustacea: Decapoda): Hydrothermal Bythograeidae versus Littoral Crabs," *Comparative Biochemistry and Physiology* B, 153 (2) 191-199.

Muiznieks, L. D., Weiss, A. S. & Keeley, F. W. (2010). "Structural Disorder and Dynamics of Elastin," *Biochemistry and Cell Biology*, 88 (2) 239-250.

Navarro, I., Leibush, B., Moon, T. W., Plisetskaya, E. M., Baños, N., Méndez, E., Planas, J. V. & Gutiérrez, J. (1999). "Insulin, Insulin-Like Growth Factor-I (IGF-I) and Glucagon: The Evolution of their Receptors," *Comparative Biochemistry and Physiology* B, 122 (2) 137-153.

Nelson, J., McFerran, N. V., Pivato, G., Chambers, E., Doherty, C., Steele, D. & Timson, D. J. (2008). "The 67 kDa laminin Receptor: Structure, Function and Role in Disease," *Bioscience Reports*, 28 (1) 33-48.

Owens, L. (2011). "The Viral Ecology of Aquatic Crustaceans", In C. J. Hurst (Ed.), Studies in Viral Ecology (Vol. 2), *Wiley & Sons*, New York, USA, pp. 175-187.

Owens, L. & McElnea, C. (2000). "Natural Infection of the Redclaw Crayfish Cherax Quadricarinatus with Presumptive Spawner-Isolated Mortality Virus," *Diseases of Aquatic Organisms*, 40 (3) 219-223.

Pan, D., He, N., Yang, Z., Liu, H. & Xu, X. (2005). "Differential Gene Expression Profile in Hepatopancreas of WSSV-Resistant Shrimp (Penaeus Japonicus) by Suppression Subtractive Hybridization," *Developmental & Comparative Immunology*, 29 (2) 103-112.

Prapavorarat, A., Pongsomboon, S. & Tassanakajon, A. (2010). "Identification of Genes Expressed in Response to Yellow Head Virus Infection in the Black Tiger Shrimp, Penaeus Monodon, by Suppression Subtractive Hybridization," *Developmental & Comparative Immunology*, 34 (6) 611-617.

Reyes, A., Salazar, M. & Granja, C. (2007). "Temperature Modifies Gene Expression in Subcuticular Epithelial Cells of White Spot Syndrome Virus-Infected Litopenaeus Vannamei," *Developmental & Comparative Immunology*, 31 (1) 23-29.

Santiago-Cardona, P. G., Berríos, C. A., Ramírez, F. & García-Arrarás, J. E. (2003). "Lipopolysaccharides Induce Intestinal Serum Amyloid A Expression in the Sea Cucumber Holothuria Glaberrima," *Developmental & Comparative Immunology*, 27 (2) 105-110.

Senapin, S. & Phongdara, A. (2006). "Binding of Shrimp Cellular Proteins to Taura Syndrome Viral Capsid Proteins VP1, VP2 and VP3," *Virus Research*, 122 (1-2) 69-77.

Somboonwiwat, K., Bachère, E., Rimphanitchayakit, V. & Tassanakajon, A. (2008). "Localization of Anti-Lipopolysaccharide Factor (ALFPm3) in Tissues of the Black Tiger Shrimp, Penaeus

Monodon, and Characterization of its Binding Properties," *Developmental & Comparative Immunology*, 32 (10) 1170-1176.

Spiess, C., Meyer, A. S., Reissmann, S. & Frydman, J. (2004). "Mechanism of the Eukaryotic Chaperonin: Protein Folding in the Chamber of Secrets," *Trends in Cell Biology*, 14 (11) 598-604.

Sun, C., Xu, W.- T., Zhang, H.- W., Dong, L.- P., Zhang, T., Zhao, X.- F. & Wang, J.- X. (2011). "An Anti-Lipopolysaccharide Factor from Red Swamp Crayfish, Procambarus Clarkii, Exhibited Antimicrobial Activities in Vitro and in Vivo," *Fish and Shellfish Immunology*, 30 (1) 295-303.

Surakasi, V. P. & Kim, Y. (2010). "Cloning and Expression Pattern of Eukaryotic Translation Initiation Factor 4A of the Diamondback Moth, Plutella Xylostella," *Journal of Asia-Pacific Entomology*, 13 (4) 297-301.

Tattersall, P., Mahy, B. W. J. & Regenmortel, M. H. V. V. (2008). "Parvoviruses: General Features," *Encyclopedia of Virology, Academic Press, Oxford*, pp. 90-97.

Tonganunt, M., Nupan, B., Saengsakda, M., Suklour, S., Wanna, W., Senapin, S., Chotigeat, W. & Phongdara, A. (2008). "The Role of Pm-Fortilin in Protecting Shrimp from White Spot Syndrome Virus (WSSV) Infection," *Fish and Shellfish Immunol*, 25 (5) 633-637.

Valpuesta, J. M., MartIn-Benito, J., Gómez-Puertas, P., Carrascosa, J. L. & Willison, K. R. (2002). "Structure and Function of a Protein Folding Machine: The Eukaryotic Cytosolic Chaperonin CCT," *FEBS Letters*, 529 (1) 11-16.

Wagner, K., Rehling, P., Sanjuán Szklarz, L. K., Taylor, R. D., Pfanner, N. & van der Laan, M. (2009). "Mitochondrial F1Fo-ATP Synthase: The Small Subunits e and G Associate with Monomeric Complexes to Trigger Dimerization," *Journal of Molecular Biology*, 392 (4) 855-861.

Wang, B., Li, F., Dong, B., Zhang, X., Zhang, C. & Xiang, J. (2006). "Discovery of the Genes in Response to white Spot Syndrome Virus (WSSV) Infection in Fenneropenaeus Chinensis through cDNA Microarray," *Marine Biotechnology*, 8 (5) 491-500.

Yao, C.- L., Wu, C.- G., Xiang, J.- H., Li, F., Wang, Z.- Y. & Han, X. (2008). "The Lysosome and Lysozyme Response in Chinese Shrimp Fenneropenaeus Chinensis to Vibrio Anguillarum and Laminarin Stimulation," *Journal of Experimental Marine Biology and Ecology*, 363 (1-2) 124-129.

Yedery, R. D. & Reddy, K. V. R. (2009). "Identification, Cloning, Characterization and Recombinant Expression of an Anti-Lipopolysaccharide Factor from the Hemocytes of Indian Mud Crab, Scylla Serrata," *Fish and Shellfish Immunology*, 27 (2) 275-284.

Yeh, M.- S., Huang, C.- J., Cheng, J.- H. & Tsai, I.- H. (2007). "Tissue-Specific Expression and Regulation of the Haemolymph Clottable Protein of Tiger Shrimp (Penaeus Monodon)," *Fish and Shellfish Immunology*, 23 (2) 272-279.

Zeng, Y. & Lu, C.- P. (2009). "Identification of Differentially Expressed Genes in Haemocytes of the Crayfish (Procambarus Clarkii) Infected with White Spot Syndrome Virus by Suppression Subtractive Hybridization and cDNA Microarrays," *Fish and Shellfish Immunology*, 26 (4) 646-650.

Zhao, Z.- Y., Yin, Z.- X., Weng, S.- P., Guan, H.- J., Li, S.- D., Xing, K., Chan, S.- M. & He, J.- G. (2007). "Profiling of Differentially Expressed Genes in Hepatopancreas of White Spot Syndrome Virus-Resistant Shrimp (Litopenaeus Vannamei) by Suppression Subtractive Hybridisation," *Fish and Shellfish Immunology*, 22 (5) 520-534.

Rusaini, Ellen Ariel, Graham W. Burgess and Leigh Owens (2013), Journal of Virology & Microbiology, DOI: 10.5171/2013. 569032

Appendix 4.3.Rusaini, La Fauce, K.A., Elliman, J., Bowater, R.O. and Owens, L. (2013) Endogenous Brevidensovirus-like elements in *Cherax quadricarinatus*: Friend or foe? *Aquaculture***396-399**: 136-145.

THIS ARTICLE HAS BEEN REMOVED DUE
TO COPYRIGHT RESTRICTIONS

Appendix 5. Presentations and workshops during PhD candidature

Appendix 5. 1. Presentations

Rusaini and L. Owens. Moulting and lunar rhythms on the lymphoid organ spheroid (LOS) cells of the black tiger prawn (*Penaeus monodon*). ***4th FRDC Aquatic Animal Health Subprogram Scientific Conference,*** The Rydges Esplanade Resort, Cairns, QLD, Australia, 22-24 July 2009.

Rusaini, E. Ariel, G.W. Burgess and L. Owens. Suppression subtractive hybridization for genes expressed in redclaw crayfish *Cherax quadricarinatus* with an idiopathic lesion. ***1st FRDC Australasian Aquatic Animal Health Scientific Conference,*** Pullman Reef Hotel, Cairns, QLD, Australia, 5-8 July 2011.

Rusaini and L. Owens. Profiling expressed genes in the lymphoid organ of Australian banana prawn (*Penaeus merguiensis*) using suppression subtractive hybridization. ***8th Symposium on Diseases in Asian Aquaculture***, Milagres Hall, Mangalore, Karnataka, India, 21-25 November 2011.

Rusaini, K. A. La Fauce, J. Elliman, R. O. Bowater and L. Owens. Endogenous Brevidensovirus-like elements in *Cherax quadricarinatus*: Friend or foe***? North Queensland Festival of Life Science***, Faculty of Medicine, Health, and Molecular Sciences, James Cook University, 30 October 2012.

Rusaini, K. A. La Fauce, J. Elliman, R. O. Bowater and L. Owens.Endogenous virus-like elements in redclaw crayfish *Cherax quadricarinatus*.***2nd FRDC Australasian Aquatic Animal Health Scientific Conference,*** Pullman Reef Hotel, Cairns, QLD, Australia, 8-12 July 2013.

Appendix 5.2. Workshops

AusAID Introductory Academic Program, 19th January – 13th February 2009, Teaching & Learning Development, James Cook University, Townsville, northern Queensland, Australia.

Biosafety Course, February 18, 2010, James Cook University, Townsville, northern Queensland, Australia.

Aquatic Animal Health Technicians Forum Workshop Wednesday 17th to Friday 19th March 2010, Aquatic Animal Health Laboratory (AAHL) CSIRO, Geelong, Victoria, Australia.

Appendix 6. Animal ethics approvalfor the research project of PhD candidature.

JAMES COOK UNIVERSITY AUSTRALIA