JAMES COOK UNIVERSITY
SINGAPORE

Aquaculture at James Cook University in Singapore

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1 university • 2 countries • 3 tropical locations
Creating a brighter future for life in the tropics world-wide through graduates and discoveries that make a difference.

Aquaculture at James Cook University in Singapore

Tropical regions of the world face unprecedented challenges due to population growth and an associated demand for high-quality seafood. This population expansion will continue to pressure wild fisheries resources and dictate ever higher efficiencies from aquaculture production.

Capitalising on its location right in the middle of Asia, James Cook University in Singapore has research expertise that specialises in the sustainable production of tropical aquaculture species. With world-class experts in aquaculture genetics, nutrition, hatchery production, husbandry and aquatic animal health, researchers are ready to partner with commercial industry, government institutions, universities, polytechnics and other stakeholders, to conduct high-quality scientific R&D.

For further information on how to work with James Cook University in Singapore please send an email to researchsupport-singapore@jcu.edu.au

Profile

Prof Dean Jerry

Director ARC Research Hub for Advanced Prawn Breeding
Deputy Director Centre for Sustainable Tropical Fisheries and Aquaculture
Dean of Research
James Cook University (Singapore)

PhD (Animal Genetics) Southern Cross University, Australia
BSc (Hons) University of New England, Australia

Background

Prof Jerry is a recognised leader in the application of genetic and genomic solutions for the aquaculture industry and leads one of the largest research teams globally devoted specifically to the application of genetic technologies to improve the productivity of aquaculture species. He has worked in the field of aquaculture genetics for 20 years and managed as Chief Investigator 30+ projects (valued at ~$24M). He has published 130 peer reviewed scientific articles and served on the editorial boards of Aquaculture Environment Interactions, Agri-Gene and Gene. He has also supervised nearly 100 research students.

Prof Jerry possesses strong skill sets in quantitative genetics, along with molecular and genomic analyses. These skill sets have resulted in numerous translations of his research and direct industry consultancies from conducting genetic audits of foundation stocks, establishment of commercial genotyping and pathogen testing laboratories, through to the design and conduct of industrial-scale advanced genomic-informed selection programs. He has worked with the genetics of most of the major tropical aquaculture industries, including marine shrimp (*Litopenaeus vannamei, Penaeus monodon, Penaeus japonicus*), pearl oysters (*Pinctada maxima, Pinctada margaritifera*), barramundi (*Lates calcarifer*), Nile tilapia (*Oreochromis niloticus*), marine and freshwater crayfish (*Panulirus ornatus, P. homarus, Cherax quadricarintus, C. destructor*), and several other species.

Areas of expertise

- Design and implementation of advanced aquaculture selective breeding programs
- Development of genetic and genomic tools to assist selective breeding
- Genomic selection of aquaculture species
- Genetic audit of aquaculture breeding populations
- Epigenetics and microbiomes
- Sustainable aquaculture
- Professional development of researcher and industry capabilities

Impact of research

- Development of DNA parentage microsatellite and SNP marker suites for seven tropical aquaculture species. These marker suites are routinely applied to conduct genetic audits for industry, determine performance of families under commercial evaluation, and as a tool in advanced selective breeding programs
- Provided an understanding of the genetic basis of commercial traits for important aquaculture species. With this information selective breeding programs can be designed based on solid genetic parameters resulting in maximisation of genetic gains
- Enabled the capability of numerous companies to instigate selective breeding programs based on a sound understanding of the genetic basis of traits and the ability to incorporate genomic information to improve accuracy of selection
- Increased understanding of the role epigenetics and microbiomes have in the expression of phenotypic traits in aquaculture species
- Assembly of the first comprehensive genomes and transcriptomes for barramundi, the black tiger shrimp, and pearl oyster
- Commercialisation of an Illumina Infinium SNP array for the Pacific White tailed shrimp

Top five publications

- Jones D.B., Jerry D.R., Khatkar M.S., Raadsma H.W., van der Steen H., Prochaska J., Forêt S., and Zenger K.R. (2017). A comparative integrated gene-based linkage and locus ordering by linkage disequilibrium map for the Pacific white shrimp, *Litopenaeus vannamei*. Nature Scientific Reports 7, 10630. doi:10.1038/s41598-017-10515-7
- Budd, A.M., Banh, Q., Domingos, J., and Jerry, D.R. (2015). Sex control in fish: approaches, challenges and opportunities for aquaculture. Journal of Marine Science and Engineering 3(2), 329-355.
- De Santis, C and Jerry, D.R. (2007). Candidate growth genes in finfish – where should we be looking? Aquaculture 272, 22-38
- Jones DB, Jerry DR, Khatkar MS, Moser G, Raadsma HW, Taylor JJ, Zenger KR. (2014). Determining genetic contributions to host oyster shell growth: Quantitative trait loci and genetic association analysis for the silver-lipped pearl oyster, *Pinctada maxima*. Aquaculture, 434, 367-375.
- Domingos, J.A., Smith-Keune, C. and Jerry, D.R. (2014). Early prediction of long-term family growth performance based on cellular processes - a tool to expedite the establishment of superior foundation broodstock in breeding programs. Aquaculture 428-429, 88-96.

Associate Prof Jennifer Cobcroft

Associate Professor, Aquaculture
James Cook University (Singapore)

PhD (Aquaculture) University of Tasmania, Australia
BAppSci (Hons) (Aquaculture) University of Tasmania, Australia
BSc (Major in Zoology) University of New England, Australia

Background

Associate Professor Jennifer Cobcroft has over 20 years experience in aquaculture, largely focussed on solving challenges in the hatchery production of marine fish species. Her research has spanned larval visual development, tank environmental conditions to optimise feeding, water treatment systems to reduce parasites and pathogens in the hatchery, and finding solutions to skeletal deformities that impact commercially cultured fish. The species studied include yellowtail kingfish, southern bluefin tuna, barramundi (Asian seabass), grouper and Atlantic salmon.

Jennifer attained a PhD in aquaculture from the University of Tasmania. She was a research scientist at the Institute for Marine and Antarctic Studies, University of Tasmania, until June 2015. She was leader of the Aquaculture Production Innovation Hub for the Australian Seafood CRC, and managed a large research and development program for hatchery production of southern bluefin tuna fingerlings in close association with industry. In 2015–17, she consulted in the strategic planning of emerging aquaculture research opportunities in Australia, marine fish hatchery trouble-shooting (Australia, New Zealand, USA and Mexico), and in aquaculture development in eastern Africa (Tanzania and Kenya) and in South East Asia (Vietnam, Indonesia, Myanmar and Singapore). She is the current Secretary of the World Aquaculture Society (WAS; 2016–18), and a former Board member of the Asian Pacific Chapter of WAS. In January 2017, she commenced as Associate Professor Aquaculture at James Cook University in Singapore.

Her emphasis on industry-driven research is evidenced in over AUD$4M in project funding. She publishes in international peer-reviewed journals, has co-authored 15 reports, including nine final reports, a water quality guide and a deformity classification guide for industry. Jennifer actively engages in sharing research results and novel technologies with students, industry, and scientists through workshops and practical training. She is passionate about doing research and equipping students that together contribute to the sustainable and profitable growth of the aquaculture industry.

Areas of expertise

- Hatchery production of marine fish
- Seawater treatment systems with ozone and UV to manage microbial communities and prevent parasite infection
- Live feed enrichment to enhance larval survival, growth and quality
- Larviculture tank environment to improve juvenile quality
- Development of the skeleton and sensory structures in fish
- Assessment of larvae and juveniles for skeletal abnormalities as a tool to improve hatchery production efficiency
- Strategic R&D planning for new and emerging species in aquaculture

Impact of research

- Significant reduction in jaw malformation in striped trumpeter through refined larval rearing methods, addressing a 15-year bottleneck. This was the first research to demonstrate mechanical interactions linked with skeletal deformity in finfish. This research paved the way for commercial farms to reduce jaw deformity in yellowtail kingfish and end the requirement for hand-sorting, with substantial economic benefit. In addition, the research is being applied with barramundi in Australia, and in difficult-to-rear marine fish larvae internationally, specifically *Seriola* sp. and tunas. The approach used to understand jaw deformity in hatchery-produced marine fish was adopted in Japan.
- Ultraviolet light treatment of seawater to prevent parasite infection (*Kudoa sp.*) in cultured juvenile finfish, with adoption of the research findings and approaches in Japan with tuna and *Seriola* sp., and in commercial applications in Korea with flatfish.
- Improved understanding of visual ability and requirements of southern bluefin tuna larvae, with application to improve culture of tuna species internationally (Japan, Panama, and Mediterranean).

Top five publications

- Hilder P, Cobcroft J and Battaglene S (2017) Factors affecting the feeding response of larval southern bluefin tuna, *Thunnus maccoyii* (Castelnau, 1872). Aquaculture Research, 48 (6), 2752-2766.
- Amoroso G, Ventura T, Cobcroft J, Adams M, Elizur A and Carter C (2016) Multigenic delineation of lower jaw deformity in triploid Atlantic salmon (*Salmo salar* L.). PLoS ONE, 11 (12), 1-21.
- Cobcroft J and Battaglene S (2013) Ultraviolet irradiation is an effective alternative to ozonation as a sea water treatment to prevent *Kudoa neurophila* (Myxozoa: Myxosporea) infection of striped trumpeter, *Latris lineata* (Forster). Journal of Fish Diseases, 36 (1), 57-65.
- Cobcroft J and Battaglene S (2013) Skeletal malformations in Australian marine finfish hatcheries. Aquaculture, 396, 51-58.
- Cobcroft, J.M., and Battaglene, S.C. (2009) Jaw malformation in striped trumpeter *Latris lineata* larvae linked to walling behaviour and tank colour. Aquaculture, 289 (3-4), 274-282.

Dr Jose Domingos

Senior Research Fellow
James Cook University (Singapore)

PhD (Aquaculture Genetics) James Cook University, Australia
MSc (Aquaculture) Federal University of Santa Catarina, Brazil
BSc (Oceanography) Federal University of Rio Grande, Brazil

Background

Dr Jose Domingos' research focuses on the development of efficient breeding programs for tropical aquaculture species. This involves the understanding and manipulation of endogenous and environmental factors affecting gonadal development and broodstock conditioning within appropriate maturation systems for reliable spawnings. Jose is passionate about marine finfish propagation (reproduction, genomics, selective breeding) and its integration with nutrition and fish health for the development of fast growing and disease resistant strains. Fingerlings of high quality and better genetics will improve farm productivity and allow aquaculture business in the tropics to achieve profitability and sustainability to feed our growing population.

Dr Domingos has a long involvement with commercial shrimp and marine finfish operations. Prior to joining the James Cook University (Australia) Aquaculture Genetics research team in 2008, Jose worked as a production manager for several shrimp farms in the South and Northeast of Brazil, where he supervised over 700 hectares of shrimp farming. Trained in Brazil (Oceanography, FURG; MSc. Aquaculture, UFSC) and Australia (PhD Aquaculture Genetics, JCU), Jose has 20 years of combined industry, government and academic background. As a new member of the James Cook University in Singapore Aquaculture Research team, Jose is excited about collaborating with industry partners in the development and use of genetically superior broodstock within reliable breeding and hatchery facilities, and in the training of students through hands-on experiences and discoveries that make a difference for life in the tropics.

Areas of expertise

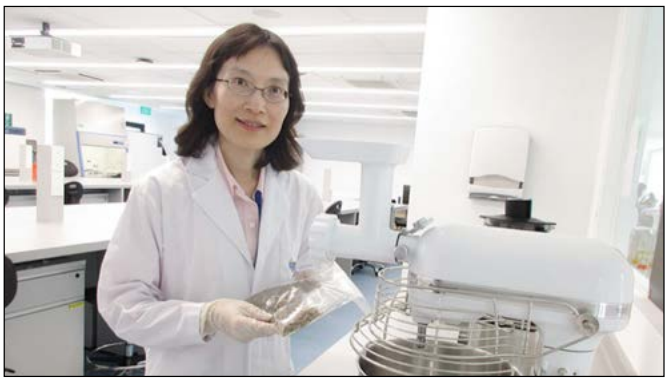
- Aquaculture applied breeding and genetics
- Quantitative genetics and genomics for selective breeding programs
- Development and application of genomic tools to boost seafood production
- Marine finfish broodstock systems and management
- Integrated shrimp farm management

Impact of research

- Identification of molecular and cellular larval traits which are highly correlated with fish weight at harvest. This allows for the estimation of broodstock breeding values (EBV) based on their offspring performance at 18 days post hatch, and enables the ranking of existing broodstock based on their genetic merit for growth. Through this technique, fish hatcheries can spawn their superior brooders and immediately improve farm productivity by avoiding costs associated with rearing of slow-growing families.
- Estimation of heritability and genotype by environment interactions of harvest growth traits, and the fate of genetic diversity within and between generations in Asian seabass, essential information for the implementation of effective selective breeding programs for the species.
- Identification of sex-specific epigenetic differences and alternatively spliced isoforms of dmrt1 and cyp19a1 genes in the protandrous hermaphrodite Asian seabass. This contribution to our understanding of the sex-determination mechanisms is the first step for improved sex-control strategies in Asian seabass broodstock populations.
- Demonstration, through the use of robust animal models traditionally used in animal breeding, of a high potential for adaptation in fitness-related traits of a coral reef fish acclimated to higher temperatures, which could enable reef fish populations to maintain their performance as ocean temperatures rise.

Top five publications

- Domingos JA, Smith-Keune C, Harrison P, Jerry DR (2014) Early prediction of long-term family growth performance based on cellular processes – a tool to expedite the establishment of superior foundation broodstock in breeding programs. Aquaculture 428- 429, 88-96.
- Domingos JA, Smith-Keune C, Robinson N, Loughnan S, Harrison P, Jerry DR (2013) Heritability of harvest growth traits and genotype-environment interactions in barramundi, *Lates calcarifer* (Block). Aquaculture, 402-403: 66-75.
- Domingos JA, Zenger, KR, Jerry DR (2015) Whole-genome shotgun sequence assembly enables rapid gene characterization in the tropical fish barramundi, *Lates calcarifer*. Animal Genetics, 46, 468-469.
- Munday PL, Donelson JM, Domingos JA (2017) Potential for adaptation to climate change in a coral reef fish. Global Change Biology, 23 (1), 307-317.
- Budd A, Banh Q, Domingos JA, Jerry DR (2015) Sex control in fish: approaches, challenges and opportunities for aquaculture. Journal of Marine Science and Engineering 3, 329-355.



Dr Katheline Hua

Senior Research Fellow
James Cook University (Singapore)

PhD University of Guelph, Canada
MSc University of Guelph, Canada

Background

Dr. Katheline Hua specializes in the field of aquaculture nutrition. She has more than 16 years of experience in working with both tropical and coldwater fish species.

Dr. Hua holds a PhD in Fish Nutrition from the University of Guelph, Canada. She worked at the University of Guelph as a Post-doctoral fellow and Adjunct Professor where she conducted research on coldwater fish. Afterwards she worked as a Junior Professor at the Humboldt University of Berlin, Germany where she led the aquaculture nutrition research group. She joined James Cook University in Singapore in 2018.

Dr. Hua's primary research interest is to develop cost-effective aquaculture feeds to promote growth and nutrient utilization of fish and crustaceans. Her research program encompasses basic and applied research topics in aquaculture nutrition. One of her expertise areas is nutritional modelling, exploring the synergy of empirical and modelling approaches to integrate and synthesize information related to optimum aquaculture diets.

Areas of expertise

- Feed formulations
- Ingredient evaluation
- Macronutrients and feed additives
- Nutrient requirement and utilization of fish
- Nutritional modeling

Impact of research

- Developed a series of nutrient digestibility models that represent significant progress from the conventional experimental approach to estimate digestibility values of lipid, starch and phosphorus. The models are being used as feed formulation tools by academic researchers and feed producers.
- Developed a model simulation-based approach that achieves broader and more flexible evaluations of nutritive values of feed ingredients than conducting individual feeding trials. This approach allows not only proper quantifications of the effect of alternative ingredients, but also simulations of growth and nutrient utilization.
- Elucidated the appropriate mode of expressing essential amino acids requirement, a fundamental issue in fish nutrition research, which contributes to a better understanding of underlying dietary factors that affect amino acid requirements of fish.

Research Projects:

- Refinement of methodologies in evaluating nutritive values of fish feed ingredients and development of mechanistic models to estimate nutrient digestibility
- Investigation of nutritive values of alternative raw materials for aquaculture species
- Investigation of strain effects on nutrient requirement and utilization in Nile tilapia
- Nutrient requirement of Striped snakehead *Channa striatus* and development of low fish meal feed formulation for aquaculture of Striped snakehead *Channa striatus*
- Comparison of bioavailability of different sources of Lysine nutrition in Nile tilapia
- Comparison of Lysine utilization efficiency by Nile tilapia at different fish sizes
- Nutritional modelling of amino acids nutrition in fish: estimating amino acids requirements through nonlinear mixed models and multilevel models
- Quantification of the effects of plant protein ingredients in fish feeds using meta-analysis and nutritional model simulation-based approaches
- Development of lipid and starch digestibility models for fish

Top five publications

- Hua, K. 2013. Investigating the appropriate mode of expressing lysine requirement of fish through non-linear mixed model analysis and multilevel analysis. British Journal of Nutrition 109, 1013–102.
- Hua, K. 2013. Estimating maintenance essential amino acids requirements of fish through a nonlinear mixed modeling approach. Aquaculture Research 44, 542–553.
- Hua, K. and D.P. Bureau. 2012. Exploring the possibility of quantifying the effects of plant protein ingredients in fish feeds using meta-analysis and nutritional model simulation-based approaches. Aquaculture 356-357, 284-301.
- Hua, K. and D.P. Bureau. 2009. Development of a model to estimate digestible lipid content of salmonid fish feeds. Aquaculture 286: 271-276.
- Hua, K. and D.P. Bureau. 2006. Modelling digestible phosphorus content of salmonid fish feeds. Aquaculture 254: 455-465.

Dr Neil Hutchinson

Senior Lecturer
James Cook University (Singapore)

PhD (Marine Biology) The University of Hong Kong, Hong Kong SAR
BSc (Hons) (Environmental Biology) Sunderland University, UK

Background

Dr Neil Hutchinson has worked as a marine ecologist for over 18 years, predominantly in the Asia-Pacific region. He has experience in a diverse range of fisheries related projects examining environmental impacts such as climate change and habitat destruction, and developing understanding of how they affect fisheries and aquaculture species. His research has traversed a variety of taxonomic groups including fish, invertebrates and algae, examining the processes governing their natural distribution patterns and abundance.

Neil has a PhD in marine ecology from The University of Hong Kong and prior to joining James Cook University in Singapore in 2012, was a fisheries research scientist at Fisheries Victoria, Australia. While there he worked on government and industry funded projects examining the impacts of coastal development on key fisheries habitat and the development of tools to assess the sensitivity of commercially important fisheries and aquaculture species to climate change. His current research on coastal fisheries encompasses at risk species, such as elasmobranchs, and the provision of ecosystem services by urban habitats. This builds on past projects on the ecology and behaviour of predatory fish at the Marine Biological Association of the UK, Kyushu University in Japan and in The Federated States of Micronesia. Additionally, through his research and consultancy on intertidal ecosystems in Hong Kong and Japan, Neil has developed an extensive suite of skills relevant to assessing human impacts on marine ecosystems. He leads the Environmental Science teaching program at James Cook University in Singapore.

Impact of research

- Advanced understanding of the relative importance of seagrass beds as key fishery habitat in temperate Australia. This research had implications in relation to management of coastal development.
- Developed assessment tools to aid the understanding of climate change sensitivity of fisheries and aquaculture species.
- Identified non-breeding habitat and home ranges of grouper in Micronesia, providing information relevant to management of a locally important fisheries species.

Areas of expertise

- Movement and behavioural ecology of marine fish and invertebrates utilizing underwater video systems and acoustic telemetry
- Environmental impact assessment
- Climate change mitigation
- Ecosystem services
- Intertidal community ecology
- Predator-prey interactions

Top five publications

- Benzeev R, Hutchinson N and Friess D (2017) Quantifying fisheries ecosystem services of mangroves and tropical artificial urban shorelines. Hydrobiologia, 803 (1), 225-237
- Hutchinson N, Jenkins G, Brown A and Smith T (2014) Variation with depth in temperate seagrass-associated fish assemblages in Southern Victoria, Australia. Estuaries and Coasts, 37 (4), 801-814
- Pecl G, Ward T, Doubleday Z, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday A, Hutchinson N, Jennings S, Jones K, Li X, Spooner D and Stoklosa R (2014) Rapid assessment of fisheries species sensitivity to climate change. Climatic Change, 127 (3), 505-520
- Doubleday Z, Clarke S, Li X, Pecl G, Ward T, Battaglene S, Frusher S, Gibbs P, Hobday A, Hutchinson N, Jennings S and Stoklosa R (2013) Assessing the risk of climate change to aquaculture: a case study from south-east Australia. Aquaculture Environment Interactions , 3 (2), 163-175
- Hutchinson N and Rhodes K (2010) Home range estimates for squaretail coralgrouper, *Plectropomus areolatus* (Rüppell 1830). Coral Reefs, 29 (2), 511-519

Dr Giana Gomes

Lecturer Aquaculture
James Cook University (Singapore)

PhD (Aquatic Animal Health) James Cook University, Australia
MVM Federal Rural de Pernambuco University, Brazil
BVM Federal Rural de Pernambuco University, Brazil

Background

Dr Gomes is an aquaculture veterinarian researcher with 14 years of experience in aquatic animal health acquired across a range of academic, governmental and industry employment in Brazil and Australia. Giana's research has a strong focus on the development and adoption of new technologies to improve disease prevention, management and biosecurity in aquaculture. Giana joined James Cook University in Singapore as a lecturer in aquaculture in 2018. Currently, Giana's R&D focus is on early identification of disease within aquaculture farms using environmental DNA (eDNA) techniques and water quality monitoring (environmental sensing) associated with microbiome investigation.

Giana worked for the largest Brazilian prawn hatchery (Aquatec, 2003-2008) and Genearch Aquacultura Ltd (first SPF – specific pathogen free – prawn hatchery from Brazil) responsible for developing and implementing biosecurity measurements and establishing biosecurity protocols and procedures for the import of SPF prawns from the U.S.A. to Brazil, respectively. Giana undertook her MSc in veterinary medicine (2006-2008) on prawn diseases caused by an intracellular bacteria (NHPB) which causes similar symptoms to the emerging prawn disease Acute Hepatopancreatic Necrosis Syndrome (AHPNS), also known as Early Mortality Syndrome (EMS). Later in Australia, Giana developed an on-farm parasite detection assay for early quantification of parasite abundance to predict infection before animals become sick. In 2016 Giana was awarded the Minister of Agriculture and Water Resources Science and Innovation Award which recognises the best emerging young talent in rural Australian industries.

Areas of expertise

- Molecular diagnostics of multiple aquaculture species
- Microbiology of aquatic species
- Histopathology of aquatic animals
- Aquaculture parasitology
- Biosecurity – prevention and control of aquatic animal diseases
- Marine/freshwater finfish health management
- Shrimp hatchery and health management

Impact of research

- Demystified the use of wet-mount as a reliable technique for the detection of necrotizing hepatopancreatitis (NHPB) a serious disease for farmed shrimp in the Americas. Giana demonstrated that neither wet mount examination nor histopathology techniques can be used alone without confirmatory PCR to diagnose NHPB;
- Improved the response capability of farmers to disease risk in Australia by developing environmental DNA (eDNA) protocols to detect parasites in fish farms early, before animals get infected;
- Demonstrated the potential of using environmental DNA (eDNA) associated with water quality and production data from aquaculture systems as a prediction tool of fish mortalities and parasite outbreaks.

Top five publications

- Bastos Gomes G, Hutson K, Domingos J, Chung C, Hayward S, Miller T and Jerry D (2017) Use of environmental DNA (eDNA) and water quality data to predict protozoan parasites outbreaks in fish farms. Aquaculture, 479, 467-473;
- Bastos Gomes G, Miller T, Vaughan D, Jerry D, McCowan C, Bradley T and Hutson K (2017) Evidence of multiple species of *Chilodonella* (Protozoa, Ciliophora) infecting Australian farmed freshwater fishes. Veterinary Parasitology, 237, 8-16;
- Bastos Gomes G, Jerry D, Miller T and Hutson K (2016) Current status of parasitic ciliates *Chilodonella* spp. (Phyllopharyngea: Chilodonellidae) in freshwater fish aquaculture. Journal of Fish Diseases, 40 (5), 703-715;
- De Santis C, B. Gomes G and Jerry D (2012) Abundance of myostatin gene transcripts and their correlation with muscle hypertrophy during the development of barramundi, *Lates calcarifer*. Comparative Biochemistry and Physiology-Part B: biochemistry & molecular biology, 163 (1), 101-107;
- Bastos Gomes G, Domingos J, Oliveira K, Mendes P, Da Silva V and Mendes E (2010) Diagnosis of necrotizing hepatopancreatitis in Pacific White Shrimp, *Litopenaeus vannamei*, through wet mount, histopathology and PCR techniques. Journal of the World Aquaculture Society, 41 (5), 816-822.

Aquaculture teaching programs at James Cook University

JCU's teaching programs in aquaculture have been designed to deliver the knowledge and skills required in the next generation of global leaders in aquatic food production and resource management.

The Singapore campus of James Cook University offers undergraduate and higher degree by research programs in aquaculture as follows:

Bachelor of Business and Environmental Science (Majoring in Aquaculture)

With aquatic food resources already under pressure and declining, it is essential to develop aquaculture products in a sustainable fashion to improve aquatic food security. With JCU's Bachelor of Business and Environmental Science (Majoring in Aquaculture), students will learn how to manage the delicate balance between profit, policy, conservation and aquaculture. This multi-disciplinary program provides students with core knowledge and training in the application of business and environmental principles, with particular attention to aquaculture.

Graduate Certificate of Research Methods (Tropical Environments and Societies) and Graduate Diploma of Research Methods (Tropical Environments and Societies)

These courses are designed for those who want to gain the formal research training experience needed to begin an exciting higher research degree.

Doctor of Philosophy (PhD) and Master of Philosophy

The Doctor of Philosophy (PhD) is a program of supervised original research. It culminates in the submission of a thesis that demonstrates the ability for critical analysis and research that makes a significant and original contribution to the knowledge and understanding of the field of study.

The Master of Philosophy offers postgraduate research supervision on a smaller scale than the PhD, towards which it can provide a pathway.

For further information on our courses, email admissions-singapore@jcu.edu.au or visit www.jcu.edu.sg

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CPE Registration No. 200100786K | Period of registration: 13 July 2018 to 12 July 2022