Scientific submission: Specific biosecurity issues with Australia's current prawn import policy

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A submission to Biosecurity Advice 2018/06: Request for scientific submissions on specific issues with Australia's current prawn import policy

For the attention of:
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Contents

Introduction

Thanks for the opportunity to make a submission regarding Australia's current prawn import policies. With the liberalization of international trade through the General Agreement on Tariffs and Trade (GATT) in 1947, and the subsequent establishment of the *Agreement on the Application of Sanitary and Phytosanitary Measures* (SPS Agreement) in 1994 (WTO 1994), World Trade Organization (WTO) member countries, such as Australia, may employ sanitary or phytosanitary measures to the extent necessary to protect human, animal and plant health. Under the SPS Agreement, these sanitary measures must be based on international standards, guidelines and recommendations, which in the case of sanitary measures for aquatic animals and their products, is the World Organisation for Animal Health's (OIE) *Aquatic Animal Health Code* (OIE, 2018a).

WTO member countries may adopt higher levels of standards that those specified in the Code, however, they are required to use the *risk analysis* process as a means to justify these additional restrictions on international trade (see WTO 1994, Rodgers 2004, OIE 2018a). Risk analysis (RA) is thus an internationally accepted science-based method for assessing whether trade in a particular commodity (in this case prawns) poses a significant risk to human, animal or plant health, and if so, what measures could be adopted to reduce that risk to an acceptable level.

This review of Australia's current prawn import policies, which were originally developed during the 2009 Import Risk Analysis for prawn products (Biosecurity Australia 2009), is not a routine or planned review. It has come about due to failure of the original sanitary arrangements which resulted in a devastating incursion of the exotic, OIE listed White Spot Disease (WSD) into Moreton Bay and the prawn aquaculture farms on the Logan River in SE QLD in the summer of 2016/17 (Scott-Orr et al. 2017). Recent surveillance results from March 2018 have confirmed the persistence of White Spot Syndrome Virus (WSSV) infections in wild prawns and crabs in Deception Bay, in northern Moreton Bay, around 70km north from the affected aquaculture farms (Biosecurity QLD 2018). The persistence of WSSV in these wild crustacean populations within the White Spot Disease Biosecurity Zone (QLD Biosecurity Act 2017) is causing ongoing (possibly permanent) damage to the significant prawn and baitworm fisheries in the affected zone because the fishery operators are no longer able to domestically trade uncooked prawns or baitworm products outside of the affected zone (QSIA 2018).

Instead, these products are allowed to be released from the biosecurity zone only if they are cooked or subject to high levels of gamma irradiation (50 kilogray or 50 kGy). Implementation of these domestic biosecurity controls has resulted in economic hardship and job losses in the wild prawn fishery, a complete stand down of the prawn aquaculture industry in the Logan River, and flow on effects such as reduction in the availability of Australian wild caught and cultured prawns for domestic consumption, significant reductions in the supply of bait prawns and worms for the recreational fishing sector, as well as a significant increase in the cost of domestic prawn and bait worm products due to the need for additional sanitary precautions, such as gamma irradiation. The impact of the WSSV incursion on these industries has been extreme.

The OIE code (OIE 2018b) requires that Australia reviews and modifies import measures following an outbreak of exotic disease and prior to any subsequent claim for freedom from that disease. See point c. below from the relevant article relating to country freedom.

Article 9.7.4 (OIE 2018b)

4. it previously made a *self-declaration of freedom* from WSD and subsequently lost its *disease* free status due to the detection of WSD but the following conditions have been met:
   a. on detection of the *disease*, the affected area was declared an *infected zone* and a *protection zone* was established; and
   b. infected populations have been destroyed or removed from the *infected zone* by means that minimise the *risk* of further spread of the *disease*, and the appropriate *disinfection* procedures (as described in Chapter 4.3.) have been completed; and
   c. previously existing *basic biosecurity conditions* have been reviewed and modified as necessary and have continuously been in place since eradication of the *disease*; and
   d. *targeted surveillance*, as described in Chapter 1.4., has been in place for at least the last two years without detection of WSD.

   In the meantime, part or all of the non-affected area may be declared a free *zone* provided that such a part meets the conditions in point 3 of Article 9.7.5.

Of course, the upcoming process of revising the prawn RA not only has to identify where things went wrong with respect to the current WSSV incursion (Scott-Orr et al. 2018), it also has to identify any new biosecurity risks to Australia under current trading conditions, properly assess those risks, and identify options for mitigating those risks to within what Australia considers its Appropriate Level of Protection (ALOP). Australia's ALOP reflects community expectations through government policy, and in Australia is expressed as providing a high level of sanitary or phytosanitary protection whereby risk of introduction of exotic diseases is reduced to a very low level, but not to zero (Wilson 2000, Parliament of the Commonwealth of Australia 2003, Biosecurity Australia 2009).

a. Australia's domestic Appropriate Level of Protection (ALOP) for prawn products.

The ALOP (sometimes referred to by its inverse, the "acceptable level of risk" or ALOR), is the level of protection deemed appropriate by a country establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO, 1994). Under the SPS agreement, the ALOP for the importing country is supposed to be consistent across all commodities, and the same ALOR should be applied at both external (international) and internal (domestic) borders (i.e. Article 5.5 of the SPS Agreement, the *principle of consistency in application*, see Wilson,2000, Bondad- Reantaso et al. 2008). In other words, the ALOP must be applied consistently across the range of commodities in which the country trades. In effect, the SPS Agreement allows countries to give food safety, animal and plant health priority over trade, provided there is a demonstrable scientific basis for their food safety and health requirements and the resulting sanitary arrangements are not enacted arbitrarily.

Australia's domestic ALOP for exotic, OIE listed prawn diseases was demonstrated by the response of the various State governments to the incursion of White Spot Disease into Moreton Bay. Soon after detection of WSD in farmed prawns on the Logan River, the Queensland

Government enacted restrictions on the movements of uncooked crustacean products from the affected farms, with the area of the restrictions increasing to include the Logan River and eventually the entire Moreton Bay region following subsequent detection of the virus in wild populations of crustaceans in northern Moreton Bay in March 2017 (QLD Biosecurity Act 2017). New South Wales, Western Australia and South Australia also quickly enacted specific legislation preventing import of uncooked prawns and polychaetes and requiring either cooking or gamma irradiation of decapod crustaceans and/or prawns and polychaetes from the infected region (Government of SA 2016, Government of WA 2016, Government of NSW 2017).

State governments throughout Australia have thus demonstrated that the domestic ALOP with respect to control of the introduction and spread of exotic notifiable diseases of prawns, such as WSD, is one that requires sanitary measures equivalent to subjecting prawn products from regions where WSSV occurs to cooking to a level where all proteins are coagulated, or exposure to high levels of gamma irradiation (50 kilogray (kGy), see Department of Agriculture 2014). This being the case, it is clear that Australia should now insist that a similar level of protection is applied to crustacean products originating overseas from areas where WSSV is known to be endemic. In other words, if Australia's ALOP is to be consistently applied across both domestic and international borders in accordance with the SPS Agreement, all prawn products originating from overseas regions where WSSV is known to occur should now also be required to be cooked or subjected to appropriate levels of gamma irradiation (Department of Agriculture 2014) prior to their importation into Australia.

If such an outcome is not supported by the revised IRA, it may suggest that the IRA is technically compromised, as by finding otherwise it would have contravened the *principle of consistency in application* of the ALOP under the SPS agreement, to the detriment of Australia's environment and the seafood and aquaculture industries of Australia. It makes no sense whatsoever to have stricter quarantine requirements domestically than at the international border. All that does is discriminate against Australian businesses while allowing entry and potential establishment and spread of diseases to other areas of the country via imported products.

b. Australia's Appropriate Level of Protection (ALOP) for other imported meat products.

It is notable that compulsory cooking is required for pork products imported into Australia from countries with foot and mouth disease and several other important diseases of pigs (see Commonwealth of Australia 2004a, b, Australian Pork 2017). This is important, as the notion of allowing certain industries to be put at greater quarantine risk to pests and diseases in order to enhance the export opportunities of other industries was rejected by the Australian Government during a review of Australia's quarantine function following a foot and mouth disease outbreak in the United Kingdom (Parliament of the Commonwealth of Australia 2003). At the same time the Federal Government declared that "*Determination of quarantine measures based on scientific assessment and risk analysis should not be compromised to facilitate free trade agreements*."

Certainly, the current risk reduction methods used for imported green prawns such as freezing and processing to removing the head, shell and alimentary canal decrease the risks of introduction of some prawn diseases (YHV1, AHPND, NHP, *Enterocytozoon hepatopenaei*), but recent science suggests that some of these processes may actually <u>increase</u> the risk of establishment of other diseases infecting prawn muscle such as WSSV, TSV or IMN, given that removal of the shell may allow potential hosts (e.g. prawns, shrimps, crabs) to eat a larger ration of muscle tissue if they encountered an imported prawn used as bait or burley. For example, recent data from Europe suggest that a ration of less than 50 mg of muscle tissue of supermarket prawns is sufficient to establish WSSV infection in susceptible hosts (Bateman et al. 2012, Tables 1a, 1b). Removing the shell may allow potential hosts to eat more of an infected prawn that it otherwise would, potentially increasing the overall dose of virions via the *per os* route and increasing chances of infection (Oidtmann and Stentiford 2011, Bateman et al. 2012).

Therefore, in the case of WSSV in imported prawns, replacement of uncooked frozen prawn products with cooked products may be the only way to reduce risks to within the ALOP consistent with the sanitary risk reduction methods employed by Australia for other non seafood products imported for human consumption (Commonwealth of Australia 2004a, b, Scott-Orr et al. 2017) while also remaining consistent with domestic biosecurity arrangements implemented for prawns originating from SE QLD during the current WSD incursion (DAF QLD 2017).

c. Likely pathway of introduction of WSSV into Moreton Bay.

WSSV was exotic to Australia (Scott-Orr et al. 2017), and while the original source of the WSSV in the incursion in Moreton Bay and the Logan River is not known with absolute 100% certainty, there is a very high probability (estimated by the author as c. 98-99% certainty) that the incursion pathway was due to use of imported, uncooked WSSV-infected prawns as bait or burley by recreational anglers. This is because genetic analysis suggests the WSSV strain in Moreton Bay is very closely related to WSSV strains in China (Knibb et al. 2018). Furthermore, high prevalence (80% or more) of often heavily WSSV infected uncooked imported prawns were found in supermarkets near the Logan River (Scott-Orr et al. 2017, Future Fisheries Veterinary Service 2017), and recreational anglers were found using WSSV-infected prawns as bait near the affected prawn farms at the time of the disease outbreak (Scott-Orr et al. 2017). Epidemiology of disease spread through the prawn farms on the Logan River, but not elsewhere, proves that the virus was not introduced via infected broodstock or aquaculture feed, but instead probably entered farms via intake water (Diggles 2017a). In contrast, the other theoretically possible alternative entry pathways of the virus (via ballast water discharge or biofouling of international shipping at the Port of Brisbane) appear far less likely (Diggles 2017b). This is because ballast water discharge or biofouling would not explain the emergence of the disease in the Logan River (which does not accommodate international shipping), nor have these two pathways ever been confirmed as methods of introduction of WSSV into new areas anywhere in the world.

As WSD had never occurred in prawn farms on the Logan River prior to November 2016, WSSV was not present in the Logan River prior to when the last prawns of the 2015/16 season were harvested (c. April 2016). This suggests that WSSV was introduced into the Logan River system between April 2016 and November 2016. Operation Cattai confirmed that large quantities of imported uncooked WSSV infected prawns were available in retail stores in Australia at least as early as March 2016 (Senate Estimates 2017). This demonstrates a temporal correlation between high levels of WSSV in uncooked prawns supplied in supermarkets with the timing of introduction of WSSV into the Logan River. In the absence of prawn farming elsewhere in Moreton Bay (and its associated active and intensive disease surveillance), it is impossible to determine the timing of introduction of WSSV into northern Moreton Bay, except that it did not spread there from the Logan River (Scott-Orr et al. 2017). However, such a patchy distribution of WSSV would most likely be explained by separate introductions of the virus at multiple locations via the bait and burley pathway. It is also now known that:

- Viable WSSV has been recovered from commodity prawns frozen at both -20 and -70°C after several years storage and used to successfully infect susceptible crustaceans (Wang et al. 1998, Durand et al. 2000, McColl et al. 2004, Hasson et al. 2006, Biosecurity Australia 2009, Bateman et al. 2012, RM Overstreet, personal communication, Nov 2009);

- Viral loads of 10^8-10^{10} viral copy units/g tissue typically occur in WSSV infected green prawns (Oidtmann and Stentiford 2011). This level of virus can infect naïve hosts after consumption of < 50 milligrams (mg) of infected tissue (Bateman et al. 2012, Tables 1a, 1b);

- Removal of the head does not reduce WSSV viral load on a per weight basis, as viral load in prawns is similar in either heads (49% of total virus) or tails (51% of total virus) (Durand et al. 2003). The viral load of the peeled shell represents c. 55% of the total viral load remaining in the tail (Durand et al. 2003). Hence full processing of green prawns as specified in the 2009 prawn IRA only reduces viral load by half, which is not sufficient to prevent establishment of WSSV infections via *per-os* route in susceptible species (Bateman et al. 2012, Tables 1a, 1b); and

- The number of recreational anglers fishing with imported green prawns purchased as seafood from supermarkets was increasing in the early 2000s (Kewagama Research 2002, 2007, Table 2) and has continued to increase to become "routine practice" as imports of green prawns have increased in volume (Fishraider.com.au 2013, Fishing Victoria 2016, Figure 1). Phone surveys conducted by Biosecurity QLD suggest that the prevalence of anglers using supermarket purchased imported prawns as bait may now exceed 50% (Biosecurity QLD 2017), representing an estimated minimum 2000% increase in use of imported uncooked prawns as bait by recreational anglers since 2002 (Table 2).

The strong possibility that this disease incursion was caused by use of imported prawns as bait or burley signals an urgent need to revise the 2009 prawn IRA and reassess this and other potential pathways of aquatic animal disease introduction into Australia. The IRA has now not only failed, it is simply out of date. The risk profiles for diversion of prawns and other imported seafood products to bait and burley have either changed or were not properly identified in the first place, and they were certainly never "negligible" as suggested by the Interim Inspector General of Biosecurity (Dunn 2010).

Table 1a. WSSV minimum infective doses based on data from the EU (Oidtmann and Stentiford 2011, Bateman et al. 2012).

	Carrier state viral load in commodity prawns	Typical viral load in infected prawns	Emergency harvest viral load in muscle	Minimum dose to initiate infection (*per os*)	Minimum lethal dose	LD50% dose
P. vannamei	4.6×10^{1} to 5×10^{2} viral copies/ng DNA[a]= 4.6×10^{7} to 5×10^{8} viral copies/g tissue*	1x 10^{9} to 7 x 10^{10} viral copies/g tissue[b]	3.65 x 10^{5} viral copies/ng DNA[a] = 3.65 x10^{11} viral copies/g tissue*	c. 100 viral copies[b]		
P. monodon		1x 10^{9} to 1 x 10^{10} viral copies/g tissue[b]	1.5 x10^{9} viral copies/g tissue[b]			
P. stylirostris			5.7 x10^{11} viral copies/g tissue[b]			
European Lobster[a]				<2 x 10^{6} viral copies[a]	c. >1 x 10^{8} viral copies ?[a]	1.82 x 10^{10} viral copies[a]
	Equivalent commodity prawn dose – carrier state			4 – 43.5 mg	0.2 – 2.2 g	36.4 – 395 g
	Equivalent commodity prawn dose – typical infection			0.028 – 2 mg	0.0014 – 0.1 g	0.26 -18.2 g
	Equivalent commodity prawn dose – emergency harvest			0.003- 0.13 mg	0.17 – 66.7 mg	0.03 -12.1 g

* Assumes that virus copy numbers reported per g of tissue are roughly 1000·x the number of virus copies reported per µg of DNA[b]

[a] Bateman KS, Munro J, Uglow B, Small HJ, Stentiford GD (2012). Susceptibility of juvenile European lobster *Homarus gammarus* to shrimp products infected with high and low doses of white spot syndrome virus. *Diseases of Aquatic Organisms* 100: 169-184.

[b] Oidtmann B, Stentiford GD (2011). White Spot Syndrome Virus (WSSV) concentrations in crustacean tissues – A review of data relevant to assess the risk associated with commodity trade. *Transboundary and Emerging Diseases* 58: 469–482.

Table 1b. Summary of experimental results from Bateman et al. (2012)

Treatment	Commodity shrimp #1	Commodity shrimp #2	Commodity shrimp #3	Positive control
Source of virus	Ecuador	Vietnam	Honduras	Lab – Emergency harvest
Viral load in muscle	4.68 x10^{1} viral copies/ng DNA	1 x10^{2} viral copies/ng DNA	5.16 x10^{2} viral copies/ng DNA	3.65 x10^{5} viral copies/ng DNA
Viral load per mg muscle	4.68 x10^{4} viral copies/mg	1 x10^{5} viral copies/mg	5.16 x10^{5} viral copies/mg	3.65 x10^{8} viral copies /mg
Viral dose in 50 mg ration	2.34 x10^{6} viral copies	5 x10^{6} viral copies	2.58 x10^{7} viral copies	1.82 x10^{10} viral copies
% lobsters infected	30%	45%	70%	94%
% lobster mortality	20%	22%	0%	55% (after 6d. at 22°C)

Table 2. Temporal trends in use of supermarket green prawns as bait by recreational fishers in Australia using WSSV as an example of risk.

	A	B	C	D[+]	E	F	G[++]	H
Date	% of fishers using prawns sold as seafood as bait	Weight of seafood prawns used as bait (tonnes)	% of seafood prawns used as bait that are imported	Quantity of imported prawns used as bait	% increase in weight of imported prawns used as bait	% prevalence of WSSV in retail prawns	Quantity of WSSV +tve prawns used as bait	% increase / decrease in WSSV +tve bait by weight since 2002
2001/2002[1]	6%	50.5 t	4%	2020 kg	-	50% (est)	1010 kg	-
2006[2]	7.9% (+33%)	59.6 t (+18%)	11%	6556 kg	324%	50% (est)	3278 kg	+324%
2012 (est)	10.5% (est)	70.3 t (est)	18% (est)	12654 kg	626%	5%*[4]	632.7 kg	-38%
2017 (est)	14% (est)	82.9 t (est)	25% (est)	20725 kg	1025%	5%*[4]	1036 kg	+2.6%
2017[3] actual	>50%[3]	82.9 t (est)	>50%[5] (est)	>41450 kg	>2051%	50-83.6%[6]	>20725 – 34652 kg	>+2051 to 3430 %

* 5% prevalence based on "as designed" testing program from 2009 IRA (65 prawns per shipment sampled at border assuming 100% test sensitivity /specificity)[4]

[+] Quantity of imported prawns used as bait calculated D = B x (C/100) x 1000 [++] Weight of WSSV+tve prawns used as bait calculated G = D x (F/100)

(est) = 5 year growth estimates for years 2012 and 2017 based on linear extrapolation of % growth trends documented between surveys done in 2001 and 2006. Actual % increase in imported bait use may far exceed this[3] hence actual quantities now used (2017 actual) are likely to be underestimates.

[1] Kewagama Research (2002). National survey of bait and berley use by recreational fishers. Report to Biosecurity Australia, AFFA. December 2002. Kewagama Holdings, Pty. Ltd., Noosaville, Queensland, Australia. 137 pgs.

[2] Kewagama Research (2007). National survey of bait and berley use by recreational fishers: a follow-up survey focussing on prawns/shrimp. Report to: Biosecurity Australia, AFFA.

[3] Biosecurity QLD (2017). Online Survey. (Unpublished).

[4] Biosecurity Australia (2009). Generic Import Risk Analysis Report for Prawns and Prawn Products. Final Report. Biosecurity Australia, Canberra, Australia. 7 October 2009, 292 pgs.

[5] FRDC (2017). Australian Seafood Trade Database. http://frdc.com.au/trade/Pages/Crustacean-Full.aspx

[6] Future Fisheries Veterinary Service (2017). Assessing compliance and efficacy of import conditions for uncooked prawn in relation to White Spot Syndrome Virus (WSSV). FRDC Project 2016-066 Report to Australian Prawn farmers Association. 103 pgs.

Table 3. List of some of the diseases of prawns that were not included in, or have emerged since the 2009 Import Risk Assessment (data collated only from Thitamadee et al. 2016, Li et al. 2016, Bateman and Stentiford 2017, Qiu et al. 2017 and is not an exhaustive list).

Disease name	Date emerged	Disease agent	Mitigated by existing sanitary measures?
AHPND	2009 (China)	Bacterium w. toxic plasmid	Yes*
Secret Death Disease	?	Possibly AHPND or mixed aetiology	?
Empty Stomach Disease	?	?	?
Aggregated transformed microvilli (ATM)	2009 (China)	Vermiform gregarine-like bodies	?
Covert Mortality Disease (CMD)	2009 (China)	Nodavirus	?
Hepatopancreatic microsporidiosis	2009 (Thailand)	Microsporidian (*Enterocytozoon hepatopenaei*)	?
Hepatopancreatic haplosporidosis	2009 (Indonesia)	Unnamed haplosporidian	?
New strains of YHD	2013 (China)	*Okavirus*	?
Shrimp hemocyte iridescent virus *(SHIV)*	2017 (China)	Iridovirus	?
Pandalus montagui bacilliform virus	2007 (North Sea)	*Nudivirus*	?

* Existing sanitary measures may prevent direct transmission of AHPND, but may not prevent release and establishment of the plasmids and genes responsible for toxin formation.

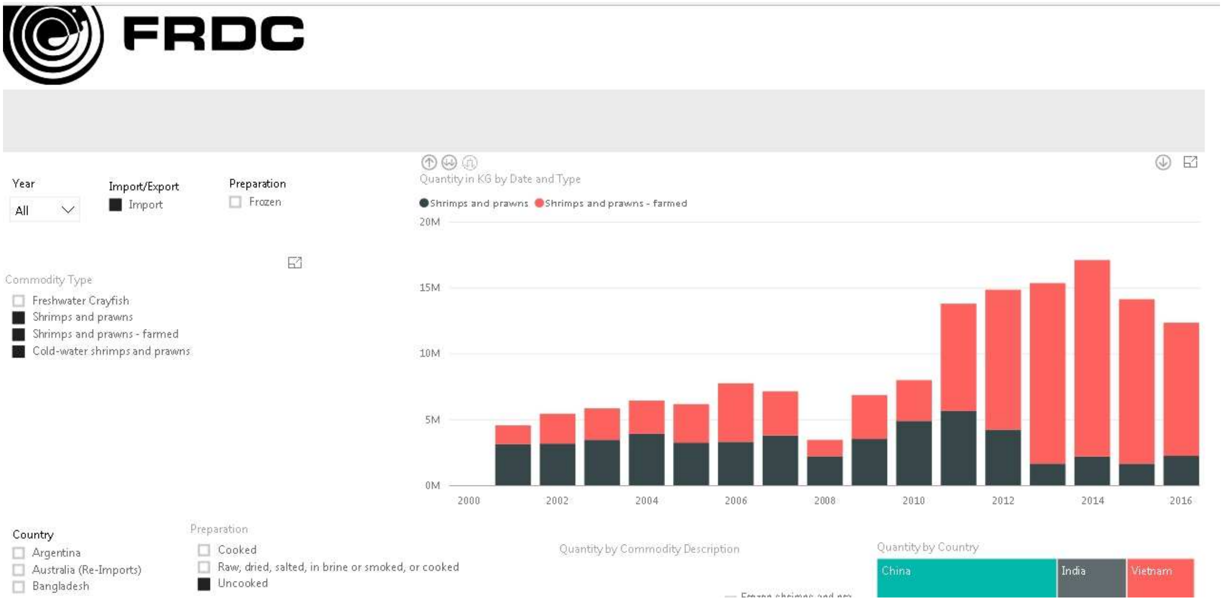

Figure 1. Quantities of uncooked prawns imported between 2001 and 2016. Data from FRDC (2017) suggest imports of farmed uncooked prawns more than tripled between 2009 and 2013-16, while overall tonnage of imports remained around 36-38,000 tonnes (Scott-Orr et al. 2017).

d. *Many new diseases of prawns have emerged since 2009*

The 2009 prawn IRA is now well out of date. New sanitary information is now available on risks related to not only WSSV, but many other emerging (post-2009) diseases (Table 3) in imported prawn commodities (see papers by Overstreet et al. 2009, Ma et al. 2009, Stentiford et al. 2009, Oidtmann and Stentiford 2011, Reddy et al. 2011a, 2011b, Bateman et al. 2012, Stentiford et al. 2012, Stentiford 2012, Jones 2012, Shields 2012, Behringer 2012, Lightner et al. 2012, Tran et al. 2013a, 2013b, Reddy et al. 2013, Nunan et al. 2014, De La Pena et al. 2015, Cowley et al. 2015, Li et al. 2016, Thitamadee et al. 2016, Bateman and Stentiford 2017, Qiu et al. 2017, amongst many others).

The reason why Australia has not yet got some of these new diseases may be pure luck. For example, the toxin related components of the bacterium that causes Acute Hepatopancreatic Necrosis Disease (AHPND) appear to be inactivated by freezing, which is fortunate otherwise Australia could be included in the estimated $5 billion US annual global losses experienced by overseas prawn producers due to AHPND (Tran et al. 2013a, 2013b, Chamberlain 2013, Thitamadee et al. 2016). Unfortunately, while freezing may stop transmission of AHPND, it may not prevent release of the genes responsible for toxin formation, leaving the door open for introduction of this disease into Australia. New diseases continue to regularly emerge in intensive prawn farming, particularly in Asia, and it is well known that many important diseases of crustaceans were spread widely before their cause was identified and diagnostic tests became available (Lightner 1999, Jones 2012). Furthermore, if disease testing programs are chosen instead of cooking, to keep risks within the ALOP the import risk assessments underpinning Australia's sanitary arrangements need to be updated very regularly, probably every year or 2 years given the high rate of emergence of new diseases in cultured prawns (Table 3).

While a risk analysis has been done to assess the risk of domestic bait translocation (Diggles 2011), its terms of reference meant that it did not consider risks associated with use of imported fish or shellfish products as bait. Any risks of use of imported products via the bait and burley pathway were supposed to be considered and mitigated in the appropriate IRAs for the imported commodities. It appears when that is not done properly, these risks "fall through the cracks" and Australia is left vulnerable to aquatic disease incursions. Given the scale of the biosecurity breaches that have been recently revealed at the international border (Scott-Orr et al. 2017), and the potentially severe consequences of introduction of exotic diseases to Australia's environment, fisheries and aquaculture industries and food security, it is clear that the biosecurity controls imposed on the importation of uncooked prawns and prawn meat into Australia have been both inappropriate and ineffective. A comprehensive review and full update of the IRAs for not only prawns, but many other seafood products, is clearly required to reduce risks to within the ALOP.

e. *Cooking is not a zero risk sanitary measure*

It is known that WSSV is inactivated by heat. For example, it has been reported that WSSV can be inactivated in 20 min at 50 °C (Maeda et al. 1998b), in 1 minute at 60°C and 0.2 min at 70°C (Nakano et al. 1998), though Chang et al. (1998) stated that 70°C for 5 min was required to completely inactivate the virus. Methodological variations may explain some of these differences, however these authors all examined free virus suspensions isolated from host tissues prior to heat treatment, and they did not examine whether WSSV was protected from heat while *in-situ* inside the tissues of infected hosts.

In contrast, Reddy et al. (2011a) used bioassays with the highly susceptible *Penaeus monodon* to find that boiling of WSSV infected *P. monodon* tissues in water for up to 30 minutes at 100°C did not fully inactivate all virus and that only cooking at 100°C for 15 min followed by quick freezing to -40°C was sufficient to completely inactivate the virus inside cooked tissues (Reddy et al. 2011b, 2013). Existing prawn meat cooking requirements for Australia only specify that products meet a minimum core temperature and time requirement, which have been approved by the Department of Agriculture and Water Resources as follows:

60°C for 1 minute, or 70°C for 11 seconds.

Based on the data presented by Reddy et al. (2011a, 2011b, 2013), these minimum requirements may not be sufficient to inactivate all WSSV *in-situ* inside infected prawn meat. Review of the effectiveness of heat for inactivation of WSSV is urgently required, possibly including bioassay work to repeat the studies of Reddy et al. under controlled conditions, so that application of cooking as a potentially useful sanitary measure (Scott-Orr et al. 2017) can be properly assessed as part of this risk analysis process.

f. Higher risk sanitary measures (testing programs) impart higher costs that may represent an increased barrier to trade

Because of the Federal Government's choice to use higher risk sanitary measures after the 2009 IRA (e.g. reliance on a testing program for imported uncooked prawns), increased costs of testing are endured by importers and increased resources are required to enforce biosecurity at the international border and post-border. The current testing regime at the border (sampling 65 prawns to test for WSSV and YHV by PCR) provides 95% confidence that these diseases will be detected if the disease agents are present at a prevalence of over 5%. However, the assumptions upon which these confidence intervals are based (presumed perfectly random testing) cannot be achieved in a practical real world situation at the border, and are also subject to error and deliberate criminal evasion, as disclosed during Operation Cattai (Scott-Orr et al. 2017). In reality, the current testing arrangements, even with enhanced procedures with full 100% seals intact inspections, do not meet Australia’s ALOP, given the fact that we now know diseases such as WSSV are more highly contagious to a much wider range of crustaceans than previously thought in 2009 (Oidtmann and Stentiford 2011, Bateman et al. 2012). Because of this, we now know that the risk of establishment of WSSV via the bait and burley pathway is higher than previously thought, and remains above the ALOP even if the virus is present in uncooked imported prawns at prevalences <5% (Government of SA 2016, Government of WA 2016, Government of NSW 2017, QLD Biosecurity Act 2017).

In a perfect world, even assuming a significant increase in resources was granted to allow disease testing of each consignment of prawns to a more rigorous standard closer to Australia's ALOP for non-seafood commodities (for example: test to a 1% prevalence level requiring samples of >300 prawns obtained in a random fashion from each consignment), the chance of non-random sampling and human error would remain and tests are not always 100% reliable (Scott-Orr et al. 2017). In fact, the requirement for effective testing is at odds with the high volumes of imported prawns that are now traded into Australia. It is easy to test low volumes of commodities thoroughly for the diseases you know of, but as trade volumes increase (see Figure 1), either resources required for testing must also increase to meet demand, dramatically increasing costs over time (Scott-Orr et al. (2017) actually found quarantine inspector numbers decreased 25 % over the past 5 years), or else errors begin to be made and risks of incursions skyrocket, like we have seen in Australia recently with Operation Cattai. And under such circumstances, when a new disease emerges, unless we are very lucky, it may become established in Australia before the IRA is updated and a reliable test becomes available. In either case, as trade volumes increase, propagule pressure increases and without increased funding for more rigorous testing procedures and more frequent reviews of IRAs, biosecurity breaches become inevitable, a situation that is unacceptable to most Australians and thus does not meet Australia's ALOP.

Furthermore, the increased costs associated with disease testing may represent a significant barrier to trade, especially if appropriate risk mitigation can be obtained using alternative lower cost sanitary arrangements. For example, cooking is a simple, cheap and effective sanitary process that inactivates most pathogens that threaten animal or human health and/or the environment (Torgersen and Hastein 1995, Tacon 2017). If appropriate sanitary measures are employed (i.e. all imported prawns are cooked and subsequently frozen (Reddy et al. 2011a, 2011b 2013), costs associated with compliance testing are much reduced, as is the need for constant updating of import risk assessments. Given that biosecurity risks remain even in the absence of disease identification (Gaughan 2002), cooking of prawns as the lowest cost sanitary measure is likely to reduce risks of introduction of WSSV and all other known diseases of concern (as well new emerging diseases) to within Australia's ALOP, while also representing the least restrictive barrier to trade (on a cost basis) compared to disease testing.

g. Wash off of battered prawns and other loopholes of current import conditions.

There are several loopholes that remain in the current biosecurity protocols that mean that less than 100% of shipments of frozen green prawns imported into Australia are subject to testing. Prior to the WSSV outbreak in Moreton Bay, testing was only conducted on frozen uncooked imported prawns. There was no testing required for other risky products like uncooked marinated prawns, battered/breadcrumbed prawns and highly processed prawn products, or other products such as soft shelled crabs, all of which have significant risks of containing viable WSSV given the large host range of the virus, which affects all decapod crustaceans. Subsequent to the WSSV outbreak in Moreton Bay, the "enhanced" testing protocols have included testing of marinated prawns, but still do not test battered and bread crumbed prawns.

However, covering prawns with marinade, batter or breadcrumbs is not a sanitary measure as it does not inactivate WSSV (or any other disease agents of concern). Furthermore, there is evidence from within the seafood importing industry that because bread crumbed prawns are not being tested, this loophole has lead to "*processors (are) ramping up and exporting massive volumes of this wash off crumbed (prawns) infected with WSSV*" (Ezekeil 2018). Similar problems with marinated prawns and other non-compliance were reported by Scott-Orr et al. (2017). The root of the problem is that importers can make large amounts of money if they evade disease testing programs and land low quality WSSV infected prawns into Australia. The bottom grade of imported prawns probably originate from emergency harvests of clinically diseased prawn ponds, and are available on the open market in Asia at prices sometimes less than $10 USD per tonne (Figure 2). Scott-Orr et al. (2017) show such a high economic incentive to cheat the system will inevitably lead to unscrupulous operators trying to exploit loopholes, such as the one currently represented by the lack of testing of battered and bread crumbed prawns.

Figure 2. Bottom grade imported uncooked prawns (probably from emergency harvests) can be obtained in Asia at extremely low prices (here $7-9 USD per tonne). The economic incentive for unscrupulous importers to cheat the system to profit from such products is extremely high.

Federal biosecurity authorities have thus not only failed to deliver an effective testing program for imported uncooked prawn products, they also have no control over end use once these risky products clear quarantine and/or are sold at the retail store. It is well known that recreational anglers commonly use supermarket bought seafood (including prawns) for bait and burley. Upon asking some of them why, I have found that besides being cheaper and more convenient (as reported by Kewagama Research 2007), anglers assume that whatever is sold in supermarkets is safe to eat and use however they see fit. They say "*if the risk to Australia was so great from* *these imported products, why would authorities let these products be sold in the first place* ?" Unfortunately it was well known by aquatic animal health professionals that imported prawn products carried viable viruses, yet it was technically not illegal to use them as bait in some jurisdictions. Indeed in all the supermarkets I visited leading up to Christmas/New Year 2016/17, not one of them were selling imported prawns over the delicatessen counter with warnings to customers that they should not be used as bait (Figure 3). In some supermarkets, bait freezers continue to be located within the seafood section, encouraging consumers to relate the two together (Figure 4, which is bad practice that should be avoided.

Since introduction of WSSV into Australia, much effort has been made to educate consumers not to dispose of seafood into waterways and alert recreational anglers not to use supermarket products as bait. However, the correct way to control risk along a supply chain is to apply appropriate mitigation at appropriate critical control points. It makes no sense to try to apply risk mitigation after the retail sale is made, and to rely on people being educated and "doing the right thing", as after the point of sale the routes of entry to high risk pathways are too numerous and widely dispersed, making effective enforcement impossible. Education of anglers and consumers has been considered to be one way of potentially mitigating the risk of introduction of diseases such as WSSV via the bait and burley pathway. However, it is always difficult to engage all recreational fishers in educational campaigns and there is evidence that compliance will decline over time unless the educational message is followed up with strong enforcement. But it is impossible to enforce some acts, such as someone “feeding the fish” or “feeding the crabs” with imported seafood in a backyard BBQ held on a waterway. And without adequate enforcement, there is no incentive for people to educate themselves or "do the right thing". Clearly the only proper way to control risk in this supply chain is either pre-border, or at the border. Once these products clear quarantine, and enter the retail chain, all control of the end use is lost. Recent (March 2018) observations from fisheries officers in NSW and other states continue to find people using imported uncooked prawns as bait, demonstrating that efforts to educate anglers and get them to heed labelling on imported products that say they are “not to be used as bait or burley” are simply not effective. Reliance on consumers abiding by food labels for national biosecurity is not tolerated in terrestrial livestock industries in Australia (Australian Pork 2017), so the question must be asked, why is it being forced upon the seafood industry?

As a final observation of the effectiveness (or lack thereof) of current end use import conditions, despite all the effort put into education programs with anglers and consumers to try to prevent disease spread from imported seafood products, what is often not talked about in risk analyses are the real risks of deliberate introductions and even industrial sabotage (Jones 2012, Scott-Orr et al. 2017). Not everyone wants to "do the right thing", and in the real world, the unfortunate but real risk of industrial sabotage of our local seafood production industries is a significant threat to Australia's food security. The findings of Operation Cattai demonstrate that some people are willing to deliberately break the law, hence the risk of industrial sabotage must also be considered real, providing yet another reason why strong border controls are necessary. The revised IRA must therefore deliver safe prawn products using sanitary arrangements free from loopholes that can be exploited to enhance the pecuniary interests of unscrupulous importers.

Figure 3. Assorted uncooked imported prawns being sold at supermarkets on the Gold Coast in December 2016. At none of the dozens of supermarkets in SE QLD I visited were there any signs or information informing consumers not to use these products as bait or burley.

Figure 4. In some SE QLD supermarkets examined, bait freezers (arrow) were located within the seafood section, encouraging consumers to relate the two together.

h. The impact of the WSD outbreak on Australia's wild and farm prawn sectors.

In other areas of the world where WSSV has been introduced, aquaculture industries based on prawns and other crustaceans (e.g. crayfish) have suffered significant cumulative production and economic losses of up to $15 billion USD (Stentiford et al. 2012). Though some adaptation to the disease agent may occur over time, in Australia the presence of the virus represents a significant obstacle to industry competitiveness and profitability. Production in many WSD affected countries overseas eventually recovered, however much of the recovery was due to switching to the faster growing *Penaeus vannamei* (see Flegel 2006, Stentiford et al. 2012), a species which is exotic to Australia and hence this recovery option is not available to the Australian prawn aquaculture industry. There are no commercially available methods of control of WSD (vaccines etc.) at present, although filtering water and covering of production ponds with mosquito netting may provide increased protection (Thitamadee et al. 2016). However, under Australian economic conditions, the required changes to infrastructure and husbandry practices (filtration of water, lining of ponds, carrier and vector exclusion, minimal/zero water exchange production cycles, development of pathogen free or pathogen resistant prawns lines, see Lightner 2005, Moss et al. 2012) imparts additional production costs that are likely to greatly reduce industry profitability to marginal levels, at least in the short term. The reduced profitability would discourage investment in prawn farming in Australia, posing a risk to Australia's future food security (Stentiford 2012, Stentiford et al. 2012). The likely impacts of introduction of WSD on the prawn aquaculture industry in Australia are therefore considered to be extreme.

In the past it was thought that wild crustaceans infected with WSSV carry the virus but it usually does not kill them (Lo et al. 1996), a situation which may aid the transmission and spread of the disease agent throughout local crustacean populations. Adverse impacts at the population level have not been previously reported in wild crustaceans in areas where WSSV has been introduced (Maeda et al.1998a, De La Pena et al. 2007, Baumgartner et al. 2009, Flegel 2009). However, because sub-clinical WSSV infections can revert to the disease state in susceptible species after periods of stress (Lo et al. 1996), this suggests that populations of wild crustaceans adversely affected by environmental stressors (e.g. floods or other adverse environmental conditions, rapid drops in water temperature or exposure to pollutants such as pesticides and herbicides) may experience reduced resilience or “silent mortalities” (Behringer 2012, Stentiford et al. 2012, Shields 2012) due to WSSV infection, as has been reported for some other viral pathogens of prawns (Couch and Courtney 1977, Morales-Covarrubias et al. 1999).

In Moreton Bay, WSSV was detected in the North-Western parts of the bay in both March 2017 and March 2018 in a region just north of Redcliffe (Biosecurity QLD 2018). Results from the surveillance surveys in March 2018 found a variety of prawns (greasyback, brown tiger prawns, banana prawns) and crabs (mangrove crab *Thalamita* spp.) were infected with WSSV, with quantitative PCR CT values as low as 13.8 in some infected animals (Australian Prawn Farmers Association 2018). The CT value is a quantitative measurement of the amount of viral DNA present in a sample. Real time PCR (also known as quantitative PCR or qPCR) monitors the amount of target DNA that is amplified during each PCR cycle (i.e. in real time during the PCR process, not only at the end as in conventional PCR). The CT value is a measure of the number of PCR cycles required to exceed a certain predetermined threshold amount of target DNA (i.e. cycle threshold value or CT value). There is an inverse relationship between viral load and CT number because the threshold is reached in fewer PCR cycles when there is more viral DNA in the original sample, i.e. a high amount of virus gives a low CT value. The CT values obtained from dying WSSV positive *P. monodon* on the first infected farm on the Logan River in November 2016 ranged from 14-21 (Diggles 2017a). The fact that wild prawns in northern Moreton Bay have been recorded with CT values as low as 13.8 strongly suggests that the WSSV disease incursion is causing mortalities in wild crustaceans in Moreton Bay. This would not be unexpected, given that WSSV is a highly pathogenic disease agent that has been introduced into a naïve population of crustaceans in Moreton Bay which have no natural resistance to the disease.

Indeed, any absence of evidence of impacts on populations of wild crustaceans in areas where WSSV has been introduced overseas is not evidence of likely absence of such impacts in

Australia, as impacts of new diseases in wild populations of crustaceans are likely to go unnoticed in countries without proper baseline ecological data (Shields 2012) and effective fisheries management. As effects of disease in wild populations vary greatly due to factors such as environmental characteristics, host susceptibility and host densities (Burge et al. 2016), it is possible that impacts of WSD introduction into Australia could be more severe due to our unique environment, isolated fauna and effective environmental and fisheries management arrangements that tend to keep host population densities relatively high, thus facilitating transmission of new diseases. Any adverse effects could result in ecological harm to aquatic environments, potentially resulting in significant, permanent cultural and socio-economic harm to regional communities in Australia and elsewhere in the country.

As WSSV is a listed disease agent notifiable to the OIE and NACA, there are significant trade implications following its introduction into Australia. Indeed, as shown in the Logan River and Moreton Bay, establishment of WSD in a region of Australia necessitates intervention by government authorities and disruption to normal trade in crustacean commodities by commercial fisheries and crustacean gathering by recreational fishers as attempts are made to try to prevent anthropogenic movements of crustaceans to limit potential spread into uninfected areas. As shown in Moreton Bay, if the disease spreads to areas where bait prawns are commercially gathered, not only commercial fishers but recreational fisheries may be disrupted due to loss of bait supplies. Under such circumstances the commercial fishers can be more heavily impacted than aquaculturists, as while the aquaculturists can (given enough financial investment) revise their farms and improve biosecurity to try to prevent the virus from entering the farm, commercial fishers cannot do this. Even if WSSV does not always kill their wild catch outright, because of the risk of spreading the infection commercial fishers may not be able to sell their product (prawns, crabs, lobsters, crayfish) into their usual markets, effectively a situation commercially equivalent to having all of the animals dying from the virus anyway, as they are no longer saleable. Establishment of diseases in the environment (such as northern Moreton Bay) means these commercial and environmental impacts are probably permanent, meaning the likely impacts of introduction of WSD on commercial crustacean fisheries in Australia are also extreme.

i. Summary

Quarantine conditions requiring cooking of imported meat products are permissible within WTO rules under the SPS Agreement, and are widely accepted by consumers in Australia as necessary to protect our local cattle, pig and sheep industries (and hence our food security) with regard to terrestrial meat products for those species susceptible to foot and mouth. State governments throughout Australia have demonstrated that Australia’s domestic ALOP with respect to prawn products originating from regions where WSSV occurs is one that requires sanitary measures equivalent to cooking or exposing those products to high levels of gamma irradiation. If similar sanitary arrangements were implemented for prawns originating from countries where WSSV is known to be endemic, Australia’s ALOP with respect to prawns would be consistent both across different commodities and also between domestic and international borders, thus fulfilling requirements under the SPS Agreement. By requiring compulsory cooking of all prawns prior to entry, the processes of inspection at the border would be simplified, additional costs of testing for diseases would be eliminated, and other risk mitigations like processing (removal of heads/peeling /deveining, gamma irradiation) may no longer be required, resulting in a more streamlined inspection process at the border and potentially a cheaper product to the end consumer, all of which represent the least restrictive barrier to trade (on a cost basis, compared to disease testing). Such are the many advantages of compulsory cooking as a “least cost, high effectiveness” sanitary process, that was originally identified back during the 2009 IRA, but, unfortunately, was not fully implemented at the time.

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About the author

Over the past 16 years Dr Ben Diggles has gained extensive experience in development and/or review of pathogen and pest Import Risk Analyses for fish and shellfish products for both domestic and international transfers. This work has been undertaken for industries and Governments not only in Australia but also for other countries such as New Zealand, Brunei Darussalam, Saudi Arabia and Oman. For more information see below and www.digsfish.com/publications.html.

Aquatic animal risk analysis documents developed or reviewed by Dr Ben Diggles.

Risk Analysis Jurisdiction	Date	Commodity	Risks	Number of Hosts / hazards / assessments
New Zealand	2002	Juvenile Kingfish from Australia to NZ	Diseases	1/ 42 / 9
New Zealand	2005	Ornamental fish and invertebrates into NZ	Diseases	394 / 500 / 35
New Zealand	2006	Aquatic pathogens important to NZ – hazard identification and RA	Diseases	>500 / 92 / 92
New Zealand	2006	*Macrobrachium* from Hawaii to NZ	Diseases	1 / 76 / 6
Australia	2007	Menhaden from USA to Australia	Diseases	1 / 42 / 1
Australia	2007	Pacific Oysters from Tasmania to NSW	Pests + diseases	1 / 18 / 13
Several	2008	Pathogen risk analysis – 9 case studies – Invited keynote paper	Pests + diseases	Summary of 9 IRA studies
Brunei	2010	Crustaceans into Brunei Darussalam	Diseases	54 / 125 / 17
Australia	2011	Hazards due to domestic bait translocation	Diseases	>500 / 80 / 44
Australia	2011	Abalone translocations in Tasmania	Diseases	1 / 1 / 1
Australia	2012	Abalone translocations in South Australia	Diseases	2 / 9 / 7
New Zealand	2012	North / South Island shellfish biosecurity assessment	Diseases	27 / 39 / 20
New Zealand	2012	Environmental assessment report Salmon farming – disease risks	Diseases	1 / 20 / 4
Saudi Arabia	2012	Technical assessment of RA – Imported prawns (live *P. vannamei*)	Diseases	1 / 30 / 30
Australia	2014	Abalone translocations in Tasmania	Diseases	1 / 1 / 1
Australia	2017	Northern Australia Biosecurity Review	Pests + diseases	>100 / 15 / 15
Australia	2017	State aquaculture centre Biosecurity risk assessment	Diseases	8 /30 /30
Australia	2017	Pathogen risk analysis for Sydney rock oyster translocations between NSW and WA.	Diseases	1/10/10
Oman	2018	Independent technical assessment: Pathogen risk analysis for the introduction of whiteleg shrimp (*Litopenaeus vannamei*) and black tiger shrimp (*Penaeus monodon*) to the sultanate of Oman	Diseases	2/31/31