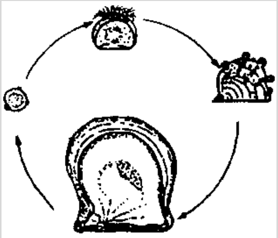
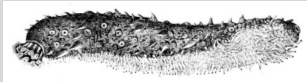


Pearl Oyster Life Cycle

Pearl Oyster Propagators P/L
ABN 87 009 290 840
and
Tropical Aquaculture Australia P/L
ABN 36 097 623 142
LPO Box 38, Brunswick South, Vic 3055
Website: www.pearloyster.com.au
www.robertsandrose.com



Trepang

To:
Australian Marine Fisheries and Aquaculture
Productivity commission
GPO Box 1428
Canberra ACT 2601
Email: fisheries.inquiry@pc.gov.au

Submission on Marine Fisheries and Aquaculture: Productivity Commission Issue Paper, February 2016

Please find my late submission to the Productivity Commission's Marine Fisheries and Aquaculture Issue Paper, February 2016.

The submission attached relate to addressing the 8 questions asked in Chapter 5 – Regulation of aquaculture.

Please contact me to confirm receipt and acceptance of this submission.

For your consideration,

Kind Regards

Robert A Rose, PhD
Proprietor and Managing Directors of POP and TAA

5 Regulation of aquaculture

Information request

1a. *Have any jurisdictions been able to successfully balance environmental and economic considerations and potential conflict with other resources uses?*

Yes: the WA Pearling Industry in partnership with the WA Fisheries Department has approximated a balance between environment, commerce and conflict for resources[1]. Their success was directly related to:

1. understanding the ecological needs of the pearl oyster under cultivation through applied R&D which closed the animal's life cycle[2,3];
2. adapting and adopting cost-effective husbandry that cultivated premium quality pearls, such as, enhancing health and wellbeing through protocols that reduced or prevented disease outbreaks[1,4-9];
3. identifying appropriate cultivation areas and their respective maximum sustainable stocking densities for sea-bottom and mid-to-subsurface water environments[1] (pers. comm. with farmers /pers. obs. at WA and NT pearl farms); and
4. reducing conflicts between competing resources by operating in pristine areas naturally protected and/or devoid of large-scale fishing, prawning or trawling activities (pers. obs. over 28 years, pers. comm. Dr L Joll, WA Fisheries).

In summary, an extensive report by Enzer Marine Environment Consulting for the Pearl Producers Association Inc., written by Dr Fred E Wells in 1998, detailed the fisheries management practices and assessed the environmental effects of the industry's operations[9].

1b. *How did they achieve this success?*

The WA Pearling Industry is a "best practice" example of balancing environment with commercial interests in a limited-entry fishery. The Industry achieved success by including aquaculture as an effective tool within its regulatory legislation to augment the wild fishery quotas to hedge bet for sporadic oyster mortalities and to ensure sustainability of the wild stock[1,10]. However, the initial regulatory environment was too restrictive and aquaculture development and innovative genetic or molecular research during the 1980-1990's was stifled. Unfortunately, the regulatory framework, aimed at maintaining sustainable wild stock, encouraged larger quota-holders and created a monopoly or duopoly and reached a scale of economy that promoted market dominance in Australia and the ability to restrict supply as a marketing mechanism[10].

Subsequently, in the late-mid 1980s, large quota-holding companies rejected a proposal to establish an industry-based, co-operative hatchery that would be run by licensee stakeholders. This facility would have supplied hatchery-bred oysters for all licence holders with hatchery-quota, including additional oysters as either a replacement of all, or a proportion of, their annual wild oyster quotas[1]. Large companies were concerned the availability of hatchery-bred oysters would disrupt the status quo revenue by adversely affecting the magical secrecy, romantic uniqueness or quality (i.e., saleability) of Australian South Sea Pearls[11,12,13]. Unfortunately, global, SSP industries were not concerned and took advantage of this self imposed restriction and continued to increase production to meet the world demand. Moreover, with the availability of published scientific R&D literature from Australia and aquaculture expertise from Japan, offshore companies (including a number of Australian ones) effectively reduced their operational costs to produce high quality SSPs by farming hatchery-bred oysters instead of fishing wild populations.

Fortunately, the pearl producers in the NT continued using aquaculture-farming husbandry developed in WA, forming commercial joint ventures with Australian aquaculturists[12,13] and later, during mid-to-late 2000 partnerships with commercial hatchery-based pearl farms and universities to research improving pearl quality through genetic research[14]. The larger companies followed after the smaller licence holders demonstrated the viability of producing premium grade pearls cost effectively from hatchery-bred pearl oysters in the NT. The turning point was reached around 2000 and now most Australian pearl producers utilise hatchery-bred oysters in addition to their wild quota (approximately 20 years after the life cycle was closed by the WA Fisheries Department).

Interestingly, the slow acceptance of aquaculture by the larger established companies reflected their perception that this new farming husbandry would create uncertainty and market share disruption. In contrast, the smaller, new companies saw an opportunity to expand and profit using a new biotechnology that gave better control over production quality through domestication and subsequent access to new niche or mainstream markets.

Finally, a review in 1998 by the Centre for International Economics found many of the legislative features of the WA Pearling Act 1990 were anticompetitive and could contravene the National Competition Policy[10]. These anticompetitive restrictions could be divided into four groups (Chapter 4, pg 15):

- controls of access to the industry;
- operational restrictions through input controls;
- limits on outputs for fishing and hatchery activities; and
- development of property rights.

The review found some of these restrictions, when compared with their rationale and effects or consequences, were definitely anticompetitive, while others could be anticompetitive under certain conditions; and yet others, which appeared anticompetitive in the short term, could result in competition in the longer term by promoting the sustainable management of the wild fishery and were justified under NCP guidelines. However, restrictions on hatchery activities related mainly to market objectives and required scrutiny.

References:

[1]Malone, F.J., Hancock, D.A., Jeffriess, B. 1988. *Final Report of the Pearling Industry Review Committee* to: Hon Julian Grill, MLA. WA Minister for Fisheries and Hon John Kerin, MP. Federal Minister for Primary Industries and Energy. Fisheries Management Paper No. 17, pp1-215.

[2]Rose, R.A. and Baker, S.B. 1994. Larval and spat culture of the Western Australian silver- or goldlip pearl oyster, *Pinctada maxima* (Jameson) (Mollusca: Pteriidae). Aquaculture 126: 35-50. abstract

[3]Rose, R.A., Dybdahl, R. and Harders, S. 1990. The reproductive cycle of the Western Australian silverlip pearl oyster, *Pinctada maxima* (Jameson) (Mollusca: Pteriidae). Journal of Shellfish Research (9)2: 261-272. abstract

[4]Jernakoff, P., 2002. Environmental Risk and Impact Assessment of the Pearling Industry. Fisheries Research & Development Corporation. Project No. 2001/099. Publ, IRC Environment. ISBN 0-9581421-0-6.

[5]Fletcher, W., Friedman, K., Weir, V., McCrea, J. and Clark, R. 2006. Pearl Oyster Fishery. WA Aust. Fisheries and Marine Research Laboratories. Publ. Dept. Fisheries, WA. ESD Report Series 5, January 2006. ISBN 1-877098-44-2. Website: http://www.fish.wa.gov.au/Documents/esd_reports/esd005.pdf

[6]Pass, D.A., Dybdahl, R. & Mannion, M.M. 1987. Investigations into the Causes of Mortality of the Pearl Oyster, (*Pinctada maxima*, Jameson) in Western Australia. Aquaculture, 65:149-169. abstract

[7]Mannion, M.M. 1983. Pathogenesis of a marine Vibrio species and *Pseudomonas putrefaciens* infections in adult Pearl oysters, (*Pinctada maxima*) (Mollusca; Pelecypoda). Honours thesis, Murdoch University, pp 1-130. abstract

[8]Humphrey, J.D. and Norton, J.H. 2005. The Pearl Oyster *Pinctada maxima*, (Jameson, 1901). An Atlas of Functional Anatomy, Pathology and Histopathology. NT Dept. Primary Industries and Fisheries, and Fisheries Research and Development Corporation (ISBN 0 7245 4722 3), NT Government Printing Office, pp 1-111.

[9]Wells, F.E., 1998. The Environmental Impact of Pearling (*Pinctada maxima*) in Western Australia, Enzer Marine Environment Consulting for the Pearl Producers Association Inc. 52 pg, 6 appendices.

[10] *Review of the Western Australian Pearling Act 1990: Under the National Competition Policy Review of Legislative Restrictions on Competition, Discussion paper*. 1998. Centre for International Economics, Canberra & Sydney, GPO Box 2203, Canberra ACT 2601, Australia, pp 1-47.

[11]Rose, R.A., 1994. Development of Pearl Oyster Hatcheries in Australia: An Historical Perspective. The International Pearling Journal, Vol 2:1, pp 6.

[12] Henricus, J. 2002. Pearling law amendments likely to lift South Sea output in Australia's Northern Territory. Jewellery News Asia, August 2002 edition, pp 38, 40, 42, 44.

13. Henricus, J. 2002. Pioneer on hatchery technology shares views on pearling. Jewellery News Asia, October 2002 edition, pp 34-36, pp 38.

14. Jackson, D.J., McDougall, C., Woodcroft, B., Moase, P., Rose, R.A., Kube, M., Reinhardt, R. Rokhsar, D.S., Montagnani, C., Joubert, C., Piquemal, D. and Degnan, B.M. 2009. Parallel evolution of nacre building gene sets in molluscs. Journal of Molecular Biology and Evolution, 27(3): 591-608

2a. ***Are existing regulatory arrangements well-targeted and efficient means for managing aquaculture operations and addressing potential environmental impacts?***

Regulatory arrangements for well-established aquaculture industries (e.g., salmonoids, tuna, barra, pearl and edible oysters, abalone, and prawns) over time have become reasonably well targeted. Their management operations are proficient enough to mitigate potentially negative environmental impacts. Feedback mechanisms between practitioners, regulators and researchers make this possible.

However, with the rapid expansion of aquaculture in Australia for export, which involves comparatively new, low-trophic marine organisms (e.g., clams, sea cucumbers, sponges and micro/macroalgae) or mid-trophic finfish and shellfish (e.g., eels, grouper and crayfish), many of the existing regulatory arrangements are not appropriate. They are more of a reflection of the Fishery regulator's incomplete knowledge of the organism's ecology. As a consequence, many current regulations are poorly targeted and derived from anachronistic management practices adopted from surrogate species originally part of the wild fishing industry.

Until effective, evidence-based management regulations are developed for both extensive and intensive cultivation of species within their zoogeographic zones, regulators will default to "precautionary principles" when addressing potential environmental impacts (i.e., a strategy that copes with possible risks without full scientific knowledge). The results invariably contribute to potentially long/expensive delays during the commercialisation phase for a number of nascent aquaculture projects in Australia; risking Australian Aquaculture becoming globally non-competitive and falling behind in production. This topic is succinctly outlined in two final reports by the Commonwealth's Joint Select Committee on Northern Australia: *Pivot North* (on the development of Northern Australia; Sept 2014[15]) and *Scaling Up* (on opportunities for expanding aquaculture in Northern Australia; Feb 2016[16]).

References:

15. *Pivot North – Inquiry into the Development of Northern Australia: Final Report.* 2014. Joint Select Committee on Northern Australia. Commonwealth of Australia, ISBN 978-1-74366-176-5, pp 1-267.

16. Scaling Up - Inquiry into Opportunities for Expanding Aquaculture in Northern Australia. 2016. Joint Select Committee on Northern Australia. Commonwealth of Australia, ISBN 978-1-74366-378-3, pp 1-151

2b. *Have regulatory arrangements inhibited the productivity and competitiveness of aquaculture in Australia?*

Yes, regulations have hindered innovation and productivity and thus competitiveness in some aquaculture activities. In the sea cucumber (trepang) fishery, for example, iterative information suggests one licence holder owns almost all of the Australian wild fishing licences. Currently, the only way for a new entity to enter the fishery as an aquaculturist to conduct subtidal grow-out (sea ranching on the seafloor) is to approach the licence holder to lease or purchase Commonwealth offshore seawater habitats. This impedes access to almost all of the national coastal zones connected to the licences, making the process of obtaining a wild fishery licence for a new aquaculture venture either impossible or prohibitively expensive. However, a solution for aquaculture projects is comparatively straight forward if Australian Pearling Industry policies are applied where Aquaculture licences are not tied to wild quota licences and given access to sea zones for grow-out/sea ranching, along with a permit to collect broodstock.

Although it is an essential, normal practice for primary industry ventures, to have compliance requirements for an aquaculture licence (including developmental licences not attached to pre-existing fishery licences), they are typically overcomplicated and require enormous amounts of time and money spent providing information on notices of intent. Further requirements include: logbook records; boat, machinery, gear certification or credentials; environmental, operational, business, financial planning documents; design and construction approvals; water usage/effluent process permits; health and safety certificates; evidence of operational expertise for various segments of the project; risk evaluations; insurance and corporate credentials and evidence of consultations with stakeholders (personal experience). This performance monitoring or "red tape" impedes the development of innovation and productivity.

Since the process involves several bureaucracies who evaluate information, as well as holding consultative meetings and inspections at their convenience, the notion of starting/establishing a business in a considered time frame is often lost. Introduction of the "one stop shop" policy, in which one central government bureaucracy representing all the other relevant departments has not worked as envisaged (see recommendations in ATSIC's *Survey into Indigenous Economic and employment Opportunities in Aquaculture in the TOP End of the Northern Territory, June 2004*)[17].

Projects starting up in remote regions of Australia (many of which are initiated because of the ideal marine conditions) are often severely disadvantaged, when schedules and logistics relating to site development, construction, broodstock collection/spawning and production are thrown out of synchronisation with the breeding season of the species under cultivation. Moreover, staff levels and investment arrangements are compromised, negatively affecting revenue/cash flows or loan agreements. The severity of the delays naturally depends on the size of the project, with larger projects absorbing the loss in time and money more easily.

According to various commercial Australian practitioners and/or national and international institutions (pers. comm.), many consultancies or private aquaculture companies have experienced inordinate delays. For example:

1. a prawn aquaculture enterprise in the Darwin area Blackmore River, Berry Springs, Lichfield, NT trading as Wild River Farmed Seafood took eight years to establish its tiger prawn hatchery/grow-out/processing operations (pers. comm. with co founder, 2005).
2. an Indigenous sea cucumber hatchery/nursery/sea ranching/processing venture in Groote Eylandt took eight years (2004 to 2012) to obtain a developmental licence and become shovel-ready, initiated by the Angabunumanja Aboriginal Corporation, Groote in a joint venture with Tropical Aquaculture Australia (TAA) trading as Traditional Trepang Traders[16]. The latter project applied for a license in 2012 and is still waiting for a letter from NT Fisheries giving approval to secure offshore coastal sea leases for grow-out/sea ranching (pers. comm., 2016).

As a consequence of not being able to commercialise in a timely manner, production aquaculturists have shifted or expanded their operations offshore to continue their careers, consultancies or businesses in the Asia Pacific region (These are primarily small to medium size mariculture ventures propagating finfish, molluscs or sea cucumbers). In S.E. Asia, where many of the wild fisheries have commercially collapsed, the demand for seafood has been strong since the mid-90s and into the new millennium. Figures from Washington, DC: Brookings Institution by Kharsa & Gertz (2010)[18] show the world middle class growing to 5 billion with 66% of the population emanating from Asia Pacific by 2030. In particular, seafood consumption in Asia is poised to increase in line with the rising middle class. To encourage aquaculture commerce, many of the Asian Pacific countries (Indonesia, Malaysia, Singapore, Vietnam, Thailand, Philippines and Korea) are providing a wide rage of competitive economic tax incentives. For instance, in the Philippines income tax holiday concessions range from four years for non-pioneer enterprises to six years for pioneer enterprises[19].

References:

[17.]ATSIC - *Survey into Indigenous Economic and employment Opportunities in Aquaculture in the TOP End of the Northern Territory.* June 2004. Prepared by RA Rose, Pearl Oyster Propagators P/L for Aboriginal and Torres Strait Islander Services (ATSIS). Contract No. S449/5343. [Electronic copy emailed upon request]

[18.] Kharas, H. and Gertz, G. 2010. The New Global Middle Class: A Cross-Over from West to East. Wolfensohn Center for Development at Brookings. Draft version of Chapter 2 in "China's Emerging Middle Class: Beyond Economic Transformation"(Cheng Li, editor). Washington DC: Brookings Institution Press. Website:
http://www.brookings.edu/~/media/research/files/papers/2010/3/china middle class kharas/03_china_middle_class_kharas.pdf

[19.] Investment Incentives in the Philippines (2015). PWC (Price Waterhouse Coopers Organization. Prepared by Lipana & Co. Website:
http://www.pwc.com/ph/en/business-guides/assets/documents/pwc-investment-incentives-in-the-philippines-2015.pdf

3. *What, if any, developments have there been in the aquaculture industry since 2004 that the Commission should specifically consider in this Inquiry?*

Technical:

- Biodiscovery – species that are low-trophic feeders and a source of protein (foods) and/or pharmaceutical and nutraceutical compounds (cures, preventives or health supplements).
- Selective/genetic breeding – domestication (breed lines) and genetic modification (GMO through genetic engineering)
- Feeds – nutritious and targeted for particular species, genera, family groups or trophic levels (e.g., carnivores, omnivores detritus omnivores or filter feeders (for either phytoplankton or zooplankton or both).
- Physiological processes associated with healing, immune systems, digestion, development and reproduction to improve seafood quality.
- Disease prevention – prophylactics/medicines from probiotic bacterial or new antibiotic compounds for species culture.
- Hygiene biotechnology – sterilisation (autoclaving), disinfection (e.g., chemicals, UV, ozone), filtration (mechanical and biofiltration) associated with HACCP systems (hazard analysis critical control points).
- Bioremediation of pollution from hatcheries/nurseries/grow-out systems to improve treatment efficiency and reduce long-term economic costs.
- Recirculation Aquaculture Systems (RAS)[20,21] to reduced effluents adversely impacting coastal seawaters.
- Biologically-based, regional zoning of aquaculture activities to ensure carrying capacity of water bodies are sustainable for given stocking densities, and help reduce organisms escaping from rearing enclosures as competition increases for water resources[22].

Non-Technical:

- Regional development - see the Pivot North and Scaling Up inquires[15,16] mentioned above.
- Strategic national development - AIMS 10-year (2015-2025) plan towards "Driving the development of Australia's blue economy"[23] and "Development strategies for the [Aquaculture] industries of Western Australia[24].

- Policy and governance - as note on page 83 in FAO's *The State of World Fisheries and aquaculture*, 2010, the level of development is most rapid in countries where entrepreneurs from the private sector have been successful and this has been directly related to governance[25].
- Triple bottom line enterprises - see *A guide to reporting against environmental indicators*, by the Commonwealth Department of Environment and Heritage[26].

One of the most important pivotal developments in the view of many practitioners is the R&D on aquaculture feeds that are cost-effective and derived from land-based nutrient sources rather than utilising marine organisms (fishmeal), for example:

- Improved feed formulation and rations derived for individual digestive nutrient levels rather than on crude gross nutrient levels (for example, CSIRO's recent patented prawn feed, Novaqc[27]).
- Nutrient rich microbial floc-based aquaculture production systems have been used to rear herbivorous/omnivorous filter feeders (e.g. carp and prawn) within the culture medium. The flocculent is used to compensate for lower-cost aquafeeds that have nutrient deficiencies. (Tacon et al. 2002, cited below in FAO Technical Paper 540[28]).

These techniques should improve growth and quality of the cultured stock and reduce production costs for all types of seafood organisms, including filter-feeding species.

References

20. Recirculating aquaculture systems Queensland Government. Website: https://www.business.qld.gov.au/industry/fisheries/aquaculture/site-selection-and-production/aquaculture-production-systems/recirculating-aquaculture-system-characteristics

21. Blue Ridge Aquaculture.
Website: http://www.blueridgeaquaculture.com/aboutus.cfm

22. *The World Fisheries and aquaculture: Opportunities and challenges*. 2014. Food and Agriculture Organisation of the United Nations (FAO). ISBN 978-92-5-108275-1, pp 1-221. Website: http://www.fao.org/3/a-i3720e.pdf

23. *National Marine Science Plan 2015-2025: Driving the development of Australia's blue economy*. 2016. Australian Institute of Marine Science. Website: http://www.marinescience.net.au pp 1-48.

24. *Aquaculture: Development Strategies for the Industry in Western Australia*. 1994. Aquaculture Development Advisory Council, ISBN 0 7309 5594 X, pp 1-41

25. *The State of World Fisheries and Aquaculture*. 2010. FAO. ISBN 978-92-5-106675-1, pp 1-197. Website: http://www.fao.org/docrep/013/i1820e/i1820e.pdf

26. *Triple Bottom Line Reporting on Australia: A Guide to Reporting Against Environmental Indicators*. 2003. Commonwealth of Australia, Department of the

Environment and Heritage. Policy Co-Ordination and Environment Protection Division, Canberra ACT. ISBN 0 642 54937 0, pp 1-80. Website: https://www.greenbiz.com/sites/default/files/document/CustomO16C45F42151.pdf

[27]. Novacq prawn feed. 2016. CSIRO. Website: http://www.csiro.au/en/Research/AF/Areas/Aquaculture/Better-feeds/Novacq-prawn-feed

[28]. Tacon, A.G.J., Metian, M., and Hasan, M.R, 2009. Feed ingredients and fertilizers for farmed aquatic animals: Sources and composition. FAO Fisheries and Aquaculture Technical Paper 540. Rome, ISBN 978-92-5-106421-4, pp 1-209. Website: http://www.fao.org/docrep/012/i1142e/i1142e.pdf

4. ***Are there factors outside the regulatory environment that have significantly limited the productivity and competitiveness of aquaculture production in Australia?***

Commercial practices:

- The factors outside the regulatory environment that pertain to restrictions on competition have been discussed in questions **1b** and **2b**. The lack of aquaculture legislation in its own right will affect productivity and competitiveness of marine aquaculture (mariculture) production as it overtakes wild fisheries (paraphrasing an analogous concept that hunting is overtaken by herding and farming by J. Diamond in his book *The World Until Yesterday* (2012)[29].
- The industry should not be an adjunct to the wild fishery limited-entry legislation. This situation effectively excludes aquaculture activities by non-wild licence holders. This stifles innovation and ultimately, Australia's capacity as a potential major seafood provider offering a wide variety of clean, premium quality sea products. Rural and remote coastal Aboriginal communities, whose sea trade flourished in Northern Australia in the 18th and 19th centuries with the Makassans[30] or Papua New Guineans, are unlikely to be able to participate noticeably due to current wild license arrangements blocking their ability to engage in this rapidly increasing, renewable, marine resource-derived commerce.

Economies of scale (cost advantages due to size, output or scale of operation)

- Regulatory frameworks must promote economies of scale that are cost saving for all varieties of aquaculture in the context of triple-bottom-line principles of businesses. Regulation must accommodate ventures, which rely on different scales of production. For example, large businesses would be able to reduce operating costs with large-volume/scale production of a standard quality seafood product over long periods (e.g., recent investment project Sea Dragon[31] for prawns, and established edible oyster, mussel, finfish ventures). Smaller businesses, in contrast, would (at least initially) operate on smaller volume/scale production when producing seafood and medicinal products (e.g., sea cucumber, giant claims, abalone and macroalgae).

Business Models (adhering to triple bottom line principles)

- To promote productivity and competitiveness, legislation frameworks should support ventures separately, or not-for-profit co-operatives, which operate on evidence-based biological reproduction models to develop the best method to selectively breed and hatchery-propagate juveniles, develop onshore and offshore nurseries, grow-out (sea pens/sea ranching), and harvest/market products. Businesses should be able to progress towards becoming vertically integrated as producers, processors, wholesalers and/or retailers (if practical). Clearly, legislation should encourage business practices that innovate, adapt and adopt to remain productive and competitive rather using market dominance as a tool to restrict supply and control prices.

Tyranny of distance

- Legislation should allow controlled expansion of aquaculture projects that help create regional business hubs in areas with poor or no infrastructure typically found in northern Australia[15,16]. Financially practical private/public investment arrangements should be encouraged to provide primary infrastructure like those available from eight Asia Pacific Economic Cooperation (APEC), including Australia[32]. Many of these Asian countries (Indonesia, Malaysia, Singapore, Thailand, Vietnam, Philippines, Korea) that are participating in five types of infrastructure partnerships also have aquaculture industries. A summary list of the tax incentives available according to Curran 1999 findings[32] presented below:
    - Tax Holidays
    - Reduced Corporate Tax Rates
    - Accelerated Capital Allowances and Investment Allowances
    - Location Based Incentives
    - Reduced Taxes on Dividends and Interest
    - Reduction in Withholding Tax
    - Carry Forward Losses
    - Deductions for Qualifying Expenses
    - Reduction in Indirect Taxes
    - Other Related Incentives (e.g., non-tax incentives for encouraging investment: guarantees that infrastructures will not be nationalized (Vietnam and Thailand); intellectual property rights protected (Vietnam); and permits available for skilled foreign workers, permits for land ownership and remittance of money abroad in foreign currencies (Thailand).

References

[29]·Diamond, J. 2012. *The World Until Yesterday*: *What Can We Learn From Traditional Societies*. Penguin Books, in Australia: 707 Collins St. Melbourne, Victoria. ISBN 978-0-141-02448

Website: http://www.jareddiamond.org/Jared_Diamond/The_World_Until_Yesterday.html

[30]. Russel, D. 2004. Aboriginal – Makassan interactions in the eighteenth and nineteenth centuries in northern Australian and contemporary sea rights claims. Australian Aboriginal Studies 2004/1, School of Earth and Environmental Science, University of Wollongong, dr34@uow.edu.au. pp 1-17. Website: http://lryb.aiatsis.gov.au/PDFs/aasj04.1_makassan.pdf

[31]. *Investment opportunities in Australian agribusiness and food.* 2015. Australian Government, Australian Trade Commission, Australia Unlimited, pp 1-37. Website: http://www.nt.gov.au/d/Content/File/Investment-opportunities-in-Australian-agribusiness-and-food.pdf

[32]. Curran, M. *Tax Incentives for Public-Private Partnerships*. RMIT School of Accounting and RMIT APEC Research Centre, pp 1-13. Website: http://www.apec.org.au/docs/Tax Incentives for PPPs.pdf

5. *What are the major challenges and opportunities facing the aquaculture industry over the next 20 years?*

A number of the major challenges/opportunities facing the aquaculture industry are:

Limited Space: water quality/habitats/wastewater

(Development of Aquaculture marine zones is as imperative as the already established captive fishing zones)

- There is a need to establish policy regulations or aquaculture acts dedicated to managing coastal inter-tidal and sub-tidal zones, similar to conservation marine reserves. The zones must account for the different types of aquaculture activities: extensive, semi-intensive and intensive (i.e., ranching to farming) to be able to evaluate their impact on the marine environment.
- These zones should to be sensitive to the level of commercial overheads and production costs used to hatchery-produce or collect wild juveniles, rear the juveniles and adults to harvesting and processing. The type of species (carnivorous, omnivorous or herbivorous) determines the dietary requirements, water quantity and quality parameters, stocking densities, and the hatchery/nursery/grow-out efforts and will determine the category. Extensive aquaculture characteristically has variable production levels in quantity and quality and can negatively impact on the environment. In contrast, semi- and intensive aquaculture, controls production and can minimise habitat degradation more reliably. Semi- or intensive aquaculture is more cost-effective for reliable high quality export production if the animal's ecology and biology are understood and the market demand is traditionally strong. However, if environmental deterioration is controlled, zones could be set-aside in marginal areas where there is a domestic market for aquaculturing hardy "weed" species that are indigenous, utilise

natural food sources, are low maintenance and tolerate variable water exchange or quality (e.g., mangrove mussels).

- All sea and land based aquaculture require pristine water sources like fishery industries and should be out of the influences of urban and industrial community pollution. As already regulated to some extent, effluent from hatcheries and nursery operations must continue to be removed and from the seawater before it is discharged back into the marine environment.
- Within these zones marine reserves should be developed to specifically preserve commercially important seafood species, their habitats and marine biodiversity generally. These zones would extend within 3 nautical miles offshore under the jurisdiction of Commonwealth States and the Northern Territory. Furthermore, similar zones with marine reserves should be delineated and held for future expansion by the Commonwealth within the three – 200 nautical mile Exclusive Economic Zone (EEZ).
- Ideally and where applicable, for example, these zones could be setup by CSIRO staff, members of AIMS, the Applied Environmental Decision Analysis (AEDA; a Commonwealth Environment Research Facility[33]), and managed by Traditional Owners from coastal communities of Northern Australia with the Northern Territory Fisheries Indigenous Community Marine Ranger program[34].

Aquaculture productivity: innovation, adaption and adoption

(Husbandry, feeds, biotechnology, RD&E projects, bio-discovery, bioremediation, disease control)

- Improve RAS systems to develop more efficient husbandry techniques and biotechnologies that process the water during bioremediation/mechanical filtration treatments[20,21],
- Continue to develop artificial feeds for different trophic level species that approximate their natural foods in nutritional content, texture and aroma. For example, as mentioned above in Question **3.**, CSIRO has recently increased health and the growth rate of prawns by 20-30% without wild fishmeal or fish oil products, by using a natural food source produced by microbial marine organisms and created a renewable food source for prawn aquaculture. Therefore, avoiding competition with wild marine organisms for their natural fishmeal food and over-exploiting wild fish for their oils to produce aquaculture feeds for prawn cultivation[27]. The higher trophic-level finfish will need similar innovative feeds.
- Continue to domesticate aquatic animals and plants through genetic selection or engineering investigations to improve their nutritious quality, rapid growth, disease resistance through selective breeding programs and genetic engineering.
- Continue bio-discovery programs screening for deep sea, pelagic and demersal marine organisms as candidates for aquaculture RD&E investigations that establish the husbandry/biotechnology required for commercial farming.

- Continue to develop medicines to control disease outbreaks affecting stock using new antibiotics, probiotics and vaccines.
- Continue bioremediation programs to manage pollution from hatchery, grow-out and processing operations using microbes to break down pollutants.
- Continue with pollution research into the ingestion of nano- and micro-plastics by marine organisms and the toxic effects these particles may have when initially incorporated into the tissue of lower trophic organisms and continue to accumulate up the food pyramid to higher trophic seafood organisms and eventually humans[35,36].
- Advance cultivation of aquaculture species that are important for nutraceutical and pharmaceutical products (vitamins, compounds, lotions or medicines).

Governance: (sustainable triple-bottom-line [profit, nature, people] business integrated with fair-trade practices)

- The current Commonwealth regulatory bureaucracies for wild fisheries and aquaculture industries have policy goals clearly designed to increase productivity and protect the environment. To successfully achieve these outcomes regulators should blend ‘top down’ (clear-precise outcomes through hierarchical driven goals) with ‘bottom up’ (local-variable, but practical, need-based outcomes driven by individual/small team innovators). Regulators should encourage aquaculture participants to operate sustainably on renewable resources, in a profitable manner that allows participants and their communities to benefit socially. Australian aquaculture will then remain competitive in a world with an increasing human population and limited resources for food (seafood) production.
- Regulatory policies developed for triple bottom line (TBL) economics would have the framework to provide opportunities for both small and large business to operate free from monopolistic practices that stifle prosperity as described above. Larger scale enterprises should not be able to over-claim sea sites that are not utilised for several decades. Practical business arrangements could encourage Traditional Owners to participate as equity partners and workers, for example. Succession schemes, like those proposed by a sea cucumber aquaculture project in Groote Eylandt NT (question **2b**), in which locals are educated and trained to manage and run the operations as part of a succession plan would give sustainability to all large and small aquaculture ventures.
- If the seafood aquaculture industry follows mining, wild fishery, telecommunication, agriculture and food retail sectors of commerce, then some of the current unfair, anti-competitive practices will likely develop (or remain active as in some of the existing fisheries) which lead to loss of innovation and future opportunities. The outcome will be large high-volume enterprises (typically, finfish and prawns) that dominate sea sites and squeeze out smaller business based on cultivating low-trophic invertebrate and finfish species. These aquaculture species may not be

ubiquitous "meat and potato" seafood, but have been a traded commodity for centuries (e.g., seahorses, eels, sea urchins, and sea cucumbers). Moreover, many are delicacies or provide important nutraceutical and pharmaceutical compounds in high demand and are generally have a more lucrative cost per unit effort than some of the larger businesses aqua culturing common fish and crustacean seafood.

- Australia's aquaculture industry is mainly located in regional Australia, making it an important contributor to regional development[37]. In remote coastal areas the seafoods and marine products available for aquaculture are often from species of low-trophic status, which do not require expensive feeds during cultivation or refrigeration after processing. Techniques for preserving meat are drying, canning, or live transport. Shells are dried and packed whole and pearls are washed and stored safely (e.g., trochus, mud crabs, giant clams, edible oysters, pearl oysters, sea cucumbers, sea urchins, sponges and marine macroalgae; pers. obs.).
- As stated in the Pivot North[15] and Scale-Up[16] inquiries cited in question **2b,** Traditional Owners from remote coastal regions with TBL businesses would have greater opportunities to participate in regional development, allowing them to continue to reclaim some of their coastal seas for recreational and commercial fishing, and aquaculture. Their business activities would extend to offshore subtidal waters and not be confined to just intertidal waters (i.e., high to low tide zones) as currently permitted for TOs living at Blue Mud Bay, NT (see High Court Decision; Brennan, 2008[38]).
- A keen interest in aquaculture amongst rural coastal aboriginal communities in the NT was reported in a survey by ATSIS for ATSIC in 2004[17], pre-existing financial structures for First Australians, are supervised by a labyrinth of government created land councils that set-up/operate/supervise trusts, business enterprise entities that primarily dispense royalty money for infrastructure investment, service-based activities for social industries, or disbursements or royalties to trustees. Very few in existence appear to be world-class money generating businesses (pers. obs.). Aquaculture could provide coastal communities, with meaningful work in seafood and marine products. Currently increasing populations of young unskilled citizens inhabiting large expanses of Northern Australia have little opportunity to actively engage in productive work.

Education: (principles of aquaculture production (gate to plate) for practitioners, regulators, researchers)

- Aquaculture education in particular needs to train students to work safely, productively and innovatively. This should be achieved by formal university education for future production biologists or by applied "TAFE" training for hatchery, nursery/grow-out and processing technicians.
- Students need to learn about working in a safe environment, for example, principles of: biochemistry (toxins, nutrients, medicines,) physics

(mechanics, electricity, hydrology) and biology (microbiology, pathology, ecology, biology) and biotechnology (filtration, bioremediation, disinfection, sterilisation, sanitation, harvesting/processing/preservation, and transportation/marketing).

- Education is the most cost-effect “under writer” to prepare future generations of aquaculturists to be productive leaders in national and international industrial developments that relate to the concepts of physiology/ecology behind biotechnologies supporting: diets; hygiene; husbandry; selective breeding, genetic/transgenic modification of species; pollution/effluent remediation from hatcheries, nurseries, grow-out (pers. Obs.).
- Equally important is that students are exposed to mentoring by experienced practitioners. These individuals would guide/inspire or motivate students in applying their education towards new techniques through innovation (pers. obs.).

RD&E programs (transform E to become more effective to meet sustainable and diverse aquaculture businesses)

- The numerous providers of research, development and extension frameworks[39] need to restructure their extension programs to reduce complex rules and regulations and avoid non-productive constraints affecting small aquaculture businesses operations. The current R&D frameworks[40,41] appear to duplicate existing services. A focused strategy should be implemented on working effectively with small and large marine aquaculture groups to facilitate equal opportunities for progressing R&D to commercialisation. This would support their national raison d’être by:
  1) Facilitating equal opportunity for small aquaculture industries.
  2) Changing regulatory framework to facilitate resolution of site selection conflicts between large and small ventures generally or particularly on Traditional Country that allows regional communities to engage in seafood commerce. Provide suitable sites, for small aquaculture business to be innovative, support competitive and commercial viability to adapt with new, improved cost-effective processes and adopt new biotechnologies or practices.
  3) When R&D extension frameworks in primary industries are commercialised then other potential non-aquaculture TBL ventures, such as, tourism, recreational and Indigenous customary fisheries[42], horticulture and native art industry may emerge. For historical sea trading communities in the Kimberley, Top End, East Arnhem Land, Gulf of Carpentaria, York Peninsula, Torres Strait, for example, the possibility of establishing a primary industry base economy improves. The failure of RD&E regulators to revamp the extension framework to support or facilitate a diverse aquaculture industry compatible with other useful industries that also benefit from preserving the marine environment would be a counterproductive. The Commonwealth’s endeavours and aspirations to become a sustainable, major global

exporter of seafood will be diminished. Particularly, when this affects the Australian rural sector's 7.7 million people or one third of the country's total population[43].

References:

[33.]Decision Point: Connecting conservation policy makers, researchers and practitioners. Two Issues: #29 / June 2009; and #30 / July 2009; #.
Website: http://decision-point.com.au/past-issues/.
Examples of articles from Decision Point magazine:

1) Treml, E. 2009. *Quantifying connectivity/conserving coral reefs: Conceptualising coral systems as graph networks.* Decision Point #29:3-4. Publication supporting article by: Teml, E.A., Halpin, D.L., Urban, D.L. and LF Pratson. 2008. Modeling population connectivity by ocean currents, a graph-theoretic approach for marine conservation. Landscape Ecology, 23:19-36.
2) Joseph, L. 2009. *Dial PPP for robust allocation: A transparent and correct method for choosing management priorities for threatened species*. Decision Point #29:8-10. One of several publications supporting article by: Joseph, L.N., Maloney, R. and Possingham, H.P. 2009. Optimal allocation of resources among threatened species: a project prioritization protocol. Conservation Biology, 23:328-338. (Note: PPP= Project Prioritisation Protocol.)
3) Gibbons, P. 2009. *Where would you put your conservation dollar?: So, you think you know a little about prioritising resources for conservation. Try this quick quiz.* Decision Point #30:7-9. One of several publications supporting article by: Turner, I.M. 2005. Landscape ecology: What is the state of the science? Annual Reviews of Ecology, Evolution and Systematics, 36:319-344.
4) Klein, C. 2009. *Marine conservation planning for a complex word: Spatial marine zoning for fisheries and conservation.* Decision Point #33:8-9. Publication supporting article by: Klein C.J., Steinback, C., Watts, M., Scholz, A.J. and Possingham, H.P. 2009. Frontiers in Ecology and the Environment doi:10.1890/090047.

[34.]Department of Primary Industry and Fisheries (DPIF). Indigenous Community Marine Ranger Program.
Website: http://www.nt.gov.au/d/Fisheries/?Header=Indigenous Community Marine Ranger Program.

[35.]Wright, A.L., Thompson, C. R. and Galloway, T.S. 2013. The physical impacts of microplastics on marine organisms: Review. Journal Environment Pollutions 178:c483-492. Elsevier, www.elsevier.com/locate/envpol
Website: http://www.sciencedirect.com/science/article/pii/S0269749113001140

[36.]Cole, M. and Galloway, T.S. 2015. Ingestion of Nanoplastics and Microplastics by Pacific Oyster Larvae. Environ. Sci. Technol. 49:14625-14632. Elsevier,
Website: http://pubs.acs.org/doi/pdf/10.1021/acs.est.5b04099

[37]. *National Aquaculture Sector Overview: Australia*. 2016. FAO Fisheries and Aquaculture Department, Country Sector.
Website: http://www.fao.org/fishery/countrysector/naso_australia/en .

[38]. Brennan, S. 2008. *Wet or Dry, It's Aboriginal Land; The Blue Mud Bay Decision on the Intertidal Zone* Indig. Law B 27; (2008) 7(7) Indig. Law Bulletin 6.
Website: http://www.austlii.edu.au/au/journals/ILB/2008/27.html

[39]. Current Fishing and Aquaculture R,D&E Structure and Processes: National RD&E Framework for Fisheries and Aquaculture Planning Workshop 22nd 23rd July 2009. FRDC.
Website: http://www.frdc.com.au/research/Documents/Final_reports/MEHDI_DOROUDI.pdf

[40]. *National Aquaculture Legislation Overview: Australia*. 2016. FAO Fisheries and Aquaculture Department, Country Sector.
Website: http://www.fao.org/fishery/legalframework/nalo_australia/en .

[41]. Commonwealth Department of Agriculture and Water Resources. National Primary Industries Research Development and Extension Framework. Website: http://www.agriculture.gov.au/ag-farm-food/innovation/national-primary-industries

[42]. *Overview of the Australian Fishing and Aquaculture Industry: Present and Future*. 2010. Produced by the Ridge Partners (Colquhoun, E. (director), Sainsbury, K., Pepperell, J., Gordon, S., and Robertson, C). Copyright Australian Government, Fisheries Research and Development Corporation and Ridge Partners. Website: http://frdc.com.au/research/Documents/Final_reports/2009-214-DLD.pdf.

[43]. Rural Research and Development Council. 2011. *National Strategic Rural Research and Development Investment Plan*. Department of Agriculture, Fisheries and Forestry. (Council Chair Fairley-Grenot, K.). Canberra. ISBN 978-1-921575-27-3.pp1-70:
Website: http://www.agriculture.gov.au/SiteCollectionDocuments/ag-food/innovation2/nsrrdip-investment-plan1.pdf

6. ***Do the existing regulatory arrangements adequately recognise the different sectors and production methods used in aquaculture and their differing environmental impacts and interaction with other resources uses?***

Generally yes, as the traditionally large finfish/shellfish aquaculture industries appear to have been able to carry out their business activities well enough to profit and expand in a cost-effective manner since the late 1970s-early 1980s. The sectors in farm production, processing/value adding, and packaging/marketing have had to comply to generic and specific environmental pollution issues within the 'chain of production' over a number of decades. This process ensured their products were healthy and ethically farmed and did not adversely affect other resource users or stakeholders. Accidents that occurred have been contained and production activities continued with minimal disruptions in the main. Moreover, each environmental mishap improved management's understanding of the ecology of the species and subsequent cultivation techniques. For additional insight into how RD&E strategies work together within "three major sectors: commercial fishing and aquaculture; recreational fishing; and Indigenous customary fishing see Ridge Partners (2010)[42] and the investment required for RD&E institutions to remain beneficial and relevant to the rural industries generally[43].

However, until state and territory aquaculture activities are formally harmonised within an Aquaculture Act[44] like that of South Australia, then the various sector activities will not have clear regulatory demarcation resulting in possible duplication due to misunderstanding between sectors. Confusion arising from service duplication is not only expensive, but also more likely to result in poor environmental outcomes and productivity. This will become particularly challenging with the scaling-up of newer large "aqua-business" farms, which may span state or territory boundaries, and extend onto the continental shelf (the Commonwealth's Exclusive Economic Zone). The intensity or severity of eco-pathological disasters may be more likely due to the sheer size and area of cultivation activity.

The health or wellbeing of the sea is ultimately related to the seasonal nutrient run-off from the continental river deltas, which fertilise coastal waters to initiate phytoplankton (microalgae) production. The availability of phytoplankton food, along with seawater quality, in turn impacts on the growth of filter-feeders[45], which underwrite the food pyramids for a particular coastal shoreline marine community. If this pattern is perturbed by weather, influenced by dams blocking or swamping coastal deltas, and compounded with run-off from urban waste or terrestrial fertilisers, then disease outbreaks may occur as was experienced by the Japanese pearling industry in the 1990s[46]. Further examples of environmental perturbations are: the destructive invasion of crown of thorns starfish in areas on the Great Barrier Reef[47]; the viral and bacterial outbreaks in sea cucumbers from December 2004 to April 2005 near Dalian[48]; and mass mortalities of sea cucumbers in 2008 due to eutrophication from green tides in Qingdao[49], China.

With global demand for seafood increasing, managing systems for both high- and low trophic species (carnivores and omnivores/herbivores) will continue have to ensure aquaculture products remain disease-free. The level of biosecurity will be demanding and require additional marine veterinarians and pathologists to monitor and control/contain disease outbreaks and infections. The ability to have clear regulatory agreements under a unifying policy will simplify rapid response teams cost-effectively (i.e., appropriate centralised testing facility able to disseminate evidence-based treatment protocols).

References

[44]. *South Australia Aquaculture Act 2001: An Act to regulate marine and inland aquaculture; and for other purposes*. Version: 1.7.2015, this version is not published under the Legislation Revision and Publication Act 2002 [3.7.2015], pp

1-50. Website: https://www.legislation.sa.gov.au/LZ/C/A/AQUACULTURE ACT 2001/CURRENT/2001.66.UN.PDF

45. Saxby, S. A. 2002. A review of food availability, sea water characteristics and bivalve growth performance at coastal culture sites in temperate and warm temperate regions of the world. Fisheries Research Report, WA Fisheries No. 132, pp 1-42.

46. Shor, R. 2007. *From Single source to Global Free Market: the Transformation of the Cultured Pearl Industry*. Gems & Gemology, Vol. 43, No. 3, pp 200-226.

47. The Possible Causes and consequences of Outbreaks of the Crown-of-thorns Starfish. 1993. Workshop Series No 18. Townsville, Qld, Aust. Editors Udo Engelhardt and Brian Lassig. Pub. GBRMPA ISSN 0156-5842. pp 1-161.

48. Deng, H., Zhou, Z., Wang, N., Liu, C. 2008. The Syndrome of Sea Cucumber (*Apostichopus jaonicus*) Infected by Virus and Bacteria. Virologica Sinica, DOI 10.1007/s12250-008-2863-9, CLC no. Q938.8, Doc code A, Article ID 1674-0769 (2008)-0063-05. 23 (1):63-67.

49. *The Sea Cucumber* Apostichopus japonicus: *History, Biology and Aquaculture*. 2015. Editors Hongsheng Yang, Jean-François Hamel, Annie Mercier. Elsevier. Academic Press Publications, pp 1-479. Website: http://www.amazon.com.au/The-Sea-Cucumber-Apostichopus-japonicus-ebook/dp/B00SR6AGJE

7a. *Are there technological solutions to the potential environmental problems associated with aquaculture?*

Yes, all state or territory fisheries with or without an Aquaculture Act equivalent to that of South Australia[44], have legislation with regulatory frameworks to ensure farming/ranching activities connected with marine organisms do not jeopardise the environment[37,40]. Aquaculture activities may be subject to Commonwealth legislation relating to the Environment Protection and Biodiversity Conservation Act, Great Barrier Reef Marine Park Act (in Queensland only) and the Native Title Act[40] (the latter, use of public land and waters). In addition, quarantine legislation can influence an aquaculturist's access to the broodstock of a species and feed.

All of the activities listed below have technical or biotechnical derived solutions and are continually re-evaluated, as new species from various regions of Australia become candidates for aquaculture. One important biotechnology is eliminating nutrient-effluent discharge from land-based aquaculture systems near iconic marine parks such as the Great Barrier Reef (see no. 5 below). These water treatment technologies will become increasingly important since more than 95% of Australian aquaculture production occurs in seawater[37]. Currently, aquaculture's volume of production has approximately doubled over the period from 2003-04 to 2013-14 according to ABARES statistics cited by the Commonwealth Department of Agriculture[48]. Moreover, this trend will continue so that by 2023 the major contributor to the rise in global seafood production by volume will most likely be aquaculture[37,48] instead of wild fisheries.

Aquaculture activities that use technologies to solve or mitigate environmental risks are listed below:

1. Replenishing healthy/viable breeding parent stock from wild populations under strict regulatory protocols use a variety of old and new technologies adapted for the marine environment that enable translocations to occur without causing biological or environmental damage, for example:
   - diving boats devoid of toxic antifouling paint;
   - fuel efficient motors;
   - safe SCUBA/hookah equipment;
   - trawling equipment with appropriate mesh sizes or escape hatches;
   - aeration/filtration transport systems;
   - anaesthetic/sedation solutions to reduce translocation stresses;
   - navigational equipment to locate stock habitats; and
   - conditioning systems to feed broodstock to enhance and promote scheduled spawnings.
2. Hatchery/nursery/processing infrastructures onshore, adjacent to seashores or nursery/grow-out structures within the inter- and sub-tidal coastal waters have efficient "foot prints" to reduce impacts on natural resources[37,49,50,51] (pers. obs.), for example:

   a) *Hatchery/nursery/processing facilities*:-
   - Infrastructure built to regional safety/environmental standards is positioned to avoid storm surges. Buildings have drainage, storage and reticulation for rainwater. Seawater is pumped to storage tanks, and reticulated to various operational subsystems. Freshwater waste is released into screened, grey-water sumps or septic tanks for treatment and/or reticulation to water vegetation. Seawater waste is directed to settlement ponds (e.g., with or without biofiltration, bioremediation or liming treatment of pond sediment). Treated seawater effluent is then released commensurate with environmental regulations and within permitted water quality parameters. Note, technology for recycled (RAS[20]) effluent treatment is more compartmentalised but still subjected to similar regulatory standards: water loss from evaporation is replaced with solids (uneaten feeds and faeces) and mechanically filtered; ammonia is removed by bio-filtration; and seawater re-oxygenated/aerated.
   - Materials used for construction that come into contact with water are cured and washed to remove any toxic residues before use. Paints are water based and biodegradable. Materials derived from renewable sources are sealed, where necessary with water based paints or membranes.
   - Cultivation plant and equipment designed and built for seawater application are used to improve productivity of live feeds, growth of larvae and juveniles, and management of diseases. Water is treated by filtration and/or food grade disinfectants (e.g., UV, ozone, and chemical

compounds) that can be diluted, denatured with water, and sterilised using autoclave units for live feed culture.

- Energy sources used vary, with the main source typically the regional grid or diesel generators. Alternative systems using a mixture of solar, wind, hydrocarbons (biogas, biofuel or fossil fuels) are being developed to augment or replace power from the grid or generators (pers. obs.).

b) *Offshore nursery/grow-out culture structures within inter- and sub-tidal waters:-*

- Structures that do not adversely affect wild stock (e.g., raceways, tanks, pens, cages, panelled nets, racks, sticks and rafts).
- GPS and marker buoys, mesh fencing, surface longlines are used for clear distinctions of boundaries to minimise navigation hazards.
- Secured rearing structures (e.g., pens or cages) with protective double netting, nonlethal acoustic or visual deterrents to avoid attracting mammalian/avian/reptilian/fish predators that damage culture structures, or eat farm stock, as well as, allowing escapees to infect or breed with wild populations, affecting their health or genetic robustness.

3. Farm stock are contained, not overstocked and monitored continuously to minimise any adverse impact on the biodiversity of marine habitats[49,50,51], and survival of commercially important wild stock[52], for example:
   - Utilising real-time, electronic monitoring equipment to measure biotic and abiotic seawater quality (i.e., levels of phytoplankton and zooplankton, microbes, dissolved oxygen or CO_2, total suspended solids (TSS), ammonia, pH, salinity, temperature), and automatic feeders to avoid waste build-up from uneaten food.
   - As above in 2 b) technologies contain farm stock in safe, escape-proof culture systems that also prevent wild predators from entering or coming in contact with farm stock.
   - Equipment and chemicals used to clean, collect, bio-fouling from longlines, nets, rope, anchors, boat hulls, and underwater bottom-culture fences/equipment for recycling or disposal[53].
   - Develop new antifouling technologies that use bactericidal nanoparticles in paints and coatings that prevent biofilm/fouling from occurring on underwater surfaces of pylons, nets or boat hulls [53,54,55].
4. The genetic profiles of wild and cultivated animals (both vertebrate and invertebrate) are being monitored to ensure that wild stocks are not genetically altered (polluted), reducing their fitness (reproductive capacity) and thus survival[49,50,51,52]. Molecular biologists, are using a multitude of innovative techniques to genetically isolate wild stock groups or subspecies, and compare differences between hatchery-produced, native and transgenic organisms (genes from other species introduced via genetic engineering techniques), for example:
   - Hatchery technology is used to breed domestic with wild animals to confirm if hybrid vigour or heterosis (e.g., survivorship, fertility, growth, disease resistance) are distinguishable. A lot of this work, for example, has

been done with finfish: salmon, trout, barramundi and channel catfish from North America, and Nile tilapia from Ghana[52].

5. Infectious disease, parasite outbreaks, occurring in stocks or their products are quarantined or destroyed to prevent infections and mass mortalities further affecting farm stock and/or wild populations[48,49,50,51,52,]. Technologies are continuously being developed to prevent disease outbreaks from re-occurring for example:
   - Detection by monitoring equipment and control by cleaning/sanitising husbandry, transportation, and processing equipment.
   - Development of instruments or machinery used to filter, disinfect, and sterilise seawater or aeration and CO_2 used in husbandry process to culture live feeds, larvae/fingerlings/juveniles/adults (e.g., autoclave units UV, ozone, submicron filtration).
   - Development of new vaccines, natural disinfectants, probiotic bacteria and strictly controlled/targeted antibiotics, to keep stock immune to pathogens.
   - Continued development of nanotechnologies as (stated above in no.3), for example:

     a) Manufacture of stainless steel food processing machinery with surfaces modified from nanoparticles to become an anti-fouling or resistant to contamination[53]; and

     b) Treatment of husbandry equipment surfaces with thin paints and coatings which contain bactericidal nanoparticles that mimic natural enzymes or surface inhibitors to prevent the occurrence of algal/bacterial biofilms or marine fouling[54].
   - Husbandry techniques used to separate stock into class sizes to reduce aggressive behaviour, which increases stress, predisposing animals to illness.
   - Development of techniques to genetically produce disease resistant farm stock[52] for both shellfish and finfish (as stated above in no. 4).
6. Marine pest outbreaks and biofouling[49,55,56,57,58] are controlled by monitoring and implementing a number of innovative techniques and hygiene protocols, similar to those stated in no. 5 above.
   - Nanotechnologies used to minimise or manage disease outbreaks are similar to those for pests and biofouling as the latter is often the reservoir/habitat for diseases, or physically affects the farm stock's growth and health by competing for space/food or impeding the flow/exchange of water and deterioration of the water quality.
   - International ships are perhaps one of the largest vectors for introducing exotic pests, such as, invasive compound acidians or bivalves (*Didemnum perlucidum;* pers. obs.) or black striped mussels (*Mytilopsis sallei*; pers. obs.). Nanotechnology films and paints can be used for hull and gunwale surfaces to control biofouling while hypersaline brine solutions can treat residual ballast water inducing complete mortality of fouling organisms suspended within the ballast water[59].
   - New technologies and strategies to control the increasing impact pests and biofouling have on an expanding seafood industry can be divided into two

groups according to Collective Research on Aquaculture Research (CRAB)[53]:

Non-coating technologies

a. Avoidance, colour of substratum, physical deterrence (air curtain), biocide injection, removal of settling stages from water (with attractants), natural grazers, high/low pH, Temperature, UV radiation and vibrations (high/low frequencies)
b. Electrochemical/electrical (e.g., precipitate/dissolved copper, surface charge, electrolysis, magnetism)
c. Cleaning on land/in water (e.g., boat wash, robot technology, manual cleaning, technical cleaning, high pressure washing, air drying, freshwater dipping chemical solutions

Coating technologies

Based on leaching of active ingredient

- (biocides – copper oxide, organic biocides) and
- (non-toxic actives – enzymes, natural compounds, living coatings (alive micro-organisms producing actives),

Based on non-leaching

- fouling release coatings (silicone PDMS, Fluor-silicones, nanotechnology based materials)
- Other (fast polishing, contact activity, removable foils, on/off demand systems, 'spiky' coatings, surfaces with defined micro-structures, hydrogels)
- Metallic layers organometallic, metal cladding

7. Pollution from hatchery/processing activities is generally well regulated to minimise the impact waste discharge has on the marine environment[49,56], for example:
   - Standard hatchery operating protocols ensure natural feeds (microalgae live, pastes, or pellets) are hygienically prepared with seawater (e.g., autoclaved, treated with sand, carbon, micron- to submicron-membrane filtration, and or UV/ozone or chlorine treated) before culturing phytoplankton feeds, embryos, larvae, and juveniles. Effluent particulates may be filtered, collected, disinfected/sanitised with food-grade chemicals, desiccated, and composted. Processing equipment, pipework and machinery are periodically, hot washed, chemically soaked, and dried when not in use.
   - There are a number of filtration systems used for intensive systems to maintain water quality and biosecurity (pathogenic-free water)[60]. At least four current filtration-technology systems are known to be used to reduce nutrient-rich aquaculture effluents: floating medium, sand, activated carbon filters; trickle bio-filters; membrane bioreactors; and algal bioremediation[61]. As reported by Jegatheesan, et al. (2006), the first two systems proved to be technically and economically practical systems for recirculating aquaculture systems (RAS) and for removing nutrient effluent discharged into marine and freshwaters environments[61].

8. The technologies used to produce Aquaculture seafoods and medicines are heavily regulated to ensure compliance with national and international (e.g., New Zealand) food safety standards and have a manageable impact on the environment[37,55,56]. For a comprehensive list of the legislative acts, codes, regulations, see FAO's overview of Australia's national aquaculture legislation[40] pertaining to water and wastewater, fish movement, disease control, drugs, feed and food safety. For an overview of the management of Australia's national aquaculture sector[37], see sections relating to the institutional framework, governing regulations, and applied research, education and training.
    - The Department of Agriculture and Water Resources[62] polices pertain to "fish and fish products" and the Department of Health[63] (Therapeutic Goods Administrations) are guidelines for prescription medicines.
    - The Commonwealth Agricultural and Veterinary Chemicals Act/Code (1995), controls the application process, registration, and manufacturing of these products, which also are used by aquaculture[40]. South Australian Agriculture and Veterinary Products (Control of Use) Act and the Fisheries (Exotic fish, Fish Farming and Fish Diseases) Regulations[40] are legislative policies and regulations also used for aquaculture.
    - The Commonwealth Food Standards Australia New Zealand Act (1991) establishes the mechanisms for joint food regulations and responsible for the Food Standards Code, and
    - Under these regulations, chemicals used for disinfectants, hormones, therapeutic and prophylactic substances, and antifoulants, for example, are approved, registered and used according to instructions on labels or permits by authorised personnel or licensees.
    - All export or domestic seafoods are required to be produced under safety and quality controls (e.g. Hazard Analysis Critical Control Point systems) legislated under the Food Standards Australia New Zealand Act/Regulations[40], the Fisheries (Fish Processors) Regulations and South Australian Primary Produce (food Safety Schemes) Act[40]. These safety and quality control processes must occur at each stage of the process to breed, grow and harvest crops that are brought to the market and sold to the consumer (chain of custody from farmer to processor to transportation to distributors to buyers).
    - All seafood/medical products are processed in certified facilities. Industry is responsible for implementing quality control systems that are HACCP based programs and a "regulatory competent authority" certifies products before distribution. Surveillance systems must be in place to trace and control the quality of foods to detect and prevent the occurrence of biotoxins and other biological/chemical contaminations.
    - How producers and processors comply with private standards depends on the market, how it is structured and type of product being sold. According to FAO's *The State of World Fisheries and Aquaculture 2010*[25] the more direct the supply from farm gate to market and the more integrated the supply chain, the greater the chance of private standards being used.

References

48. Inquiry into Opportunities for Expanding the Aquaculture Industry in Northern Australia: Submission 11. 2015. Submission from the Australian Government Department of Aquaculture to Joint Select Committee on Northern Australia. Submitter: Tompson, I., 1st Assist. Secretary, Sustainability and Biosecurity Policy. Ref 2015/37729E. pp1-8.

49. *Abalone Aquaculture Translocation Protocol*. 2007. Fisheries Management Paper No. 25. Victoria State Government. ISBN 978-1-74199-060-7. Website: http://agriculture.vic.gov.au/fisheries/policy-and-planning/moving-and-stocking-live-aquatic-organisms/abalone-aquaculture-translocation-protocol

50. *National Aquaculture Plan*. 1983. [Requirement of National Aquaculture Act of 1980, Law 96-362, USA]. Submitted by the Joint Subcommittee on Aquaculture of the Federal Coordination Council on Science, Engineering, and Technology. Vol 1, pp1-67. Website:
https://books.google.com.au/books?id=8kjxAAAAMAAJ&pg=PA65&lpg=PA65&dq=research+of+genetic+differences+between+domestic+aquaculture+organisms+and+wild+stock&source=bl&ots=2hEv6EVQOL&sig=dtEsjYn6mh2g3eOCNmFQoSZoU&hl=en&sa=X&ved=0ahUKEwjqse3O4vvLAhVHMaYKHZNh

51. *Marine Aquaculture in the United States: Environmental Impacts and Policy Options*. 2002. Prepared for the Pew Oceans Commissions by Golberg, R.J., Elliot, M.S., and Rosamond, L.N.
Website: http://www.iatp.org/files/Marine_Aquaculture_in_the_United_States_Enviro.htm

52. *Review of the Status of Aquaculture Genetics in Aquaculture in the Third Millennium*. 2001. Subasinghe, R.P., Bueno, P., Phillips, M.J., Hough, C., McGladdery, S.E., and Arthur, J.E. (Editors). Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand. 20-25 Feb 2000. NACA, Bangkok and FAO, Rome. ISBN: 974-7313-55-3. pp 1-471.
Website: http://www.fao.org/docrep/003/ab412e/ab412e03.htm

53. European Best Practice in Aquaculture Biofouling: CRAB. 2003 (circa). Commission of the European communities, specific RTD programme "Collective Research" contract COLL-CT-2003-500536. Sixth Framework Programme. www.crabproject.com.
Website: http://www.crabproject.com/index.php/109/best-practice-guidelines/

54. Addy, R. 2013. Nanotechnology delivers anti-fouling surface for food factories. Dairy Report.com.
http://www.dairyreporter.com/Technology/Processing-Equipment-Systems-Automation-Control/Nanotechnology-delivers-anti-fouling-surface-for-food-factories
Source 'Anti-fouling surface modified stainless steel for food processing'; Food and Bioproducts Processing; available online doi:http://dx.doi.org/10.1016/j.fbp.2013.01.003; Authors Barrish, J, Goddard, J., Dept. of Food Science, University of Massachusetts website: http://www.fbp.ichemejournals.com/article/S0960-3085(13)00004-7/abstract

[55.]Natalio, F., André, R., Hartog, A.F., Stoll, B., Jochum, K.P., Wever, R. and Tremel, W. 2012. Vanadium pentoxide nanaoparticles mimic vanadium haloperoxidases and thwart biofilm formation. Nature Nanotechnology 7:530-535 doi:10.1038/NNANO.2012.91. Website: http://www.uni-mainz.de/eng/15482.php

[56.]Pest, diseases and weeds: Marine pests. Australian Government Department of Agriculture and Water Resources. Websites: http://www.agriculture.gov.au/pests-diseases-weeds/marine-pests

[57.]Proposed Australian biofouling management strategies: Anti-fouling and in-water cleaning guidelines. Australian Government Department of Agriculture and Water Resources.
Websites: http://www.agriculture.gov.au/biosecurity/avm/vessels/anti-fouling-and-inwater-cleaning-guidelines

[58.]Keeping Marine Pests Out of Australian waters: The National system for the Prevention and Management of Marine Pest Incursions. An Australian Government Initiative. Website:
http://www.marinepests.gov.au/fishing/pages/Ballast-water-management.aspx

[59.]Bradie, J.N., Bailey, S.A., van der Velde, G., Maclsaac, H.J. 2010. Brine-induced mortality of non-indigenous invertebrates in residual ballast water. Marine Environmental Research. doi:10.1016/j.marenvres.2010.08.003. Vol 70:5, pp395-401.
Website: http://www.sciencedirect.com/science/article/pii/S0141113610001182

[60.]Summerfelt, S. T., Wilton, G., Robert, D., Rimmer, T. and Fonkalsrud, K. 2004. Development in recirculating systems for Arctic char culture in North America. Elsevier, Aquaculture Engineering 30:31-71. Science Direct. Available online at www.sciencedirect.com

[61.]Jegatheesan,V. Zeng, C. Shu, L., Manicom, C. and Steicke, C. 2006. Technological advances in aquaculture farms for minimal effluent discharge to oceans. Elsevier, Aquaculture Engineering 15:1535-1554. Science Direct. Available online at http://www.sciencedirect.com

[62.] Exporting fish and fish products. Department of Agriculture and Water Resources. Website: http://www.agriculture.gov.au/export/controlled goods/fish?wasRedirectedByModule=true

[63.]Australian regulatory Guidelines for Prescription Medicines. Australian Government Department of Health: Therapeutic Goods Administration. Website: https://www.tga.gov.au/publication/australian-regulatory-guidelines-prescription-medicines-argpm

7b. ***Where and how has the industry invested to develop solutions?***

The aquaculture industry, through producer-grower association/guilds (e.g., pearling, edible oyster, prawn salmonid, tuna, and abalone), have provided funding for research and development from licence and membership fees and in-kind contributions to collaboratively develop industry strategies and participate in projects described above in question **7a** with RD&E institutions (e.g., CSIRO, AIMS, FRDC, PIRSA). This also includes industry organisations[9] independently or in conjunction with Fisheries Departments[10] to invest in non-government, third-party consultancies to evaluate/audit their business practices relating to governance, production operations, safety standards and environmental practices (i.e. triple bottom line principles intentionally or inadvertently).

Individual companies or "syndicates" within an aquaculture sector will conduct discrete/issue specific technical, biotechnical, R&D projects, for example, that aimed at improving productivity and quality of goods marketed. Typically, deductions for eligible expenditures are usually claimed through Australian Government R&D Tax Concession programs, such as, AusIndustry (now apart of The Department of Industry, Innovation and Science's Single Business Service) [64].

In addition, to finance start-up construction production phases or expansion of projects, both proprietary and public listed enterprises, have sought to seek loans, equity investors or sell shares through a plethora of financial institutions, such as, Banks with rural/agriculture/aquaculture investment departments (e.g., NAB, Commonwealth Bank and the ANZ), and domestic/international venture capitalist (pers. obs. and comm.). Further, many of these ventures have utilised the Commonwealth's Australian Trade Commission to promote/facilitate their aquaculture "agri-business" investment programs to major international Asia-Pacific seafood trading partners[31]. One of the prawn aquaculture ventures currently receiving exposure appears to have the appropriate husbandry and location, and if it can operate to the benefit of shareholders and stakeholders on a renewable basis then this seafood enterprise will make a notable contribution towards Australia's seafood industry.

7c. *To what extent, and under what funding arrangements, should governments be involved in developing innovative solutions?*

One proposal to extent the national government's of involvement in developing innovative solutions was presented to the Minister for Agriculture, Fisheries and Forestry (DAFF) in 2011 a document produced by the Rural RD&E Council: the *National Strategic Rural Research and Development Investment Plan*[43]. This plan also included aquaculture as a major sector in Fisheries, as well as, all associated "value chain" industries that diversified raw products to new and improved commodities.

The Plan recommends the Australian Government increase its investment in rural RD&E to a level that would double output over the next 30 years. To achieve this goal, the Investment Plan proposes an "initial balance of investment across the rural RD&E" sectors should be:

- "40% transformational investment for long-term outcomes";
- "30% near-term adjustments for mid-term outcomes";
- "20 % capacity building in people"; and
- "10% international linkage."

As part of "transformational investment for long-term outcomes", RD&E institutions should as a priority include but (not be limited to) activities supporting new regional TBL aquaculture businesses access to marine environments currently blocked or contested by anachronistic wild fishery legislation. This could be undertaken under the "extension framework services" by linking candidate aquaculture species to habitat zones selected on the organism's ecological/zoogeographic distribution for aquaculture and fisheries, and secondarily sub continental/marine mineral mining. The solutions should be evidence based and non-political (i.e. not relying on cautionary principles). The regulatory policies could be established after consulting with aquaculture and fishery practitioners, scientists, bureaucrats and regional stakeholders. To use a "bottom-up" or "grass-roots" approach initially, will result in an informed, simple, practical foundation of concepts. These will in turn frame a simple and intuitive "top-down" hierarchal system of cost-effective regulations that would guide Australian aquaculture towards sustainable, globally competitive seafood commerce.

Further, Australian aquaculture cannot remain globally competitive, if it does not encourage/support the use of innovative research carried out overseas by Australian scientists in R&D programs as far back as the 1900s to the early 2000s and continuing to the present. For example, the Australian Centre for International Agriculture Research (ACIAR)[66] aquaculture investigations on commercially important species within Southeast Asian countries. Particularly studies involving species with zoogeographic distributions extending into northern Australian waters, for example, giant clams, mud crabs or sea cucumbers (per. comm. with R. Braley, S. Battaglene, R. Pitt and B. Giraspy).

Currently large wild fishery quota holders are unlikely to invest into aquaculture as they have already invested heavily in their fishing infrastructure, and plant & equipment. Thus, there is no incentive to engage immediately in aquaculture for monopoly licence holders (particularly if fleet operations are not cost effective). The culmination of their actions delay comprehensive, evidence-based, ten-year strategies as recommended by AIMS 10 year plan for Australia's blue economy[23].

Government funding arrangements for innovative solutions needed for the aquaculture industry and associated industries (e.g., commercial wild fisheries, recreational fishing, tourism, boat building, and transport) should be carried out under similar public/private equity/funding partnerships as described in question **4** above. The tax incentives occurring with APEC countries in the Asian-Pacific region[32] should be transferable to Australian's aquaculture development. These funding arrangements would be cost-effect and keep Australia competitive as a seafood producer in S.E. Asia. Equally important, regional development of commercial aquaculture hubs would be especially beneficial to First Australian communities wanting to have 'a life after mining'.

References

[65]. Australian Government, One Website–Single Business Service,
Website: http://www.business.gov.au/about-businessgovau/Pages/One-Website.aspx

[66]. *Publications*. Australian Government, Australian Centre for International Agricultural Research.
Website: http://aciar.gov.au/search/type/publication?terms=mud+crabs&sort_by=search_api_relevance&sort_order=DESC&items_per_page=25

8. *Is a regulatory framework required for aquaculture in Commonwealth waters?*

Yes. According to FAO's profile of Australia's *National Aquaculture Legislation Overview*: Australian state and territories manage inland and coastal waters out to the three nautical mile limit[40]. The Commonwealth is responsible for managing marine waters between three and 200 nautical miles off the continent's shore to the edge of the continental shelf. This Exclusive Economic Zone (EEZ) of marine areas is one to the largest in the world and consists of 8.2 million square kilometres off continental Australia and its offshore islands and 2 million sq km off the Australia's Antarctica territory (totalling about 10 million sq km)[67].

Australia is yet to explore over 75% of its marine jurisdiction[23]. It would be prudent to be proactive and develop regulatory framework as part of a stand alone Act that anticipates aquaculture activities involving offshore, deep sea shellfish, finfish, invertebrates and plankton (plant and animal) and macroalgae within Australia's economic zone. This regulatory framework could be modelled initially after South Australia's Aquaculture Act[44] since S.A. is the largest aquaculture producer (38% of gross value of the production) in the Commonwealth[40]. Regulatory policies and framework extensions should be planned for the next 30 years (per. opinion) and one that allows for a wide range of commerce to flourish sustainably over the nation's marine resources.

This task should be given priority for several reasons, for example:

- The projected expansion of humanity's population to 9.2 billion makes establishing marine sovereignty and biosecurity over our "blue" estate imperative to avoid any future conflicts with adventurous seafaring nations.
- The marine organisms inhabiting this marine zone may become economically important and could be maricultured extensively or intensively for seafoods, pharmaceutical & nutraceutical products, animal/fish feeds and/or energy, enhancing our wellbeing.
- Exploration of the EEZ will extend our scientific knowledge of the marine biology and ecology of marine organism inhabiting the continental shelf regions. In turn, this knowledge under writes our innovative nature to create sustainable commerce.

References

67. *Oceans and Seas: National Location Information*. Australian Government Geoscience Australia. Website: http://www.ga.gov.au/scientific-topics/national-location-information/dimensions/oceans-and-seas.