Submission from the Tasmanian Abalone Council Ltd (TACL) regarding the Draft Sustainable Industry Growth Plan for the Salmon Industry

This submission was prepared by:

Dean Lisson, Chief Executive of the Tasmanian Abalone Council Ltd

262 Argyle Street, Hobart, Tasmania, 7000

On behalf of the Council and its Members

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Tasmanian Abalone Council Ltd
262 Argyle Street, Hobart, Tasmania
Phone; +61 3 6169 2050
Email; admin@tasabalone.com.au
deanlisson@tassie.net.au
Web: www.tasabalone.com.au
ABN: 80 009 590 578

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Policy Branch, Strategic Services Division
GPO Box 44
Hobart TAS 7001
Email: salmonplan@dpipwe.tas.gov.au

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The Tasmanian Abalone Council (TACL) notes the following:

The Government is developing a sustainable industry growth plan for the salmon industry. The plan will detail the Government's vision and priorities for the industry and provide the community with surety on the way forward.

http://dpipwe.tas.gov.au/Documents/Draft%20sustainable%20industry%20growth%20plan%20for%20the%20Salmon%20Industry.pdf

The Draft Sustainable Industry Growth Plan for the Salmon Industry ("the Draft Plan") is being released for comment, before the Plan is finalised in September.

The Draft Plan is a high level document. It includes a number of actions, organised under three headings:

- *Maintaining public confidence in the salmon industry*
- *Improving the efficiency, effectiveness and transparency of the industry's environmental regulation, and the effectiveness of its biosecurity systems*
- *Supporting industry growth*

This submission discusses key issues and raises concerns that the Tasmanian abalone industry has in relation to the Draft Sustainable Industry Growth Plan for the salmon Industry.

1. Executive Summary

Tasmania has the world's largest wild abalone resource – the Tasmanian commercial abalone fishery produces a staggering 25% of total global production of *wild caught* abalone

The Tasmanian abalone industry has grown from very humble beginnings in the mid sixties to an industry that now generates approximately $100 million of export revenue and an additional $200 million of associated economic activity annually for the Tasmanian economy. The industry has an estimated capitalised value of around $1 billion (processing factories, vessels, quota licenses etc) – and it has achieved this with no subsidies from the Tasmanian Government. Indeed, the abalone industry is a net provider of revenue to the Tasmanian Government and has paid in excess of $150 million in licence fees and royalties over the last 32 years.

The Tasmanian abalone fishery depends on complex environmental factors to replenish and maintain healthy stock levels. Many of these environmental factors are not well understood and are beyond the control of managers, fishers and researchers.

Anthropogenic inputs and influences on coastal ecosystems are increasing (e.g. urban runoff, effluent from sewerage systems, organic and inorganic inputs from intensive agriculture and aquaculture, sediments from forestry "run off") and have the potential to reduce the productivity of wild abalone populations.

The burgeoning Tasmanian salmon aquaculture industry has long been identified by the Tasmanian abalone industry as posing a potential risk to the health of delicate inshore reef systems.

There is a commonly held view amongst many commercial abalone divers who harvested abalone in the D'Entrecasteaux Channel during the seventies, eighties and nineties that the benthic community in some sections of the lower Channel has altered in a way that is less supportive to habitation by abalone and other benthic reef dwellers that were once abundant in this area.

For over two decades, abalone divers have regularly reported a fine layer of "milky dust" covering parts of the inshore benthic community – they also report a change in the type and form of algae that grows in some of the bays and around the shoreline of the lower D'Entrecasteaux Channel.

Rightly or wrongly, divers attribute the burgeoning salmon aquaculture industry as a significant source of pollutants (nutrient and sediment) into the lower D'Entrecasteaux Channel.

It is a widely acknowledged fact that salmon aquaculture has a detrimental affect on water quality and substrate characteristics in close proximity to farming operations - recent events in Macquarie Harbour have confirmed this statement beyond any doubt. The degree to which these impacts occur depends on the intensity of the farming (i.e. stocking density and fish feed inputs) and the capacity of the receiving marine environment to buffer or assimilate these impacts.

An understanding of the environmental sensitivities of abalone during its life cycle and the complex interactions within reef ecosystems are required for assessing the potential impacts of pollutants from anthropogenic activities such as open-cage salmon farming.

Salmon farm inputs potentially detrimental to abalone habitat include the *principal* inputs of artificial fish feed and fish excreta plus *incidental* inputs such as bio-fouling from net cleaning practises, anti-foulants, heavy metals (principally copper and zinc), fuel & oil spills, rotting and/or dead fish, fish escapees, recoverable and non-recoverable farm debris and cleaning chemicals. Other detrimental impacts may occur as a result of the restriction of wave action and water flow around and through cage systems to neighbouring marine habitats. This list is by no means exhaustive.

In summary however, there are two key environmental inputs from open-cage salmon farming systems that may have a detrimental impact on wild abalone populations. These are:

- Sustained nutrient loads and
- Sustained sediment loads

The **primary risk** for wild abalone reef habitat **adjacent to** salmon farming operations is the broader-scale medium to long-term environmental degradation caused in part or wholly by **sustained nutrient and sediment inputs** from open-cage farming systems.

As detailed later in this submission, there is plenty of scientific evidence to support the supposition that abalone may be detrimentally affected by excess nutrient and sediment loads from salmon farming systems. Excess nutrient and sediment load may detrimentally affect larval growth, larval settlement and the early grow-out stages of the lifecycle. In addition, sustained nutrient and sediment loads may also change the balance of micro and macro algal species within delicate reef ecosystems – creating less than optimal environmental conditions and availability of preferred food for abalone during some or all lifecycle stages.

Tasmanian inshore reef ecosystems are complex interactive systems within which it is hard to define or predict the potential impacts from changes in environmental or anthropogenic inputs, since there are many oceanic and reef scale feedback mechanisms that may compensate for one change or multiply/amplify another. As there is currently a lack of specific scientific research dealing with the impact of salmon farm derived pollutants on wild abalone reef systems it makes absolute sense to be cautious when siting salmon cage systems in close proximity to productive abalone reef habitat.

The Tasmanian Abalone industry recommends that there be a **minimum proximity threshold or "environmental" buffer zone** that serves to separate in-water salmon farms from inshore reef systems which are home to a multitude of marine flora and fauna including abalone.

The buffer should be of sufficient magnitude to ensure that the potentially deleterious effects of salmon farm derived pollutants are rendered benign by "separation distance", in-water currents and associated dilution and dispersal.

The Tasmanian Abalone Council is also seeking formal engagement with the Tasmanian Government in the development of future salmon aquaculture policy.

There is simply too much at stake for the Tasmanian abalone sector to be excluded from key management decisions related to the continued expansion of Tasmania's burgeoning salmonid sector.

Tasmanian Abalone Council Ltd . 262 Argyle Street . Hobart . Tasmania . 7000 . Australia . T: +61 3 6169 2050
e: admin@tasabalone.com.au . w: www.tasabalone.com.au . ABN: 80 009 590 578

2. Key Recommendations

The Tasmanian Abalone Council respectfully makes the following recommendations in response to the Governments recently released *Draft Sustainable industry growth plan for the salmon industry*:

1. In relation to the Map included within the Salmon Growth Plan entitled Proposed "grow" and No-grow" zones for finfish in Tasmania,

    i. **The "No-Grow" zone should extend from the South East Cape to Boreel Head.** This section of coastline is home to the most productive abalone reef systems in Tasmania. Indeed, the Actaeons Reef system is regarded globally as the world's most productive abalone reef.

    ii. **For all other parts of Tasmania's coastline, a buffer zone between the "outer" edge of rocky reef habitat and any proposed finfish farm lease should be mandated. This buffer zone should be no less than 1.5 nautical miles wide at its narrowest point and should exclude all finfish aquaculture activities.** A buffer zone of this magnitude is necessary to ensure that the potentially deleterious effects of finfish farm derived pollutants are rendered benign by "separation distance", in-water currents and associated dilution and dispersal. It does not make sense on any level to expand industrial finfish farming that in any way reduces the health and vitality of the inshore reef systems existing along Tasmania's 5000 kilometres of coastline – these reef systems have immense cultural, recreational and commercial value to the citizens of Tasmania and the world. Additionally, it makes sense from a "safe" navigation and operational perspective to maintain a minimum "proximity threshold" between the commercial abalone and salmon sectors.

2. In relation to the "Draft for Comment" Growth Plan for the salmon industry,

    i. The TACL welcomes the concept of "Grow" and "No Grow" zones for finfish farming provided the recommendations in point 1 above are adopted.

    ii. All future expansion of the finfish sector should be either offshore (and at least 1.5 nautical miles from the edge of rocky reef habitat) or onshore (closed cycle).

    iii. The TACL supports the development of a "Tasmanian Salmon Industry Scorecard" that benchmarks the industry against international good practice and is regularly reviewed and updated and made available to the public via an independently managed web portal.

    iv. The TACL supports the establishment of an industry funded Finfish Farming (Compliance and Monitoring) Unit within the Environment Protection Authority.

v. The TACL supports the collection of additional real time environmental data from within and adjacent to all finfish leases, and increased public access to relevant environmental information via an independently managed web portal.

vi. The TACL recommends that the *Broadscale Environmental Monitoring Program* (BEMP) be reviewed by the Government and relevant Marine Research institutions for data gaps and expanded to include oceanic reef sampling and monitoring sites in the lower D'Entrecasteaux Channel, Storm Bay, Port Arthur, Nubeena/Wedge Island and Okehampton Bay/Mercury Passage - i.e. additional sampling sites adjacent to all finfish leases that include ecosystem monitoring of nearby oceanic rocky reef habitat - these sites to monitor macro-faunal communities, micro and macro algal structure/abundance/distribution as well as water and sediment quality. The TACL also recommends that all BEMP data be made available to the abalone industry to conduct its own regular review and analysis to determine if reef habitat is changing as a result of salmon farm pollutants and/or other anthropogenic inputs. This process will be guided by outcomes from the Fisheries Research & Development Corporation (FRDC project) 2015/024[1].

vii. The TACL supports a robust industry wide finfish Biosecurity program with appropriate checks and balances to ensure robust compliance by all finfish farmers.

viii. The TACL supports R&D investment that may result in the adoption of new technologies within the finfish farming sector – particularly those that reduce impacts on the marine environment.

ix. The TACL recommends that comprehensive baseline environmental assessment is conducted on any rocky reef systems that lie adjacent or proximate to proposed finfish leases PRIOR to the lease being granted. In the event that a lease is then granted, comprehensive ongoing environmental monitoring should occur with the results being publically available via an independently managed web portal.

x. The TACL supports the establishment of a broad based industry body as a reference group throughout the Growth Plan's implementation. Given the socioeconomic value of the abalone industry to Tasmania and the immense importance of maintaining healthy inshore reef systems, the TACL will seek (and expect) membership on this reference group.

Fisheries Research and Development Corporation (FRDC) project *"2015/024 - Managing ecosystem interactions across differing environments: building flexibility and risk assurance into environmental management strategies"* and commenced in July 2015 [1]

3. Introduction - Tasmania's iconic wild Abalone fishery

Tasmania has the world's largest wild abalone resource – the Tasmanian commercial abalone fishery produces a staggering 25% of total global production of *wild caught* abalone and generates approximately $100 million of annual export revenue for the state.

The foresight, innovation and responsible custodial attitude of abalone stakeholders over the past 5 decades has created and sustained a valuable export industry that injects substantial income into the Tasmanian economy in many diverse ways creating employment in regional and coastal communities around the state.

Fundamental and substantial restructuring of the abalone industry in the early nineties has seen more and more Tasmanians investing directly and participating in the industry. Approximately 83% of Tasmanian abalone quota is currently owned by Tasmanian family businesses – many of these businesses are located in regional Tasmania providing crucial "local" economic stimulus within small coastal communities. The total capitalised value of the industry exceeds $1 billion taking into account the value of abalone quota plus fishing, processing and exporting infrastructure.

On a broader scale, Abalone industry stakeholders provide many areas of Tasmanian commerce with vital and solid investment capital – this capital supports important infrastructure in other industries/businesses such as agriculture, viticulture and wine making, retail, wholesale, property development and tourism.

Inbound Chinese tourists are visiting Tasmania and seeking out seafood related experiences. Indeed, the Chinese visitor market for Tasmania has grown at a spectacular annual rate of 29 per cent for the past 5 years.

Chinese Visitor Snapshot - Tourism Tasmania Research Snapshot February 2016:
https://tourismtasmania.com.au/__data/assets/pdf_file/0020/39251/chinese-snapshot.pdf

Wild abalone is the most revered food in Chinese cuisine and as such there is much potential for Tasmania tourism and food & beverage businesses to capitalise on this growing opportunity by featuring abalone (and other premium Tasmanian seafood) as a part of the visitor experience.

Tasmania will produce 1561 tonnes of live weight abalone during the 2017 quota year with 95% of this exported principally to China, Hong Kong, Singapore, Taiwan and Japan and 5% consumed within Australia. All Tasmanian abalone export premises must comply with strict export standard food safety regulations.

Tasmanian wild abalone is harvested from one of the world's most pristine marine environments, has a high nutritional value and is a 100% natural and organic product.

Because it is "hand-harvested' in a sustainable manner, there is negligible environmental impact on the reef ecosystem.

The Tasmanian Abalone fishery was one of the first fisheries in Australia accredited as 'sustainable' under the Commonwealth *Environment Protection & Biodiversity Conservation Act 1999.*

Australian (and Tasmanian) wild abalone is recommended for consumption by the World Wildlife Fund (WWF) because they recognise and acknowledge that it is harvested from well managed sustainable fisheries and is harvested in an ecologically friendly way.

http://assets.wwfhk.panda.org/downloads/seafood_guide_hk_card_fold.pdf

The industry is continually investing in a range of R&D projects and initiates and funds millions of dollars worth of research much of which is conducted right here in Tasmania by UTAS, CSIRO and IMAS.

Tasmanian abalone is sold into an increasingly sophisticated and highly competitive global market. Tasmanian abalone exports are subjected to various tariff and non-tariff barriers across a number of global markets – these trade barriers present an ever-changing and complex series of challenges to our exporters.

Despite these challenges, the Tasmanian abalone industry has grown from very humble beginnings in the mid sixties to an industry with a conservative capitalised value of around $1 billion that generates $300 million of economic activity annually – it has achieved all of this with no subsidisation from the Tasmanian Government. The industry is a net provider of revenue to the Tasmanian Government and has paid in excess of $150 million in licence fees and royalties over the last 30 years.

For further information please refer to:

www.tasabalone.com.au

www.abalonecouncil.com.au

www.australianwildabalone.com.au

In addition to the commercial harvest of abalone, the wild abalone fishery also supports significant indigenous and recreational fishing activities.

4. Risks posed to the wild abalone fishery from open-cage salmon farming systems

The Tasmanian abalone fishery depends on complex environmental factors to replenish and maintain healthy stock levels. Many of these environmental factors are not well understood and are beyond the control of managers, fishers and researchers.

Anthropogenic (man made) influences on coastal ecosystems are increasing and have the potential to reduce the productivity of wild abalone populations – i.e. via pollutants from various sources such as urban runoff, effluent from sewerage systems, organic and inorganic inputs from intensive agriculture and aquaculture, sediments from forestry "run off" etc.

The Tasmanian salmon aquaculture industry has long been identified by the Tasmanian abalone industry as an anthropogenic influence that poses a potential risk to the health of inshore abalone reef systems.

By virtue of their affinity with the ocean, their general concern for its well being and the fact that they spend so much time underwater, Tasmania's abalone divers are "early detectors" of any short, medium or long term changes to the underwater environment.

There is a commonly held view amongst many commercial abalone divers who harvested abalone in the D'Entrecasteaux Channel during the seventies, eighties and nineties that the benthic community in some sections of the lower Channel has altered in a way which is less supportive to habitation by abalone and other benthic reef dwellers which were once abundant in this area.

For over two decades, abalone divers have regularly reported a fine layer of "milky dust" covering some parts of the inshore benthic community – they also report a change in the type and form of algae that grows in some of the bays and around the shoreline of the lower D'Entrecasteaux Channel.

Note: Tasmania's 120 Abalone divers have averaged over 27,000 hours underwater per year for the last 10 years (aggregated total figure based on DPIPWE catch data). This puts them in a unique position as the "sentinels" of Tasmania's inshore oceanic environment simply because they witness with their own eyes almost all of Tasmania's coastline which is 4882kms long (including islands).

It is a widely acknowledged fact that salmon farming has a detrimental affect on water quality and substrate characteristics in close proximity to farming operations - recent events in Macquarie Harbour have confirmed this statement beyond any doubt. The degree to which these impacts occur depends on the intensity of the farming (i.e. stocking density and fish feed inputs) and the capacity of the receiving marine environment to buffer or assimilate these impacts.

An understanding of the environmental sensitivities of abalone during its life cycle and the complex interactions within reef ecosystems are required for assessing the potential impacts of anthropogenic activities such as open-cage salmon farming.

Salmon farm inputs potentially detrimental to abalone habitat include the *principal* inputs of artificial fish feed and fish excreta plus *incidental* inputs such as bio-fouling from net cleaning practises, anti-foulants, heavy metals (principally copper and zinc), fuel & oil spills, rotting and/or dead fish, fish escapees, recoverable and non-recoverable farm debris and cleaning chemicals. Other detrimental impacts may occur as a result of the restriction of wave action and water flow around and through cage systems to neighbouring marine habitats. This list is by no means exhaustive.

The *principal* inputs of *fish feed* and *salmon excreta* introduce soluble and insoluble components into the water column around and underneath salmon cages. The soluble component (principally fish excreta) is nutrient rich and is dispersed by water movement through and around the cages. The insoluble component sinks to the seabed and creates a layer of sediment that builds up under the cages. Near-farm water quality testing and video monitoring of sediment accumulation under the cages is used to determine when to move the cages to new sites and allow *fallowing* of the original site – *fallowing* is the process whereby the salmon companies relocate cage systems from time to time so that the marine environment within their lease footprint is given time to assimilate - i.e. "break down" the organic components of the farm inputs. Tidal currents and bottom currents may disperse the sediment beyond the salmon farm lease boundary – indeed, as mentioned above, abalone divers regularly report a fine layer of sediment covering inshore reef systems that are adjacent to salmonid farms within the Lower D'Entrecasteaux Channel region

In summary, there are two key environmental inputs from open cage salmon farming systems that may have a detrimental impact on abalone populations. These are:

1. Sustained nutrient loads and
2. Sustained sediment loads

The **primary risk** for wild abalone reef habitat **adjacent to** salmon farming operations is the broader-scale medium to long-term environmental degradation caused in part or wholly by **sustained nutrient and sediment inputs** from open-cage farming systems.

5. The effect of sustained nutrient loads on abalone

Abalone are localised spawners and are at their most vulnerable during the early stages of their life cycle – localized anoxic conditions due to physico-chemical changes in the sediment and/or nutrient overload in the water column (whether sustained or periodic) may have a deleterious effect on larval growth, larval settlement and the early grow-out stages of the lifecycle **(James and Barr 2012)** leaving abalone stunted and unfit for harvest.

While oyster and mussel farms remove excess nitrogen, salmon farms dump excess nitrogen into the marine ecosystem (hence the need for a nitrogen "cap" that limits salmonid production capacity in the D'Entrecasteaux Channel). Artificial salmon feed residues and salmon excreta in high concentrations can lead to eutrophication within the water column – i.e. nutrient overload which in turn can lead to hypoxia (oxygen depletion) and phytoplankton blooms. Eutrophication causes a severe reduction in water quality and generally promotes excessive plant growth and decay, favouring simple algae and plankton over other more complex marine plants such as the macro-algae that mature abalone feed on.

All abalone species are herbivorous and show a strong preference for red algae **(Shepherd & Edgar 2013)**. During the larval stage, the primary food source is the yolk sac, potentially supplemented with filtering nutrients out of the water column. During the post larval stage, they eat diatoms, bacteria and the upper layer of *non-geniculated coralline algae* – NCA (more on this later). As juveniles, they switch to eating mainly drift algae, as diatoms and bacteria do not contain enough energy to support the increase in growth although may remain as supplementary food. As adults, abalone feed mainly on drift algae, but may also graze on turf algae and microalgae films. Abalone have a serrated "tongue" to eat algae as they move across the ocean floor. To support a healthy comprehensive age range of animals a complex assortment of feed is required. Large brown algae such as cray weed, giant kelp and bull kelp along with some species of red algae including the encrusting corallines are necessary. Juvenile abalone graze on rock encrusting coralline algae, diatoms and bacterial films. As they grow they increasingly rely on red and brown macro-algae.

Sustained nutrient loads from salmon farms or other sources may alter the types and proportions of algae that grow within pristine and healthy marine ecosystems (**Kraufvelin et al. 2010)** – the type where wild abalone thrive. Sustained nutrient loads change the balance of micro and macro algal species in the environment in turn changing reef community structure and biodiversity. Species of algae that thrive under regular and increased nutrient loads *may not* support an ecosystem with healthy populations of wild abalone, lobster and other species of marine fauna.

6. The effects of sustained sediment loads on abalone

Increases in sediment within abalone reef systems have two potential adverse impacts: smothering and resultant death of NCAs, and burial of suitable protection (cryptic) sites for abalone. Sediment that builds up on crustose coralline algae can quickly smother and kill the algae, and will have an immediate effect on recruitment as the NCAs are required for abalone larval settlement and metamorphosis. Inundation of sediments can result in the loss of safe habitat for juvenile and adult abalone due to cryptic sites and home scars becoming inundated with sediment, thus exposing abalone to predators.

Abalone has also been shown to be particularly sensitive to sedimentation even at low levels, potentially affecting all life stages. Larval abalone have shown significant reductions in settlement in response to low level sedimentation **(Onitsuka et al. 2008).** Sediment has also been shown to indirectly increase the mortality of juvenile abalone through displacement from their cryptic refuges by sediment accumulation to seek out sediment free exposed areas which leaves them more exposed to predation - vulnerability to predation is then increased further as sedimentation also results in a decreased ability for juvenile abalone to "hold fast" to surfaces and impedes abalone's righting response resulting in higher abalone mortality in areas where sediment is present **(Chew et al. 2013).**

The effect of sediment on abalone was discussed in depth at the 6th National *Trans Tasman* Abalone Convention in Queenstown, New Zealand in August 2014. New Zealand has a commercial abalone industry based on a species of abalone called *haliotis iris,* commonly referred to as *paua*. A presentation at the convention by Dr Norman Ragg of the Cawthron Institute in Nelson, New Zealand entitled *"Fighting for breath: how does oxygen exchange limit abalone performance in a changing coastal environment?"* focused on the gill structure of paua and how it struggles to respire under sediment loads; (http://abalonecouncil.com.au/wp_content/uploads/2014/08/14_RAGG_Fighting_for_ breath.pdf)

Dr Ragg concluded his presentation by stating the following:

- *Haliotis iris* are absolutely dependent on their gills for oxygen uptake
- The gill surface of *haliotis iris* may be damaged (directly or indirectly) by sedimentation events
- *Haliotis iris* gills appear to have a limited capacity to clear sediment or associated mucus

Clearly then, there is robust scientific evidence that abalone do not cope well under seasonal or sustained sediment loads. This fact may explain why abalone divers have witnessed fewer abalone on reefs adjacent to salmonid farming systems in the Lower Channel region. In short, any input that causes degradation to the health of the inshore benthic community which wild abalone and other marine fauna inhabit *must be* regarded as a risk. It is commonly accepted that benthic molluscs (such as abalone) serve as the "canary in the coal mine" when it comes to sensitivity to environmental changes within oceanic reef communities. It is also an accepted fact that significant loss of benthic biodiversity and localised changes in the physico-chemical properties of sediments occur in close proximity to salmon farms.

In summary, there is plenty of scientific evidence to support the supposition that abalone may be detrimentally affected by excess nutrient and sediment loads from salmon farming systems. Excess nutrient and sediment load may detrimentally affect larval growth, larval settlement and the early grow-out stages of the lifecycle. In addition, sustained nutrient and sediment loads may also change the balance of micro and macro algal species in the environment – creating less than optimal environmental conditions and availability of preferred food for abalone during some or all lifecycle stages.

7. The importance of non–geniculated coralline algae (NCA) to the survival of wild abalone

In temperate oceans and seas around the globe, coralline algae are the main builders of a typical algal reef system - many are encrusting and rock-like and more often than not, are pink or pink-grey in colour. There are over 1600 described species of non-geniculate coralline algae (NCA) found in marine waters all around the world and in many places, NCA may cover close to 100% of the rocky substrata.

Many corallines produce chemicals that promote the settlement of the larvae of certain herbivorous invertebrates, particularly abalone.

NCA induce settlement of invertebrate larvae such as soft corals, polychaetes, limpets, chitons, asteroids, sea urchins and abalone **(Daume 2013).** It has been shown that crustose coralline algae cover was positively correlated with abalone abundance **(Valentine et al. 2010).** As the larvae prepare to settle, the veliger develops a foot and is attracted to the substratum by chemical cues from NCA. In South Australia, newly metamorphosed larvae of Roe's abalone settle on the NCA species *Lithothamnia*, and it was noted that at <10 mm size these abalone were the same colour as the settlement substratum **(Shepherd 1972)**. This produces excellent camouflage from visually oriented predators.
Macromolecule fractions from red algae induce abalone settlement and metamorphosis.

There are high levels of these macromolecules in many forms of red algae, but they are only available at the surface in NCA (**Morse & Morse 1984)** that allows for substratum species specific recruitment.

The surface micro-environment of the NCA (i.e. oxygen levels, microalgal growth, surface topography, water flow and pH) is critical for abalone larval settlement and subsequent survival **(Daume 2013).** Grazing by limpets, chitons, gastropods and sea urchins removes filamentous algae, diatoms and bacteria from the coralline surface and keeps it clean (**Daume 2013**). Sea urchin grazing on NCA can have an adverse effect on NCA if they remove too much surface layer **(Daume 2013).**

The thickness of the oxygen diffuse boundary layer (DBL) will limit success of post larval invertebrates based on their size. The DBL can be adversely affected if there is inadequate water flow, a bio-film of detritus, substantial microalgal growth, a significant protozoa and/or bacteria accumulation or **sedimentation present** on the surface of the NCA. When this occurs, the DBL can become >1 mm and thus the 0.5 mm larvae can become oxygen stressed **(Daume 2013).** Grazing and adequate water flow reduces the DBL and improves conditions for post larvae **(Daume 2013).** Post larval abalone graze the biofilms, microalgae growth, diatoms and bacteria from the surface of the NCA.

A Tasmanian Blacklip abalone resting on pink-grey non-geniculate coralline algae (NCA). Often the pink coloured NCA will grow on the shell of abalones as well as on the substrate surface – this can be clearly observed in this photo.

Once settled, the abalone veliger is triggered to metamorphose by chemicals on the surface of NCA. The development of the post larvae begins with deposition of peristomal shell, and then through to formation of respiratory pores **(Leighton 1974**). Abalone of 0.5–1 mm in length were only found on NCA where they originally settled (**Shepherd & Turner 1985),** and remain there until ~5-10 mm in size. The colour of the newly growing shell will quickly become the same as the NCA they settled and developed on, as in addition to eating diatoms and bacteria, they consume the upper layer of the NCA which contains coloured pigments. This supplies excellent camouflage from visual predators.

Once post larval abalone have developed a shell and reach ~5 mm, they become juveniles or 'spat'. These juvenile abalone still retain the colour of the surrounding NCA (which covers the majority of barren reef surfaces), with abalone <10 mm rarely taken by fish predators due to the colour camouflage and protection from topography on crustose NCA **(Shepherd & Turner 1985)**.

Abalone <10 mm are rarely taken by fish predators due to colour camouflage provided by ingested NCA pigments, and protection supplied from the microhabitat on the crustose coralline algae **(Shepherd & Turner 1985**). In this mutualistic relationship, the NCA surface micro-environment is critical for larval settlement and survival. This micro environment includes: oxygen levels, microalgal growth, surface topography, water flow and pH **(Daume 2013).**

Recruitment is also heavily dependent on availability of suitable substratum for the larvae to settle on. It is known the abalone larvae are dependent on non-geniculated coralline algae species for successful settlement and metamorphosis. Specific inducing molecules on the NCA interact with stereo-chemical specific receptors on the larvae to provide a fail-safe mechanism for appropriate substratum recognition by the larvae **(Morse & Morse 1984**). Actual contact of larvae with the surface of the NCA must occur to trigger settlement and metamorphosis **(Morse & Morse 1984),** which greatly reduces the risk of predation. It is known that there is a contact requirement with the chemical on the surface as the specific molecule on the NCA, and not morphological characteristics (e.g. lumpy vs flat), is the trigger that encourages the larvae to settle.


Blacklip abalone lining a gutter - pink coloured non-geniculate coralline algae can be clearly observed living on the rock surface.

Nutrient shifts (e.g. increased nitrogen) may favour certain algal community species (i.e. Ulva spp.) within the abalone populated zones on the reef, which may increase total canopy cover. Rapid increases in nutrients often result in increased foliose and filamentous turfing algae, which can reduce NCA coverage. This occurs as the turfing algae increases sedimentation due to baffling effects, and can lead to smothering of NCA. Increases in nutrients and sedimentation favours growth of turf algae **(Shepherd & Edgar 2013),** compared to the present algal communities in the zones that support abalone. **Gorgula and Connell (2004**) found that increased nutrients and

increased sedimentation had an additive effect that increased turf algae by 77%. Nutrients had six times the effect on increasing turfing algae compared to sediment alone.

An increase in sediment and/or filamentous algae decreases the amount of crustose NCA available within a reef system for abalone larval settlement and also decreases juvenile abalone habitat, thus limiting the available area for colonisation (Scheibling 1994). Where filamentous algae overgrows NCA, trapped sediments may ultimately result in the death of NCA communities which may not recover (Daume 2013). In an experiment in Japan, abalone recruitment was measured over one year and when crustose coralline algae were wholly covered with colloidal mud-like ephiphytes, no abalone recruitment occurred (Saito 1981).

8. A cautious approach is warranted

There can be little doubt that abalone are susceptible to certain changes to the physico-chemical environment at the reef level. If excess nutrients and sediments combine to produce algal community changes (i.e. increased turfing algae or changes in canopy structure), this may have an adverse effect on coralline algae that will in turn limit critical settlement habitat to abalone larvae during recruitment **(Morse & Morse 1984, Shepherd et al. 1985, Daume et al. 1999, Valentine et al. 2010)**. Population loss may potentially reduce recruitment capabilities of larvae being returned to the natal reef. Sediment and water quality are largely variable in the natural environment, and the alibility of the reef to resist ecosystem changes will likely depend on the magnitude, duration and extent of the changes to these parameters.

Tasmanian inshore reef ecosystems are complex interactive systems within which it is hard to define or predict the potential impacts from changes in environmental or anthropogenic inputs, since there are many oceanic and reef scale feedback mechanisms that may compensate for one change or multiply/amplify another. As there is currently a lack of specific research dealing with the impact of salmon farm derived inputs on wild abalone reef systems it makes absolute sense to be cautious when siting salmon cage systems in close proximity to productive abalone reef.

9. The best way to minimise the risk to abalone reef systems from industrial salmon farming systems

In the absence of robust research focussing specifically on the impact of salmon farm derived pollutants on wild abalone reef systems, there is an obvious need for caution.

The Tasmanian Abalone industry recommends that there be a proximity threshold or buffer zone which serves to separate in-water salmon farms from inshore reef systems which are home to a multitude of marine flora and fauna.

The TACL recommends that a buffer zone between the "outer" edge of rocky reef habitat and any proposed finfish farm lease should be mandated. This buffer zone should be no less than 1.5 nautical miles wide at its narrowest point and should exclude all finfish aquaculture activities.

A buffer zone of this magnitude is necessary to ensure that the potentially deleterious effects of finfish farm derived pollutants are rendered benign by "separation distance", in-water currents and associated dilution and dispersal.

It does not make sense on any level to expand industrial finfish farming that in any way reduces the health and vitality of the inshore reef systems existing along Tasmania's 5000 kilometres of coastline – these reef systems have immense cultural, recreational and commercial value to the citizens of Tasmania and the world.

Additionally, it makes sense from a "safe" navigation and operational perspective to maintain a minimum "proximity threshold" between the operational activities of the commercial abalone and salmon sectors.

Dean Lisson: September 2017

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