ALTERNATIVE MACROALGAL DIETS FOR JUVENILE GREENLIP ABALONE (*HALIOTIS LAEVIGATA*) IN THE LATER NURSERY PHASE

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DECLARATION

I declare that this thesis is my own account of my research and contains as its main content work, which has not previously been submitted for a degree at any tertiary education institution.

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ABSTRACT

Greenlip abalone (*Haliotis laevigata*) are a highly valued fishery resource, grown in aquaculture facilities around the southern states of Australia. These commercial farms have a nursery system that utilises natural algal diets adhered to vertical plates for rearing postlarval and juvenile abalone. However, as the juvenile abalone grow (5 – 15 mm shell length), the current commercial nursery diet of the green alga *Ulvella lens* plus the diatom *Navicula* cf. *jeffreyi* does not supply adequate algal biomass to maintain commercially viable abalone growth rates at the required stocking densities. The focus of this research was to identify, develop and evaluate alternative macroalgal diets to overcome the restrictions in algal biomass during the later nursery phase.

Macroalgae as an alternative natural diet for juvenile abalone can increase the algal biomass supplied on the vertical plates given its fast, 3-dimensional growth; while also considered a suitable nutrition source, as it is the primary feed of wild adult abalone. Australian abalone species have a preference for red macroalgae and to accommodate this, propagation methods including carpospore liberation, protoplast production and vegetative propagation; were assessed to determine the fitness of Rhodophyta species as an alternative diet for juvenile abalone in the later nursery phase. Protoplasts were readily isolated from red macroalgal species, however due to their limited regeneration, high cost of production and significant expertise required, the method was deemed unsuitable for utilisation in a commercial abalone nursery.

Vegetative propagation successful established fragment culture of several red macroalgal species. The development of an artificial adhesion protocol, utilising active immobilisation processes through gel entrapment by the natural polysaccharide agar; enabled macroalgal fragments to be presented to juvenile abalone on the vertical plates in the nursery system. A diet of *Laurencia* sp. fragments adhered to the plates with agar produced juvenile abalone growth rates (50 $\mu m.day^{-1}$) comparable to the current commercial nursery diet of *U. lens* and *N. jeffreyi*. The grazing resistance of the *Laurencia*/agar diet was low and fragments did not regenerate; so regular re-application

was required, making artificial adhesion protocols unsuitable for use in the development of juvenile abalone diets within the nursery system. Instead of integrating alternative macroalgal diets in the nursery system, a different abalone management (weaner) system utilising an artificial diet, was able to produce significantly greater juvenile abalone growth rates and weight gain for abalone larger than 8 mm shell length.

Macroalgal sporelings were incorporated as an alternative diet to remove the need for artificial adhesion protocols, as they can be seeded directly onto the plates whilst still presenting high algal biomass to the juvenile abalone. The morphology and life cycle of the green alga, *Ulva* allows for the high spore production and sporeling densities required to create a juvenile abalone diet. An *Ulva* spp. sporeling diet on the nursery plates produced abalone growth rates of nearly 100 $\mu m.day^{-1}$ and was comparable to the current commercial nursery diet (*U. lens*/*N. jeffreyi*). However, the *Ulva* sporeling diet was unable to maintain suitable growth rates for abalone greater than 8 – 9 mm shell length and consequently, did not overcome the biomass limitation of natural algal diets in the nursery system.

Given the *Ulva* sporeling diets ability to produce commercially viable growth rates for juvenile abalone less than 8 – 9 mm shell length and Australian abalone preference for red macroalgae, a composite green and red macroalgal sporeling diet was identified as an alternative diet for juvenile abalone in the later nursery phase. To incorporate Rhodophyta species into the diet, propagation via carpospore liberation was achieved for several red macroalgal species by temperature, dark and osmotic pressure induction treatments, with *Hypnea* sp. liberating the greatest number of carpospores ($67.23 \pm 10.19 \times 10^3$ carpospores.g^{-1}). Therefore, the combination *Hypnea* and *Ulva* sporeling diet was developed, which also reduced the biomass of red macroalgal carposporophyte required compared to that needed for creating a monospecies diet. This composite sporeling diet produced larger juvenile abalone (15 mm shell length), faster growth rates (87 $\mu m.day^{-1}$) and weight gain (2.5 $\mu g.day^{-1}$), when compared to the current commercial diets in the nursery (*U. lens*/*N. jeffreyi*) and weaner (artificial feed) systems. The addition of new seeded plates for all nursery diets during the trial allowed the composite sporeling diet to provide sufficient algal biomass. The *Hypnea*/*Ulva*

sporeling diet was able to overcome the biomass limitations of algal diets and accommodate the juvenile abalone (<15 mm shell length) high grazing pressure, while producing commercial viable growth rates throughout the entire later nursery phase. This composite sporeling diet has been incorporated into a detailed feeding regime for Australian commercial abalone nursery practices, to help improve juvenile *Haliotis laevigata* culture and increase overall farm production of this highly valued resource.

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PUBLICATIONS

The published material listed below forms the basis for parts of this thesis.

Peer Reviewed Scientific Manuscripts

Strain, L.W.S., Borowitzka, M.A. & Daume, S. (2006) Growth and survival of juvenile greenlip abalone (*Haliotis laevigata*) feeding on germlings of the macroalgae *Ulva* sp. Journal of Shellfish Research, 25: 239-247.

Strain, L.W.S., Isdepsky, A., Borowitzka, M.A. & Daume, S. (2007) Three algal propagation methods assessed to create a Rhodophyta diet for juvenile greenlip abalone (*Haliotis laevigata*) in the later nursery phase. Journal of Shellfish Research, 26: 737-744.

Scientific Manuscript in Preparation

Strain, L.W.S., Borowitzka, M.A. & Daume, S. (in prep) Development of natural algal diets for juvenile greenlip abalone (*Haliotis laevigata*) in the later nursery phase.

Conference Proceeding

Strain, L., Borowitzka, M. & Daume, S. (2005). Red algae fragments (*Laurencia* sp.) as an alternative feed for juvenile greenlip abalone (*Haliotis laevigata*). In: Fleming, A.E. (Ed.), Proceedings of the 12th Annual Abalone Aquaculture Workshop, 1st - 3rd August 2005, McLaren Vale, Australia. Fisheries Research and Development Corporation, Abalone Aquaculture Subprogram, Canberra, Australia, pp. 111-124.

Research Reports

Strain, L.W.S., Borowitzka, M.A. & Daume, S. Chapter 6. Growth and survival of juvenile greenlip abalone (*Haliotis laevigata*) feeding on germlings of the macroalgae

Ulva sp. pp 86-102. In: Daume, S. (2007) Improvement and evaluation of greenlip abalone hatchery and nursery production. Final Report to Fisheries Research and Development Corporation on Project No. 2003/203. Fisheries Research Contract Report No. 16, Department of Fisheries, Western Australia, 160p.

Strain, L.W.S., Borowitzka, M.A. & Daume, S. Chapter 8. Red algae fragments (*Laurencia* sp.) as an alternative feed for juvenile greenlip abalone (*Haliotis laevigata*). pp 115-128. In: Daume, S. (2007) Improvement and evaluation of greenlip abalone hatchery and nursery production. Final Report to Fisheries Research and Development Corporation on Project No. 2003/203. Fisheries Research Contract Report No. 16, Department of Fisheries, Western Australia, 160p.

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