# The Second International Symposium On Abalone Biology, Fisheries And Culture

## Project 93/116

Final Report to the Fisheries Research & Development Corporation

Warwick J. Nash

December 1994

# 1 INTRODUCTION

The First International Symposium on Abalone Biology, Fisheries and Culture was held in La Paz, Mexico in November 1989. In the closing session of that symposium it was decided to hold the second abalone symposium in Australia in 1993 or 1994. Subsequently, Hobart was chosen as the site and 7-11 February 1994 as the date of the second symposium.

The majority of the papers presented at the first symposium, as well as several invited reviews, were published in book form (Shepherd *et al.* 1992). This book has become a major reference for abalone workers. Partly because of the long period between the first symposium in 1989 and publication of the book three years later, it was decided to expedite publication of papers from the second symposium by publishing them in special issues of two internationally recognised journals: *Aquaculture* and the *Australian Journal of Marine and Freshwater Research*. These two journal issues will be published in early 1995, approximately 12 months after the symposium.

# 2 OBJECTIVES

The objectives of the study were:

- to organise the Second International Symposium on Abalone Biology, Fisheries and Culture; and
- to organise workshops after the symposium on key topics relevant to abalone culture, stock assessment and management.

## EXECUTIVE SUMMARY

1 The Second International Symposium on Abalone Biology, Fisheries and Culture was held in Hobart on 7-11 February 1994. It was attended by 212 delegates from all States of Australia and 13 other countries.

2 Sixty-eight papers were presented during the first three days of the symposium. Slightly more than half the presentations were on aquaculture-related topics, and the remaining papers addressed either fishery-related matters or general abalone biology. (See Appendix I: the symposium program.)

3 Eight workshops were conducted during the final two days of the symposium. These workshops addressed topics within the fields of aquaculture, fisheries, enforcement and management of fishery regulations and evolutionary biology (Appendix I).

4 A selection of aquaculture-related papers from the symposium are to be published in the international journal *Aquaculture* in early 1995. Similarly, a selection of papers on abalone biology and fisheries from the symposium are to be published in the journal *Australian Journal of Marine and Freshwater Research* in early 1995. Progress toward acceptance of papers submitted for publication in these two journals is given in Appendices 2 and 3.

5 Benefits arising from the symposium to the abalone community took several forms:

- Transfer of information and ideas from the symposium papers and workshops;
- Strengthening of the level of communication within the abalone community through personal contact and verbal exchange of ideas;
- Publication of papers from the symposium in the journals *Aquaculture* and *Australian Journal of Marine and Freshwater Research*;
- Establishment of an e-mail abalone communications network (AbNet) on the AARNET communications system. Benefits so far have included rapid exchange of information and data between abalone workers, and the

development of an electronic abalone bibliography that is being contributed to by AbNet members;

- Support for *Abalone News*, a newsletter compiled in California, through a subscription system;

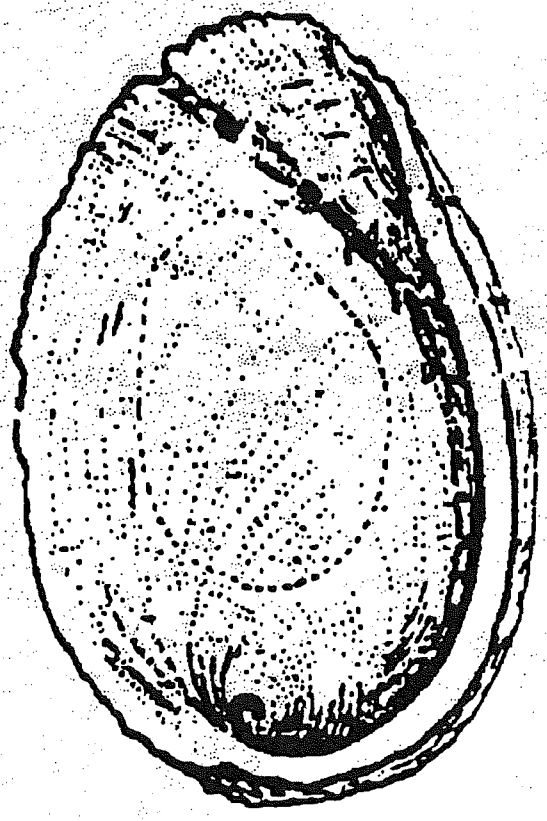
- Establishment of the International Abalone Society (IAS). The constitution for the IAS has been prepared and has been circulated among abalone workers for comment for being adopted. *Abalone News* will become the official newsletter of the IAS.

**REFERENCE**

Shepherd, S.A., M.J. Tegner and S.A. Guzmán del Próo (1992). *Abalone of the World: Biology, Fisheries and Culture*. Blackwell Scientific Publications: Oxford. 608 pp.

Appendix I

# SECOND INTERNATIONAL SYMPOSIUM ON ABALONE BIOLOGY, FISHERIES & CULTURE



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Hobart, Tasmania

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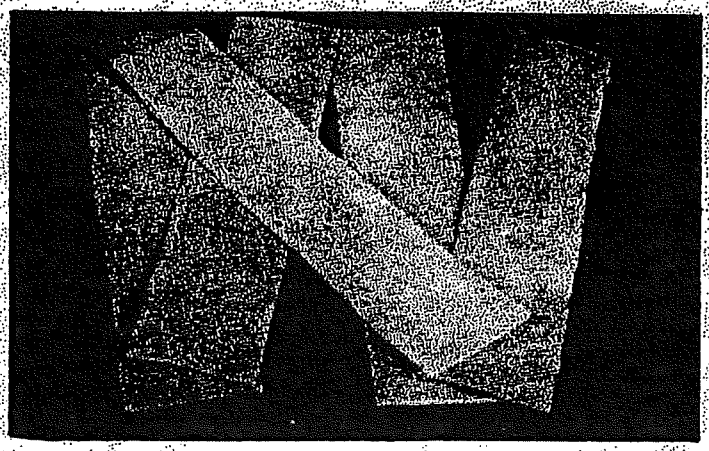

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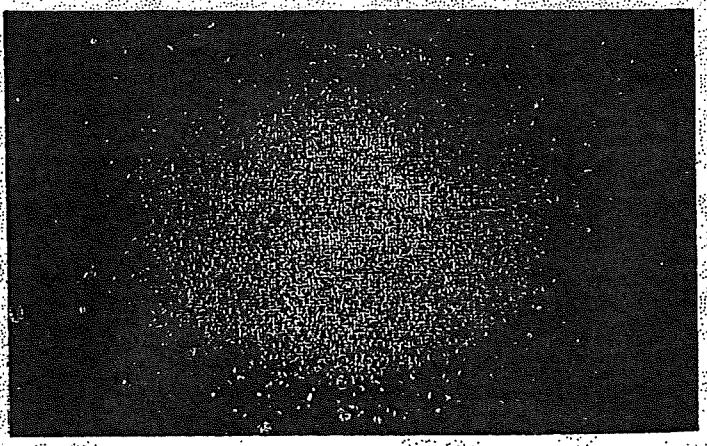

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# SECOND INTERNATIONAL SYMPOSIUM ON ABALONE BIOLOGY, FISHERIES AND CULTURE


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**FISHERIES RESEARCH & DEVELOPMENT CORPORATION**

**DEPARTMENT OF INDUSTRY, TECHNOLOGY & REGIONAL DEVELOPMENT**

## ORGANISING COMMITTEE

| | |
|---|---|
| Mr Warwick J. Nash | Sea Fisheries Division, Hobart, Tasmania |
| Dr Scoresby Shepherd | South Australian Research & Development Institute, Adelaide, South Australia |
| Dr Rob W. Day | University of Melbourne, Victoria, Australia |
| Dr Susan McBride | Sea Grant Extension Program, Eureka, California, USA |
| Mr Rob Tarr | Sea Fisheries Research Institute, Cape Town, Republic of South Africa |
| Dr Paul McShane | MAF Fisheries, Wellington, New Zealand |
| Dr Nagahisa Uki | National research Institute of Fisheries Science, Tokyo, Japan |

## ADMINISTRATION

MURES CONVENTION MANAGEMENT
Victoria Dock
Hobart 7000

Telephone: (002) 312121
Facsimile: (002) 344464

Beth Pocock
Mike Annand
Trudi Dwyer
Sally Philpott

# Welcome to the Second International Symposium on Abalone Biology, Fisheries and Culture

*Dear Delegate,*

*On behalf of the Organising Committee, I welcome you to the Second International Symposium on Abalone Biology, Fisheries and Culture. A special welcome to those of you from overseas and interstate.*

*We hope that you will not only benefit from the scientific program that is the focus of the symposium but that you will also enjoy the social events, tourist attractions and beauty of Hobart and the rest of Tasmania.*

*There are many to whom we are indebted for the success of the symposium: the speakers themselves, without whose efforts we would not be here at all; the sponsors – Promak Pty Ltd; Dover Fisheries Pty Ltd; the Fishing Industry Research and Development Corporation; and the Department of Industry, Technology and Regional development.*

*We hope that you enjoy your stay.*

***Warwick Nash***
***Local Organiser***

## ORGANISING COMMITTEE

| | |
|---|---|
| Mr Warwick J. Nash | Sea Fisheries Division, Hobart, Tasmania |
| Dr Scoresby Shepherd | South Australian Research & Development Institute, Adelaide, South Australia |
| Dr Rob W. Day | University of Melbourne, Victoria, Australia |
| Dr Susan McBride | Sea Grant Extension Program, Eureka, California, USA |
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# Contents

# GENERAL INFORMATION

## VENUE

University Centre
University of Tasmania
Churchill Ave., SANDY BAY 7005
Telephone:- 202234 / 232039 Fax:- 202186 / 202095

## REGISTRATION AND INFORMATION DESK

The registration desk is located in the foyer of the University centre and the staff of Mures Convention Management will be at the desk to assist you with any problems between the following times:

| | |
|---|---|
| Sunday 6th | 3.00 pm - 7.00 pm |
| Monday 7th | 8.00 am - 5.30 pm |
| Tuesday 8th | 8.30 am - 5.30 pm |
| Wednesday 9th | 8.30am - 5.30 pm |

## NAME BADGES

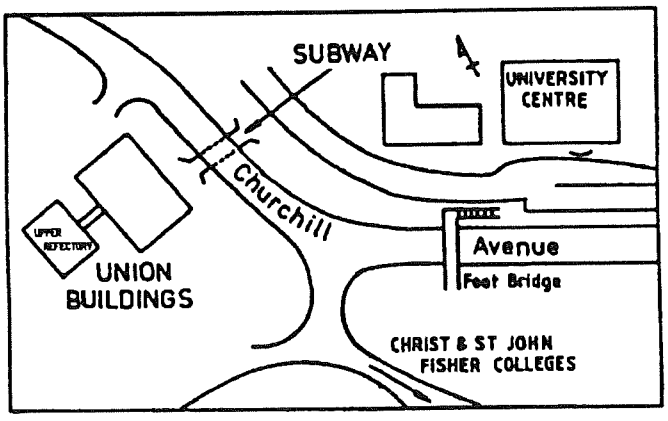
Each delegate to the symposium will receive a name badge on registration. The badge is your official pass and must be worn to obtain entry to all sessions, morning and afternoon teas and lunches. Tickets will be issued for the Symposium Dinner and delegates will need to present these at the door to gain entrance.

## MORNING AND AFTERNOON TEAS

Morning and afternoon teas will be served in the foyer of the University Centre.

## LUNCHES

Lunches will be served in Lazenby's, located in the Upper Refectory of the Union Buildings on Churchill Ave. (see map). Access to the Union Buildings is gained via the subway under Churchill Ave. Please ensure that you are wearing your badge or the staff may not serve you.




## MESSAGES

Messages can be collected and left at the registration desk. All messages will be posted on the message board, near the registration desk.

**BANKING:**
Full banking services are available in the heart of the Sandy Bay shopping centre, a five minute taxi ride from the University Centre.

Banks represented include the Commonwealth, ANZ, Westpac, National and Trust Banks.

In addition, there are limited card withdrawal terminals in the foyer of Wrest Point Hotel Casino near the Porters Desk.

**SHOPPING**:
Sandy Bay shopping centre is the closet area, five minutes by taxi from the University. There are quality shops in this area in Magnet Court and Mayfair in the Bay: Ladies and Gents fashions, Chemists, Shoes, Hairdressers, Deli, Gift Shops, Bakery, M.B.F., Books-cards-newsagent, and the banks.

**POST OFFICE:**
Situated on the corner of King Street and Sandy Bay Road in the Sandy Bay shopping area.

**EMERGENCIES**
**DOCTORS:**

| | |
|---|---|
| Sandy Bay Clinic, 270 Sandy Bay Road, Sandy Bay | Ph. 23 6822 |

**MEDICAL SERVICES:**

| | |
|---|---|
| Royal Hobart Hospital (Public), 48 Liverpool St. | Ph. 38 8308 |
| St Helens Hospital Casualty (Private) - 24hr | |
| 186 Macquarie St | Ph. 21 3636 |

**DENTISTS:**

| | |
|---|---|
| Dr Ian Gurner | Ph. 24 3636 |
| Dr John Austwick | Ph. 23 5620 |
| Australian Dental Association | Ph. 28 0953 |

**TAXI CAB SERVICES:**

| | |
|---|---|
| Taxi Combined (Cabcharge) | Ph. 34 8444 |
| City Cabs | Ph. 343633 |
| Maxi Taxi (disabled, special requirements) | Ph. 34 8061 |

**METROPOLITAN TRANSPORT TRUST BUS SERVICES:**
Churchill Ave. - City Service 52, approximately 30 minute intervals
Sandy Bay Road - City Services 54/55/56, approximately 15 minute intervals

**INTER-CITY COACHES**

| | |
|---|---|
| Hobart Coaches, 4 Liverpool Street | Ph. 34 4077 |
| Tasmanian Redline Coaches, 199 Collins Street | Ph. 31 3233 |

**RESTAURANTS:**

| | | |
|---|---|---|
| ***GENERAL*** | | |
| Ball and Chain, Charcoal Grill, Salamamca Place | Mon - Sun | 23 2655 |
| Battery Point Brasserie, 59 Hampden Rd | Mon - Sat | 23 3186 |
| Mawsons Hut, 80 Queen Street, Sandy Bay | Mon - Sat | 23 2969 |
| Roche's Restaurant, 9 Murray Street | Mon - Sat | 23 7983 |
| Sullivan's Fine Dining, Sheraton, 1 Davey St | Tue - Sat | 35 4535 |
| The Astor Grill, 157 Macquarie St | Mon - Sun | 34 3809 |
| ***CHINESE*** | | |
| Ming Court, 636a Sandy Bay Rd | Mon - Sun | 25 3107 |
| Flourishing Court, 252 - 256 Macquarie St | Tue - Fri | 23 2559 |
| ***FRENCH*** | | |
| The Paris Restaurant, 365 Macquarie St | Tue - Sat | 24 2200 |
| Panache, 89 Salamanca Place | Mon - Sun | 24 2929 |
| Le Provencial, 417 Macquarie St | Tue - Sat | 24 2526 |
| ***GREEK*** | | |
| Aegean, 121 Collins St | Tue - Sat | 31 1000 |
| ***INDIAN*** | | |
| Gur Pertabs's, 47 Hampden Rd | Mon - Sat | 23 7011 |
| Round Asia, 182 Goulburn St | Wed - Sat | 34 9385 |
| ***INDONESIAN*** | | |
| Little Bali, 84a Harrington Rd | Mon - Sun | 34 3426 |
| Warung Bali, 305 Elizabeth St | Tue - Sun | 31 1068 |
| ***ITALIAN*** | | |
| Don Camillo, Magnet Court, Sandy Bay | Mon - Sat | 34 1006 |
| Etna Pizza House, 201 Elizabrth St | Mon - Sun | 34 4105 |
| Marti Zucco's, 364 Macquarie St | Mon - Sun | 34 9611 |
| Rivera Ristorante, 15 Hunter St | Mon - Sat | 34 3230 |
| Solo Pasta and Pizza, 50B King St, Sandy Bay | Mon - Sat | 34 9898 |
| Tarantella Italian, 16A Princes Street, Sandy Bay | Mon - Sat | 23 6652 |
| ***JAPANESE*** | | |
| Orizuru Sushi Bar, Mure's, Victoria Dock | Mon - Sat | 31 1790 |
| ***KOREAN*** | | |
| Seoul Korean Restaurant, Cnr Harrington & Collins | Mon - Sat | 34 7090 |
| ***MEXICAN*** | | |
| Taco Bill Mexican Restaurant, 41 Hampden Rd | Tue - Sun | 23 5297 |
| Amigos, 329 Elizabeth St | Mon - Sun | 34 6115 |

*SEAFOOD*

| | | |
|---|---|---|
| Mure's Fish Centre, Victoria Dock | | |
| - Mures Lower Deck (Bistro) | Mon - Sun | 31 2121 |
| - Mures Upper Deck (a la carte) | Mon - Sun | 31 1999 |
| Drunken Admiral, 17 Hunter St | Mon - Sun | 34 1903 |
| Prossers, Beach Rd Long Point, Sandy Bay | Mon - Sun | 25 2276 |

*SINGAPOREAN*

| | | |
|---|---|---|
| Singapore Eating House, Cnr Murray and Despard | Mon - Sun | 31 1777 |

*THAI*

| | | |
|---|---|---|
| Thai Hut, 80 Elizabeth St | Tue - Sat | 34 4914 |
| Vanidol's Asian Cuisine, 353 Elizabeth St | Tue - Sun | 34 9307 |

*LEBANESE*

| | | |
|---|---|---|
| Ali Akbar, 321 Elizabeth St | Mon - Sat | 31 1770 |

*SPANISH*

| | | |
|---|---|---|
| Sisco's, 121 Macquarie St | Tue - Sat | 23 2059 |

# SOCIAL PROGRAMMME

**SUNDAY, 6 FEBRUARY**

A Welcome reception will be held in the University Centre foyer on Sunday evening from 5.30pm until 7.30pm. Drinks and "nibbles" will be served during the evening to allow delegates to meet before commencement of the scientific programme.

**WEDNESDAY, 9 FEBRUARY**

The Symposium Dinner will be held on Wednesday 9 February, at the Long Gallery, Salamanca Place, at 7.00pm.

Buses will depart from hotels at the following times:

| | | |
|---|---|---|
| Bus 1 | Christ College (including St John Fisher) | 6.45pm |
| | Sandy Bay Motor Inn (including Wrest Point) | 6.55pm |
| Bus 2 | Grosvenor Court | 6.45pm |
| | Blue Hills (including Dr Syntax ) - on Sandy Bay Rd. | 6.50pm |
| | Jane Franklin Hall | 6.55pm |

PLEASE NOTE: Delegates staying at Colville Cottage may either catch the bus at Blue Hills, or they may prefer the short stroll through Battery point to Salamanca place.

One bus will depart from the Long Gallery at 11.00pm to transport to their hotels those wishing to have an early night . Remaining revellers may use public transport or taxi cabs to return to their hotels after the dinner.

Extra dinner tickets may be purchased from the Registration Desk for $50 each. Please purchase them as early as possible to facilitate catering arrangements.

# TOURS

## ACCOMPANYING PERSON TOURS

Day tours may be arranged for anyone accompanying a Symposium delegate to Hobart. Please enquire at the Registration desk for tour information.

## ABALONE HATCHERY TOURS

PLEASE NOTE: there will now be TWO visits to the Tasmanian Univalve abalone hatchery at Webber Point (near Swansea). **It is very important that you confirm your participation in one of these tours (and make full payment) by the close of sessions on Monday afternoon.**

### VISIT 1 - FRIDAY 11 FEBRUARY

Depart from the University Centre at 7.30am to arrive at the hatchery at about 9.00am.

Depart the hatchery at 11.30am to arrive back at the University Centre in time for the afternoon workshop session. A boxed lunch will be provided.

The cost of the tour is $35 per person, including lunch.

**NOTE: This visit is to be the more technical session, and it is requested that only current abalone growers attend.**

### VISIT 2 - SATURDAY 12 FEBRUARY

A more relaxed and general tour of the hatchery. Technical discussion at this session will be less detailed because senior hatchery personnel will not be present.

Delegates will be picked up from the carpark at Mures Fish Centre, Victoria Dock (opposite the Sheraton Hotel), **NOT** Wrest Point as previously published, at 9.00am before travelling via the East Coast to Webber Point for a tour of the facility.

A gourmet Tasmanian lunch will be served at Schouten House, Swansea, before returning to Hobart.

The cost of the tour is $50 per person, including lunch.

# SCIENTIFIC PROGRAMME

# DAY 1 (MONDAY, 7 FEBRUARY)

| | | |
|---|---|---|
| 9:00 | Welcoming address (Minister for Primary Industry and Fisheries)<br>Welcoming address (Warwick Nash)<br>Information update (Warwick Nash) | |
| 9:20 | A review of international abalone trade patterns and pricing.<br>Murray Rudd | |
| 9:40 | Markets for cultured abalone.<br><br>Frank Oakes and Raymond Fields | |
| 10:00 | Abalone price determination in the Japanese import and wholesale markets.<br><br>Murray Rudd | |
| 10:20 | Stable isotopes in abalone conservation and management.<br><br>Peter Cook* and Neville Sweijd | |
| 10:40-11:10 | MORNING TEA | |
| 11:10 | Genetic diversity within and between laboratory-reared and natural populations of abalone (*Haliotis* spp.) [presented by Thomas McCormick]<br><br>Robert Carpenter, Kenneth Jones and Sepideh Zareparsi | |
| 11:30 | Effective population numbers in hatchery populations of *Haliotis rufescens*.<br><br>Lynna Hereford, Valarie Powell, Dennis Powers, Susan McBride* and Dennis Hedgecock | |
| 11:50 | Analysis of structural gene regulation at metamorphosis: A model for targeting essential genes in differentiation and growth.<br><br>Bernard M. Degnan*, T. Naganuma, D. Nees, J.C. Groppe, S.M. Degnan, G. Fenteany, *et al.* | |
| 12:10 | Production of transgenic abalone.<br><br>Lynna Hereford, Toby Cole Marta Gomez-Chiarri and Dennis Powers | |
| 12:30-2:00 | LUNCH | |
| 2:00 | A chronology of the abalone *Haliotis fulgens*.<br><br>Scoresby Shepherd, M. Avalos Borja, M. Ortiz Quintanilla | Primary culture of abalone cells, and *in vitro* myogenesis.<br>Takeshi Naganuma*, K. Horikoshi, T. Akutsu, N. Kawashima, B.M. Degnan and D.E. Morse |
| 2:20 | Growth and ageing of blacklip abalone (*Haliotis rubra*) in southern Tasmania.<br>Warwick Nash*, S.R. Talbot, J.C. Sanderson, A.J. Cawthorn, S. Dickson and B. Hislop | A new method for induction of triploid abalone.<br><br>Lynna Hereford, Teri Nicholson, Vicky Lee Kirby and Dennis Powers |
| 2:40 | Comparison of fluorochromes for marking abalone shells.<br><br>Rob Day, M.C. Williams and Gerry Hawkes | Effect of recombinant vertebrate growth hormone on growth of adult abalone *Haliotis kamtschatkana*<br>Deborah Donovan*, Barbara Taylor, E. McLean |
| 3:00 | Growth rate affects morphology of *Haliotis rubra*.<br><br>D.G. Worthington, Neil Andrew and N. Bentley | Genetic aspects of abalone culture.<br><br>Neville Sweijd* and Peter Cook |
| 3:20-4:00 | AFTERNOON TEA | |
| 4:00 | Growth of the greenlip abalone *Haliotis laevigata* on the south coast of Western Australia.<br><br>Fred Wells* and P. Mulvay | The development of artificial feeds for abalone: a worldwide review of past and present research.<br><br>Ann Fleming and Rob van Barneveld |
| 4:20 | Growth of the asses ear abalone (*Haliotis asinina* Linné) on Heron Reef, tropical eastern Australia.<br><br>David C. McNamara and Craig R. Johnson | The financial dynamics of an abalone start-up venture.<br><br>Frank Oakes and Jefferson Boswell |
| 4:40 | Rates of breakdown of algae in South African abalone and algae-trapping limpets.<br><br>Rob Day*, R.H. Bustamante and Peter Cook | Abalone aquaculture in Australia: A pre-feasibility study of a small-scale farm.<br><br>Antonio Mozqueira |

## DAY 2 (TUEDAY, 8 FEBRUARY)

| | | |
|---|---|---|
| 9:00 | Observations of growth responses on red abalone (*Haliotis rufescens*) when subjected to various types of natural, non-marine and artificial diets.<br><br>*Michael J. Machuzak and John D. McMullen | |
| 9:20 | Preliminary trials of a casein-based abalone diet - Makara.<br><br>Peter Redfearn | |
| 9:40 | Casein – Chemistry and application.<br><br>Lynton Bridger | |
| 10:00 | Recruitment variation in abalone: its importance to management.<br><br>Paul E. McShane | |
| 10:20 | Some attempts to investigate larval recruitment processes of Ezo abalone, *Haliotis discus hannai*, in the adjacent water of Keasennuma Bay, Japan.<br><br>Ryo Sasaki | |
| 10:40-11:10 | MORNING TEA | |
| 11:10 | Larval settlement of blacklip abalone (*Haliotis rubra*) to conditioned artificial substrates in the sea.<br>W. Nash, J. C. Sanderson*, J. Bridley, *et al.* | Growth of green abalone juveniles, *Haliotis fulgens*, fed with two macroalgae in Mexico.<br><br>Eugenio Carpizo-Ituarte and Alfredo Salas-Garza |
| 11:30 | Measuring settlement intensity in greenlip abalone (*Haliotis laevigata*) in southern Australia. | Digestibility of potential feed ingredients in artificial diets for blacklip (*Haliotis rubra*) and greenlip (*Haliotis laevigata*) abalone.<br>Greg Maguire, L. Wee and S. Hindrum |
| 11:50 | Studies on southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations.<br>Scoresby Shepherd and Debra Partington | Nutrition of newly settled larvae of the South African abalone *Haliotis midae*.<br><br>Ismail Matthews and Peter Cook |
| 12:10 | Differences in reproduction between the blue abalone *Haliotis fulgens* and pink abalone *Haliotis corrugata* in ...Baja California, Mexico.<br>Daniel Gerardo Romero Arce | Hose culture of benthic marine diatoms.<br><br>George Trevelyan* and D. Sommerville |
| 12:30-2:00 | LUNCH | |
| 2:00 | The potential use of macroalgae as a feed in abalone aquaculture.<br><br>Patrick Hone | |
| 2:20 | Present status of abalone and fish feed production in Korea.<br><br>Chul-Won Park, Yong-Gu Kiin and Soon-Kil Yi | |
| 2:40 | The development of a practical diet for abalone farming in South Africa.<br><br>Peter Britz and Jens Knuaer | |
| 3:00 | Kelp and algae-based artificial foods for juvenile South African abalone (*Haliotis midae*).<br><br>Brynn Simpson and Peter Cook | |
| 3:20-4:00 | AFTERNOON TEA | |
| 4:00 | The predatory behaviour of the seastar *Coscinasterias calamaria* toward *Haliotis rubra*.<br><br>Ashley Dowell, Rob Day* and G. Sant | Characteristics of gut microflora in the abalone *Haliotis midae*.<br><br>Jean Erasmus, V.E. Coyne and Peter Cook |
| 4:20 | The foraging behaviour of *Dicathais baileyana* on *Haliotis rubra*.<br><br>Mark Thomas and Rob Day | The use of silage from fish and abalone viscera as an ingredient for abalone feed.<br>Maria-Theresa Viana*, L.M. Lopez and E.G. Mendes |
| 4:40 | Infestation of *Haliotis rufescens* shells by a sabellid polychaete.<br><br>Frank R. Oakes and Raymond C. Fields* | Probable feeding attractants in allspice *Pimenta officinalis* for black abalone (*Haliotis discus*).<br>K. Harada*, T. Miyasaki, S. Kawashima and H. Shiota |

## DAY 3 (WEDNESDAY, 9 FEBRUARY)

| | | |
|---|---|---|
| 9:00 | Exploitation patterns of abalone fishers.<br><br>Paul E. McShane | |
| 9:20 | Stock assessment of blacklip abalone (*Haliotis rubra*) by the change-in-ratio method.<br><br>Warwick Nash*, Craig Sanderson, Simon Talbot, Andrew Cawthorn, Stewart Dickson, Brett Hislop and James Bridley | |
| 9:40 | Recruitment, growth and per-recruit analysis of the Omani abalone *Haliotis mariae*.<br><br>S.A. Shepherd, Dawood Al-Wahaibi, Adnan Rashid Al-Azri, D.W. Johnson and J.L Baker | |
| 10:00 | Protein utilization in abalone: an investigation of the influence and plasticity of the protein-sparing through consumption of fats and carbohydrates.<br><br>Barbara E. Taylor | |
| 10:20 | Patterns in catch and effort in the NSW abalone (*Haliotis rubra*) fishery<br><br>N. Bentley, Neil Andrew and D.G. Worthington | Food consumption and faecal output for blacklip (*Haliotis rubra*) and greenlip (*Haliotis laevigata*) abalone fed a range of artificial diets.<br>S. Hindrum, Greg Maguire and L. Wee |
| 10:40-11:10 | MORNING TEA | |
| 11:10 | Effects of fisheries regulations on two abalone stocks in Punta Abreojos, Baja California Sur, Mexico.<br>Mario R. Ramade Villanueva | *Haliotis fulgens* larvae induced to metamorphosis with GABA and other inductors on vinyl plates<br>Alfredo Salas-Garza, E. Vazquez-Moreno, E. Carpizo-Ituarte and L.S. McAnally-Salas |
| 11:30 | Population dynamics of three abalone species (*Haliotis corrugata, H. rufescens* and *H. cracherodii*) at the California Channel Islands.<br>Daniel V. Richards | Current use of gamma-aminobutyric acid (GABA) in massive-scale abalone seed production. |
| 11:50 | Differences in recruitment patterns and fishery productivity in two areas: A link?<br><br>Rob Tarr | Experiments to raise survival and maintain normal growth of juvenile abalone, *Haliotis discus hannai*, in winter.<br>Zong Qing Nie, M.F. Ji and J.P. Yan |
| 12:10 | *Concholepas concholepas*, the Peruvian / Chilean abalone.<br><br>Rabí, M.*, Maraví, C. and Valdivia, J. | A comparative discussion of a closed and open sea-water system for a pilot scale abalone (*Haliotis midae*) hatchery.<br>Neil Henry |
| 12:30-2:00 | LUNCH | |
| 2:00 | Abalone stock enhancement through the release of artificial seed.<br><br>Hiroshi Kojima | |
| 2:20 | Juvenile abalone recruitment measured in artificial habitats.<br><br>Gary E. Davis | Embryonic development, larval development and early growth of hatchery-produced abalone seed, *Haliotis ovina* (Gmelin, 1791).<br>P. Jarayabhand, H. Kojima & M. Kaenmanee |
| 2:40 | Behaviour studies on the mobility of two species of abalone (*Haliotis* spp.): Implications for reseeding programs.<br>Iris Werner*, Gavin Burnell & Stefan Flothmann | Growth and mortality of blue abalone (*Haliotis fulgens*) under culture on the island of Cedros, Baja California, Mexico.<br>José Guadalupe González Aviles |
| 3:00 | The South African recreational abalone fishery: How important is it?<br><br>Rob Tarr | Experiments on the introduction and culture of Japanese abalone (*Haliotis discus*) in Fuzhou, China. Zong Qing Nie, S.P. Wang, M.B. Lee, X.B.Wang and J. Ma |
| 3:20-4:00 | AFTERNOON TEA | |
| 4:00 | The New Zealand abalone fishery - a case study.<br><br>Paul E. McShane | Can dead-shell assemblages of cultured abalone post-larvae provide information about the causes of their death?<br>Ricardo Searcy-Bernal |
| 4:20-5:00 | GENERAL MEETING OF SYMPOSIUM PARTICIPANTS<br><br>1: To decide the venue and date of the Third International Abalone Symposium<br>2: To form an International Abalone Association | |

## WORKSHOP PROGRAMS

| | Thursday, 10 February | | Friday, 11 February | |
|---|---|---|---|---|
| | Workshop 1 | Workshop 2 | Workshop 1 | Workshop 2 |
| MORNING (9:00-12:30) | Artificial foods and systems design for abalone (Session 1) | Methods of enforcement of the legal harvest | Estimating stock abundance | Evolutionary biology and genetics of abalone |
| AFTERNOON (1:30-4:00) | Artificial foods and systems design for abalone (Session 2) | Management of fisheries: government-industry cooperation | Age determination using abalone shells | Biotechnology and abalone |
| (4:00-5:00) | Culture of tropical species of abalone | | | |

**NOTE:** The afternoon sessions of the workshops commence at 1:30 pm (30 minutes earlier than the symposium sessions) to allow as much time as possible for discussion—as well as to make the half-day sessions all the same length.

| Session | Convenor |
|---|---|
| Artificial foods and systems design for abalone | Patrick Hone<br>telephone: 08 226 0636<br>fax.: 08 226 0693<br>e-mail: |
| Methods of enforcement of the legal harvest | Brian Hemming<br>telephone: 08 226 0672<br>fax.: 08 226 0664<br>e-mail: |
| Management of fisheries: government-industry cooperation | Jeremy Prince<br>telephone: 09 242 3564<br>fax.: 09 242 3563<br>e-mail: |
| Estimating stock abundance | Neil Andrew<br>telephone: 02 527 8423<br>fax.: 02 527 8576<br>e-mail: andrewn@fisheries.nsw.gov.au |
| Age determination using abalone shells | Rob Day<br>telephone: 03 344 6262<br>fax.: 03 3447909<br>e-mail: |
| Evolutionary biology and genetics of abalone | Daniel Geiger<br>telephone:<br>fax.: 0011 1 213 740 8123<br>e-mail: |
| Biotechnology and abalone | Bernard Degnan<br>telephone: 07 365 2491<br>fax.: 07 365 1655<br>e-mail: |
| Culture of tropical abalone species | Patrick Hone<br>telephone: 08 226 0636<br>fax.: 08 226 0693<br>e-mail: |

# ABSTRACTS

**ORAL PRESENTATIONS:**
(* denotes the presenter of a paper, where this has been indicated.)

[*A note on the numbering notation used*: For consistency, all numbers have been changed so that the comma (,) and period (.) are used in the same way. For example, one thousand is written as 1,000 and one-and-a-half is written as 1.5). In some countries this notation is reversed.]

**Patterns in catch and effort in the NSW abalone (*Haliotis rubra*) fishery.**

N. Bentley, N.L. Andrew and D.G. Worthington
Fisheries Research Institute, P.O. Box 21, Cronulla, NSW 2230, Australia

The New South Wales fishery for abalone began as an open-access fishery in the 1960s. Both the number of divers and their total catch increased to a peak of about 1200 t in 1971. Since then, a range of management controls have been used, and the present fishery is restricted to 37 divers each with a quota of 9 t. A large proportion of this total catch is collected from areas in the south of the state. In areas further north thetotal annual catches have been declining for several years, particularly close to urban areas. Such patterns in catch are closely related to spatial and temporal patterns of effort. For example, in the south of the state there are consistent patterns in effort in response to consistent catch rates. In contrast, in areas further north, effort is more sporadic and catch rates can be highly variable. A knowledge of the patterns in behaviour of the fishers and the factors that affect it is essential for an understanding of the development of the fishery, and provides a basis upon which management decisions can be made.

**Casein – chemistry and application.**

Lynton Bridger
Promak Technology (NZ) Ltd, P.O. Box 444, Hawera, New Zealand

A breakdown of the chemical and physical nature of the milk protein casein is discussed, and the *in situ* preparation of bovine casein is described. Variations in structure and concentration caused by climate, breed and physiology, and the stabilising effect casein has on other constituents found in bovine milk are discussed. Common manufacturing methods are outlined for rennet, acids (including lactic acid), caseins and caseinates, and the world production statistics, key quality attributes and standard chemical, physical and microbial parameters are presented. Key and unique factors give casein the wide and varied properties that ensure certain functional attributes. The importance of dietary protein is discussed, and the nutritional value for abalone of several protein sources (soy, fish and casein) are compared. Common and not-so-common end-use applications, both edible and non-edible (technical or industrial), are listed and discussed.

**The development of a practical diet for abalone farming in South Africa.**

Peter Britz* and Jens Knuaer
Department of Ichthyology and Fisheries Science, Rhodes University, PO Box 94, Grahamstown 6140, Republic of South Africa

As a first step in the development of a practical diet for abalone, different protein-rich ingredients were fed to abalone (*Haliotis midae*) in semi-purified diets bound with agar. The proteins included casein, fishmeal, torula yeast,*Spirulina* and soya oil cake. These were compared with two natural diets, fresh *Plocamium corallorhiza* and dried *Ecklonia maxima*. Fishmeal and *Spirulina* produced the best growth performance and condition factors and were selected for use in practical diets. Abalone growth rates were positively correlated with protein content when fed fishmeal based practical diets ranging from 27% - 47% protein. A practical diet based on the abalone body amino acid and fatty acid profile was fed to young abalone (5-6 mm SL), and produced superior growth to those reared on diatoms. The present results demonstrate that formulated practical diets produce superior growth to natural diets, and that abalone can be weaned directly from diatoms to artificial diets and reared through to market size.

**Genetic diversity within and between laboratory-reared populations of abalone (*Haliotis* spp.).**

Robert C. Carpenter, Kenneth Jones and Sepideh Zareparsi (presented by Thomas B. McCormick)

The techniques used in this preliminary study required the extraction and isolation of genomic DNA of sufficient quality to allow amplification of a specific region using the polymerase chain reaction (PCR). An additional constraint was that non-lethal sampling was desirable in order to sample large numbers of animals in the field. Following extraction of DNA from several tissues (nephridium, foot, epipodium), we found that sufficient quantities of DNA could be obtained easily form epipodial tissue. The sample required was small enough (100 mg) to allow non-lethal sampling from animals both in the field and in the lab. Amplification of the internal transcribed spacer (ITS) region of the rDNA was successful and resulted in PCR product useful for restriction analysis. Restriction analysis from four locations (Fort Bragg, Santa Rosa Island, Santa Cruz Island, San Nicholas Island), using seven restriction enzymes, revealed polymorphisms for five enzymes. No restriction fragments were population-specific; however the frequencies of restriction fragments varied between populations, and provide a measure of the degree of similarity between populations separated by distances ranging from 15 to 1,500 km. Work is continuing on higher resolution DNA-based techniques to identify markers specific to different abalone populations. A new technique involving short tandem repeat (STR) sequences called microsatellites is being tested. This technique has been used successfully with other taxa to detect genetic variation at the population level.

**Growth of green abalone juveniles, *Haliotis fulgens*, fed with two macroalgae in Mexico.**

Eugenio Carpizo-Ituarte and Alfredo Salas-Garza
Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California, Apdo. Postal 453, Ensenada, B.C. 22800, México

With the growing interest in abalone culture in Mexico, it is fundamental to know the growth rate of local species. *Haliotis fulgens* juveniles were fed during a ten-month period with two species of macroalgae, and the rates of growth in length and weight on each diet were compared. The abalone were maintained in four fiberglass tanks (460 l capacity) and were distributed according to their size: 10.3 mm in tanks 1 and 4, and 6.9 mm in tanks 2 and 3. In tanks 1 and 3 the abalone were fed *ad libitum* with *Macrocystis pyrifera*, and in the other two tanks a combination of *M. pyrifera* and *Egregia laevigata*. Fifty individuals were measured monthly in each tank, and on two occasions their total weight was determined. The largest growth rates and weight increases were obtained with the combination of algae (tanks 2 and 4). The average size and weight in these tanks at the end of the period was significantly different ($p<0.01$) from that obtained in tanks 1 and 3. Feeding with a mixture of microalgae could increase the growth of cultured juveniles. However, the availability of *E. laevigata* could be limiting.

**Cloning of abalone growth factors.**

Zhonglin Chai[1]*, Keith Gough[2] and Peter Hanna[1]
[1] School of Biological and Chemistry Sciences, Deakin University, Geelong, Vic 3217, Australia
[2] CSIRO, Division of Biomolecular Engineering, 343 Royal Parade, Parkville, Vic 3052, Australia

The amino acid and nucleic acid sequences of growth hormone (GH) and insulin-like growth factors (IGF) have been analysed for a wide range of animals. Mollusc insulin-related peptide (MIP) has been identified from a fresh water snail, *Lymnaea stagnalis*. Its cDNA has been cloned, sequenced and compared with other insulin superfamily members by Smit and associates (*Nature* 331: 535-538, 1988; *Eur. J. Biochem.* 199: 699-703, 1991). Conserved regions in the sequences have been identified. In this study, oligonucleotides were synthesized corresponding to the conserved regions in GH, IGF and MIP to identify the corresponding genes in either a cDNA library or genomic DNA from abalone, by DNA hybridization and PCR studies. A salmon GH cDNA and a sheep IGF-II cDNA were used as reference probes in the studies. The results will be presented.

**Stable isotopes in abalone conservation and management.**

Peter Cook* and Neville Sweijd
Zoology Department, University of Cape Town, Private Bag, Rondebosch 7700, Republic of South Africa

A case of the alleged poaching of 5 tons of the abalone *Haliotis midae*, on the South African coast in 1990, has led to a study of the use of stable isotope ratios as a suitable marker for identifying the geographic origin of abalone. This technique has been applied successfully as a means to identify the geographic origin of commodities such as ivory and honey. The application of this technique to abalone on a local, national as well as international level is presented and evaluated.

The carbon and nitrogen stable isotope ratios were measured in the foot tissue of samples of abalone taken from several locations along the South African coast during summer and winter over two years. These ratios were correlated with changes in season, location within the geographic range, and depth of sampling; and compared to the same ratios in macroalgae common in the diet of *H. midae*. The stable isotope ratios of samples from confiscated abalone are also presented, demonstrating the location of their geographic origin from the above data set. The results of a pilot study comparing the stable isotope ratios of several commercially exploited species from different international sources are presented and the implications for the abalone industry will be discussed.

**Juvenile abalone recruitment measured in artificial habitats.**

Gary E. Davis
U. S. National Park Service, 1901 Spinnaker Dr., Ventura, CA 93001 USA

Fishery managers need reliable estimates of juvenile recruitment to evaluate the efficacy of regulations, stocking, and other restoration efforts. Cryptic juvenile abalone abundance is difficult to assess without considerable natural habitat disruption, that impairs long-term monitoring. We tested artificial structures designed to provide surrogate juvenile habitat as quantitative sampling devices to measure recruitment. In September 1989, 45 concrete block habitats were deployed at three sites, 25 km apart, along the south shores of Santa Rosa and Santa Cruz Islands, California, at depths of 10-16 m. In October 1989, 7,200 small (1.5-9.0 cm) hatchery-reared red abalone, *Haliotis rufescens*, were introduced into 36 of the habitats. Nine habitats remained empty as controls. Habitats were censused *in situ* periodically for two years. Sufficient numbers of native abalones, *H. rufescens* and *H. corrugata*, were detected to identify spring recruitment events. Habitats with introduced abalone contained twice as many native abalones as empty control habitats. An estimated 32% of the introduced abalone survived for one year, 24% for two years. Seven artificial habitats will detect abalone recruitment events, but adult densities and recruitment levels were so low in the study area that we could not evaluate the ability of the habitats to quantify recruitment.

**Rates of breakdown of algae in South African abalone and algae-trapping limpets.**

Rob Day[1]*, Rodrigo Bustamante[2] and Peter Cook[2]
[1] Zoology Department, The University of Melbourne, Parkville, Vic. 3052, Australia
[2] Zoology Department, University of Cape Town, Rondebosch 7700, Republic of South Africa

In order to assess whether gut contents can be used as a good measure of diets, South African abalone, *Haliotis midae*, were collected and starved for one month in aquaria, then fed a variety of algae, and frozen at intervals thereafter. Similarly, groups of the algal trapping limpet, *Patella argenvillei*, were caged for a month in the field to prevent them from feeding on macroalgae, then fed and frozen in the same way. Brown algal fragments disappeared more slowly than green or red algae in the abalone crop, as expected from previous work on the Australian *Haliotis rubra*, and from the fact that the two brown algae contain high levels of polyphenols. Thus, previous reports that *H. midae* feeds extensively on the brown *Ecklonia maxima* may be based on biased data. In the limpet *Patella argenvillei* the mechanism of digestion appeared to be different, in that the material that enters the crop after maceration by the radula is trapped by a meshwork of mucous filaments and is moved rapidly into the intestine, whereas the liquid fraction remains in the crop. Thus, the identifiable crop contents reveal only what has been eaten within less than 48 hours, and there is less variation in the residence time of identifiable fragments.

**Comparison of fluorochromes for marking abalone shells.**

Rob Day, Michael Williams* and Gerry Hawkes
Zoology Department, The University of Melbourne, Parkville, Vic. 3052, Australia

The validity of growth checks as indicators of age is often difficult to establish. In abalone, it is not known whether the alternate layers of aragonite and calcite are laid down at regular intervals. This study assessed the potential of five fluorochromes in marking shells of the abalone, *Haliotis rubra*, using an immersion technique so as to "time stamp" the shells and thus determine when layers are deposited. The fluorescent stains used and their respective concentrations were: Oxytetracycline and Tetracycline HCL 300 to 1,000 mg/l; Calcein 10 to 120 mg/l; Alizarin Red 10 to 60 mg/l; Xylenol Orange 20 to 100 mg/l. Immersion times of 12, 24 and 48 hours were used.

We obtained good marks for all stains at high concentrations and at 24 and 48 hour time intervals, and mortality was low in all treatments. There were three problems encountered with the Tetracyclines: (i) solutions were very acidic and required neutralising with sodium hydroxide to prevent mortality, (ii) there was excessive foaming of the solutions, and (iii) a natural fluorescence in the shells closely resembled that of the Tetracyclines. We also had problems in assessing Alizarin Red and Xylenol Orange because their excitation and emission wavelengths are close together, resulting in poor contrast. Calcein, although expensive, was the most effective stain as it produced the most consistent marking.

**Analysis of structural gene regulation at metamorphosis: A model for targeting essential genes in differentiation and growth.**

B.M. Degnan*, T. Naganuma, D. Nees, J.C. Groppe, S.M. Degnan, G. Fenteany, A.N.C. Morse, N. Hooker, J. Hydannas and D.E. Morse
Marine Biotechnology Centre and Department of Biological Sciences, University of California, Santa Barbara, CA 93106, USA

Cellular differentiation and morphogenesis require the expression of a suite of cell type-specific genes. Differentiation events are initiated by cellular signals that induce the transcription of genes coding for regulatory proteins that in turn directly control the expression of a suite of unique, cell-specific target genes. Structural genes, which encode proteins integral to cell and tissue morphogenesis and physiology, are a subset of the target genes expressed in a given cell type. Sustainable improvement in the growth of cultured abalone is likely to require a detailed understanding of the central steps in this biochemical cascade from the synthesis and recognition of cellular signals to the differential expression of target genes.

Settlement and metamorphosis of red abalone (*Haliotis rufescens*) larvae are controlled by two convergent chemosensory pathways, regulated by chemical stimuli from the environment. Induction of metamorphosis in the laboratory provides a model system that allows dissection of these chemosensory pathways that lead to the activation of tissue-specific gene transcription at metamorphosis. We are investigating the regulation of two structural genes – tropomyosin and serine protease – that are differentially expressed during larval development, metamorphosis and juvenile growth in *H. rufescens*. The tropomyosin gene, which encodes a 284 amino acid myofibrillar structural protein in *H. rufescens*, is expressed in cells undergoing myogenesis or myofibril formation, and in some mature muscle cells. At metamorphosis, there are a number of changes in the spatial accumulation of the tropomyosin transcript, with the most prominent decrease occurring in the larval retractor muscle and the most pronounced increase in the juvenile columnar muscle. The larval serine protease gene is activated in a small set of cells located in the dorso-caudal region of the veliger larva when it becomes competent to settle and begin metamorphosis. This is followed by a marked increase in serine protease mRNA accumulation in the same cells shortly after induction of metamorphosis. Later in juvenile development, the larval gene is repressed and a second serine protease gene (coding for a digestive enzyme) is transcribed in the intestine; this expression is maintained in the adult. By studying the tropomyosin and serine protease genes, we hope to determine the factors controlling differential, spatial and temporal transcription and, more importantly, those involved in attenuating the level of expression of these genes. Modification of regulatory pathways in transgenic abalone with biotechnologically altered genes provides a means to target specific tissues and promote increased expression of specific suites of structural genes—for example, those encoding the muscle-specific proteins of the myofibrillar apparatus.

**Effect of recombinant vertebrate growth hormone on growth of adult abalone, *Haliotis kamtschatkana.***

Deborah A. Donovan*, Barbara E. Taylor, E. McLean, and T.H. Carefoot
Department of Zoology, University of British Columbia, 6270 University Boulevard, Vancouver, B.C. V6T 1Z4, Canada

Enhancement of cultivar growth through hormone therapy is currently an area of interest in aquaculture research, due to its potential for increasing production. Somatotropin therapy was investigated as a means of enhancing growth in adult abalone, *Haliotis kamtschatkana*. Fifty individually caged abalone were held in a common aquarium tank with a constant flow of fresh ambient seawater and fed *ad libitum* on kelp (*Nereocystis leutkeana*). The abalone were divided into five groups of ten animals similar in their mean weight (~78 g) and length (~7 cm). Four groups received weekly intramuscular injections (5 $\mu g \cdot g$ body $wt^{-1}$) of either 1) recombinant bovine somatotropin, 2) recombinant porcine somatotropin, 3) somatostatin, or 4) a sham injection of bovine serum albumin. The remaining group of abalone served as an untreated control. The abalone were weighed biweekly throughout the 12-week duration of the experiment. Water content and gonad index were assessed for each group at the end of the experimental period. There were no significant differences in weight gain, water content or gonad index among the five groups. Thus, we have concluded that adult abalone of this species are not responsive to hormone therapy. This contrasts with juvenile *Haliotis discus hannai*, which responded to somatotropin therapy with enhanced growth. Reasons for the unresponsiveness to hormone treatment exhibited by these adult abalone are discussed.

**The predatory behaviour of the seastar *Coscinasterias calamaria* toward *Haliotis rubra*.**

Ashley Dowell, Rob Day* and Glen Sant
Zoology Department, The University of Melbourne, Parkville, Vic. 3052, Australia

The seastar *Coscinasteris calamaria* is known to feed extensively on the blacklip abalone *Haliotis rubra*, but only at some times and places. This study investigated the abundance and feeding habits of the seastar on reefs in Port Phillip Bay. *C. calamaria* usually feeds predominantly on mussels (*Mytilus edulis*), but was found feeding on abalone when few other prey were available. A previously unobserved component of the abalone escape response may explain the variable rate of predation on abalone by *Coscinasterias*. This apparently involves the production of a chemical deterrent on the mantle edge. The escape response is believed to be a significant factor affecting *Coscinasterias* behaviour when attacking abalone.

**Characteristics of gut microflora in the abalone *Haliotis midae*.**

Jean Erasmus[1]*, Vernon Coyne[2], and Peter Cook[1]
[1] Zoology Department, University of Cape Town, Rondebosch 7700, Republic of South Africa
[2] Microbiology Dept., University of Cape Town, Rondebosch 7700, Republic of South Africa

Manipulation of the growth rate of farmed abalone is important in mariculture as it influences the productivity of the enterprise. Various factors, such as temperature and diet, can affect the growth rate of the animal. Previous studies on other cultured shellfish have shown that resident bacteria can be important contributors towards the nutrition of the host animal. This study reports the initial steps towards analysing the relationship between the nutrition of *H. midae* and resident gut bacteria. Scanning electron microscopy has indicated that bacteria are associated with the gut wall throughout the digestive system and are not evident on ingested food. Viable gut bacteria were shown to occur at an average titre of $1.85 \times 10^8$ colony-forming units per gram (wet weight) of gut tissue. Biochemical and physical taxonomic tests identified members of the bacterial genera *Vibrio, Pseudomonas, Flavobacterium, Alcaligenes, Actinobacillus* and an isolate belonging to the family *Enterobacteriaceae*. Scanning electron microscopy revealed bacteria resembling members of the genus *Microcyclus*. Two bacterial isolates remained unclassified using the above methodology. Bacterial strains isolated from the abalone digestive system were found to hydrolyse a variety of complex polysaccharides which occur in algae. These results indicate that the gut bacteria may have a significant effect on the physiology and digestion process of *H. midae*.

**The development of artificial feeds for abalone: a worldwide review of past and present research.**

Ann Fleming[1*] and Rob van Barneveld[2]

[1] Zoology Department, The University of Melbourne, Parkville 3052, Australia
[2] South Australian Research and Development Unit (Pigs). Northfield Pig Research Unit, GPO Box 1671, Adelaide, SA 5001, Australia

In recent years there has been a significant increase in the number of countries developing artificial feeds to supplement or replace macroalgae in abalone aquaculture. Today researchers are fortunate to have the experience and expertise of agricultural nutritionists and feed formulators. Their experience of the last 100 years or so can be used to identify the most likely path to a nutritionally valuable and cost effective feed for abalone. While most research on the nutrition of abalone is of value, some information is more likely to result in major nutritional improvements of a basic formulation, while other information will be of value in the long term, when refining and fine-tuning is required. In addition, the Japanese have about 30 years' experience in formulating artificial feeds for abalone, culminating in the commercial production of feeds of high quality. Although it can not be assumed that the optimal diet for Japanese abalone is the same for species in other countries, an historic account of the research undertaken is of value in identifying those areas of research that were of most value in improving their feeds. This paper reviews the research done, both past and present, on abalone nutrition and feed formulation, and reports on the requirements of an artificial feed from the farmer's perspective. An outline of the areas of investigation most likely to result in major nutritional improvements will be given, based on the current understanding of abalone nutrition and the experience of agricultural nutritionists and Japanese researchers.

**Growth and mortality of blue abalone *Haliotis fulgens* under culture on the island of Cedros, Baja California, Mexico.**

José Guadalupe González Aviles
S.C.P.P. Pescadores Nacionales de Abulón, B.C.L., Ave. Ryerson 117, Ensenada, Baja California, México

The growth and mortality of the blue abalone was examined in a culture system for one year. Changes in growth rate were associated with seasonal changes, particularly in the temperature and food supply. The growth rate was linear over time. The initial mean shell lengths of seed grown in canisters suspended in the sea were 12.4 and 14.8 mm, corresponding to ages of 6 and 7.6 months respectively. The mean growth rates were 100 μm per day and 160 μm per day. Mortality was 6-11% per month at the beginning and 16-20% at the end of the experiment.

**Crecimiento y mortalidad en abulon azul de cultivo *Haliotis fulgens* en Isla de Cedros, Baja California, México.**

Se presenta la dinámica de incrementos mensuales en crecimiento y mortalidad de abulón azul de cultivo en sistema intermedio; durante un período de un año, se asocian los cambios estacionales en las condiciones ambientales principalmente a la temperatura y suplemento alimenticio. Se presenta una correlación de tipo lineal en los incrementos encontrados. La semilla de abulón azul que se colocó en las canastas en suspensión fueron de una talla promedio de 12.4 mm en el primer lote de semilla y de 14.8 mm longitud de concha mismos que corresponden a una edad de 6 y 7.6 meses respectivamente. La velocidad promedio de crecimiento fué de 100 micras/día y en algunos casos mayor que 160 micras/día. La mortalidad que se presentó fue de 6.6 a 11.36 % al inicio del ciclo y de 15.8 a 20% al final.

**Probable feeding attractants in allspice (*Pimenta officinalis*) for black abalone (*Haliotis discus*).**

K. Harada*, T. Miyasaki, S. Kawashima and H. Shiota
Shimonoseki University of Fisheries, P.O. Box 3 Yoshimi, Shimonoseki 759-65, Japan

Attraction activities of extracts were statistically estimated on the basis of the exploratory and feeding behaviour of black abalone *Haliotis discus*. The ether fraction from the water extract of allspice *Pimenta officinalis* was, first of all, ascertained to have the highest attraction. The essential oil of allspice was separated into four fractions (phenolic, acidic, neutral and basic ones) by extraction with a mixture of pentane-dichloromethane (1:1, w/w). The neutral fraction was the most attractive of these four fractions. This was then subfractionated into eight fractions by using Silicagel 60 (Merck) with a series of pentane-ether mixtures of a different mixture ratio. The fraction eluted with pentane-ether (80:20) solution was the most attractive. A gas chromatogram of the eluate showed the presence of many diverse components. Each peak was identified by combined gas chromatography-mass spectrometry. Among the components identified, ten representative specimens were selected and examined as to their attractiveness. *p*-Cymene, ß-elemene and *a*-terpineol were effective attractants, and ß-elemene was the most attractive. Other specimens such as ß-caryophyllene, eugenol, methyl eugenol, linalool, linaool oxide, terpinen-4-ol and ß,*y*-terpineol were faint or not effective as attractants. The attractive activity of ß-elemene appreciably increased at higher concentrations..

**A comparative discussion of a closed and open sea-water system for a pilot scale abalone *(Haliotis midae)* hatchery.**

Neil Henry
Zoology Department, University of Cape Town, Private Bag, Rondebosch, 7700, Republic of South Africa

Studies on the culture of the abalone, *Haliotis midae*, necessitated the construction of a seawater holding system. Two systems, a closed and an open seawater system, were used during the investigation. Criteria used to identify and speculate on the advantages and disadvantages of both systems were temperature, salinity, pH and nitrite levels. The closed system utilised a biological filter. The chosen medium for the colonising bacteria was a scintered glass disc called 'siporax'. Fluctuating levels of waste products from adult *H. midae* during and after active feeding, could not be adequately processed by the biological filter. This led to the development of an open seawater system which was to replace the closed system and secondly, to an evaluation of the intake water from the potential pumping site for a planned commercial scale abalone farm. Successful broodstock conditioning and spontaneous spawnings only occurred in the open seawater system. The open seawater system proved to be easier to manage than the closed seawater system and could easily be expanded by increasing pumping capacity.

**Production of transgenic abalone.**

Lynna Hereford[1,2], Toby Cole[2], Marta Gomez-Chiarri[2] and Dennis Powers[2]
[1] SeaGenes, Inc., 236 Bonita Avenue, Piedmont, CA 94611, USA
[2] Hopkins Marine Station , Stanford University, 120 Oceanview Avenue, Pacific Grove, CA 93950, USA

The slow growth of abalone exacerbates efforts to select for traits by classical breeding techniques. Recombinant DNA technology in combination with gene transfer methodologies offers a means to make rapid changes by the introduction of genes conferring any number of desirable traits. With this goal in mind, we have developed an efficient method for the production of transgenic abalone. We have perfected a highly efficient method for introducing foreign genes into abalone embryos and have demonstrated that those genes are expressed. Presently, we are constructing a series of 'all abalone' expression vectors that we intend to introduce into abalone embryos. We have cloned the DNA for an abundant abalone gene and its promoter. We are currently constructing vectors containing various elements of this promoter region in order to generate a series of vectors which will allow differing levels of gene expression.

**A new method for induction of triploid abalone.**

Lynna Hereford[1,2], Teri Nicholson[2], Vicky Lee Kirby[3] and Dennis Powers[2]
[1] SeaGenes, Inc., 236 Bonita Avenue, Piedmont, CA 94611, USA
[2] Hopkins Marine Station, Stanford University, 120 Oceanview Avenue. Pacific Grove, CA 93950, USA
[3] Pacific Mariculture Inc., 5515 Coast Road, Santa Cruz, CA 95060, USA

Triploid abalone have previously been produced by either temperature or pressure treatments, but these techniques are cumbersome, time consuming and inefficient on a commercial scale. We have recently developed a highly efficient chemical method to generate triploid abalone. Treatment of abalone eggs at Meiosis I or II generates approximately 80% triploids. Induction of Meiosis I triploids results in a 50% decrease in larval mortality. Our analysis suggests that this is most likely due to the production of anuploids during treatment. No decrease in mortality is observed with Meiosis II triploids. Preliminary experiments suggest that both Meiosis I and Meiosis II triploids have significantly enhanced growth relative to their diploid counterparts. In agreement with theoretical expectations for increased heterozygosity, enhanced growth is greater for Meiosis I triploids than Meiosis II triploids.

**Effective population numbers in hatchery populations of *Haliotis rufescens*.**

Lynna Hereford[1,2], Valarie Powell[2], Dennis Powers[2], Susan McBride[3*] and Dennis Hedgecock[4]
[1] SeaGenes, Inc., 236 Bonita Avenue, Piedmont, CA 94611, USA
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Using starch-gel electrophoresis, we scored genetic differences for four polymorphic enzymes in juveniles from three separate spawns from Pacific Mariculture, Inc. Although there was no evidence of inbreeding depression, in two of the three spawns the effective per-generation population number (estimated from temporal variance in allelic frequencies (Hedgecock D., Chow V. and Waples, R.S., 1992 *Aquaculture* 108: 215-232)) was significantly lower than recorded breeding numbers. These results are best explained by variable reproductive success of mass spawned animals. Such breeding practices will eventually lead to loss of genetic diversity and inbreeding depression. Simple expedients to counter these effects will be discussed. In the course of these studies samples were also analysed from San Miguel Island, the current site of most of the commercial abalone fishery in California. Although preliminary, the data suggest that some fraction of the present day population is derived from hatchery-produced animals. The implications of these results for the success of the California abalone enhancement programs will also be discussed.

**Food consumption and faecal output for blacklip (*Haliotis rubra*) and greenlip (*Haliotis laevigata*) abalone fed a range of artificial diets.**

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In conjunction with digestibility trials, food consumption and faecal output by abalone were recorded on a daily basis. The data are discussed in relation to the dietary history of the animals and the composition and digestibility of the diets.

**The potential of macroalgae as a feed for Australian abalone culture.**

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Currently a difficult question to answer in Australian abalone aquaculture is the importance of macroalgal diets to industry development. Most states and territories in Australia have adopted policies that limit or ban the harvesting of wild macroalgal stocks. It is important therefore for abalone farmers to have data on the potential of macroalgal diets and their alternatives when discussing with legislators access to wild macroalgal stocks, and also when developing business plans. Results are presented on comparative feeding rates of *Haliotis rubra* and *H. laevigata* for 69 macroalgal diets (58 macroalgal species), comprising 17, 8 and 33 species of Phaeophyta, Chlorophyta and Rhodophyta respectively. Growth rates, consumption rates and feed conversion efficiency (FCE) for 15 of the more abundant macroalgal species clearly show that mixed macroalgal diets produce the fastest growth. The growth results from these experiments show that selected macroalgal diets can achieve growth rates in excess of 50 mm/yr under optimal conditions. These results are discussed in relation to algal polyculture, wild and drift macroalgal harvest, and artificial food.

**Embryonic development, larval development and early growth of hatchery-produced abalone seed, *Haliotis ovina* (Gmelin, 1791).**

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Among three species of abalone found in Thailand, *Haliotis ovina* (Gmelin, 1791) has a great potential for commercial production. Some aspects of the basic biology, ecology, genetics and nutrition of *H. ovina* were studied with an aim to develop a commercial abalone hatchery in Thailand. In this paper, the embryonic development, larval development and early growth of hatchery-produced *H. ovina* are reported. Newly released eggs are spherical with an elevated egg membrane. The average egg diameter was about 180 microns. At an average temperature and salinity of 29° C and 32 ppt., the first and second polar body were observed within 10 and 15 minutes after insemination, respectively. The trochophore stage was obtained within 6 hours whereas hatching into a swimming blastula was completed within 7.30 hours. The creeping larval stage was obtained within 36 to 40 hours when pre-prepared plate bundles covered with benthic diatoms were provided for settlement of competent larvae. Juvenile abalones (1-3 respiratory pores) with a size range from 1 - 3 mm were obtained within 24 days. Three month old juveniles had shell lengths between 6.5 and 15.1 mm, with a mean and standard deviation of 10.53 ± 1.99 mm (n=69). At this stage, juvenile abalones were fed separately with three species of macroalgae, *Gracilaria salicornia, G. tenuistipitata* and *Enteromorpha intestinalis*. An artificial diet was also provided. The abalones fed with *G. salicornia, E. intestinalis* and an artificial diet were not significantly different in their growth rate, whereas abalones fed with *G. tenuistipitata* had a significantly lower growth rate.

**Measuring settlement intensity in greenlip abalone (*Haliotis laevigata*) in southern Australia.**

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Larval settlement and recruitment processes are currently receiving long-overdue attention in marine ecology and fisheries biology. We will present the results of the first year of a study now underway to examine the utility of settlement collectors to determine spatial and temporal variability in the settlement rates of greenlip abalone. Measurements of settlement are being carried out in conjunction with recruitment studies in areas of contrasting adult abundance.

**Abalone stock enhancement through the release of artificial seeds.**

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Abu Fishery Cooperative Association (AFCA) has released cultured abalone seeds of *Haliotis discus discus* since 1981. The number of seeds of 15-40 mm in shell size released varied between 34,000 and 185,000 per year during 1981 to 1990. The released abalone were found among landed abalone after 1983. Abalone fished by about 180 commercial skin divers have been landed during the fishery seasons lasting 29 to 56 days from July to September between 1983 and 1992. Abalone are packed in 8 kg plastic baskets for sale. Samples of the landed *H. d. discus* were examined in seven to ten days out of each fishery season, and the total numbers of released abalone estimated. The shell colour of artificial seeds is green, caused by the diet in the aquarium, and the released abalone with this prominent green mark were easily recognised, and could be distinguished from wild abalone which have a reddish brown shell colour when one year old. The age of the released abalone was determined by counting the number of annual rings. The number of baskets sampled ranged from 29 - 92 and the number of abalone from 1,183 to 4,536 respectively for ten fishery seasons. The numbers of total and released abalone landed were estimated by a two-stage sampling survey (Kitada *et al.* 1992), using the investigating day at the first stratum and the sampled basket as the second stratum. Some released abalone had reached 9 cm in shell size (commercial size) 21 months after release and they are generally recognisable until 7 years old. Thus abalone from the1980-1985 year classes were all mostly recaptured by 1992, and the recapture rates (number of recaptured abalone/number of released abalone) were estimated to range between 11 and 50% in these year classes.

**Observations of the growth responses of red abalone, *Haliotis rufescens*, when subjected to various types of natural, non-marine and artificial diets.**

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As the demand for farmed abalone steadily increases over the years, the search for a readily available, cost-effective and growth-enhancing alternative diet has become increasingly important. During the past five years we have made an aggressive effort to obtain alternative diets that may be suitable in the culture of the red abalone, *Haliotis rufescens*. In some instances, the diets tested were formulated on site at our farm. The necessity for a standard test protocol was paramount, as we envisioned this testing period to be continuing as new diets became available. Each test period was set up to run for 60 days with intermediate measurements taken at 30 days. In addition, a control sample utilizing a commercially available fish food that has given consistent growth results was run concurrently with each series of tests conducted. This control sample helped to isolate any environmental factors that may have contributed to, or detracted from, the performance of the particular diet being evaluated. Rate of shell length increase, weight increase, unit costs, availability and stability of the various diets were considered during these evaluations. To date we have evaluated 40 alternative diets and will continue as others become available. These observations demonstrate how significant advances in the search for an alternative abalone diet have been made in a relatively short period of time. It is our desire, that by presenting this information, we will assist in the development of an alternative abalone diet that will be beneficial to growers worldwide.

**Digestibility of potential feed ingredients in artifical diets for blacklip (*Haliotis rubra*) and greenlip (*Haliotis laevigata*) abalone.**

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Using chromic oxide as an external marker and acid-insoluble ash as an internal marker, the digestibility of a range of potential ingredients for abalone diets was investigated. Test ingredients were included as 15 - 30 % of the diet, with the remainder being a fish meal-based reference diet. Nutrient categories included dry matter, crude protein, energy, crude lipid, crude fibre and ash.

**Nutrition of newly settled larvae of the South African abalone *Haliotis midae*.**

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Gut content analyses of abalone post larvae (*Haliotis midae*) that settled on diatom-covered plates were conducted to determine any selectivity in feeding. Diatoms in the analyses were counted using the Utermohl method and scanning electron microscopy was used for their identification. Results indicate that the relative abundance of diatoms in the gut, faeces and areas on settlement surfaces from which post larvae were removed were similar, which suggests that post larvae are probably not selective in their feeding, but rather ingest what is available on the settlement surface. The potential for isolating and culturing diatoms and other microalgae to improve growth rates of juvenile abalone for aquaculture purposes is discussed.

**Growth of the asses ear abalone (*Haliotis asinina* Linné) on Heron Reef, tropical eastern Australia.**

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Growth rates of asses ear abalone (*Haliotis asinina*) were measured *in situ* (mark-recapture of adults) and in aquaria (juveniles) on Heron Reef, Queensland. A growth curve ($y = 6.8\ell^{1.83}e^{-u}$, where $u = 0.2\ell^{0.83}$, $y$ = growth rate and $\ell$ = length) was derived from these data, and a sigmoidal age/length relationship obtained from the curve. It is estimated that *H. asinina* may reach 37 mm in length in the first 6 six months of growth and 61 mm in 12 months. Peak growth rates were measured at greater than 100 mm $year^{-1}$ for a short period in young abalone. These are probably the highest growth rates recorded for any abalone, and reinforce the suitability of *H. asinina* for aquaculture. The number of growth rings were also measured and increased with size, but showed no clear relationship with the estimated age of the abalone. However, it is clear that more than one ring can be laid down annually. These data are regarded as preliminary and further work is required to verify the estimates obtained, especially for animals between 20 and 60 mm in length.

**Estimation of the abundance of abalone: the importance of patch size.**

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An assessment of the abundance of abalone stocks has rarely been documented, primarily because of the disaggregate stock structure of abalone and because of the practical difficulty of conducting surveys of abalone over large spatial scales encompassing inaccessible coastlines. A method to assess the relative abundance and biomass of abalone stocks over large spatial scales (hundreds of kilometres) is described. Stratified random surveys can have sufficient power to provide precise estimates of relative abundance. Such data can be used to assess temporal changes in the abundance of abalone stocks relative to particular harvest regimes. However, abalone fisheres, unlike some scientists, do not sample populations randomly. Rather, abalone fishers selectively target large patches of abalone. The relative frequency of various patch sizes of abalone may well be a more sensitive indicator of fishing intensity than the relative abundance of the population. The relationship of relative abundance, density and patch size / frequency is described for the New Zealand abalone *Haliotis iris*. Relative abundance can be predicted from patch size data. The use of survey data in stock assessment of abalone stocks is described. Surveys of abalone are usually biased to include mostly emergent (mature) individuals. While such surveys may be useful in examining abundance trends in exploitable stocks they do not provide information on the abundance of pre-recruits or juveniles. A survey method to examine juvenile abundance is described and its utility in predicting recruitment patterns is discussed.

**Exploitation patterns of abalone fishers.**

Paul E. McShane
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Fishers for *Haliotis iris* are not allowed to use underwater breathing apparatus (UBA). Consequently, it is often assumed that fishers in the New Zealand abalone fishery have low efficiency. However, others have shown that fishers with UBA exert low rates of exploitation on abalone stocks. The results of other studies suggest that abalone fishers selectively target large aggregations, and fishing intensity is related to the incentive or price paid for the catch. Thus, exploitation rates may vary due to many factors but exploitation patterns are poorly understood for fishers of *H. iris*. An experimental fishery in which exploitation patterns are examined over small spatial scales (tens of metres) is described. The study aimed to examine the degree of selection of various patch sizes or aggregations of *H. iris* and to investigate the rate of reformation of aggregations after fishing. Exploitation rates of six commercial fishers were examined directly by rates of return of tagged individuals and by comparison of pre- and post-fishing densities and the relative abundance and size composition of abalone. The results are described and compared with the results of other abalone fisheries employing UBA. This study is part of a larger one aimed at examining density-dependent growth of abalone.

**The New Zealand abalone fishery - a case study.**

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The New Zealand abalone fishery produces about 1,200 tonnes annually. The commercial value of the fishery has increased in recent years concomitantly with demand from Asian markets and associated with declining world production of abalone. The increased value has intensified the scrutiny of stock assessment, which, for abalone, has a poor record of predicting harvest levels under various management strategies. The results of biological studies suggest that the New Zealand fishery, mainly for *Haliotis iris*, may have low productivity compared with other fisheries such as those for *H. rubra*. *Haliotis iris* evidently has relatively low rates of natural mortality and recruitment. Stock assessment of this species is primarily based on research surveys that provide a time series of relative abundance / biomass and size composition. The surveys also provide information on the abundance and size composition of pre-recruits. Commercial catch sampling and compulsory log-book data are used to examine the spatial development of the fishery and to correlate changes in the size composition of the catch with field observations. The inadequacy of managing disaggregate stocks of abalone over large spatial scales is discussed along with current initiatives aimed at improving the management of the New Zealand abalone fishery.

**Recruitment variation in abalone: its importance to management**

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Recruitment failure has been implicated in the decline of several abalone fisheries. Traditionally, fisheries scientists invoke theoretical stock-recruitment relationships to predict trends in abundance of an exploited stock associated with various harvest regimes. The empirical evidence in support of a relationship between spawning stock and recruits is not strong. A further problem in interpretation of such relationships is that recruitment has various definitions in the fisheries and ecological literature. The abundance of spawners is one of many sources of variation in recruitment for exploitable marine species. Yet relevant studies examining variation in recruitment in a wide range of marine taxa, reported primarily in the ecological literature, are rarely considered or cited in the fisheries literature. The available evidence for invertebrate species, particularly those with high fecundity, is that recruitment varies independently of the abundance of spawners. This is also the case for abalone, where recruits have been measured as the density of immediate post-settlement individuals, juveniles, or as adults entering the exploitable stock. Significant sources of variation in recruitment of abalone include density of conspecifics, temperature and regional hydrodynamics.

A problem in the falsification of stock-recruitment hypotheses is that they have intuitive appeal. It is considered 'dangerous' to manage fisheries under the assumption that a reduction in the number of spawners by fishing will not affect recruitment. Such danger to abalone stocks has been more recently assessed by egg-per-recruit analyses whereby various harvest strategies are examined relative to a 'critical' level of egg production. These studies are reviewed and assessed relative to the often conflicting aims of managers and scientists. My review of studies of recruitment variation in abalone emphasises the need for a more rigorous autecological approach to stock assessment where appropriate field experiments are conducted over realistic spatial and temporal scales permitting robust testing of hypotheses.

**Abalone aquaculture in Australia: a pre-feasibility study of a small-scale farm.**

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Abalone farming is perceived by most investors as a high risk, high return investment. The development of abalone farming has been hampered by the scarcity of high level financing required to establish large-scale farms. Unfortunately, appropriate levels of funding for large-scale projects do not guarantee success, as initial production levels may not achieve projected goals. One alternative is to develop a small-scale hatchery and growout facility; this would require a significantly lower level of financing throughout the start up phase and reduce investment risk. This report was prepared to serve as a guide for the likely costs and returns on investment of a model small-scale farm. The model farm was designed in modules for a one or two person operation. Modules can be added as production levels are met. The financial performance and risk assessment of the model farm have been projected. The financial model incorporates the use of recent developments in the use of artificial feeds.

**Primary culture of abalone cells, and *in vitro* myogenesis.**

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Primary cell cultures were established from the larvae of the California red abalone *(Haliotis rufescens)* and the Japanese black abalone *(Haliotis discus)* and from the heart and nerve tissues from the Japanese black abalone. The culture medium was Leibovitz's L-15 medium, modified as follows: 3% (w/v) NaCl, 10% (v/v) fetal bovine serum (FBS), 0.2% (w/v) yeast extract and the GIBCO antibiotic-antimycotic solution. Trochophore/veliger larvae or heart/nerve tissues were trypsinized for 1-3 h, then 10 volumes of the modified L-15 was added.

The cells started attaching to the culture flask surface in 6-24 h. The attached cell population consisted mainly of epitheloid and fibroblastic cells. Attachment was enhanced by the addition of FBS. Collagens (types I and IV), poly-D-lysine, Peptite 2000 and Pronectin F promoted the cell attachment. The seeding density of the cells did not have visible effects on attachment. The attached cells typically were maintained in culture for 3-4 weeks, although some cells remained viable for more than 15 weeks. Fungal contamination occurred occasionally, and traustochytrid phycomycetes were the major and common contaminant. Protozoan contamination was found only several times in the *H. discus* cell culture, which was conducted in less controlled conditions. Bacterial contamination was much rarer. Cellular distribution of the cytoskeletal filaments such as actin and microtubules was observed with reference to muscle differentiation. The progressive development of myogenic processes, including striation of actin filaments, cell contraction and development of myosin and desmin filaments was observed. Although the frequency of the myogenic cells was low and no further myogenesis was observed, the myogenic differentiation seen in tissue culture may provide us with a model to help understand the control of cellular differentiation in the abalone.

**Larval settlement of blacklip abalone (*Haliotis rubra*) to conditioned artificial substrates in the sea.**

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Settlement rates of blacklip abalone (*Haliotis rubra*) larvae were measured at fortnightly intervals for twelve months at George III Reef in southern Tasmania. The spat settlement unit was a cluster of nine spat collectors in a 3 x 3 array at about 7 m depth. Each spat collector contained four closely spaced 25 cm x 30 cm sheets of transparent, corrugated polycarbonate aligned horizontally. The settlement sheets were conditioned prior to use in a flow-through seawater system at the Sea Fisheries Division laboratories in a two-stage process: in the first stage a film of diatoms (mainly *Nitzschia* and *Navicula* species) was established on the plates using 20 µm-filtered seawater. The plates were then transferred to another tank and 10-40 mm juvenile *H. rubra* were placed on the plates. The grazing activity of these juveniles then allowed second-phase algae (principally *Myrionema* species) to establish on the plates, as described by Suzuki *et al.* (1987). The plates were then ready for use. Larval settlement occurred over several months of the year, particularly during winter / early spring. A peak settlement rate of 1,408 larvae per collector (2,347 larvae.$m^{-2}$) occurred in mid-August. Although the stimulus for spawning is not known, the possible implication of an influx of freshwater, emanating from a nearby river, across the site at this time is discussed. Having established the effectiveness of this method for measuring and monitoring larval settlement rates in the sea, its usefulness for addressing several fishery assessment questions is examined.

**Stock assessment of blacklip abalone (*Haliotis rubra*) by the change-in-ratio method.**

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Blacklip abalone (*Haliotis rubra*) in Bass Strait do not grow as large as they do elsewhere in Tasmanian waters. Consequently only a small fraction of the populations there grow larger than the minimum legal size limit that exists throughout Tasmania. The region is therefore virtually unfished by Tasmanian abalone divers. These Bass Strait stocks were made accessible to fishing by a temporary (one-month) reduction of the size limit to a suitable level in 1991 and 1993. During each of these fishing exercises a substantial proportion of the legal-sized abalone were taken. These conditions—a brief fishing period and a large reduction in the fishable stock—are those under which the change-in-ratio (CIR) method for assessing abundance and fishing mortality may be most effectively applied. The principle behind the CIR method is that the undersized fraction of a population (which is unaffected by fishing) may be used as a yardstick against which the reduction in abundance of legal-sized abalone may be measured. When the size of the catch is known, this proportional reduction in the fishable stock may be translated into absolute abundance. Surveys to measure length-frequency composition of the population, conducted immediately before and immediately after fishing, are sufficiently close together (six weeks apart) that changes in abundance of the undersized fraction caused by growth or natural mortality may safely be ignored. In conjunction with information on growth, natural mortality and fecundity, the CIR method is used to assess the Bass Strait *H. rubra* stocks. Finally, the CIR method is evaluated with respect to the assumptions upon which it is based, its applicability to abalone stocks in general, and its usefulness for appraising other methods currently in use for assessing or monitoring abalone populations.

**Growth and ageing of blacklip abalone (*Haliotis rubra*) in southern Tasmania.**

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Growth of blacklip abalone (*Haliotis rubra*) was investigated at three sites in southern Tasmania by mark-recapture methods (for abalone _60 mm shell length) and at one site by modal progression analysis (for abalone <60 mm). Absolute growth rates were maximal in animals of 60-80 mm ($\ell_{max}$), indicating that the age-length relationship is sigmoid. The growth data for abalone _$\ell_{max}$ were fitted to the von Bertalanffy growth function (VBGF). Modal progression analysis was used to measure the growth rate of three distinguishable length classes (modes) smaller than 60 mm over a 12-month period; sampling was at two-monthly intervals. A comparison of the length-frequency plots of the samples taken 12 months apart showed these modes to be annual. A very strong cohort (modal length 18 mm) in November 1992 was clearly distinguishable 12 months later (modal length 36 mm). The growth rings in shells sampled from this cohort in November 1992 and November 1993 were counted, and the mean difference in number of rings between these two sampling periods was one, consistent with the finding of Prince *et al.* (1988) of one major growth ring being deposited per year. Externally visible growth checks on the shells of the juveniles are deposited annually: thickening of the shell occurs during winter months. This is followed by a surge of growth in August/September (early Spring), at which time the thickening of the shell (the growth check) appears behind the new growth. Marginal increment analysis showed that growth layers in the spire of the shell of sexually mature adults are deposited at a rate of one per year. The identity of this rate with that in juveniles suggests that ring deposition in adults is not related to reproduction. This is further supported by the observation that, within a ring (~age) class, sexually mature abalone are significantly larger than immature abalone. It is argued that this pattern would not be possible if a spawning-related growth check were deposited. The VBGF growth parameters $L_{\infty}$ and $K$ obtained by the mark-recapture and ring-ageing methods were then compared. It was found that comparable VBGF parameter values and growth curves could be obtained only for a shell ring deposition rate of three per year and a $t_0$ value of 0.33. The discrepancy between this finding and the other lines of evidence which suggest a deposition rate of one ring per year is provisionally explained by poor fit of the growth of *H. rubra* to the von Bertalanffy growth function.

**Experiments to raise survival and maintain normal growth of juvenile abalone, *Haliotis discus hannai* in winter.**

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*Haliotis discus hannai* is a commercially important species in China. Its natural distribution is along the northern China coast. But a great majority of the juveniles which are born in the natural breeding season (June - August) will die in the following winter. Therefore, this is a major factor limiting the increase of resources and development of culture. The authors carried out a series of experiments on the effects of individual size and water temperature on the mortality of juveniles in the sea and in indoor tanks in the winter of 1984-1985. The results indicated that the smaller the size and the lower the water temperature were, the higher the mortality would be. It seems that a shell length of 8-10 mm is the critical size. Most of those which are less than 8 mm in length will die in the normal winter seawater temperature. The survivors almost do not grow in the period of low water temperature (< 6° C) from late December to early May. The two mechanisms of controlled temperature and recirculating water systems were used to culture juveniles over winter, and high survival and fast growth were obtained.

**The experiments on introduction and culture of Japanese black abalone, *Haliotis discus*, in Fuzhou, China.**

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Some parental stock and juveniles of Japanese black abalone, *Haliotis discus*, were introduced from Nagasaki, Japan to Fuzhou in December 1986. Their adaptability in new circumstances, such as sea water temperature, salinity and food, were observed after introduction. Their growth and breeding were also studied. The results showed that they grew and bred normally in the coasts of Fuzhou. The average shell length of the imported juveniles at about one year of age was 14 mm and they reached 47 (max. 57) mm after the 13th month, 55 (max. 63) mm after the 16th month and 80 (max. 101) mm after 3.5 years. The juveniles that were bred and raised in indoor tanks in Fuzhou grew faster than the released juveniles. The length reached 49 mm in the 17th month after fertilisation (Nov. 1991 - June 1993). About 200,000 seeds have been distributed and are being raised in indoor tanks along the coasts of Fujian Province. The preliminary results are satisfactory.

**The financial dynamics of an abalone start-up venture.**

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The success of new commercial aquaculture companies depends greatly on their ability to accurately forecast start-up costs and initial cash flows. Adequate financing for the start-up phase can only be achieved if the initial financial plan is based on realistic cost and growth assumptions. In established segments of the aquaculture industry, such as catfish, salmon and shrimp production, performance models based on case histories are available and industry standards are well established. In abalone aquaculture there is a lack of historical data on actual costs and production profiles available for start-up ventures, thus limiting the effectiveness of managers and financiers in formulating and evaluating business plans. This report details the actual costs and return profiles for the start-up phase of the Abalone Farm, Inc. abalone hatchery and commercial grow-out facility. The report includes detailed financial statements and inventory growth profiles for a 180 metric ton/year facility.

**Markets for cultured abalone.**

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Cultured abalone are currently being distributed in numerous international markets and the abalone aquaculture industry is rapidly becoming respected as a reliable source for year-round supply of high quality abalone products; yet there is very little information available in the literature relating to the opportunities and market requirements for cultured abalone in the major world markets. The Abalone Farm, Inc. has been marketing cultured abalone on a commercial basis since 1982 and is currently distributing cultured abalone products in the U.S., Japan, Hong Kong and Canada. AFI has effectively developed product concepts which are well suited to the advantages and limitations of intensive farming, while carefully refined to fit specific high margin market niches within these market areas. This report details the product concepts and market niches that AFI has found to offer the greatest opportunity for long term profitability while providing the best opportunity for immediate acceptance of product from emerging abalone producers.

**Infestation of *Haliotis rufescens* shells by a sabellid polychaete.**

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A parasitic infection of the shell by a sabellid polychaete was observed in cultured red abalone (*Haliotis rufescens*). After a cursory review of the literature, it appears that this is the first reported case of sabellids that bore into abalone shell. The sabellid is an unknown species. The sabellid worm interferes with the abalone's ability to create new shell, resulting in abnormal shell growth. It is unclear how the sabellid initially occupies the abalone shell.; however, once it becomes established in the shell, the adult appears to brood eggs that hatch into juveniles in the adult's burrow. These juveniles then move to an area where new shell is being produced and cover themselves with a thin membrane. The abalone then attempts to cover the juvenile with a nacreous layer of shell. From this point on, the abalone exhibits abnormal shell production and reduced growth. The polychaete can spread rapidly among a population of abalone contained within the same culture vessel. Transfer by water flow between culture tanks does occur, but at a much reduced rate. Older, slower growing abalone appear to be more susceptible to infestation. Some abalone have been observed to resume normal shell production and growth while serving as host to the sabellids, but most do not. While an infestation is seldom a terminal condition for the abalone, it does represent a serious condition for the producer as it restricts the growth rate and limits the maximum size of the abalone. As there are no previous reports of sabellids burrowing into native red abalone on the Pacific Coast, we surmise that the sabellid may be a non-native species that was introduced by the discharge of bilge water from foreign vessels near hatchery intakes.

**_Concholepas concholepas_ (Bruguière, 1789), (Mollusca, Gastropoda, Muricidae), the Peruvian / Chilean abalone.**

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*Concholepas concholepas* (Bruguière, 1789) is the most important gastropod fishery in Chile and the south of Perú. Its economic importance is based on the great size and quality of the foot, and the similar morphology to the well known abalone (family Haliotidae). In the 1970s the Asiatic market opened to this alternative to abalone and this was the beginning of over-exploitation. In 1980 the total landings in Chilean ports reached the maximum, 24,000 tons. This represented 28.7% of the total world gastropod landings, including abalones and Queen conchs. The geographical distribution of *Concholepas* ranges from Magellan Strait (Chile) to Lobos de Afuera Island (Perú). The main biological features, such as reproduction, sexual maturity, capsule and larval stages, growth, length - weight relationships, feeding and ecological strategies are reviewed by the authors. The fisheries in Chile and Perú are analyzed, using data on 33 years of landings of *Concholepas concholepas*, and the differences between Chilean and Peruvian treatment are discussed for the first time. In the same way, the government regulations and the attempts to design a management policy are also discussed by the authors. The culture of *Concholepas concholepas* is by now at experimental levels. The juvenile growth rates in laboratory cultures range between 0.4 to 11.1 mm . month$^{-1}$ in different sites and treatments. The main obstacle to beginning a re-stocking program by culture or for commercial culture is the settlement and metamorphosis of the cultured larvae.

**Effects of fisheries regulations on two abalone stocks in Punta Abreojos, Baja California Sur, Mexico.**

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The changes in density, biomass and population structure during 1991 to 1993 of the blue abalone *Haliotis fulgens* on the banks named 'La Lobera' and 'Las Caguamas' (in the southern portion of harvest zone III on the west coast of Baja California, México) are analysed and described. This period includes 2 years of no commercial catch. The results suggest a recuperation of these abalone stocks, including an increase in densities and mean body sizes.

**Efectos de las medidas regulatorias aplicadas sobre dos bancos abuloneros en el area de Punta Abreojos, Baja California Sur, Mexico.**

En este trabajo se analiza el cambio en la densidad, biomasa y estructura poblacional de abulón azul (*Haliotis fulgens*) de 1991 a 1993, incluyendo un período de veda de 2 años, en los bancos denominados 'La Lobera' y 'Las Caguamas' ubicados en la parte sur de la zona III de explotación en la Península de Baja California México. Se destaca una sensible recuperación del banco abulonero además del incremento en las densidades encontradas así como en las tallas promedios.

**Preliminary trials of a casein-based abalone diet - Makara.**

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Two feeding trials on the Makara diet have been carried out. The first, under ambient winter on-farm conditions (mean temperature 10°C) compared Makara with three macroalgal feeds (*Gracilaria*, *Macrocystis* and *Durvillaea* spp.). In this trial Makara was shown to be as good as *Gracilaria* in maintaining abalone condition in winter. The second trial was carried out at 18°C and compared Makara with *Gracilaria* and *Undaria*. Makara was also provided at three feeding rates and three feeding periods. All the abalone were tagged and individual weights and lengths were recorded. Makara is as good a food as *Gracilaria* and *Undaria*. The optimal feed-out rate will vary with temperature, but should be in the 0.5 to 2% range and the best feed-out period would be at four-day intervals.

**Population dynamics of three abalone species (*Haliotis corrugata, H. rufescens* and *H. cracherodii*) at the California Channel Islands.**

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Harvests of the five species of abalone commercially fished in California have declined precipitously in the last two decades. Most of the commercial harvest of all abalone species comes from the California Channel Islands. Results from monitoring of pink, red and black abalone in the Channel Islands National Park reflect this decline. Current population densities are below 10% of the levels found a decade ago. As abalone populations declined, so did recruitment. Recent surveys for white abalone indicate that this deep water abalone is becoming rare. Other species of molluscs have not undergone this sort of decline. A mass mortality, known as Withering Syndrome (WS) is primarily responsible for the decline of black abalone. While WS has been observed in both pink and red abalone, its effects have probably been negligible until recently.

**Differences in reproduction between the blue abalone *Haliotis fulgens* and pink abalone *Haliotis corrugata* in the islands of Cedros and Benitos, Baja California, Mexico.**

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Analysis of variance was applied to visual observations on the state of reproductive maturity blocked by species and by area around Cedros and Benitos islands. There were no statistically significant differences between species or areas, although some differences in the timing of spawning were apparent. These considerations should be included in management strategies for these abalone fisheries.

**Determination de diferencias en el proceso reproductivo del abulón azul *Haliotis fulgens* y amarillo *Haliotis corrugata* por campo pesquero en las Islas de Cedros y Benitos, Baja California, México.**

En el presente trabajo se apliçó un analisis de varianze (ANOVA) por bloques utilizando resultados de madurez sexual por observacion directa, para determinar la existencia de diferencias significativas en el proceso reproductivo por campo pesquero y por especie. Se concluye que estadisticamente no existen diferencias en el proceso reproductivo por campo pesquero y especie, sin embargo se han observado diferencias biologicas en un mismo intervalo de tiempo. Se recomienda añadir a la pesquera estrategias de pesca para la temporada de captura 1992/1993.

**A review of international abalone trade patterns and pricing.**

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A descriptive overview of abalone trade patterns and pricing in international markets is presented, with an emphasis on recent developments in Japanese, American, and Hong Kong markets.

Australian abalone imports have been dominant in the Japanese market for the past twenty-five years, but China is emerging as a major supplier of high value fresh and live abalone. Sourcing of frozen abalone is also becoming increasingly diverse. Real (deflated) import prices of abalone rose almost 100% from 1983 to 1989, but have more recently declined. A strong Japanese currency caused export prices in producing countries to soar through the mid 1980s. The American abalone market has been supplied primarily by domestic production and Mexican imports for the past twenty years. Dwindling domestic landings, which at one time consisted of up to 60% of total supply, now account for only about 10%. Abalone prices have appreciated steadily in the USA Hong Kong imports a variety of product forms from a number of sources. Australia had supplied as much as 90% of frozen imports and almost 50% of canned imports in the early 1980s. Frozen imports are now more diversified . Two distinct classes of dried abalone are imported: a low-valued product supplied by the Philippines and an extremely high-valued product from Japan. Real import prices of abalone have been generally increasing at varying rates since the early 1980s.

**Abalone price determination in the Japanese import and wholesale markets.**

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Abalone pricing in two Japanese market segments was examined using price-dependent single equation estimation techniques.

In Part One, the real (deflated) Japanese import price for Australian fresh / frozen / chilled (FFC) abalone for the period 1970 to 1991 was estimated. Import price in the model was significantly influenced by the quantity of Australian FFC abalone imported annually and Japanese consumer income levels. Estimation of price flexibility coefficients of demand show demand for Australian abalone at the import level to be highly elastic. Price flexibility of income was estimated at approximately 1.4, indicating that abalone import price will rise (fall) at a proportionally greater rate than real consumer income rises (falls). In Part Two, Tokyo Central Wholesale Market prices for domestic Japanese abalone were estimated using monthly data for the period January, 1986 to December, 1990. Abalone price was significantly influenced by Japanese real consumer income and quantity delivered to the market from July to September. A strong positive time trend was evident, suggesting shifts in preference of Japanese consumers during the period. Price flexibility of income was estimated to be greater than 1.2. Deliveries of abalone in excess of about 220 t to 240 t per month will depress wholesale prices from July to September while lower volumes will cause prices to rise. A high degree of market segmentation is suggested in both import and wholesale markets.

***Haliotis fulgens* larvae induced to metamorphose with GABA and other inducers on vinyl plates.**

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The metamorphosis and settlement of abalone larvae on vinyl plates (Japanese system) was compared using GABA (g-amino butyric acid), benthic diatoms and abalone mucus as inducers. Each treatment was carried out in 460-l tanks which contained three racks (replicas), each containing 15 vinyl plates (40 x 40 cm). With the exception of the control group, all the plates were covered with a film of benthic diatoms at the time of induction. Two densities of diatom inoculum, 3,000 and 6,000 cells/cm$^2$, were also tested on the plates for the first two inducers. The density of the larvae was 1/cm$^3$. No differences were found within the same treatment with different diatom densities on the plates; however, significant differences ($P<0.05$) between inducers did occur in settlement on the plates, and in the growth and survival of the postlarvae. With GABA, the average settlement per plate on the fourth day was 1434 postlarvae, followed by mucus with 508 and benthic diatoms with 315. On the twenty-first day, the densities, in the same order, were 684, 53 and 166 postlarvae. On the twenty-first day, using benthic diatoms as an inducer, the size was significantly greater ($P<0.05$), with an average of 775 µm, whereas with the mucus a smaller size was obtained: 731 µm. The GABA yielded better results than the other two inducers, and it can be used effectively in the Japanese system.

**Some attempts to investigate larval recruitment processes of Ezo abalone, *Haliotis discus hannai*, in the adjacent water of Keasennuma Bay, Japan.**

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The larval development of 10 species of Archaeogastropoda was examined to establish a key to aid larval identification for monitoring plankton samples. The criteria from a practical viewpoint were the colour of the soft tissue, shell length, shape and sculpture under the microscope. Fluctuations (1983-1992) in the larval appearance of abalone and allied species (*Tegula* spp, *Septifer*) were closely coincident with wave action caused by a typhoon during the spawning season. From these observations, the average date and density of highest abundance, surface water temperature and cumulative temperature for spawning were 15th September, 4.5 individuals/10m vertical haul, 20.9° C, and 1225° C, respectively. It is relatively easy to get sufficient samples for a field survey by taking account of these spawning characteristics provided above, with the degree of gale as a trigger. Considering the larval distribution in the water adjacent to Kesennuma Bay, locations with high densities were horizontally recognised in the mouth of the bay and nearby open sea coastline. These were mainly dispersed over a range of several km because of the duration of larval stage. Vertical distributions were sporadically observed above 10m depth; the highest density recorded so far was 86 ind./ton recorded at 6m depth on 23 September 1991. In addition to the swimming larvae, deposited larvae collected from natural boulders were observed particularly within the 3-8 m depth zone on reef floor; the highest density so far recorded was 370 individuals/$m^2$ (av. S.L.:0.33 mm) on 26 September, 1991. Serial collecting indicated that in the transition from deposited larvae to juveniles, densities were abruptly decreased to less than 10% after a fortnight and to ca. 0% after a month.

**Current use of gamma-aminobutyric acid (GABA) in massive-scale abalone seed production.**

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In the late 1970s it was discovered that the requirements of abalone (*Haliotis* spp.) larvae for induction of metamorphosis are highly specific, and that the conventional systems used in this culture stage by farmers were very inefficient. It was also found that GABA (gamma-aminobutyric acid), an expensive amino acid related to the natural chemical cue, is a potent inducer. However, early attempts to apply GABA to commercial conditions met with unexpectedly poor results, probably because of microbial interference with the induction process. Therefore, it was suggested that the successful application of this inducer would require the use of antibiotics, which was not considered an affordable alternative by the industry. However, recent research has shown that GABA is an efficient inducer even in the usual bacteriological conditions found in commercial hatcheries and that antibiotics are not a crucial requirement. As a consequence, an increasing number of abalone farmers are now using GABA in the critical settlement induction stage. At present, about one half of the abalone seed produced in the USA and Mexico are settled with GABA. This contribution summarises the different methods and potential problems of using GABA in massive-scale trials, based on our research and the experience of commercial farmers.

**Can dead-shell assemblages of cultured abalone post-larvae provide information about the causes of their death?**

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In abalone (*Haliotis* spp.) seed production, most mortality (ca. 90-99%) occurs during two processes: 1) the induction of larval settlement; 2) the culture of post-larvae, but the evaluations of mortality usually performed do not allow the separation of the effects of these two culture stages. This information would be valuable from productive and research perspectives. The analysis of dead-shell assemblages collected periodically from the culture containers, interpreted using basic biological information, provides a method that can suggest the relative importance of those culture stages. For instance, using this method in an experiment with *H. rufescens*, which compared the diatom-film and the GABA methods for settlement induction, we determined that 35% of the larvae died before metamorphosis in the diatom-film method, while the figure for the GABA method was only 3%. Other examples and methodological details are discussed in this contribution.

**Recruitment and growth of the Omani abalone *Haliotis mariae*.**

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Settlement of the Omani abalone *Haliotis mariae* Wood occurs on the Dhofari coast from January until April. Growth was measured by analysis of modal progressions of cohorts in length-frequency data and of mark-recapture data. These analyses established that growth was about 43 mm in the first year and 20-25 mm in the second and third years. Annual primary growth checks in the shell were used to derive length-at-age data for determination of the growth rate at several sites. Parameters of fitted Von Bertalanffy growth curves were K = 0.27 to 0.43 per year and $L_{\infty}$ 139-149 mm according to site. The rate of deposition of rings in the spire was examined and it is postulated that 4 rings per year are laid down, but that one ring per year is lost through abrasion of the shell.

**A chronology of the abalone *Haliotis fulgens.***

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The micro-structure of the shell of the abalone *Haliotis fulgens* consists of alternate layers of aragonite and darker organic matrix (conchiolin) which are visible as rings. This abalone deposits about 4 rings in the first year and 3 rings each year thereafter. Rings are laid down in about April, August and November, corresponding with sea temperature minima and maxima and with the spawning season. After about 3 years of age, rings at the spire of the shell begin to be lost through erosion of the outer layers of the nacre. The first rings deposited are 5-10 μm thick, and later rings successively increase in thickness to a maximum of about 80 μm. This property is used to estimate the rate of erosion of rings; this is about one ring per annum. When the rate of deposition and the rate of erosion is known for a locality, an estimate of the true age can be made.

**Una cronologia del abulón *Haliotis fulgens.***

La microestructura de la concha del abulón *Haliotis fulgens* consiste de placas alternadas de aragonita y una matriz orgánica más obscura o conquiolina, la cual es visible como anillos. Esta especie de abulón deposita alrededor de 4 anillos en el primer año y 3 en años subsecuentes. Los anillos son formados aproximadamente en los meses de abril, agosto y noviembre, correspondiendo con la temperatura minima y maxima, así como con la época del desove. Aproximadamente después de los 3 años de edad los anillos de la espira comienzan a perderse por la erosión de las capas externas de nácar. El grosor de los primeros anillos depositados alcanzan entre 5-10 μm y los anillos subsecuentes incrementan paulatinamente en grosor hasta un máxiīno de aproximadamente 80 μm. Esta propiedad es utilizada para estimar la tasa de erosión de anillos que es de alrededor de un anillo por año. En la medida en que se conozcan las tasas de depositación, así como las de erosión para una localidad, podrá estimarse la verdadera edad en conchas de abulón.

**A yield- and egg-per-recruit analysis of the Omani abalone, *Haliotis mariae.***

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The fecundity, size and sexual maturity, sex ratios and total mortality of *Haliotis mariae* were measured on the Dhofar coast of the north Arabian sea. These data and estimates of the growth rate were used to do yield-per-recruit and egg-per-recruit analyses. Maximum yields occur at 3+ to 4+ years of age according to the natural mortality rate chosen. At the present age at first capture, egg production levels are 2-29% of the unfished stock depending on estimates of $F$ and $M$, and are considered to be far too low to maintain recruitment. At a 40% egg production level, widely accepted as a minimum safe level, the age at first capture is 4 to 4.5 years, i.e. 105-115 mm shell length according to site.

**Studies on southern Australian abalone (genus *Haliotis)* XVI. Recruitment, habitat and stock relations.**

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The dynamics of a population of the greenlip abalone, *Haliotis laevigata*, was studied from 1978 to 1990 in Waterloo Bay, South Australia. During this period there was a closure from 1982 to 1986 and the size limit was increased in 1986. The spatial distribution of recruitment (measured as the abundance of the 2+ age class) was correlated during every year of the study with a complex gradient comprising water movement, habitat complexity and predator density, and for six years of the study with an independent factor, depth. Recruitment increased significantly after the closure and the succeeding re-opening, by 2.7 times.

The intensity of aggregation of the adult (_ 4 years) fraction of the population varied with density and habitat complexity. Under intense fishing, aggregations were fewer and smaller. After weighting stock abundance according to a model relating intensity of aggregation with fertilisation success, we present a stock-recruitment relation for this abalone in Waterloo Bay. The curve is a classical Ricker type, which suggests depensation (reverse compensation) at low stock sizes and compensation at high stock sizes. Below adult densities of about 0.15 to 0.2 $m^{-2}$ the population is increasingly vulnerable to recruitment failure and ultimately collapse.

**Kelp and algae-based artificial foods for juvenile South African abalone (*Haliotis midae*).**

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The kelp *Ecklonia maxima* is abundant on the west and south west coast of South Africa and will probably form a major component of farmed abalone diets in this region, but it is possible that artificial food may be useful to increase growth rates at the weaning stage. Numerous artificial foods were developed, using kelp or algae as the base. These were then supplemented with different types of protein as well as vitamin and mineral mixes. Growth rates were monitored over 3 - 6 month periods and food conversion and absorption efficiencies measured. The results will be presented.

**Genetics aspects of abalone culture.**

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This paper deals with the use of various molecular techniques applied to the culture of abalone. Stock identification, hatchery genetics and genetic growth markers have been investigated using allozyme and several DNA techniques in a study on the South African abalone *Haliotis midae*. The results of a population genetic study of *H. midae* (with a distribution of over 1000 km) using (starch and cellulose acetate gel) allozyme electrophoresis, as well as Restriction Fragment Length Polymorphisms (RFLP) of mitochondrial DNA will be contrasted and evaluated as a means of elucidating population structure and stock identification. Genetic variability in hatchery-produced populations relative to wild stocks was also assessed by means of starch gel electrophoresis of polymorphic loci. These results are contrasted with published data.

Results of a possible linkage between the phosphoglucomutase (PGM) locus and growth rate are presented and evaluated. The presence or absence of particular alleles in faster or slower growing individuals, as well as published data for other *Haliotis* species, indicate that a growth marker in *Haliotis midae* may exist. The opportunity to artificially select for faster growing individuals and the risks therein will be discussed. Finally, the future prospects for the use of molecular techniques in the study of abalone and the abalone industry will be discussed.

**The South African recreational abalone fishery: how important is it?**

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The South African recreational fishery is directed at one subtidal species, *Haliotis midae*, and is concentrated mostly in the waters of the south-western Cape Province, with intermittent fishing of populations along the eastern Cape and Transkei coasts. In the S.W. Cape, abalone are found in the shallow (<10 m) inshore area within forests of the kelp *Ecklonia maxima*. Divers may only use snorkel equipment, not SCUBA. A recreational abalone permit was required from 1984, and annual permit sales provided the first indices of recreational effort. Requests for voluntary submission of catch statistics that accompanied these permits elicited a very poor response rate of less than one percent. From 1988 to the present, sales of permits have escalated constantly, from around 20,000 to more than 34,000. From 1991 the permits required the holder's telephone number to be supplied, and a copy became available to the Sea Fisheries Research Institute, permitting a telephone survey of permit holders to be carried out. A market research company was contracted to interview permit holders, and during the course of the season, random samples of permit holders were interviewed every two weeks and questioned about their past two weeks diving activity. Results for the past two seasons are now available.

Results showed that certain areas were particularly popular among recreational divers, and that as expected, most activity took place during the summer December to January holiday period. Average daily catch per outing was 3.0 to 3.3 abalone. Average total catch per person for both seasons was 20. Estimated total recreational take was 367 tons in 1991/92 and 484 tons in 1992/93, as compared with an annual commercial take of around 605 tons. In addition ground "creel" surveys were carried out in certain areas during the December/January period. Divers were interviewed and questioned on diving success, and their abalone were measured. These results showed that the recreational take comprises on average smaller abalone than that of the commercial take, with a tendency in some areas towards knife-edge selection above the legal minimum size. A ground truthing exercise is planned for December 1993, when an intensive localised ground survey will be carried out concurrently with a high-intensity telephone survey. This should permit validation and calibration of the telephone survey results.

**Differences in recruitment patterns and fishery productivity in two areas: a link?**

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The South African abalone fishery began in the late 1940s, directed at one species, *Haliotis midae*. Initially both the west coast and the south-west coasts supported dense abalone populations which were heavily exploited during the early stages of the fishery. After this "mining" phase only the "traditional" south-west coast, between Cape Hangklip and Quoin Point, provided sustained landings. When management of the fishery changed to area-based Total Allowable Catches in 1985, experimental TACs were allocated to three west coast zones. CPUE data for two of these showed dramatic declines over a few years, accompanied by complaints from the divers of reducing stock abundance. The TAC set for the third west coast zone has been consistently declining over the recent past, in response to the decrease in past biomass levels.

Recruitment cycles have been monitored at four sites since November 1988. Three of the sites are within the "traditional" south-west coast area, and one of these is in a marine reserve. The fourth site is on the cooler South African west coast. Numbers of recruits from 2 mm to 45 mm shell length were monitored every 8 weeks at these sites. *H. midae* larvae settle in shallow (<5 m) inshore waters, on crustose coralline algae. They become visible on close inspection (without magnification) from 2-3 mm long. From around 5 mm until more than 20mm shell length the juveniles seek shelter under the spines of sea urchins (*Parechinus anglosus*), particularly where these are aggregated in crevices or gullies. From 20 mm shell length the juveniles can be found under boulders, and within crevices. Significant settlements of recruits became visible during November to January each year at the three traditional area sites. However on the west coast site recruitment cohorts have settled intermittently. Growth rates and survival appear similar between sites, and monitoring of gonad bulk indices shows evidence of regular spawning. It is suggested that intermittent or failed recruitment has been the cause of the low productivity of the west coast, and that the recruitment failures may be due to larval mortality induced by environmental factors such as offshore currents.

**Growth of the greenlip abalone *Haliotis laevigata* on the south coast of Western Australia.**

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Growth rates and deposition of shell growth rings were examined in the abalone *Haliotis laevigata* at Augusta, Western Australia. There was no difference between growth rates of males and females, nor was there a difference between "normal" and "stunted" populations. Animals reach reproductive maturity at an age of 2.5 to 3 years and legal size of 140 mm at 5 to 6 years. "Stunted" animals initially had slightly less than three growth rings per year on average, but after about five years of age this relationship changed and they began to form an average of more than three rings per year. The pattern for animals from the "normal" population was initially similar to that of the "stunted" animals, but after five years of age they began to lay down fewer than three rings per year on average. All of the large (>140 mm) individuals from the "normal" population and most of those from the "stunted" area at Augusta had fewer than 20 growth rings, but about a third of the "stunted" individuals had significantly greater numbers of rings.

**Behaviour studies on the mobility of two species of abalone (*Haliotis* spp.) on sand: implications for reseeding programs.**

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Reseeding of hatchery-reared juvenile abalone (*Haliotis* spp.) as a means of stock enhancement has been employed in many countries, but recapture rates have usually been too low to guarantee a profit and a high percentage of "unaccounted for" seed abalone has often plagued the interpretation of reseeding programs. Abalone have been widely regarded as fairly sessile organisms. In particular, areas of bare sand have been thought to pose an effective barrier to abalone movement. Thus, the possibility of seed emigration has mostly been neglected. The present investigation was carried out to evaluate in laboratory experiments, the movement behaviour on sand of two species of abalone (*H. tuberculata and H. discus hannai*) with two size classes in each species.

Test animals of all groups examined moved across open areas of sand, however, at highly variable rates. *H. discus hannai* was far more mobile than *H. tuberculata*, and the larger size class (29-40 mm) was much more mobile than the smaller size class (11-22 mm) in both species. The search for food was found to be the major incentive to move for *H. tuberculata*, whereas an arousal state generated by handling stress and acclimatization to a new environment was thought to account for most movements undertaken by *H. discus hannai*. It can be concluded that the common view of abalone as simply sessile organisms might not apply to all species and circumstances. The significance of these findings for fisheries management and reseeding programs are discussed.

**Growth rate affects morphology of *Haliotis rubra*.**

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Abalone of a range of sizes (14-152 mm) were tagged at seven sites separated by almost 600 km on the New South Wales coast. Over 1,500 of these abalone were recaptured after periods of up to 6 years. Growth varied enormously both within and among sites, but included some of the fastest natural rates recorded for the species. Abalone at sites where they grew quickly were morphologically different to those at sites where they grew slowly. Similar morphological differences were evident among fast and slow growing abalone at the same site. By using the morphology of abalone to estimate their growth, broad-scale surveys of variation in growth rates may be possible. The morphological differences among sites also suggest potential changes to management that could enhance the fishery for abalone in N.S.W.

## PAPERS PRESENTED AS POSTERS:

### A device to mark abalone shells *in situ* by immersion in fluorescent dyes.

Gerry Hawkes*, Rob Day and Michael Williams
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An Underwater Aquarium System (UAS) has been designed to mark mollusc shells with fluorochrome dyes *in situ*. The UAS is a sealable plastic box with connectors to a scuba tank and a bleeder valve. The air supply both aerates and circulates the water at a controlled rate. Stains are added to the aquaria in concentrated solution via a quick release coupling. The advantages of the UAS are to minimise stress caused by the emersion and transport of animals to aquaria on boats or laboratories. Following exhaustive laboratory trials tagged abalone were immersed in fluorescein in the field at concentrations of 80 mg/L over a 24 hour period to produce identifiable marks within the shell. Using five aquaria and eight diver hours up to 150 abalone can be double tagged and marked using fluorescent dyes over a two day period.

### Biochemical compositions of benthic diatoms used in juvenile abalone culture.

Graeme A. Dunstan[1], Malcolm R. Brown[2], Stephanie M. Barrett[1], Jeannie-Marie Leroi[2], Shirley W. Jeffrey[2] and John K. Volkman[1].
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The biochemical compositions of nine pennate and five centric diatoms were examined in order to assess their potential nutritional value for maricultured animals. Benthic pennate diatoms are the principal food of newly settled juvenile abalone. The major lipid class in diatoms was polar lipid, although some species contained significant amounts of triacylglycerols and free fatty acids. Of the three polyunsaturated fatty acids implicated to be nutritionally important to abalone, 20:5(n-3) was a major component of the fatty acids in all diatom species. The mean proportion of 22:6(n-3) was significantly higher in centric diatoms relative to pennate diatoms. Most species examined contained very low proportions of (n-6) polyunsaturated fatty acids, although four of the pennate diatoms contained significant proportions of arachidonic acid, 20:4(n-6). The sterols were dominated by phytosterols and varied significantly between species. The proportions of total (free plus protein) amino acids were similar, although there were significant differences in the content and proportions of phagostimulatory free amino acids. Based on biochemical composition, the diatom species examined are potentially nutritious feeds for maricultured animals.

### An improved sampler for the removal of newly settled invertebrates from hard substrata.

Paul E. McShane and Reyn Naylor
MAF Fisheries Research, PO Box 297, Wellington, New Zealand

A suction sampler has been applied in the assessment of spatial and temporal variation in recruitment of abalone (*Haliotis rubra*). The sampler was able to remove immediate post-settlement individuals (_ 300 µm shell length) of that species. Application of similar methodology revealed low rates of recruitment of *H. iris*. One explanation for low rates of capture of *H. iris* by the suction sampler was that suction was camparatively poor in the shallow waters (_ 2 m) preferred by juveniles of *H. iris*. However, studies of the efficiency of the sampler revealed no difference between shallow and deep (_ 6 m) habitat. Yet sampling of known densities of recruits of *H. iris* (300-600 µm shell length) revealed that overall effciency was low (about 1% of available recruits were captured by suction). This result was shown to be due to wear of the brush used on the sampler. It was shown that, in wearing, the bristles occluded the suction intake of the sampler relative to new brushes. An improved brush design, resulting in efficient removal of small invertebrates from hard substrata, is described.

**Metamorphosis in *Haliotis rufescens* abalone larvae of different ages, related to the number of rows of teeth in the radula**

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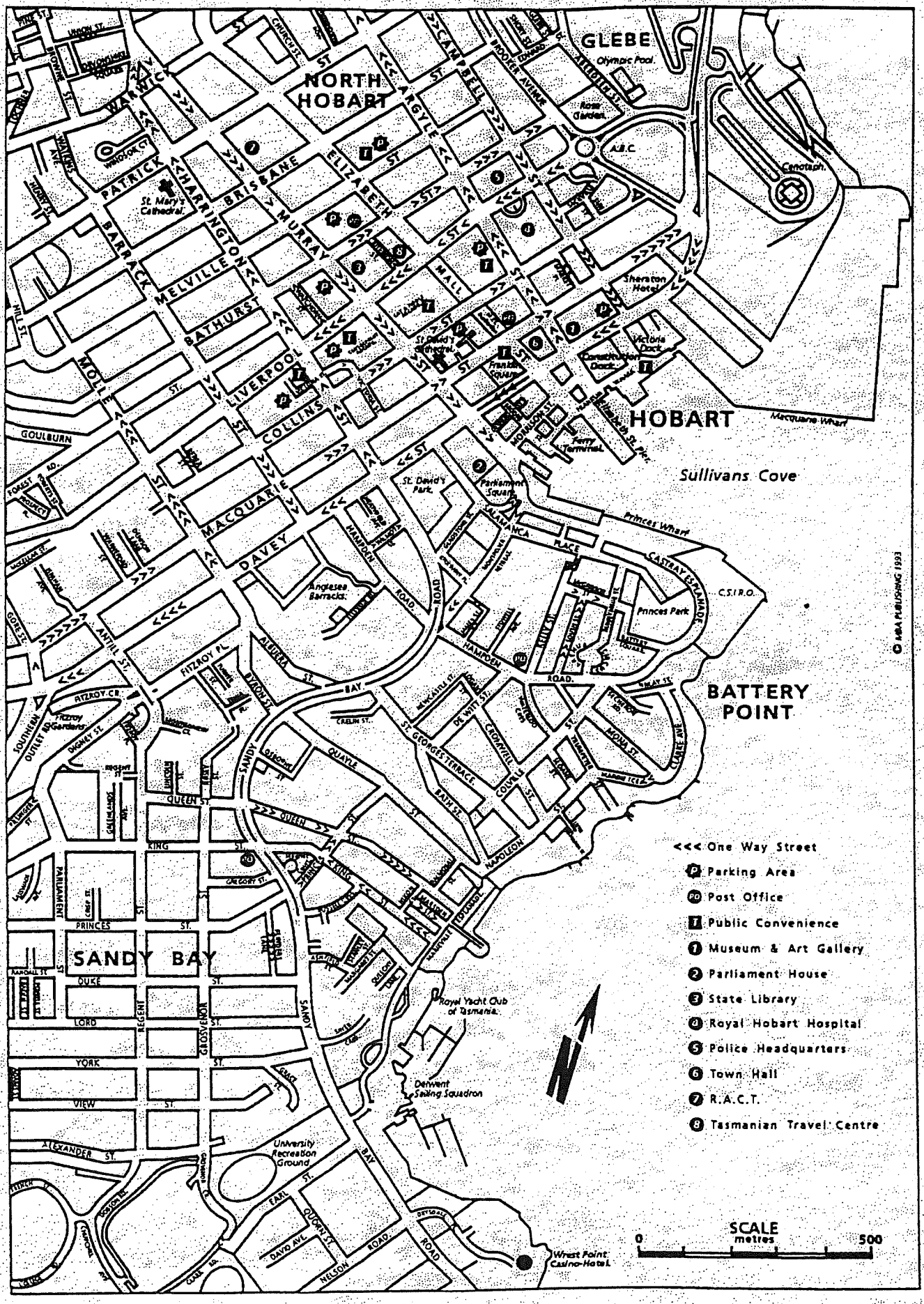
The response of competent larvae from 7 to 12 days old to inducers of metamorphosis was evaluated, by exposing them to the stimulus of two inducers: bethic diatoms and g-aminobutyric acid (GABA). The rows of teeth in the radulae from 20 larvae were counted daily before the induction. Each treatment was conducted in triplicate, including the control group, in 18-litre containers each containing 2500 larvae. The response varied significantly with age when induced by the benthic diatoms ($p=0.018$) from 11 to 37%; these values corresponding to the seventh and eighth days. The highest rate of metamorphosis, 37%, occurred in the 8-day-old larvae where the radulae showed between seven and nine rows of teeth. With GABA the response was significantly higher ($p<0.05$) for the seventh and twelfth day respectively. In this inducer the percentages of metamorphosis were higher than 90% when the rows of teeth in the radula were 10 or more, and 24 hours after the induction, 75% of the oldest larvae showed peristomal shells, and the younger ones only 4%. The age of greater sensitivity in the larvae can be different for each inductor, and the radula can be a better indicator of competence than the ramifications in the cephalic tentacles.

**The effect of four anaesthetics on *Haliotis midae* in commercial abalone culture.**

Hermien White, Tom Hecht and Ben Potgieter
Department of Ichthyology and Fisheries Science, Rhodes University, PO Box 94, Grahamstown 6140, Republic of South Africa

The removal of abalone from tank surfaces during harvesting and size-sorting is normally accomplished by physical means often resulting in injury and mortality. This investigation was conducted to isolate suitable chemicals for the safe removal of cultivated abalone through anaesthesia. Magnesium sulphate, 2-phenoxyethanol, EDTA (ethylenediaminetetraacetic acid) and procaine hydrochloride were tested *in vitro* and *in vivo*. All four chemicals produced *in vitro* relaxation of isolated tarsal muscle. *In vivo* tests were conducted on three size classes (*viz.*, 5-15, 20-50 and 60-90 mm shell length (SL)) to determine the most effective concentration in relation to size. Magnesium sulphate and 2-phenoxyethanol effectively produced anaesthesia in all three size classes at concentrations of 3-24 $g.100ml^{-1}$ and 0.05-0.7 $cm^3.100\ ml^{-1}$ respectively. From these results, the recommended concentrations of magnesium sulphate for 5-15, 20-50 and 60-90 mm SL abalone are 4, 14 and 22 $g.100ml^{-1}$, and for 2-phenoxyethanol: 0.05, 0.2 and 0.3 $cm^3.100\ ml^{-1}$ respectively. EDTA also produced anaesthesia in all three size classes at 0.1-5 $g.100ml^{-1}$. However, due to its insolubility in seawater it is impractical for commercial application. Procaine hydrochloride 0.5 g.100ml-1 produced mortalities in two size classes and is therefore considered unsafe for commercial application.



**APPENDIX II.** Progress toward acceptance of papers submitted for publication in the special issue of *Aquaculture* (in October 1994).

| **Author** | **Title** | **Progress towards final acceptance** |
|---|---|---|
| Britz, P. | Effect of dietary protein on growth performance of South African abalone, *Haliotis midae*, fed fishmeal based semi-purified diets. | Accepted with minor revision |
| Britz, P. | An investigation into the suitability of selected protein sources for inclusion in artificial diets for the South African abalone, *Haliotis midae.* | Second draft contesting reviewer's comments sent to a third reviewer |
| White, H.I., Hecht, T. & Potgieter, B. | The effect of four anaesthetics on *Haliotis midae* and their application in commercial abalone culture. | Accepted with minor revision |
| Knauer, J., Britz, P. & Hecht, T. | Comparative growth performance and digestive enzyme activity of juvenile South African abalone, *Haliotis midae*, fed on diatoms and a practical diet. | Accepted with minor revision |
| Henry, N. | A comparative discussion of a closed and open seawater system for a pilot scale abalone (*Haliotis midae*) hatchery. | Rejected |
| Jarayabhand, P. & Paphavasit, N. | A review of tropical abalone with special reference to Thailand. | Accepted with minor revision |
| Nie, Z.Q., Ji, M.F. & Yang, J.P. | Preliminary studies on increased survival and accelerated growth of overwintering juvenile abalone, *Haliotis discus hannai* Ino. | Accepted with major revision |
| Nie, Z.Q., Wang, S.P., Lee, M.B. & Ma, J. | The experiments on introduction and culture of Japanese black abalone, *Haliotis discus*, in Fuzhou, China. | Will be rejected |
| Viana, M.T., Lopez, L.M., Garcia-Esquivel, Z. & Mendez, E. | The use of silage from fish and abalone viscera as an ingredient for abalone feed. | Will be accepted with major revision |
| Harada, K., Miyasaki, T., Kawashima, S. & Shiota, H. | Probable feeding attractants in allspice *Pimenta officinalis* for black abalone *Haliotis discus* (Studies on the feeding attractants for fish and shellfishes-XXVI). | Accepted with major revision |
| Park, C.W., Kim, Y.G., & Yi. S.K. | Present status of abalone and fish feed production in Korea. | Rejected |

**APPENDIX II** – continued.

| **Author** | **Title** | **Progress towards final acceptance** |
|---|---|---|
| Oakes, F. & Boswell, J. | The financial dynamics of abalone aquaculture. | Will be accepted with major revision |
| Oakes, F. & Ponte, R. | The abalone market. Opportunities for cultured abalone. | Will be accepted with minor revision |
| King, R.H., Rayner, C.J., Kerr, M., Gorfine, H.K. & McShane, P.E. | The tissue protein and amino acid requirements of abalone (*Haliotis rubra*). | Accepted |
| Oakes, F.R. & Fields, R.C. | Infestation of *Haliotis rufescens* shells by a polychaete. | Will be accepted with minor revision |
| Taylor, B.E., Donovan, D.A., McLean, E., Donaldson, E.M. Carefoot, T.H. | Effect of recombinant vertebrate growth hormone on growth of adult abalone, *Haliotis kamtschatkana.* | Will be accepted with major revision |
| Hone, P.W. | The potential use of macroalgae as a feed in abalone aquaculture. | Not submitted |
| Fleming, A.E., Van Barneveld, R.J. & Hone, P.W. | The development of artificial diets for abalone: a review and future directions. | With reviewers |
| Trevelyan, G.A. & Sommerville, D. | Hose culture of benthic marine diatoms. | Will be accepted with minor revision |
| Searcy-Bernal, R. | Boundary layers and abalone postlarval culture: Preliminary studies. | Will be accepted with major revision |
| Aviles, J.G.G. & Shepherd, S.A. | Growth and survival of the blue abalone *Haliotis fulgens* in barrels at Cedros Island, Baja California, with a review of abalone barrel culture. | Will be accepted with minor revision |

**APPENDIX III.** Progress toward acceptance of papers submitted for publication in the special issue of *Australian Journal of Marine and Freshwater Research* (in August 1994).

| Author | Title | Progress towards final acceptance |
|---|---|---|
| McShane, P.E. | Spatial variation and commercial fishing of New Zealand abalone populations (*Haliotis iris* and *H. australis*). | Rejected |
| McShane, P.E. | Recruitment variation in abalone: its importance to fisheries management. | Accepted with minor revision |
| Shepherd, S.A., Johnson, D.W. & Baker, J.L. | A yield- and egg-per-recruit analysis of the Omani abalone, *Haliotis mariae*. | Accepted |
| Shepherd, S.A., Al-Wahaibi & Al-Azri, A.R. | Recruitment and growth of the Omani abalone *Haliotis mariae*. | Accepted with minor revision |
| Shepherd, S.A. & Partington, D. | Studies on southern Australian abalone (Genus *Haliotis*). XVI. Recruitment, habitat and stock relations. | Revised MS with one referee |
| Keesing, J.K., Grove-Jones, R., & Tagg, P. | Measuring settlement intensity of abalone: results of a pilot study. | Accepted with major revision |
| Kojima, H. | Abalone stock enhancement through the release of hatchery-reared seeds. | Revised MS with one referee |
| Davis, G.E. | Juvenile abalone (*Haliotis* spp.) recruitment measured in artificial habitats. | Accepted with minor revision |
| Wells, F.E. & Mulvay, P. | Reproduction, fecundity and growth of the greenlip abalone *Haliotis laevigata* on the south coast of Western Australia: a comparison of normal and stunted populations. | Referees' reports with authors |
| Werner, I., Flothmann, S. & Burnell, G. | Behavioural studies on the mobility of two species of abalone (*Haliotis tuberculata* and *H. discus hannai*) on sand: implications for reseeding programmes. | Referees' reports with authors |
| Goggin, L. & Lester, R.J.G. | *Perkinsus*, a protistan parasite of abalone in Australia: an update. | Accepted with major revision |
| Day, R.W., Williams, M.C. and Hawkes, G.P. | A comparison of fluorochromes for marking abalone shells. | Accepted |

**APPENDIX III** – continued.

| **Author** | **Title** | **Progress towards final acceptance** |
|---|---|---|
| Shepherd, S.A., Avalos-Borja, M. & Ortiz Quintanilla, M. | Toward a chronology of *Haliotis fulgens* with a review of abalone shell microstructure. | Referees' reports with authors. |
| Thomas, M. & Day, R.W. | Feeding by the drilling gastropod *Dicathais baileyana* on *Haliotis rubra*. | Referees' reports with authors. |
| Sasaki, R. & Shepherd, S.A. | Larval dispersal and recruitment processes of *Haliotis discus hannai* and *Tegula* spp. | Accepted with minor revision |
| Day, R.W. & Cook, P. | Bias towards brown algae in determining diet and food preferences: *Haliotis midae*. | Referees' report with authors |
| Tarr, R. | Growth and movement of the South African abalone *Haliotis midae*: a reassessment. | With referees |
| Nash, W.J., Sanderson, J.C., Bridley, J., Dickson, S. & Hislop, B. | Post-larval recruitment of blacklip abalone (*Haliotis rubra*) on artificial collectors in southern Tasmania. | Accepted |
| Matthews, I. & Cook, P. | Nutrition of newly settled larvae of the South African abalone *Haliotis midae*. | With referees |