

# Offshore Artificial Reefs

## Best Practice Study

*John Diplock and Heath Folpp*



NSW DEPARTMENT OF  
**PRIMARY INDUSTRIES**



Australian Government  
**Fisheries Research and  
Development Corporation**

## Project No. 2007/248

**ISBN Number 978-0-646-48859-2**

This work is copyright. Except as permitted under the Copyright Act 1968 (Cth), no part of this publication may be reproduced by any process, electronic or otherwise, without the specific written permission of the copyright owners. Neither may information be stored electronically in any form whatsoever without such permission.

## TABLE OF CONTENTS

Non Technical Summary	3
Acknowledgements	5
Background	5
Need	5
Objectives	5
Methods	6
Discussion	7
Benefits	8
Further development	9
Presentations	9
Conclusions	10
Appendix 1 Personnel	11
Appendix 2 Detailed Trip Report	12
Appendix 3 Additional photographs	25
Appendix 4 Financial Report	44
Appendix 4 Fishing World Article – May 2008	45

**PRINCIPAL INVESTIGATOR:** John Diplock

**ADDRESS:** Cronulla Fisheries Centre  
PO Box 21  
CRONULLA NSW 2230  
Telephone: 02 95278411 Fax: 02 95278536

**OBJECTIVES:**

1. To investigate artificial reef construction and deployment methodologies to ensure that the NSW program employ world's best practice.
2. To study artificial reef site selection techniques and site specific location criteria to maximise reef effectiveness.
3. To observe and record techniques for monitoring and measuring the effectiveness of artificial reefs in improving recreational fishing particularly those using innovative technologies to deliver enhanced fishing and environmental outcomes from NSW artificial reefs.
4. To provide up-to-date advice on artificial reef methodologies available to interested Australians by reporting to ACoRF, RFSTEC, NSW Planning Dept. and FRDC, and through publications in the recreational fishing media, scientific journals, meetings of fishing organizations and fisheries managers, and on the web.
5. To improve the skills of key personnel responsible for artificial reef projects in NSW by meeting with artificial reef experts and inspecting artificial reefs in countries with extensive successful reef development experience.
6. To satisfy the Fisheries Research and Development Corporation that the deployment of artificial reefs in inshore ocean waters off NSW meets the highest environmental standards and is therefore eligible for FRDC funding.
7. To note the processes used for assessing the environmental impact of artificial reefs to ensure that artificial reefs in Australia are deployed and managed in an environmentally responsible way.

## **NON TECHNICAL SUMMARY:**

### **OUTCOMES ACHIEVED**

This study provided an in-depth examination of artificial reef technology in Japan and Korea that fundamentally changed the direction of artificial reef design and construction for use in the new Offshore Artificial Reefs Program in NSW through adoption of purpose built, sophisticated reef designs and materials, and species specific reef module groupings.

It also provided information otherwise unavailable in Australia that will assist the implementation of best-practice artificial reef design, construction and deployment throughout this country.

The study provided access to Japanese and Korean government and business contacts that will allow Australian artificial reef proponents to access state of the art artificial reef technology.

The information obtained has been widely disseminated through presentations to government agencies and stakeholder groups, and to recreational fishers through radio and popular print media.

The skills of the fisheries management team responsible for the artificial program in NSW has been significantly enhanced through exposure to Korean and Japanese artificial reef technology.

The Environmental Assessment currently underway in NSW has been significantly improved through the incorporation of new reef technology observed in Korea and Japan, and through expert advice obtained from overseas experts met via the study.

Mr Diplock and Mr Folpp visited Korea from 2-8 September 2007 and Japan from 8-16 September to investigate artificial reef construction and deployment methodologies to ensure that the developing NSW program employ world's best practice. They visited government research institutes and universities in both countries and gave presentations on the state of artificial reef research and development in Australia. They also visited artificial reef construction sites and met with reef design and construction companies in both countries.

### **Korea**

In Korea and Japan artificial reefs have been used to enhance commercial fisheries for more than 30 years. Over this period many refinements to design and deployment have increased the effectiveness of the structures. A diverse range of designs are utilised for the production of fish, seaweed, abalone, rock lobsters and molluscs including octopus and squid. Design refinements such as the inclusion of natural materials in concrete and the development of patented ceramics to promote settlement of algae have boosted seaweed, mollusc and shellfish production. New, species specific designs, and purpose built multi-species reefs are now

commonplace. A key feature of all reef designs was the stability and structural strength requirements to withstand the typhoons common in this region

At the National Fisheries Research & Development Institute in Busan they met with experts in artificial reef design, construction and monitoring. The Institute has extensive hydraulic testing facilities for optimising reef module design. The Institute also conducts extensive research into the biology of reef dwelling animals and has world class wave and flume tank simulators to model reef responses to various simulated oceanographic conditions.

At the Pukyong National University, Busan they met researchers specialising in artificial reef design and monitoring and discussed methodologies. The university conducts a wide range of research projects on the design and effectiveness of artificial reefs including hydraulic assessments of scale models to improve stability and durability and biological studies into the behavioural responses of different fish species.

At Cheju Island, they inspected artificial reefs *in situ* to observe mature reef modules with associated algal growth and fish assemblages. The reef was a reinforced concrete cube construction with rock ballast showing prolific epiphyte growth and numerous associated fish including amberjacks. They inspected artificial reef manufacturing plants to observe the production of species specific concrete module designs incorporating biological aggregates to enhance algal settlement, complex surface and void shapes to promote shellfish settlement and growth, and site specific structural design characteristics for shallow water deployment in high energy wave zones. They observed numerous concrete modules designed for specific purposes. Most reef construction is funded by the national government with monies provided to provincial governments who may provide additional funds.

Basic concrete cube reefs have been used for more than two decades but remain popular due to its strength, durability and cheapness. The dimensions of the void space are critical to success in attracting fish. Note these modules are made of construction grade reinforced concrete with no additives to enhance algal settlement. These modules have a live span of approximately 30 years. Steel artificial reefs are becoming more popular in Korea, particularly for sophisticated designs. Steel modules are designed to last approximately 30 years and thus have a comparable live span to concrete reefs.

The Haejoong Artificial Reef Construction Company showed many sophisticated designs and use of refined materials with species specific design features are evident in all reef modules. Many of these design features are patented and the modules are manufactured by contractors under licence. At Goseong they visited a marine ranching business comprised of an integrated fish farm and recreational fishing platform operated by a private research institute, the Korean Ocean Research and Development Institute (KORDI). The \$US400,000 moveable recreational fishing platform is designed to be towed to one of the several hundred artificial reefs in the area and can accommodate several hundred fishers. The automatic fish feeding device conditions fish to expect food when a submerged buzzer sounds, and will be used in conjunction with the floating to provide enhanced recreational fishing.

## **Japan**

They visited the National Research Institute of Fisheries in Choshi, Chiba Prefecture. The Institute has extensive facilities for hydraulic testing of designs and material for artificial reefs and conducts numerous research programs into the artificial reefs construction methods and refinements to design.

At the Sugawara Corporations artificial reef construction site at Nakaminato Fishing Port, Ibaraki Prefecture they were shown many sophisticated concrete reef modules to be tested in local waters. As this part of the coast is very exposed the modules are particularly robust to withstand typhoon conditions.

They also saw a number of intricate experimental designs being tested for abalone. These showed precise crevice shapes designed to promote abalone growth and survival. These modules were made from construction grade concrete with normal formwork surfaces and weighed approximately 8 mt. The Sugawara Corporation kindly supplied detailed printed descriptions of the manufacturing and deployment process.

At the Shimonoseki Fisheries University they were given a detailed presentation on the state of Japanese research on artificial reefs and the use of sonic arrays to estimate fish school size and composition. They inspected the research work being undertaken on fish behaviour, including that on the effects of rabbit fish on algal reef production. Artificial reef experts kindly reviewed the NSW artificial reef program, and provided very useful information on the need for artificial reef design specificity. In Tokyo they visited the Japanese Institute of Technology on Fishing Ports where the government's role in reef design and funding was explained. Their meeting with the Kaiyodoboku Artificial Reef Construction Co. in Tokyo provided information on the reef design and construction expertise available in Japan.

**KEYWORDS: Artificial reef, marine ranching, Korea, Japan**

## **ACKNOWLEDGEMENTS**

Dr Chang Gil Kim of the Korean South Sea Fisheries Research Institute kindly hosted the Korean segment of this study. Dr Sadamistu Akeda from the Japan National Research Institute of Fisheries Engineering kindly hosted the Japanese segment of the study. Mr Folpp's salary was paid from the NSW Recreational Fishing Saltwater Trust.

## **BACKGROUND**

In 2004 an estuarine artificial reefs program was initiated with funding from the NSW Recreational Fishing Saltwater Trust. Reefs have been deployed in 3 coastal lagoons using concrete "Reef Ball" modules. As a precursor to expanding the artificial reefs program into inshore ocean waters, funding from the Saltwater Trust was approved in 2006 to undertake an Environmental Assessment. Negotiations with the Fisheries Research and Development Corporation (FRDC) on complementary funding

highlighted the need to ensure best practice in artificial reef technology. The FRDC funded this study tour in 2007.

## NEED

Artificial reefs in Australia have historically been ship wrecks, scuttled ships or other “materials of opportunity” including tyres, vehicles and unwanted building and construction materials. Tighter environmental legislation, and the need to optimise effectiveness has focused attention on design specific reef structures and the need to assess the environmental impacts. Well funded research and development on artificial reefs has been conducted in Korea and Japan for more than three decades. A study of the resultant sophisticated suite of tailored reef designs and deployment regimes was considered timely given the re nascent interest in artificial reefs in this country.

## METHODS

The itinerary and meeting schedule for the study in Korea and Japan are listed below.

### Itinerary

Date	From	To	Transport
1 Sept	Sydney		Air
2 Sept		Busan Korea	Air
4 Sept	Busan Korea	Cheju Do Korea	Air
5 Sept	Cheju Do Korea	Busan Korea	Air
8 Sept	Busan Korea	Tokyo Japan	Air
9 Sept	Tokyo Japan	Choshi Japan	Rail
10 Sept	Choshi Japan	Tokyo Japan	Rail
11 Sept	Tokyo Japan	Kokura Japan	Rail
12 Sept	Kokura Japan	Shimonoseki Japan	Rail
13 Sept	Kokura Japan	Tokyo Japan	Rail
16 Sept	Tokyo Japan		Air
17 Sept		Sydney	Air

### Activities

Date	Details
3 Sept	Meeting and presentation National Fisheries Research & Development Institute Busan;
4 Sept	Meeting and presentation at University of Bukyung Busan; Fly to Cheju Do
5 Sept	Artificial Reef site inspection Cheju Island; Meeting Bumin Composition Construction Co. construction site No.1.
5 Sept	Meeting Kyong Nam Provincial Government; Visit Bumin Artificial Composition Construction Co. artificial reef construction site No. 2. Return to Busan
6 Sept	Meeting with Haejoong Artificial Reef Construction Co.
7 Sept	Travel to Goseong Artificial Reef construction site inspection; Inspection of Korean Ocean Research and Development Institute fish farm and recreational fishing platform.
8 Sept	Busan Fish Market inspection; Fly toTokyo

25 Geils Court, Deakin ACT

Postal address: PO Box 222, Deakin West ACT 2600, Australia

Tel: (02) 6285 0400 International: 61 2 6285 0400 Fax: (02) 62854421 International: 61 2 6285 4421

Email: frdc@frdc.com.au

9 Sept	Transfer Tokyo to Choshi, Chiba Prefecture
10 Sept	Meeting and presentation at National Research Institute of Fisheries Choshi; Artificial reef construction site inspection Sugawara Corp. Nakaminato Fishing Port, Ibaraki Prefecture.
11 Sept	Transfer Choshi to Kokura
12 Sept	Meeting and presentation at Shimonoseki Fisheries University
13 Sept	Transfer Shimonoseki to Tokyo
14 Sept	Tskuji Fish Market visit; Meeting Japanese Institute of Technology on Fishing Ports; Kaiyodoboku Artificial Reef Construction Co., Tokyo
15 Sept	Meeting with National Fisheries Research & Development Institute Tokyo.

## DISCUSSION

### Lessons Learned

- Artificial reefs must be specifically designed to suit the target species, one size does not fit all.
- Using general purpose artificial reef designs will ensure sub-optimal results.
- There large body of published and unpublished research into the effectiveness of various reef designs on species identical or similar to those found in Australia such as snapper, yellowtail kingfish and yellowtail scad exists in both countries.
- Modules must be designed for the bottom sediments, currents, prevailing sea conditions and extreme weather events.
- Extensive commercial expertise in reef design and manufacture based on decades of experience and research exists in both Japan and Korea.
- Very little of the research and development literature is published in English.
- Artificial reef design and manufacturing companies are keen to expand their operations to Australia.
- Many of the most effective designs are patented.
- Artificial reef designs are rapidly increasing in sophistication.
- Steel reef modules allow more sophisticated designs and are increasing in popularity.
- Japanese and Korean commercial and recreational fisheries have benefited enormously from decades of well funded research and development programs on reef design and biological interactions.
- The national and provincial governments in both countries have recognised the benefits of artificial reefs in increasing fisheries production and continue to expand their programs from Consolidated Revenue.

## BENEFITS

This study showed that effective artificial reefs must be purpose designed for the location, target species and fisheries application. As a consequence of the overlap and similarities in fish, invertebrate and algal species between Australia and Japan and Korea, much of the species specific design research is likely to be applicable here.



This study showed conclusively that materials of opportunity are to be avoided, and that properly designed and tested artificial reefs will contribute to better environmental and fishery outcomes. As a result, the Environmental Assessment of offshore artificial reefs will be significantly improved.

## **PRESENTATIONS**

### **Presentations/Reports on Korea - Japan Study**

<b>Date</b>	<b>Organisation</b>	<b>Location</b>
19/09/2007	Offshore Artificial Reefs Planning Focus Meeting – Meeting 1	Sydney
16/10/2007	Marine and Estuarine Charter Management Advisory Committee	Sydney
13/10/2007	Recreational Fishing Freshwater Trust Advisory Committee	Sydney
14/10/2007	Recreational Fishing Saltwater Trust Advisory Committee	Sydney
5/12/2007	Recreational Fishing Research Meeting	Hobart
11/12/2007	Advisory Council on Recreational Fishing	Sydney
12/12/2007	Botany Bay Game Fishing Club	Sydney
09/01/2008	HMAS Adelaide Artificial Reef Meeting	Sydney
16/01/2008	Queensland EPA and DPI	Brisbane
06/02/2008	HMAS Adelaide Artificial Reef Meeting	Terrigal
20/02/2008	Lake Macquarie Project Management Committee	Newcastle
12/03/2008	Offshore Artificial Reefs Planning Focus Meeting – Meeting 2	Sydney
12/03/2008	Basin Lure and Fly – Club Meeting	St Georges Basin
27/03/2008	Recfish Research Meeting	Adelaide
09/04/2008	Marine Parks Authority and Community meeting	Lord Howe Island
17/04/2008	FutureFish Artificial Reefs Meeting	Melbourne
18/04/2008	Victorian Department of Primary Industries	Melbourne

## **FURTHER DEVELOPMENT**

NSW DPI has sought detailed expert advice from Korea on reef module types appropriate for offshore conditions. A Preliminary Environmental Assessment (PEA) has been completed for offshore artificial reefs identifying and prioritising

environmental risks and incorporating the Constraints Mapping to identify suitable sites in three locations. The PEA will form the basis for the guidelines for the full Environmental Assessment conducted under Part 3 of the NSW Environmental Planning and Assessment Act.

## **CONCLUSIONS**

As a result of this study and the processes detailed above will be a comprehensive Environmental Assessment of site and species specific artificial reefs for identified offshore ocean areas of NSW.

## **APPENDIX 1 STAFF INVOLVED**

John Diplock MSc.

Heath Folpp BSc. Hons.

## APPENDIX 2 DETAILED TRIP REPORT

### Artificial Reefs Study Tour Korea and Japan 3-15 September 2007

#### Background

In 2004 estuarine artificial reefs program was initiated with funding from the Saltwater Trust. Reefs have been deployed in 3 coastal lagoons using concrete "Reef Ball" modules. As a precursor to expanding the artificial reefs program into inshore ocean waters, funding from the Saltwater Trust was approved in 2006 to undertake an Environmental Assessment. Negotiations with the Fisheries Research and Development Corporation (FRDC) on complementary funding highlighted the need to ensure best practice in artificial reef technology. The FRDC funded this study tour in 2007.

#### Objectives of the proposed visit

8. To investigate artificial reef construction and deployment methodologies to ensure that the NSW program employ world's best practice.
9. To study artificial reef site selection techniques and site specific location criteria to maximise reef effectiveness.
10. To observe and record techniques for monitoring and measuring the effectiveness of artificial reefs in improving recreational fishing particularly those using innovative technologies to deliver enhanced fishing and environmental outcomes from NSW artificial reefs.
11. To provide up-to-date advice on artificial reef methodologies available to interested Australians by reporting to ACoRF, RFSTEC, NSW Planning Dept. and FRDC, and through publications in the recreational fishing media, scientific journals, meetings of fishing organizations and fisheries managers, and on the web.
12. To improve the skills of key personnel responsible for artificial reef projects in NSW by meeting with artificial reef experts and inspecting artificial reefs in countries with extensive successful reef development experience.
13. To satisfy the Fisheries Research and Development Corporation that the deployment of artificial reefs in inshore ocean waters off NSW meets the highest environmental standards and is therefore eligible for FRDC funding.
14. To note the processes used for assessing the environmental impact of artificial reefs to ensure that artificial reefs in Australia are deployed and managed in an environmentally responsible way.

## Funding

Economy airfares, accommodation, sustenance and all other travel costs in Korea and Japan were fully funded by a grant from the Fisheries Research and Development Corporation. Mr Folpp's salary was fully funded from the Recreational Fishing Saltwater Trust. Mr Diplock's salary was funded from Consolidated Revenue.

## Itinerary

Date	From	To	Transport
1 Sept	Sydney		Air
2 Sept		Busan Korea	Air
4 Sept	Busan Korea	Cheju Do Korea	Air
5 Sept	Cheju Do Korea	Busan Korea	Air
8 Sept	Busan Korea	Tokyo Japan	Air
9 Sept	Tokyo Japan	Choshi Japan	Rail
10 Sept	Choshi Japan	Tokyo Japan	Rail
11 Sept	Tokyo Japan	Kokura Japan	Rail
12 Sept	Kokura Japan	Shimonoseki Japan	Rail
13 Sept	Kokura Japan	Tokyo Japan	Rail
16 Sept	Tokyo Japan		Air
17 Sept		Sydney	Air

## Activities

Date	Details
3 Sept	Meeting and presentation National Fisheries Research & Development Institute Busan;
4 Sept	Meeting and presentation at University of Bukyung Busan; Fly to Cheju Do
5 Sept	Artificial Reef site inspection Cheju Island; Meeting Bumin Composition Construction Co. construction site No.1.
5 Sept	Meeting Kyong Nam Provincial Government; Visit Bumin Artificial Composition Construction Co. artificial reef construction site No. 2. Return to Busan
6 Sept	Meeting with Haejoong Artificial Reef Construction Co.
7 Sept	Travel to Goseong Artificial Reef construction site inspection; Inspection of Korean Ocean Research and Development Institute fish farm and recreational fishing platform.
8 Sept	Busan Fish Market inspection; Fly toTokyo
9 Sept	Transfer Tokyo to Choshi, Chiba Prefecture
10 Sept	Meeting and presentation at National Research Institute of Fisheries Choshi; Artificial reef construction site inspection Sugawara Corp. Nakaminato Fishing Port, Ibaraki Prefecture.
11 Sept	Transfer Choshi to Kokura
12 Sept	Meeting and presentation at Shimonoseki Fisheries University
13 Sept	Transfer Shimonoseki to Tokyo
14 Sept	Tskuji Fish Market visit; Meeting Japanese Institute of Technology on Fishing Ports; Kaiyodoboku Artificial Reef Construction Co., Tokyo
15 Sept	Meeting with National Fisheries Research & Development Institute Tokyo.

## Presentations

Mr Folpp made formal presentations on artificial reefs in Australia at :  
 03/9/07 Korean National Fisheries Research & Development Institute, Busan Korea  
 03/9/07 Pukyong National University, Busan Korea

- 10/9/07 Fisheries Research Agency National Research Institute of Fisheries Engineering Choshi Japan  
12/9/07 National Fisheries University, Department of Fisheries Science and Technology, Shimonoseki Japan  
14/9/07 Japanese Institute of Technology on Fishing Ports, Grounds and Communities, Tokyo Japan

### Overview

In Korea and Japan artificial reefs have been used to enhance commercial fisheries for more than 30 years. Over this period many refinements to design and deployment have increased the effectiveness of the structures. A diverse range of designs are utilised for the production of fish, seaweed, abalone, rock lobsters and molluscs including octopus and squid. Design refinements such as the inclusion of natural materials in concrete and the development of patented ceramics to promote settlement of algae have boosted seaweed, mollusc and shellfish production. New, species specific designs, and purpose built multi-species reefs are now commonplace. A key feature of all reef designs was the stability and structural strength requirements to withstand the typhoons common in this region.

### Korea

Our Korean host was Dr Chang Gil Kim, Korea's foremost artificial reef expert. At the National Fisheries Research & Development Institute in Busan we met with experts in artificial reef design, construction and monitoring. The Institute has extensive hydraulic testing facilities for optimising reef module design.



Complex steel and ceramic plate modules with stone ballast Cheju Do Korea

The Institute also conducts extensive research into the biology of reef dwelling animals and has world class wave and flume tank simulators to model reef responses to various simulated oceanographic conditions. Mr Folpp gave a presentation on the development of artificial reefs in Australia to staff at the Institute.

At the Pukyong National University, Busan we met researchers specialising in artificial reef design and monitoring and discussed methodologies. Mr Folpp gave a presentation to staff and students. The university conducts a wide range of research projects on the design and effectiveness of artificial reefs including hydraulic assessments of scale models to improve stability and durability and biological studies into the behavioural responses of different fish species.



Korean National Fisheries Research & Development Institute, Busan; Flume tank

At Cheju Island, we inspected artificial reefs *in situ* to observe mature reef modules with associated algal growth and fish assemblages. The reef was a reinforced concrete cube construction with rock ballast showing prolific epiphyte growth and numerous associated fish including amberjacks.

We inspected artificial reef manufacturing plants to observe the production of species specific concrete module designs incorporating biological aggregates to enhance algal settlement, complex surface and void shapes to promote shellfish settlement and growth, and site specific structural design characteristics for shallow water deployment in high energy wave zones.



Site inspection of mature artificial reef Cheju Do, Korea

The Bumin Composition Construction Co. constructs numerous concrete modules for specific purposes. Most reef construction is funded by the national government with monies provided to provincial governments who may provide additional funds. The location of reefs and reef module design is negotiated with local commercial fishers. Recreational fishers may use the reefs, but this does generate local conflict. Most reefs are unmarked to discourage use by recreational fishers.



Oyster shell aggregate module for algae and top shell Cheju Do, Korea



Ceramic and oyster shell aggregate algal settlement panels Cheju Do, Korea



Standard concrete cube reef modules Cheju Do, Korea

The basic concrete cube reef has been used for more than two decades but remains popular due to its strength, durability and cheapness. The dimensions of the void space are critical to success in attracting fish. Note these modules are made of construction grade reinforced concrete with no additives to enhance algal settlement. These modules have a live span of approximately 30 years.

25 Geils Court, Deakin ACT

16

Postal address: PO Box 222, Deakin West ACT 2600, Australia

Tel: (02) 6285 0400 International: 61 2 6285 0400 Fax: (02) 62854421 International: 61 2 6285 4421

Email: frdc@frdc.com.au



Steel artificial reefs are becoming more popular in Korea, particularly for sophisticated designs. Steel modules are designed to last approximately 30 years and thus have a comparable live span to concrete reefs.



Steel reef module for pelagic and demersal fish Cheju Do Korea (note lower panels to deflect current up through the structure)



Complex steel reef module for rockfish and pelagic fish Cheju Do, Korea (note complex voids and high vertical relief)



Algae and shellfish concrete reef modules and oyster shell attachment plate Cheju Do, Korea



Tetrahedral concrete fish and shellfish modules Cheju Do, Korea



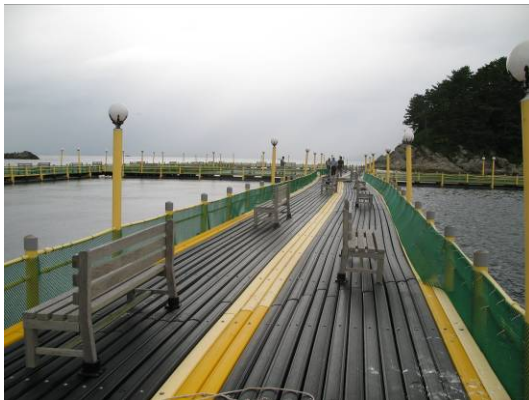
Shellfish void units fit in each corner of tetrahedral modules above. Cheju Do Korea

The Haejoong Artificial Reef Construction Company showed many sophisticated designs and use of refined materials with species specific design features are evident in all reef modules. Many of these design features are patented and the modules are manufactured by contractors under licence.



Abalone concrete modules (inverted) Cheju Do Korea

At Goseong we visited an integrated fish farm and recreational fishing platform business operated by a private research institute, the Korean Ocean Research and Development Institute. The \$US400,000 moveable recreational fishing platform is designed to be towed to one of the several hundred artificial reefs in the area and can accommodate several hundred fishers. The automatic fish feeding device conditions fish to expect food when a submerged buzzer sounds, and will be used in conjunction with the floating to provide enhanced recreational fishing.



Purpose-built moveable recreational fishing platform and integrated fish farm Goseong, Korea



Automatic fish feeding device, KOR&D Institut, Goseong, Korea

## Japan

25 Geils Court, Deakin ACT  
 Postal address: PO Box 222, Deakin West ACT 2600, Australia  
 Tel: (02) 6285 0400 International: 61 2 6285 0400 Fax: (02) 62854421 International: 61 2 6285 4421  
 Email: frdc@frdc.com.au

Our host in Japan was Dr Akeda, one of Japan's foremost artificial reef experts. Mr Folpp gave a presentation at the National Research Institute of Fisheries in Choshi, Chiba Prefecture. The Institute has extensive facilities for hydraulic testing of designs and material for artificial reefs and conducts numerous research programs into the artificial reefs construction methods and refinements to design.



National Research Institute of Fisheries Choshi; Nakaminato Fish Market

At the Sugawara Corporations artificial reef construction site at Nakaminato Fishing Port, Ibaraki Prefecture we were shown many sophisticated concrete reef modules to be tested in local waters. As this part of the coast is very exposed the modules are particularly robust to withstand typhoon conditions.



Experimental artificial reef modules for algae and abalone, Sugawara Corp. Nakaminato, Japan

We also saw a number of intricate experimental designs being tested for abalone. These showed precise crevice shapes designed to promote abalone growth and survival. These modules were made from construction grade concrete with normal formwork surfaces and weighed approximately 8 mt. The Sugawara Corporation kindly supplied detailed printed descriptions of the manufacturing and deployment process.



Abalone experimental module; shellfish and algal module Sugawara Corp. Nakaminato, Japan

At the Shimonoseki Fisheries University we met Dr Hamano and Dr Kakimoto, key artificial reef researchers. Mr Folpp gave a presentation to students and staff. Dr Hamano provided a detailed presentation on the state of Japanese research on artificial reefs and the use of sonic arrays to estimate fish school size and composition. We inspected the research work being undertaken on fish behaviour, including that on the effects of rabbit fish on algal reef production. Dr Kakimoto kindly reviewed our artificial reef program, and provided very useful information on the need for artificial reef design specificity.



Mr Folpp's presentation; fish behaviour studies, Shimonoseki Fisheries University, Japan

Back in Tokyo we met with Dr Ito at the Japanese Institute of Technology on Fishing Ports where the government's role in reef design and funding was explained. Our meeting with the Kaiyodoboku Artificial Reef Construction Co. in Tokyo provided information on the reef design and construction expertise available in Japan.

### Lessons Learned

- Artificial reefs must be specifically designed to suit the target species, one size does not fit all.
- Using general purpose artificial reef designs will ensure sub-optimal results.
- There large body of published and unpublished research into the effectiveness of various reef designs on species identical or similar to those found in Australia such as snapper, yellowtail kingfish and yellowtail scad exists in both countries.

- Modules must be designed for the bottom sediments, currents, prevailing sea conditions and extreme weather events.
- Extensive commercial expertise in reef design and manufacture based on decades of experience and research exists in both Japan and Korea.
- Very little of the research and development literature is published in English.
- Artificial reef design and manufacturing companies are keen to expand their operations to Australia.
- Many of the most effective designs are patented.
- Artificial reef designs are rapidly increasing in sophistication.
- Steel reef modules allow more sophisticated designs and are increasing in popularity.
- Japanese and Korean commercial and recreational fisheries have benefited enormously from decades of well funded research and development programs on reef design and biological interactions.
- The national and provincial governments in both countries have recognised the benefits of artificial reefs in increasing fisheries production and continue to expand their programs from Consolidated Revenue.

## Korea

Person	Institute	Context
Dr KIM Chang Gil	South Sea Fisheries Research Institute	Artificial Reef Design and Assessment
Dr LEE Jeong-Woo	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr KIM Ho-Sang	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr LEE Pil-Yong	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr KIM Jin-Yeong	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr CHOI Jung Hwa	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr KIM Yoon	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr SOIHN Sang-Gyu	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr WON Seung-Hwan	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Professor CHOI Tae-Jin	Pukyong National University	Artificial Reef Technology
Dr KOH Jeong-Rack	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr KIM Kwang-Soo	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr ING Seong-Jae Jeong	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
Dr SUH Young-Sang	National Fisheries Research & Development Institute	Artificial Reef Design and Assessment
KIM Jin-Gab	Hae Joong Co. Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring
KIM Hoon-Gyu	Hae Joong Co. Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring
HA Hyun-Chul	Hae Joong Co. Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring
Dr CHO Hyun-Man	Pukyong National University	Artificial Reef Research
Dr KIM Yun-Tae	Pukyong National University	Artificial Reef Research
Dr KIM Heon-Tae	Pukyong National University	Artificial Reef Research
Dr RYU Cheong-Ro	Pukyong National University	Artificial Reef Research

## Japan

Dr AKEDA Sadamitsu	National Research Institute of Fisheries Engineering	Artificial Reef Design, Deployment and Assessment. Japanese Host
Dr TERAWAKI Toshinobu	National Research Institute of Fisheries Engineering	Artificial Reef Research
Dr TAKEUCHI Tomoyuki	National Research Institute of Fisheries Engineering	Artificial Reef Research
Dr KAKIMOTO Hiroshi	The Japanese Institute of Technology, Fishing Port Ground and Communities	Artificial Reef Research
Dr HAMANO Akira	National Fisheries University Department of Fishery Science and	Artificial Reef Research

	Technology	
Dr NODA Mikio	National Fisheries University Department of Applied Aquabiology	Artificial Reef Research
ITO Yasushi	The Japanese Institute of Technology on Fishing Ports, Grounds and Communities	Artificial Reef Design
OTSUKA Koji	The Japanese Institute of Technology on Fishing Ports, Grounds and Communities	Artificial Reef Design
KOSEKI Ryoji	Kaiyo Doboku Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring
OKASHIGE Fumihisa	Kaiyo Doboku Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring
HACHIKI Kazumi	Kaiyo Doboku Ltd	Artificial Reef Design, Site Selection, Manufacture, Deployment and Monitoring



**APPENDIX 3 ADDITIONAL PHOTOS**



Flume tank for testing artificial reefs, Busan Korea



Flume tank for testing artificial reefs, Busan Korea



Flume tank for testing artificial reefs, Busan Korea



Flume tank for testing artificial reefs, Busan Korea



Steel reef for pelagic and demersal fish, Korea



Concrete reef construction, Korea



Concrete reefs, Korea



Steel reef modules, Korea



Concrete moulds (fore), Steel reefs (rear), Korea



Concrete reef moulds, Korea



Concrete reef moulds, Korea



Concrete reef modules, Korea



Steel reef with stone ballast, Korea



Steel reef modules, Korea



Steel reef modules, Korea



Concrete reef moulds, Korea





Mobile fishing platform, Korea



Mobile fishing platform, Korea



Marine ranching, Korea



Marine ranching, Korea



Abalone reef, Korea



Abalone reef, Korea



Mixed purpose reef, Korea



Mixed purpose reef construction, Korea



Mixed purpose reef construction, Korea



Mixed purpose reef construction, Korea



Concrete reef construction detail, Korea



Concrete reef construction detail, Korea



Concrete reef construction detail, Korea



Concrete reef construction detail, Korea



Concrete reef construction detail, Korea



Hydraulic testing for reefs and breakwaters, Japan





Busan fish market, Korea



Research reef modules, Japan



Research reef modules, Japan



Research reef modules, Japan



Reef fish research, Japan

# APPENDIX 4 FINANCIAL REPORT

PERSON IN CHARGE: "diplock,, John Henry"  
 PROJECT: NSW DEPARTMENT OF PRIMARY INDUSTRIES  
 PROJECT / WORK BREAKDOWN STRUCTURE REPORT  
 WBS ELEMENT: 2661-1 FRDC-Artificial Reefs Korea - Japan  
 COST ELEMENT / GROUP: IMIO-GEN TOTAL  
 PERIOD FROM 1 TO 12 OF 2008  
 PLAN VERSION: 0  
 Date: 11.04.2008  
 Page: 1 of 1  
 User: VDWALTB

Details	Budget	Actual	Commitment	Actual + Commit.	Variation	\$ Var
11805 TRAVEL - AIRFARES	10,000.00	7,229.40		7,229.40	2,770.60	28
11810 TRAVEL - FARES		1,717.98		1,717.98	717.98	28
11830 TRAVEL - SUBSISTENCE	5,000.00	1,534.54		1,534.54	3,465.46	69
11831 TRAV-SUBS-ACTUAL EXP		186.09		186.09	186.09	
11835 TRAVEL - OVERSEAS		12,344.85		12,344.85	12,344.85	
17010 TRAV-OBJECT-CARS		329.16		329.16	329.16	
* Travel & QPlet Expenses	15,000.00	22,342.02		22,342.02	7,342.02	49-
12235 FEES - GENERAL	3,000.00	104.78		104.78	2,895.22	97
13530 PURCHASES - CONSUMABLES	1,000.00				1,000.00	100
* Operating Expenditure	4,000.00	104.78		104.78	3,895.22	97
** TOTAL EXPENDITURE	19,000.00	22,446.80		22,446.80	3,446.80	18-
* 24130 GRTS PR IND/PVTR BOD	19,000.00-	17,100.00-		17,100.00-	1,900.00-	10
* All Revenue Items	19,000.00-	17,100.00-		17,100.00-	1,900.00-	10
** TOTAL REVENUE	19,000.00-	17,100.00-		17,100.00-	1,900.00-	10
*** TOTAL		5,346.80		5,346.80	5,346.80-	



**Fishing for the future**

The artificial reefs trialled in NSW are working well, as evidenced by these shots from Botany Bay and Lake Macquarie. Bigger artificial reefs offshore have the potential to replace areas lost to marine parks.

NSW DPI staffers John Diplock (left) and Heath Folp in front of a huge artificial reef system in Korea. Imagine a system of these dropped a few miles off the east coast!

# DIY fishing spots

*Restrictions in the form of sanctuary zones and no-go fishing areas are causing big problems for anglers around the country. Could artificial reefs help solve our access woes? JOHN DIPLOCK investigates.*

**A**CCCESS to quality spots for recreational fishing has been reduced in many places by the creation of sanctuary zones in marine parks, or to protect threatened species such as grey nurse sharks or black cod. Furthermore, protection zones for trans-oceanic cables and extensions to ports and runways have also reduced popular fishing areas. As a consequence, recreational and commercial fishers have been forced to exploit remaining grounds more heavily.

Constructing artificial reefs is a way to improve fishing and restore some of the quality fish habitat that's been lost. The artificial reefs program in NSW kicked off in 2004 using fishing licence money from the Saltwater Trust. Concrete "reef ball" modules, which have been used in more than 2500 projects worldwide, were dropped into Lake Macquarie, Botany Bay and St Georges Basin, all recreational fishing havens.

The results in NSW have been spectacular – within a few months the balls were covered in seaweed and are now fishing extremely well.

58 FISHING WORLD MAY 2008

## Expansion

The success of the NSW estuarine reefs program has prompted the expansion into oceanic waters. But tackling the ocean means thinking big, and to do that requires an environmental assessment. There have been big mistakes made overseas and we need to make sure that all the environmental issues are properly addressed. And given the scale of our proposals, we also need to make sure we use the best possible materials and designs.

The Fisheries Research and Development Corporation (FRDC) came to the party and funded a tour to Korea and Japan last September to study the world's best practice in artificial reef technology.

Artificial reefs have been used in Japan and Korea to enhance commercial fisheries for more than 30 years. Over this period many refinements to design and deployment have increased the effectiveness of the structures. Specific designs are used for the production of fish, edible seaweed, abalone, rock lobsters and molluscs, including octopus and squid. Design refinements such as the inclusion of natural materials in concrete and the

development of patented ceramics to promote settlement of algae have boosted seaweed, mollusc and shellfish production. New species specific designs, and purpose built multi-species reefs are now commonplace. A key feature of all reef designs is the stability and structural strength requirements to withstand the typhoons common in this region.

During our research trip in Korea we met experts and university researchers specialising in artificial reef design, construction and monitoring.

At Jeju Island, we inspected artificial reefs to observe mature reef modules with associated algal growth and fish assemblages. The reef was a reinforced concrete cube construction with rock ballast showing prolific weed growth and numerous associated fish, including amberjacks.

The Korean government funds most reef construction and the location of reefs and reef module design is negotiated with local fishers.

The basic concrete cube reef has been used for more than two decades but remains popular due to its strength, durability and cheapness. The dimensions



Another perspective of the sort of artificial reef technology available.



of the void space are critical to success in attracting fish. These modules are made of construction grade reinforced concrete with no additives to enhance algal settlement. These modules have a life span of about 30 years.

Steel artificial reefs are becoming more popular in Korea, particularly for sophisticated designs and are also designed to last about 30 years.

Many of the reef design features are patented and contractors, under licence, manufacture the modules.

At a place called Tongyeong in southern Korea, we visited an integrated fish farm and recreational fishing platform business operated by a private research institute. This fish farm features a moveable recreational fishing platform, worth

US\$400,000, which can be towed to any of the hundreds artificial reefs in the area, and can accommodate several hundred fishers. The platform also features an automatic fish feeding device that conditions fish to expect food when a submerged buzzer sounds. This is probably not something that will appeal to Australian anglers, but it gives an indication of the advanced artificial reef program in Asia.

### Japan

At the National Research Institute of Fisheries in Choshi, Chiba Prefecture, we witnessed facilities for hydraulic testing of reef designs and research programs into artificial reef construction.

Further up the coast at Nakaminato Fishing Port, Ibaraki Prefecture, we were shown sophisticated concrete reef modules to be tested in local waters. As this part of the coast is very exposed the modules are particularly robust to withstand typhoon conditions.

This is interesting research that could prove useful when designing artificial reefs for use in Northern Australia.

Visiting the Shimonoseki Fisheries University, we saw research on artificial reef designs, and the use of sonic arrays to estimate fish school size and composition.

Back in Tokyo at the Japanese Institute of Technology on Fishing Ports, the government's role in reef design and funding was explained, and we also visited several artificial reef design and construction companies.

### Lessons Learned

It was obvious that Australia is a long way behind these countries in artificial reef research and development. Extensive commercial expertise in reef design and manufacture based on decades of experience and research exists in both countries. Japan and Korea have moved on from using "materials of opportunity" i.e. junk. All artificial reefs now are specifically designed to suit the target species; one size does not fit all. Artificial reef designs are rapidly increasing in sophistication and many of the most effective designs are patented. We can utilise the published and unpublished research into reef designs on species identical or similar to those found in Australia, such as snapper and kingfish.

### The Future

The guidelines for the environmental assessment were completed in February. Later in the year the sites will be determined, and tenders let for the design and manufacture of the reefs. The NSW Saltwater Trust has earmarked almost \$1 million dollars a year for the next three years to make the offshore artificial reefs program happen.

The first reefs should be in the water in early 2009.

*John Diplock is the principal manager, recreational fishing, at NSW DPI. He thanks the FRDC for funding his artificial reef study trip.*

MAY 2008 FISHING WORLD 59