West Australian Department of Fisheries
Delegation to
South Korea & China

Review and assessment of artificial reefs for use in Western Australia

November 2010

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Introduction

Fish stocks in Western Australia are coming under increasing pressure from sectors such as population growth, new technology and improved access. This pressure is not uniform across the State and may be regionally localised, around population centres, and on a small scale such as waters adjacent to boat ramps.

The Department of Fisheries uses a range of tools to manage fish stocks in State and Commonwealth waters off Western Australia. Most of these tools are directed at regulating catch and effort associated with fishing such as gear restrictions, bag limits and closures.

Artificial reefs could provide another tool to manage pressure on a fishery by increasing stock abundance. In some instances, artificial reefs have been created by depositing available materials like old boats or as cheap waste products like rubble or tyres. These reefs have produced mixed results and tyre reefs are not accepted as being environmentally acceptable. Some early artificial reefs appeared merely to act as aggregation devices, which attract fish and improving catchability, but don't expand fish habitat or carrying capacity. In these instances, the reefs may have a detrimental impact on fish stocks or the environment. Vessels that have not been properly stripped prior to sinking may also negatively impact the environment. Purpose built artificial reefs, particularly those built to create suitable habitat, appear to become effective production devices and improve fish stocks.

Experience around Australia already suggests that artificial reefs may also have broader environmental benefits through increasing biodiversity.

North Asian countries such as Korea, China and Japan have been at the forefront of research into artificial reef construction, deployment and research. The purpose of the Department of Fisheries Delegation to South Korea and China in October/November 2010 was for key decision makers in Western Australia to learn more about the effectiveness of artificial reefs and investigate current research and construction expertise to prior to consideration for the possible deployment of artificial reefs in Western Australia.

There is a strong appetite amongst recreational fishers to trial artificial reefs in Western Australia and gain expertise in their deployment. Several regions have been identified for potential deployment around the Western Australian coast with further research into likely impacts to be conducted. This research could be conducted at least partially in collaboration with researchers from North Asia.

Western Australia has expertise within Government, academia and industry with stock enhancement programs which can be shared. However, this expertise has not been employed in concert with artificial reefs in this country opening the way for future collaboration.

The Delegation participated in numerous meetings and site visits related to the issues identified above including meetings with researchers, artificial reef manufacturers and Government regulators.

The possibility of utilizing artificial reefs to improve fish, shellfish and crustacean production in key areas could well now become a reality.

STUART SMITH
CHIEF EXECUTIVE OFFICER
Department of Fisheries

November 2010

Objects of the delegation's overseas visits;

1. To investigate artificial reef construction and deployment methodologies to ensure that any West Australian programs employ world's best practice.

2. To determine the effectiveness of artificial reefs in relation to productivity.

3. To examine the potential impacts of artificial reefs on eco-systems and biodiversity.

4. To study artificial reef site selection techniques and site specific location criteria to maximise reef effectiveness.

5. 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 West Australian artificial reefs.

6. To have the ability to provide up-to-date advice on artificial reef methodologies available to interested parties through meetings of State and Commonwealth Government agencies, key stakeholders and the media.

7. To improve the skills of key personnel responsible for artificial reef projects in Western Australia by meeting with artificial reef experts and inspecting artificial reefs in South Korea and China. Both countries having had extensive artificial reef development experience.

8. 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.

9. With information gathered on ARs report back to Government on their potential use in Western Australia.

10. To ascertain interest among countries that are at the forefront of artificial reef research in collaboration with Western Australian researchers.

Summary of delegation findings

1. China has been using ARs widely and successfully for hundred of years, while Japan has also used them for 100 years and South Korea 40 years. They are not new and are widely accepted and are actively being deployed.
2. There is a consensus amongst Korean and Chinese scientists and government officials that artificial reefs increase production, and are not merely aggregation devices. Productivity of ARs has been measured at anywhere between 5 – 50 kg/m^3 though performance is influenced by many factors.
3. The commercial value of the increased production on its own is sufficient to justify substantial investment in artificial reefs. In Korea, for example, the Government has invested over AU$885M in its AR program to increase productivity over the past 40 years and this is increasing based upon the success of the program.
4. A research project conducted over 25 years, at King Harbor in California, has found that the AR has a higher carrying capacity, and its population is self-maintaining and does not draw from natural reefs (Pondella *et al.*2002).
5. Research suggests that well designed artificial reefs provide better production outcomes than natural reef, based upon monitoring of commercial catches and the use of ARs over time.
6. No apparent environmental downside as ARs provide productive additional habitat for many non-target and unfished species. Indeed ARs can be deployed for environmental benefits associated with increased habitat and biodiversity.
7. Adding artificial reef structure to the coastal benthic environment has also been documented repeatedly to increase species abundance and diversity at the reef site (Seaman 2008).
8. ARs should be purpose built for the marine environment and circumstances into which they are deployed. While alternatives like sinking boats may have some beneficial effects the impacts are less certain and likely to be significantly diminished.
9. Deployment should follow appropriate benthic mapping and other environmental considerations.
10. Site assessments for shallow water ARs should include investigation of potential impact on coastline (sedimentation or erosion) if placed in a location that modifies current and/or wave action.
11. Local communities, including fishers and other interest groups, should be consulted on appropriate deployment sites.
12. An appropriate regulatory and monitoring regime should be in place prior to deployment.
13. The fishery and environmental objectives should be clearly defined prior to deployment (site, species, use) as part of the regulatory regime.
14. New South Wales and Victoria already have successful ARs deployed, and Queensland is to have three more shortly.
15. South Korea and China both agree that initial fishing closure of between 1-2 years is advisable to allow the reef to establish and populate itself.
16. In conjunction with the deployment of ARs both the Koreans and the Chinese are actively restocking a suite of fish species and also cultivating and replanting seagrasses, kelp and algae.
17. ARs will be productive without stocking, although stocking may increase their effectiveness and speed production.
18. Resource sharing between the sectors in Western Australian fisheries is different to the challenges in South Korea and China as it will be important for the West Australian Government to determine up front who is able to access the ARs.
19. Recognising that the deployment of ARs will likely result in increased fish numbers the additional fish produced will have to be considered in the context of either formal or informal allocations between the sectors.
20. Artificial reef research and technology appears to have developed sufficiently for regulators to be confident in the potential for deployment in WA.
21. The Delegation is also confident that ARs will provide marine environment benefits in West Australian waters when deployed in appropriate locations.
22. Western Australia would benefit from further research collaboration with Korean and Chinese researchers in regard to ARs.

It should be pointed out that Korean and Chinese waters appear to be more productive than West Australian waters. It is therefore possible that we may not achieve the same levels of productivity increases.

South Korea artificial reef program overview

The South Korean Government commenced their AR program in 1971 and between then and 1980 deployed ARs over 1,539 hectares. The artificial reefs program was designed to halt a serious decline in fisheries production caused by overfishing, habitat destruction and pollution. The artificial reefs were also deployed to restrict the area accessible to commercial trawlers in order to reduce the impact of their activities.

Between 1981 and 1990 a further 52,851 hectares of ARs were deployed and the concept was actively promoted by the government. From 1991 to 2001 there was an expansion period when a further 157,000 hectares of ARs were deployed. Over this time the benefits of stock enhancement and increased marine biodiversity associated with ARs have been extensively researched, along with any ongoing maintenance issues.

To-date South Korea has spent AU$885 million on ARs around the country, and for the last decade this has been at the rate of AU$55 million per year. The total area of ARs now installed exceeds 207,000 hectares.

Purpose designed and built ARs have been proven to restore marine biodiversity by some scientific studies (Seaman 2008) and to increase fishery production (Kim *et.al.* 2008). Some species of rock fish have been shown to increase eight fold on ARs and they are now proven to be beneficial to both recreational and commercial fishers.

All AR designs need to be approved and undergo two years of testing and there are many approved designs available.

Several South Korean Company's have set up businesses to produce ARs and most are winning contracts for deployment.

The recreational sector appears at this point in time to be relatively small and primarily shore-based. ARs have largely been deployed in deeper water primarily for commercial fishing.

South Korea is interested in scientific collaboration with Western Australia.

Artificial reef manufacturers inspections in South Korea

Dong Seong Marine Development Co., Gangneung City, Gangwon Province – Ms Soo-A Kim (President)

This company produces reinforced concrete artificial reef (AR) structures, primarily for the production of kelp and shellfish. Seed kelp is secured to the top of the modules using wooden battens.

A typical AR comprises four units per module with five modules making up an AR that covers an area of 96 square metres to a height of 1.6 metres. The AR is generally deployed in water 8 – 12 metres in depth.

Approximate costs indicated were AU$65,000 for one module, excluding deployment, which is AU$16,500 per unit.

The manufacturer indicated that their ARs are very good for habitat replacement and as nursery areas. The manufacturer indicates that this AR has Government approval.

These artificial reefs units where primarily designed for growing shellfish and sea weed, which is attached using the wooden battens shown.

Now & How Artificial Reef Company, Joomoonjin, Gangwon-do – Mr Choi

The Now & How Company manufacture large reinforced concrete AR structures that measure 2.1m x 2.1m x 2.5m and weight some 10.5 tonnes. They are designed with large surface contact area to be laid on soft ocean floors. They can be deployed in various configurations including a three unit module that includes a steel central structure. Construction of the units is preferably undertaken at the loading site. Life expectancy for this AR is 40 years plus.

In 2009 a total of 61 AR units were deployed at a depth of two kilometres offshore in 35 metres of water at a site off Jeju Island, in the south of South Korea. A further 119 were deployed at the same site in 2010.

These large AR units are suitable for use by divers

A total of 72 units comprise a typical complete AR in a range of configurations depended on their intended use. Each unit costs approximately AU$3,000.

The ARs are placed in water 6 – 8 metres in depth when their intended use is providing habitat for shellfish and kelp. These ARs are also suitable for providing underwater dive sites as the openings in each unit are large enough to permit safe diver ingress and egress.

Marine animals have been shown to attach themselves to this AR in as little as four months after deployment, and occupation and population rates continue to increase over time. The net result in that these ARs have been found to be more productive than adjacent natural habitat.

The manufacturer indicates that this AR has Government approval, and that they hold patents in other Asian countries.

Unknown manufacturer, Sokcho Harbour, Gangwon-do

While driving past Sokcho Harbour several large ARs were observed and the Delegation stopped to examine them. There were twelve untreated steel fabricated modules in two designs on the wharf, one square and one round. The modules also include polycarbonate panels.

These modules were estimated to cost around AU$60,000 each.

Apparently neither of the modules wharf had government approval and were for testing purposes only.

These as yet to be approved deepwater ARs were approximately eight metres high

Haeyoung Ltd, Gangwon-do – Mr Yoon-muk Kim

Haeyoung Ltd produce reinforced concrete AR structures which can be deployed in various configurations. Each unit comprises a central concrete structure approximately 2m x 2m x 1.5m which contains large granite boulders which are retained by untreated steel bars. In addition an untreated steel cage is secured to the top of the concrete unit and again filled with large granite boulders.

This AR design in typically deployed in 10m -15m of water.

An AR using these units would generally comprise 48 units at a cost of AU$2,000 to A$5,000 including deployment.

This AR design has been in use for 30 years.

These ARs by Haeyoung Ltd were well made and intricate

Taewha Construction Co, Ongjin-Gun, Incheon City – Mr Choi

The structures are manufactured from untreated steel and are 12 metres in height. Each unit is fabricated on the wharf and comprises a combination of steel plate, RHS beams and heavy angle, and is approximately 555 cubic metres in volume and weighs 40 tonnes. They take 35 man days to fabricate and can be deployed on mud or sand.

Both the size of these deep water ARs and the numbers deployed were impressive

This design has been in use for 3 years during which some 300 have been deployed in approximately 30 metres of water. A project may contain 30 – 40 of these fabricated units.

The cost to manufacture and deploy these ARs is approximately AU$140,000.

This AR design is Government approved.

HaeJoo Pty Ltd, Seoshin-myeon, Hwasung City – Mr Ryan Paik

This company, the largest in this field in South Korea and has a subsidiary company in Sydney. It manufactures a range of six reinforced concrete units designed for a range of applications. These vary from the 1.0m x 1.3m high Australian Reef Shade to the 2.4m x 3.8m high Double Dome Reef. Their Marine Pyramid design has the highest surface area to volume of any comparable unit. A single AR may be up to 1000 square metres in area.

They also produce untreated steel structures up to 11 metres in height for offshore deployment.

Hae Joo Corp (Korea) have deployed over 1500 AR units in South Korean waters to-date and have a range of patents. Haejoo Corp set up an Australian company Haejoo Pty Ltd, based in Sydney in 2009, which is contracted to construct three ARs, composed of concrete and steel to be deployed in the Moreton Bay Marine Park in southern Queensland.

These triangular pyramid units were a good example of quality South Korean engineering and design

The steel AR structures will each cost around AU$80,000 including deployment and concrete units range upwards from AU$5,000 each including deployment.

HaeJoo would prefer to finish the ARs with a textured surface to encourage faster settlement and growth of marine organisms, but Govt regulations prevent it being done.

The company advised that its AR designs are targeted at specific types of fish and that they manufacture ARs that are tailored to pelagic, mid-water or demersal species.

Hae Joo's Korean units are all approved by the South Korean Government for deployment in Korean waters and two new models specifically designed for Australian conditions are now approved by the Queensland Government. The growing demand for purpose built artificial reefs in Australia has seen Hae Joo establish its office in Australia.

The company provides a range of services including;

- International AR project management.
- Supply of a range of environmentally friendly AR units with applications to a wide range of marine species.
- Assistance with site assessment, selection of suitable AR design and mapping.
- Construction of AR units and their deployment.
- Stabilisation of reefs as a result of dredging or anchoring.
- Monitoring of productivity of installed ARs including involvement of research team and/or fishing community.

Hae Joo believe that sloping sides on ARs deployed in shallow water are preferable whereas this is not so critical in deeper water.

Large untreated steel ARs are designed to attract up to 70% pelagic species and are generally designed to be at least one tenth of the depth of the water in which they are deployed.

The Hae Joo Fish House is a relatively new design and is understood to be well priced. The life expectancy of concrete ARs is thought to be up to 100 years following the recovery of a 40 year old AR which was found to be stable.

Yulin Ltd, Incheon – Mr Y D Choi

Yulin Ltd supplies reinforced concrete AR units in a range of designs and they also produce untreated steel ARs.

Mr Choi indicated that a typical AR consisting of concrete units would consist of up to 40 units over a 4 hectare site.

The typical cost of a concrete AR unit is AU$3,000.

Mr Choi indicated he had three design patents for concrete ARs and the "hedgehog" design has been Government approved for seven years. This reef is designed primarily for abalone and would be deployed in about five metres of water.

Yulin Ltd had a range of ARs on display, some of which were designed for shellfish with ample flat surface area for attachment

Presentation by Dr Chang Gil Kim National Fisheries R&D Institute, Gijang-Gun Busan, Korea

Responses to Delegation questions;

The South Korean Government approvals process takes 2 - 3 years during which AR designs are deployed and monitored. They are assessed on the basis of cost, economic efficiency and quality. An AR has to be equal or higher in productivity and effectiveness than any surrounding natural reef. A twenty member panel then finally adjudicates based upon the findings.

Funding is provided by the National Government who contribute 80% of the cost with 20% being funded by the Provincial (State) Government. In South Korea the Central government is in charge of planning and budgeting for ARs. Local government is in charge of their production and installation. National Fisheries Research & Development Institute recommends the suitable site and evaluates the productivity of each site.

There are two basic types or AR deployed in South Korea. Firstly ARs that are predominantly constructed from reinforced concrete, for shellfish, crustaceans and seaweed, and are deployed in water depths of between 5 to 15 metres.

Secondly those used for finfish production are generally deployed in 15 to 70 metres of water and are constructed from untreated low corrosion steel. The rule of thumb for a fish ARs is that they should be deployed in water where the height of the steel AR is not less than one tenth of the depth of the water column, and bigger than this is better.

The two categories for ARs are ‘void’ structures (frame type) or ‘face’ structures, both of which comprise approximately 80 % by volume.

When designing a reef, there are four main considerations: physical, biological, engineering, and socioeconomic

There are three fish ‘types’ related to ARs, they are: close contact fish species such as rockfish and cods; demersal species that stay within close proximity of the structures; and pelagic fish which only visit ARs from time to time.

ARs are generally constructed using the same units throughout in order for the performance of a particular single unit to be monitored. ARs of a different type must be at least one kilometre apart. The best topography for placement of concrete ARs is a gently sloping bottom.

The gaps, or distance between individual units is important to produce turbulence or disturbance of the currents which attract fish.

The Government tries to leave all ARs unfished for a period of two years, but this is difficult to enforce. It is considered that it takes up to 5 years for a ‘contact fish’ reef to be a fully effective production platform, less time for others.

The South Korean Government requires that concrete surfaces on ARs are left with a smooth finish once out of their formwork moulds, as shot blasted or textured finishes tend to accumulate silts in turbid water discouraging the settlement of marine organisms.

The minimum area for an AR to be effective is 800 square metres. It is usual to deploy 100 concrete ARs of 8 cubic metres each over this area.

ARs are normally around 800 cubic metres in size.

The pelagic steel ARs are usually 600 meters apart and demersal ARs 400 metres apart.

Several alternative materials for use on ARs have been tested over the years to find the optimum material for desirable marine growths and organisms. It has been found that concrete is best as plastic is too durable and will ultimately not break down after time and wood does not last long enough.

Reinforcing bar in concrete ARs should have a minimum of 25mm cover.

Untreated steel reefs are best for pelagic species.

ARs have been developed to increase marine animal production, not to aggregate existing populations. Productivity of individual ARs has been measured at anywhere between 5 – 50 kg/m^3

ARs which are elevated off the bottom are best suited to area with a soft or mobile ocean floor.

Deployment costs vary, but a complete concrete unit AR would be around AU$80,000 and steel reefs will vary considerably.

Commercial fishers are the principle users of ARs, but more recently they are increasingly used by recreational fishers and divers.

Steel pelagic reefs are generally deployed in water where the height of the steel AR is no less than one tenth of the water column in order to be most effective.

ARs must not be too heavy when placed on sand or mud ocean floors.

Sloping sides on concrete structures are desirable and optimum dimensions for beam widths have been calculated to provide the most desirable environment for fish.

Steel is used untreated and uncoated to ensure good accretion of marine animals, and careful steel selection is important to avoid early corrosion issues.

Over time catches increase showing that ARs produce more marine life, including fish, thus showing that production is increased rather that species simply aggregating.

Optimum overall productivity on ARs is found to occur after five years.

Six of the ARs in South Korea are monitored on an annual basis.

ARs have been found to increase commercial catches by 2 – 4 times depending on the species of fish.

Both China and Korea stock a large number of fish species in association with artificial reefs. Numerous scientific studies have been conducted to investigate the results of such stocking, but with variable results (see Seaman 2008). There is no doubt however, that there is a widely held belief in Korea and China, backed up with ongoing restocking programs, that restocking of fish on AR's is beneficial. Further desktop investigation is required to gain a better understanding of this.

The 4th International Symposium for Stock Enhancement and Sea Ranching, to be held in China in April 2011 and to be attended by representatives from WA Fisheries, Challenger Institute, Murdoch University and others, will be another opportunity to further investigate this issue.

Some suitable AR units have been stacked three high to create more compact and complex reefs.

The Government is currently undertaking a review of some of the earlier old designs of ARs and in some cases is replacing them with new ones. If an AR is replaced another is deployed near the old one, but importantly it does not remove the old.

Dr Kim was interested in establishing a research MOU with Western Australia that would see the exchange of researchers from both countries with South Korea providing expertise on artificial reefs and Western Australia providing expertise on sustainable management of fish stocks and recreational fishing.

China artificial reef program

Discussion with WA Office in Shanghai – Mr BJ Zhuang

Community sponsors for AR project could include Chinese companies in Australia, who may be looking to support Australian communities as part of their business plans. It was suggested that contact be made with the Chinese Consulate in Perth to further this opportunity, as this would assist with reaching the relevant companies.

The Delegation was briefed about marine production in China, which is forecast to have 51.9MMT of aquatic production this year, of this total, around 70% (32.8MMT) is produced by aquaculture. Shellfish is the highest production tonnage and China is close to become self reliant with aquaculture raised abalone. China's wild caught fishery catches have continued to decline.

Aquatic product consumption is 14kg per person for urban residents and 5.4kg per person for rural residents. There is an increasing demand for premium imported seafood products by hotels and restaurants where the preference is for live seafood wherever possible. Australia is currently the largest supplier of fresh or brined abalone.

Meeting with the Rural Bureau of The East China Sea Fisheries at Tianjin – Mr Zhong Xiao Jin

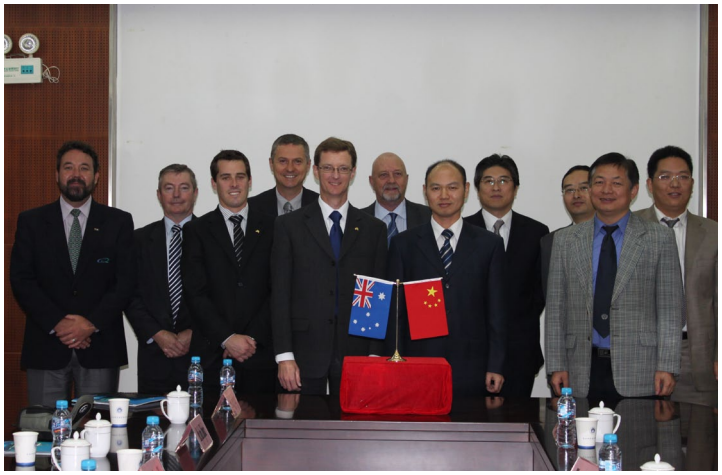
China has some 30,000 fisheries officers, with a further 30,000 part time officers. There are approximately one million commercial fishers in China and nine million people work in aquaculture.

Mr Zhong admitted that China had 'big problems with declining wild catch, with pollution and with damage of the environment by a large number of fishermen'. There are many areas where they are aiming to improve the conditions, including licences for fishermen, removing fishing activity, reducing the area available for fishing, creating 'protection areas' for fish, restocking key species and deploying artificial reefs. He made the point that 'Protection of natural resources is a very hard job.'

The East China Sea Fisheries agency currently has four locations for modern experimental reefs on the east coast of China. Indications are that these ARs are providing good results, especially environmental benefits; in some cases the biodiversity has increased whereas in others the harvest has increased. Some of the ARs being assessed are also being stocked with rock cod, but as yet no monitoring results are available.

Mr Jin explained that it is difficult to evaluate the success of every project and therefore it is difficult to progress rapidly with AR deployment. But fish numbers and harvest is increasing.

The Government provides guidelines for AR design and there are currently 200,000 square metres of concrete ARs deployed (2 - 3 cubic metres per unit average), which amounts to 70 – 100,000 units in test areas. Some of the ARs are not fished during the assessment period.



The East China Sea Fisheries staff and WA Delegation

Meeting with Tianjin Fisheries Bureau Division of Science Technology – Mr Zhang Yi

Tianjin is a city with a population of 12 million people, covers 11,000 square kilometres, and has 70,000 people in the area involved in the fishing industry. There are 44,000 hectares of area under aquaculture which produces 300,000 tones of product. Average fish consumption in the Tianjin area is 28 kilos per year of which 42% is high quality product.

Up to one billion fish and prawns are stocked each year, with prawns being the main species released. In some circumstances up to ten different species are stocked in one location. The scale and sophistication of some of these operations visited were impressive and relevant when comparing to WA where the capacity to stock reefs is limited potentially to a single species in most instances.

The main species which go to market from the wild fisheries in this area are prawns, crabs and several species of fish, but there are catch limits placed on wild stocks. Recreational fishing occurs in the Tianjin City area, but the major industry is commercial fishing.

The Tianjin Fisheries Bureau is currently investigating new technologies to provide environmental benefits.

The Tianjin region has 153 kms of coastline which is under heavy fishing pressure. Protection and enhancement schemes include setting up special protection areas, closed fishing seasons and AR and stock enhancement programs. It was reported that the stock enhancement programs have already made a significant, positive impact.

The development of ARs in the area has only just begun and the ten year plan is to have 13.7 square kilometres of ARs deployed. The area is very tidal and the ocean floor is predominantly thick mud. Water depth is approximately 3 to 3.5 metres depth and therefore small AR’s are deployed.

In 2008 a Marine Protection Plan was introduced, which included ARs. The first stage of the project in the Binhai area comprises 1900 units, which will be deployed over 810,000 square metres. Simple concrete units are being trialled in shallow water mainly to accommodate oysters.

Swimmer crabs were down to less than10% of virgin biomass at one point and were successfully restocked to provide a viable commercial fishery within a very short time-frame. The restocking was undertaken at the high water mark on appropriate tides.

The Bureau suggested staff exchanges with WA scientists, and co-operation on special projects including recreational fishing, ARs and environmental remedial options. Western Australia will be pursuing the development of an MOU with the China Department of Agriculture (via the China Society of Fishers). Such an MOU should then see the exchange of researchers from both countries with China providing expertise on artificial reefs and WA providing expertise on sustainable management of fish stocks and recreational fishing.

It was suggested that Tianjin could be a good future entry point for WA seafood into northern China.

Visit to Tianjin Binhai Ornamental Fish Science and Technology Park – Ms Grace Guo

This is a huge site with a total investment of AU$160 million, which includes provision for a future recreational fishing lake and associated accommodation. The first stage of the development includes an impressive exhibition centre and aquaculture buildings behind, which are to be leased to private enterprise and include basic accommodation. These buildings will raise both marine and freshwater aquarium species, including corals, for domestic sale and export.

A tour of this large new facility was arranged to illustrate the kind of aquaculture enterprises being developed in the area

The park is part of an overall government plan that includes two square kilometres allocated to aquaculture to provide future opportunities in the area.

The government provided the land and the park is privately owned.

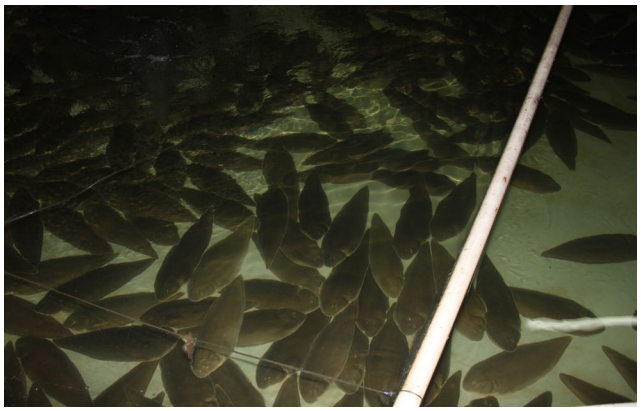
This privately developed facility has a considerable number of fully reticulated aquaculture units for lease.

Known Ltd, Haifa Farms & Resort – Mr Wenfa Jing

This is an unusual development by Australian standards as in incorporates both aquaculture and water based activities with on site holiday accommodation, indeed the swimming pools double as rearing tanks in the winter.

Recirculation Aquaculture System (RAS) facilities

There were two RAS sites visited with the largest containing 40,000 square metres of recirculation tanks under cover which grow out four marine fish species namely, flounder, sole, rock fish and toadfish (fugu) for the Japanese market. The same business also carries out small scale salt production from shallow evaporation ponds.



This company, like many in China, have imported several international species of fish for aquaculture, including red drum from the US and gilt head sea bass from Europe.

At another nearby facility rockfish, local red drum and sea bream where being grown out.

Sole were being grown indoors in recirculating tanks

Visit to Beijing Jingshes Fish Markets

This market has an annual turnover in excess of AU$1.2 billion which includes high value imports including lobster and abalone. There is a mix of international and local product available with products from Russia, Indonesia and even salmon from Norway. The Beijing fish market supplies the north-east and north-west regions of China.

Wild caught product is mostly sold frozen and locally produced products are sold live, of which the local rockfish is the most popular fish species. There are all manner of marine products on sale including species not normally found in Australian markets such as sea squirts, sea cucumbers, blob fish and a myriad of small crustaceans and small fish species.

South China Sea Fisheries Research & Fujian Fisheries Research – Mr Tang Young, Mr Chen Pimao, Mr Guo Fu Zheng

ARs in China started in a rudimentary form during the Shang Dynasty in 1562BC, there are now some 25,000,000 cubic metres of ARs deployed covering 23,562 square hectares.

In Guangdong Province the AR site selection process is extensive and selection considerations includes water depth, current, temperature over the year, construction material, AR unit configuration and fish responses to AR shape and size. There are over 100 different AR designs on their database, but most reefs are 3-4 metres in height.

Each year between two and eight new ARs, depending on cost, are deployed with each reef being approximately 4,000 cubic metres in volume.

Stocking then follows deployment after a period of time to allow marine organisms to accrete on the AR structures. Several hundred million marine animals and fish species have now been stocked over time and these include small juveniles at 25mm in length up to 50mm tagged fish. Common fish species stocked are snappers, rockfish and sea bream the sizes of which are specified by the Bureau of Agriculture.

It was indicated that some species can generate up to a 10 fold increase in biomass on ARs. The ongoing sustainability of ARs and stocking practices are supported by research and stocking levels are maintained each year.

There are currently eight new reinforced concrete designed AR units being trialled. Between 1980 and 1987 18,227 square metres of ARs, using six different types up to 30 metres in depth, were trialled. A budget of AU$1.2 billion was allocated by the Provincial Government in 2002 and subsequently 109 sites have had ARs deployed, some of which are purely for ecological purposes. The annual AR budget in the Province ongoing is now AU$1.5 million.

The WA Delegation received a very informative presentation by South China

The measured economic benefit of the ARs deployed to-date is estimated at A$375 million per year, well in excess of the annual AR budget.

Interestingly some of the ARs are paid for by commercial fishers and are privately owned, but of the total number of ARs around 50% can be accessed by commercial fishers.

There has been no identified damage incurred to ARs during typhoons or heavy storms since the program began.

In Central Province some 70 ARs are planned with 35 already deployed. These are funded 70% by commercial fishers with the remaining 30% coming from the government. Some ARs are deployed purely for their environmental benefits and these are not fished at all.

Abalone and sea cucumbers are harvested from shallow inshore ARs deployed over existing natural reefs.

There is very little offshore recreational fishing as recreational boat ownership is very low, but the government is watching as there is increased activity in the recreational area and they are looking at recreational licensing options. Some charter boats own ARs too, but management arrangements for fishing ARs are not fully developed.

The annual Government budget for ARs is AU$2.25 billion and on top of this commercial fishing operators pay for restocking and 400,000 black prawns alone are stocked annually. Mixed species are stocked on ARs and this maybe 10 or even 20 different species, but stocking with a single species has proved to be successful too. It is planned to trial stocking ARs with 50cm fish in the future.

Sand accretion does not appear to be a major problem and if it is likely to be then the AR selected is an elevated structure.

China Society of Fisheries – Professor Situ Jian Tong

The China Society of Fisheries (CSF) is part of China's Department of Agriculture. The CSF analyses various data sources and provides market analysis and reports on the international and national aquaculture trade. They arrange academic exchanges relating to aquaculture and they already have several Australian contacts in this area.

CSF has 10,000 members and handles communications, promotes quality assurance and product safety in relation to aquaculture. They are also responsible for determining research priorities.

The CFS also suggested staff exchanges with WA scientists, and co-operation on special projects including recreational fishing, ARs and environmental remedial options. Western Australia will be pursuing the development of an MOU with the China Department of Agriculture (via the China Society of Fishers). Such an MOU should then see the exchange of researchers from both countries with China providing expertise on artificial reefs and WA providing expertise on sustainable management of fish stocks and recreational fishing.

KOREA & CHINA DELEGATION ITINARY
26 October – 7 November 2010

Tuesday 26 October 2010
Perth-Hong Kong-Seoul
0005 Depart Perth International Airport for Hong Kong
0930 Depart Hong Kong International Airport for Seoul

Wednesday 27 October 2010
Seoul-Gangneung-Joomoonjin-Seorak
0730 Breakfast meeting with Mr Jean Ough, WA Regional Director, and Mr Young Yu, Trade Commissioner, Austrade Seoul
0830 Drive to Gangneung City, Gangwon Province
1130 Site visit to Dongseong Marine Development
1230 Lunch
1330 Drive to Joomoonjin
1400 Site visit to Now & How Artificial Reef Company
Kyohyang-Ri, Joomoonjin-eup, Gangneung-Si
1600 Arrive at hotel

Thursday 28 October 2010
Seorak-Goseong-Seoul
0800 Inspect Sokcho Fish Market, fishing fleet and squid processing plant
0930 Drive to Goseong–Gun
1100 Site visit to Haeyoung Ltd artificial reef construction
445-3, Janshin-Ri, Ganseong-Eup, Goseung-Gun, Kangwon-Do
1400 Drive back to Seoul
1830 Australian Chamber of Commerce in Korea G20 Australian Business Awards Gala Dinner
Jean Ough, Stuart Smith & John Diplock only
2200 Conclusion of Australian Business Awards Gala Dinner

Friday 29 October 2010
Seoul-Seonjaedo-Seoul
0800 Drive to Seonjaedo in Incheon City
1030 Visit Taewha Construction
Yeongheung Bridge, Ongjin-Gun, Incheon City
1130 Drive to Jeongok-ri in Hwasung City
1200 Visit Haejoo Group's construction site
607-1, Jeongok-ri, Seoshin-myeon, Hwasung City
1400 Drive back to Seoul
1900 Dinner meeting with Haejoo Group
Mr Stephan Paik, Managing Director Haejoo Group, Seoul

Saturday 30 October 2010
Seoul-Shanghai
1000 Meeting with Dr Chang Gil Kim
Dr Kim provides a presentation on artificial reefs in Korea.
1230 Lunch with Dr Chang Gil Kim
1845 Depart Seoul Incheon International Airport for Shanghai

Sunday 31 October 2010
Shanghai
0900 Visit last day of Expo 2010 Shanghai, China
1000 Visit Australian Pavilion

Monday 1 November 2010

Shanghai-Beijing

0830 Briefing by WA Trade Office - BJ Zhuang & Austrade Shanghai

1000 Visit and meeting with Regional Bureau of East China Sea Fishery Management, Ministry of Agriculture PRC
Level 7, No. 2166, Fishery Building, Zhen Bei Road, Putuo District, Shanghai

1230 Lunch with Easter Sea Fishery

1400 Visit Tongchuan Road Fish Market (accompanied by Easter China Fishery)
No. 871, Tongchuan Road, Shanghai

1630 Depart for Shanghai Hong Qiao Airport

1855 Depart Shanghai Hong Qiao for Beijing

Tuesday 2 November 2010

Beijing-Tianjin-Beijing

0800 Visit Tianjing Recreational Fishing site
Tianjin Binhai Ornamental Fish Science & Technology Park

1130 Meeting with Department of Agriculture, International Co-operation Division

1300 Lunch with Department of Agriculture, International Co-operation Division

1530 Haifa Zhenpin Aquaculture facilities

1630 Known Ltd, combined aquaculture facility & resort

1730 Dinner with Department of Agriculture

Wednesday 3 November 2010

Beijing-Xiamen

AM Sightseeing and cultural exchange

1315 Depart for Beijing Capital Airport

1545 Depart Beijing Capital Airport for Xiamen

Thursday 4 November 2010

Xiamen

AM 2nd China International Recreational Fishing Forum

PM Presentations by Chinese professions and academics

PM Meeting with Secretary of China Fishery Society re: artificial reefs or stock enhancement

Friday 5 November 2010

Xiamen-Hong Kong

2nd China International Recreational Fishing Forum

Visit recreational fishing site
Meet and cultural exchange with researchers/academics re: artificial reef and stock enhancement
Meeting with artificial reef producers

1700 Depart for Xiamen International Airport

1945 Depart Xiamen International Airport for Hong Kong

Saturday 6 November 2010

Hong Kong

1000 Visit Hong Kong Aberdeen Fish Markets

Sunday 7 November 2010

Hong Kong-Perth

1200 Depart for Hong Kong International Airport

1505 Depart Hong Kong International Airport (HKG) Terminal 1

2245 Arrive Perth

Appendix

Chang Gil Kim, December 2001. *Artificial reefs in Korea* – article from American Fisheries Society journal

Chang Gil Kim, February 2008. *Post placement management of artificial reefs in Korea* – article from American Fisheries Society journal

Chang Gil Kim, Sung Ho Suh, Jae Kwon Cho and Min Woo Park. *Design of Multi-Functional-High-Storied Steel Reef and Its Effectiveness* from proceedings of the 5th World Fisheries Congress, CD 6d-1022-075, Yokohama, Japan, October 20-24, 2008 (2009)

Kim, G.G, Kim, H.S, Baik, C.I, Kakimoto, H, Seaman, W. 2008. *Design of Artificial Reefs and Their Effectiveness in the Fisheries of Eastern Asia*. American Fisheries Society Symposium 49:933-942

Seaman, W, 2008. *Coastal Artificial Habitats for Fishery and Environmental Management and Scientific Advancement*. Fisheries for Global Welfare and Environment, 5th World Fisheries Congress 2008, pp. 335–349.

Diplock, J. November 2010 *The future of our artificial habitats*. North Australian Fishing and Outdoors magazine

Glossary

Artificial reef – An artificial reef is one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological, or socioeconomic processes related to living marine resources (Seaman *et al*., 2000).
Artificial reef unit – a single manufactured structure
Artificial reef module – a combination of units placed together
Deployment – Transport of units from the wharf to the AR location including placement on the ocean floor.

References

Stephens, J and Pondella, D. (2002) *Larval productivity of a mature artificial reef: the ichthyoplankton of King Harbor, California, 1974–1997*. ICES Journal of Marine Science, Vol. 59, Pp. S51 – S58