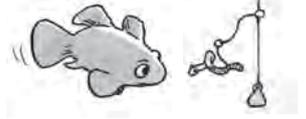


# TARFish

Tasmanian Association for Recreational Fishing Inc.



## *Artificial Reefs in Tasmania: a Background Report to inform Future Developments*

**By Sven Frijlink**



January 2012

## *Artificial Reefs in Tasmania: a Background Report to inform Future Developments*

### **Prepared for:**

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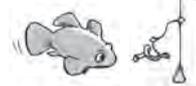
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## FOREWARD

The Tasmanian Association for Recreational Fishing Inc. (TARFish) commissioned the report Artificial Reefs in Tasmania: a Background Report to Inform Future Developments to collect factual information about artificial reefs so that informed thought could be given should they be considered within our waters. Many people we have spoken to over the last couple of years are enthusiastic about implementation of artificial reefs however we were of the opinion that there was a gap in the public's general knowledge about the scope of artificial reef information and this was the primary reason we have commissioned this report. The environment in Tasmania and its coastal waters is changing and adapting, new species are showing up in our waters, marine pests are establishing themselves and our water currents and temperatures are altering permanently. Adapting to our new environment will require change, and reflective thinking about how to adapt affectively is a challenge that we all face in the future.

Tasmania has seen in recent years non local fish species that are following the East Australian Current as it extends further south into our waters. This phenomenon is not expected to stop according to CSIRO, rather it is expected to increase stocks of Snapper, Yellowtail Kingfish, King George Whiting and even Dolphin Fish (Mahi Mahi). Their natural habitat may be enhanced through artificial reefs which may encourage local populations to establish themselves faster. Habitat destruction on the East Coast has already started with the marine pest "Long Spined Sea Urchin" overgrazing large areas of our rocky reefs which have been turned into underwater barren areas where few species live. Fish species need healthy and dynamic habitat to live, breed and become resilient to the changes that have, and are expected to continue. Artificial reefs may be an effective option which could provide enhanced habitats and lead to improved ecosystems.

TARFish have an open mind in relation to artificial reefs and we have been keeping a watchful eye on developments in other states over the last couple

of years. Larger states are spending considerable amounts of money on artificial reef deployments with many positive recreational fishing benefits now being reported. I hope you find the report informative as we believe the independent consultant who researched and developed the report on our behalf has effectively gathered, researched and consolidated the extensive knowledge about artificial reefs both here in Australia and Overseas.

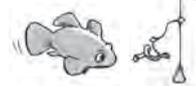
Mark Nikolai  
Chief Executive Officer  
TARFish



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## EXECUTIVE SUMMARY

Artificial reefs have been used extensively around the world to fulfil a variety of functions including habitat restoration and fisheries enhancement. In Australia and North America, artificial reefs have been principally deployed to create additional habitat for attracting fish in order to provide recreational fishing and diving opportunities. Historically, artificial reef deployments in Australian waters have been largely unregulated and have comprised opportunistic materials including decommissioned vessels, industrial waste and concrete pipes. Since 2001 however, there has been a renewed interest in artificial reefs in Australia, coinciding with considerable research inspired developments in purpose-built reef modules. A growing understanding of the ecology of fish and invertebrate species, and greater focus on planning, management and monitoring of reef sites have enabled reefs to be deployed with a greater level of certainty and with more specific objectives.

So far, New South Wales, Victoria and Queensland have made the greatest progress in deploying purpose-built reef structures. In NSW and Victoria, most reefs have been deployed in shallow inshore waters using concrete hemispherical units known as Reef Balls™. Reefs of this nature are primarily intended to provide substrate for demersal species such as snapper in areas easily accessed by anglers. However, fisheries management agencies in both NSW and Queensland have recently deployed large steel high-profile reef units in offshore waters that are designed to attract both demersal and pelagic fish. In most of the recent Australian deployments, the design and construction materials of reef units have been chosen based on successful trials conducted overseas (usually in South Korea or Japan), and in consideration of the habitat requirements of local species and conditions. Comprehensive pre and post deployment assessments of artificial reefs are also often conducted to determine their effectiveness and their impacts on local fish and invertebrate communities.

Many factors are implicated in the renewed interest of artificial reef deployments in Australia. One key

factor is the fast pace of development of purpose built structures which have alleviated many of the problems associated with using opportunistic materials. Artificial reefs are becoming increasingly popular with anglers, and fisheries managers in some States have integrated artificial reefs with other fisheries management tools to enhance recreational fishing opportunities, usually to the exclusion of commercial fishers. Despite this, artificial reefs may be inconsistent with the goals of sustainable fisheries management and stock conservation. While some research suggests that artificial reefs may confer ecological benefits, little research has demonstrated commensurate benefits for reefs deployed for fishing enhancement. As such, the South Australian Government so far remains opposed to any artificial reef developments, despite pressure from South Australia's peak angling body.

With regard to ecological concerns, the primary issue surrounds the manner and degree in which artificial reefs may excessively contribute to fisheries exploitation by aggregating fish from neighbouring areas for easier extraction. While some artificial reef proponents suggest that the provision of additional structure will offset this by contributing to fisheries production (i.e. by providing food and refuge for fish and substrate for larval settlement), this remains unsupported by a considerable body of research. However, research also suggests that many factors can influence the balance between fish aggregation and fisheries production on artificial reefs. Factors include the level of fishing activity, reef location, ecological characteristics of local species and design elements of reef structures – especially size, configuration and structural complexity. Nonetheless, most relevant studies suggest that if reefs of a size consistent with recent Australian deployments are exposed to fishing, net productivity gains are very unlikely. As such, any reef development proposals for Tasmanian waters will need to carefully consider the likely impacts of artificial reefs on local species and undertake necessary measures to reduce the likelihood of detrimental ecological impacts. In doing

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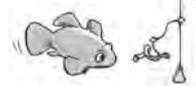
so, efforts should be undertaken to both decrease the incidence of concentrating fish from surrounding natural habitats and increase the potential for reefs to contribute to fisheries production. The latter may include incorporating specific habitats to aid the recruitment of fish and invertebrates during vulnerable life stages. Clearly, a detailed understanding of the ecological requirements of local species is required during the design and planning process to achieve the most sustainable outcomes.

Whilst ensuring that proposed developments accord with sustainable fisheries management principles and goals is paramount, the primary goals driving the deployment of reefs to enhance fishing are to derive social benefits. Underpinning the recent reef developments in Victoria and New South Wales is the provision of fishing opportunities where limited opportunities existed – particularly for species that utilise reef habitat/ For the recent deployments in Queensland's Moreton Bay Marine Park, reefs were deployed to compensate recreational fishers for fishing grounds no longer accessible due to the expansion of fishing exclusion zones within the Park. If reef developments are proposed for Tasmania, careful consideration is required to assess whether the likely benefits (i.e. usage and satisfaction) are sufficient to offset the considerable costs involved in reef planning, deployment and management. Social assessments also need to consider the likelihood of social costs including conflict within and between user groups and fisher dissatisfaction if excessive exploitation results in decreased catches on artificial reefs and/or neighboring habitats. If economic arguments are offered in support of artificial reef developments, economic assessments should also be undertaken to investigate the likelihood of their validity.

The planning, administration and management of artificial reefs is a complex process. In addition to ecological, social and economic considerations, reef design and site selection will need to address physical factors including wave exposure, tidal flows and sedimentation. With regard to the approvals process, legislation and regulations administered by Commonwealth, State and locals agencies will need

to be observed. While the exact process is not clear (and will vary according to the nature of proposals), relevant laws will likely address issues of reef design and emplacement, ownership and liability, coastal lease and tenure, environmental protection, effects on coastal processes, the spread of exotic species, shipping and navigation, and impacts on amenities and recreational activities. Management implications are also considerable. Prior to deployment, a policy framework integrating objectives of numerous Government agencies would need to be developed and resources would need to be allocated for stakeholder engagement, public consultation, and public information/outreach efforts. Post deployment, additional costs would be required to manage activity access and for regular assessments of fishery and environmental impacts in addition to the structural integrity of reefs. It may also be advisable to conduct on-going social assessments to determine the performance of reefs against social objectives.

On a global scale, artificial reefs for recreational fishing (and diving) have often been deployed within severely degraded ecosystems. In comparison, Tasmanian marine ecosystems and fishing opportunities are relatively healthy. Therefore, it is likely that possible reef development proposals in the foreseeable future will be based on the perceived need to provide fishing opportunities in easily accessible areas, and/or in areas where a lack of suitable substrate constrains fishing for desirable species. Alternatively, in the event of marine protected area expansion, artificial reefs may be deployed as 'compensation' for excluding fishers from previously accessible fishing grounds. Regardless of the rationale, a structured and thorough planning process is integral to the success of any reef deployment. Central to this is the development of clear objectives and extensive consultation on potential ecological, social and economic impacts. Questions regarding whether or not an artificial reef is the most appropriate, logistically feasible and financially cost-effective means of achieving key objectives need to be addressed. If a reef is deemed to be most appropriate means of achieving them, a prudent approach



considering expert advice and assessments of reefs deployed in areas with similar species and/or environmental conditions is needed.

## GLOSSARY OF TERMS

*Mariculture.* Cultivation of marine organisms in their natural habitats, usually for commercial purposes

*Demersal.* Living or occurring on the bottom of a sea or a lake

*Biomass.* The total quantity or weight of organisms in a given area or volume

*Pelagic.* Of, relating to, or living in open oceans or seas rather than waters adjacent to land or inland waters

*Epibenthic.* Living on the surface of the substrate

*Piscivorous.* Habitually feeding on fish

*Fecund.* Capable of producing offspring

## SCOPE OF REPORT

This paper has been prepared for the Tasmanian Association for Recreational Fishing Inc. (TARFish) to provide an overview of available information on artificial fishing reefs with implications for potential future deployment within Tasmanian waters. Specifically, this report evaluates the status of artificial reefs in Australia and overseas, reviews information relating to reef design and construction, identifies potential environmental, social and economic issues relating to reef deployment and outlines considerations relating to the management and monitoring of artificial reefs. Information for this report has been derived from reviewing published literature (scientific, technical and non-technical), including online resources, and through direct communication with relevant parties. Information sources have been appropriately referenced.

## INTRODUCTION

### What is an Artificial Reef?

The European Artificial Reef Research Network (EARRN) defines an artificial reef as “a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef” [1]. Artificial reefs have been further defined as “any material purposefully placed in the marine environment to influence physical, biological, or socio-economic processes related to living marine resources” [2].

As the term ‘artificial reef’ relates to a wide variety of materials deployed for a broad range of purposes (these will be outlined in detail in following sections), a degree of uncertainty and inconsistency often accompanies the use of the term. However, artificial reefs may be broadly divided into two categories based on their material composition. ‘materials of opportunity’ and purpose built and designed structures. While these reef types will be explained in detail in later sections, it is important to note that this report will primarily focus on the latter category.

### What are Artificial Reefs used for?

Artificial reefs may also be defined by their functionality, according to their intended purpose. The most common purpose guiding the placement of artificial reefs has been for the enhancement of fishing (recreational and commercial) and diving opportunities. Central to this purpose is the assumption that local fish availability and consequent fishing opportunities can be limited by a lack of suitable and/or accessible hard substrate attracting and supporting targeted/desirable species. While uncertainty exists over the extent to which artificial reefs contribute to fisheries production, it is well recognised that artificial reefs provide structure for the settlement of marine organisms and can provide food and refuge for recreationally and commercially important species [3]. The provision of structure is also thought to provide suitable environments for many species by creating refuges from tidal flow and turbulence [4].

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While purposes relating to the enhancement of fishing opportunities are consistent with the scope of this report, artificial reefs have also been deployed for other purposes. These include mariculture, biodiversity conservation (e.g. by providing habitat for the re-establishment or enhancement of vulnerable species), the restoration of damaged habitat, scientific research, habitat and coastal protection and as compensation to stakeholders for habitat loss. The latter includes compensating fishers for reef habitats that are no longer accessible by the creation of marine protected areas. Furthermore, in severely overfished regions including south-east Asia, artificial reefs have also been deployed for fisheries restoration [5].

## Artificial Reef Types: Materials and Profile

As mentioned, artificial reefs may be defined by their material composition. 'Materials of opportunity' have traditionally been used for the creation of artificial habitat used to enhance fishing opportunities. Such materials include rocks, rubble, wood, plastic, concrete pipes, building waste, white goods, car bodies and tyres. Sunken vessels and oil platforms are also considered to be 'materials of opportunity'. However, environmental problems associated with the use of these materials have resulted in reduced community acceptance over their deployment, particularly in developed countries. Of particular concern is the



Figure 1a: Reef Ball™ units (photo courtesy of D. Lennon, Reef Ball Australia).

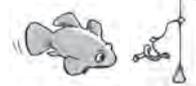


Figure 1b: Fish Box™ units (photo courtesy of R. Paik, Haejoo Pty Ltd).

leaching of chemicals into the marine environment and the degradation of environmental values. As a result, increasingly stringent environmental regulations have, in many countries, effectively prohibited the use of many opportunistic materials as reef structure and mandated expensive treatment of vessels and oil platforms prior to deployment.

More recently however, environmental concerns about opportunistic reef materials and a better understanding of the habitat requirements of valued species has directed the focus towards prefabricated reef structures incorporating design elements informed by a growing body of research. Due to the greater effectiveness of purpose built structures in supporting marine life [6], coupled with environ-

mental concerns over reefs made from opportunistic materials, investigations into potential deployments of artificial reefs in Tasmanian waters should be based on structures designed to accommodate Tasmanian fish species and be appropriate for local physical conditions. As such, the remainder of this report will focus on purpose built structures.

Artificial reefs may be further categorised according to their elevation [7]. Low profile or demersal reefs generally comprise a horizontal spread of duplicated low profile 'modules', generally made from concrete (see Figure 1). From a fisheries perspective, low profile reefs generally attract demersal species and have been used extensively within Australia and overseas to enhance fisheries production and fishing opportu-

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nities. Typically, low profile reefs are deployed in shallow and/or inshore environments.

High profile reefs are primarily constructed from low corrosion steel and are primarily designed to attract pelagic fish (see Figure 2). They are typically deployed in deeper water at offshore locations. As such, high profile reefs should be designed with sufficient stability and anchorage to withstand oceanic conditions.

Another type of structure that is often considered to be a form of artificial reef are fish aggregating devices (FADs). FADs are floating, drifting or mid-water structures that are often anchored to the seabed and are used to facilitate the harvest of fish (generally pelagic species) by attracting them. They are not the focus of this report and further use of the term 'artificial reef' will not include FADs.

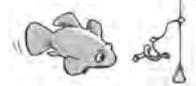
## STATUS OF ARTIFICIAL REEF DEVELOPMENTS

### International

Artificial reefs have been deployed in more than 50 countries worldwide [8], though their intended function/s vary considerably between regions. In North America and Australia, artificial reefs have been primarily used for the enhancement of recreational fishing and/or diving. While the development of artificial reefs in Australia may be considered embryonic at present, the state of reef development in the United States is considerably more advanced. More than 1500 artificial reefs have been deployed in Florida alone [2]. Over the last 30 years, reef deployment in the US has evolved from ad hoc efforts by fishing groups using 'materials of opportunity', to a well organised system co-ordinated by a national



Figure 2. Fish Cave™ unit (photo courtesy of R. Paik, Haejoo Pty Ltd).



plan. A major development in this evolution was the passing of the *National Fisheries Enhancement Act 1984*, which led to the National Artificial Reef Plan 1985. Federal funding initiatives for fisheries enhancement projects have included a 10% manufacturer's excise tax on sport fishing equipment [9].

Japan and South Korea have used artificial reefs to enhance fisheries production (primarily for commercial fishing) on a large scale for approximately 100 years and 40 years, respectively. Such is the scale of reef deployment in South Korea that their Government has invested over \$885M in artificial reefs over the past 40 years [8] and continues to spend \$80 annually on their reef program. South Korea and Japan are also at the forefront of global research and development of large scale, pre-fabricated reef modules for fisheries enhancement.

Artificial reefs have been used in Europe for around 40 years [10]. Over this period, reefs have evolved from small-scale projects focussed on species conservation to larger scale programs aimed at developing and sustaining regional fisheries and promoting research into reef colonisation and fisheries enhancement. Of particular note are extensive artificial reefs placed in the Mediterranean Sea to prevent damage from illegal trawling activity around sensitive fish nursery areas, particularly seagrass meadows. In 1995, the European Artificial Reef Research Network (EARRN) was created to encourage regional collaboration between artificial reef researchers. The EARRN also aspires to promote the awareness of issues and to develop research priorities of affiliated agencies.

## Australia

Artificial reefs have reportedly been used by aborigines to attract fish for thousands of years [11]. Since European colonisation however, the deployment of artificial reefs in Australia has followed a similar trajectory to that experienced in other regions, albeit on a smaller scale. That is, earlier deployment efforts (by public interest groups, private individuals and fisheries management agencies) were often unregulated using 'materials of opportunity', and with little regard for pre-deployment objectives or post-deploy-

ment monitoring. Projects of this description typify deployments undertaken between 1965 and 2001, though considerably fewer reefs were deployed after 1986 [4]. Since 2001 however, there has been a renewed interest in artificial reefs in Australia, coinciding with considerable research inspired developments in purpose built reef modules.

A detailed review of the history of artificial reef developments in Australia is outside the scope of this report. Comprehensive reviews covering the design, construction, deployment and monitoring of artificial reefs between 1965 and 2001 have already been undertaken [3,4,11,12]. Furthermore, a recent FRDC report has detailed reef developments since 2001 [8]. To avoid duplication of material, the following overview of the status of artificial reefs in Australian States will summarise information from these reports and incorporate more recent developments in reef deployment.

## New South Wales

Two notable developments have facilitated the recent progress of artificial reef deployments for recreational fishing enhancement in NSW. Firstly, the introduction of a general recreational fishing licence in 2001 has allowed monies to be allocated towards reef investigation, construction and deployment. Secondly, the closure of 24% of the State's estuarine waters to commercial fishing in 2002 effectively created 30 recreational 'fishing havens', and consequent opportunities for recreational fishing reefs to be effectively trialled and assessed.

Since then, five artificial reefs comprising concrete Reef Balls™<sup>1</sup> (see Figure 1a) of different sizes have been deployed in five estuary systems (Lake Macquarie, Botany Bay, St Georges Basin, Lake Conjola and Merimbula Lake). The reefs cover an average area of 2500m<sup>2</sup> and their effectiveness continues to be monitored through a combination of assessment techniques. Complementary surveys of natural reefs in the surrounding area are being used to compare changes in the structure of fish assemblages between the two reef types. So far, published results from monitoring efforts have demonstrat-

<sup>1</sup> Reef Balls™ are the world's leading prefabricated artificial reef modules. They are hollow concrete hemispherical units and are ideally suited to shallow waters. For more information, see <http://www.reefballaustralia.com.au>

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ed the successful recruitment and succession of many fish and epibenthic invertebrate species on reefs in Lake Macquarie [13] and Botany Bay [14]. The encouraging results from these two sites resulted in the subsequent expansion of reefs into Lake Macquarie, Botany Bay and St Georges Basin.

In October 2011, a large, high-profile steel offshore reef unit was deployed near Sydney Heads at a depth of 38 metres. It was the first of three offshore modules planned for deployment in NSW waters. The unit, which was based on a Korean design, is 12 m high, weighs 42 mt and has an internal volume of approximately 700 m<sup>3</sup>. Two tower sections are designed to attract pelagic fish, while a highly complex bottom section is designed to provide habitat for demersal species. The deployment of another two units (planned for offshore Newcastle and Wollongong) will depend on results of an intensive monitoring program for the Sydney Heads reef.

## Victoria

In 2008, the Victorian Department of Primary Industries commenced a three year trial of three artificial reefs for recreational fishing enhancement in Port Phillip Bay. The reefs comprise of Reef Balls™ of assorted sizes deployed over sand in about 11 metres of water in an area commonly accessed by recreational fishers. The reef modules were chosen and configured to provide suitable habitat for snapper, a key recreational target species in Port Phillip Bay. In a recent assessment report [15], 56 fish species were recorded inhabiting the reefs during the trial period compared to 58 and 33 species reported from neighbouring natural reef and soft bottom habitats, respectively. The same paper also reported high satisfaction levels by Victorian anglers who had fished the reefs.

The reef project in Port Phillip Bay was sponsored by Victoria's Enhanced Recreational Fishing Program, which is funded through recreational fishing licence sales. Funds have already been committed to developing another eight inshore reefs plus at least one reef accessible to shore-based anglers (P. Hamer 2012, pers. comm.).

## Queensland

Between 2008 and 2011, six artificial reefs were deployed within the Moreton Bay Marine Park by the Department of Environment and Resource Management (DERM). Underpinning project development was the perceived need to compensate recreational fishers for fishing grounds no longer accessible due to the expansion of recreational fishing exclusion zones within the Park.

Reef materials vary according to the characteristics of each site and 'target' species. Five of the six reefs have been constructed using specially designed, pre-fabricated materials. Of these, two are comprised of Reef Balls™, two reefs made from Fish Boxes<sup>2</sup> and another reef comprises three Fish Cave<sup>3</sup> structures. While these reefs have been developed in areas where no previous reef existed, the sixth reef (the Harry Atkinson Reef) is an extension of an older artificial reef made from 'materials of opportunity' dating back to 1975/ This reef was augmented by scuttling of the ex-trawler, the Tiwi Pearl. Monitoring programs for Queensland reefs will be done on an ad hoc basis and are not likely to be published (S. Hoseck 2012, pers. comm.).

## Northern Territory

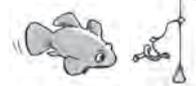
There are 14 artificial reefs in close proximity to Darwin which have been, and continue to be developed to enhance recreational fishing. All reefs have been created from 'materials of opportunity' including decommissioned vessels, railway carriages, concrete pipes and culverts. Reef deployment commenced in 1988 and the latest addition of reef material occurred in May 2011. A monitoring program has been implemented for the most recent reef to assess fish and invertebrate colonisation and succession. The reefs are very popular fishing destinations and reportedly attract both demersal and pelagic species. A commercial fishing exclusion zone surrounds each of the reefs.

## Western Australia

So far, artificial reefs in WA for fisheries enhancement are confined to an abalone mariculture trial

<sup>2</sup> Fish Boxes are low-profile prefabricated concrete reef units manufactured by Hae Joo Artificial Reefs. They are 4x4m and weigh 17 tonnes

<sup>3</sup> Fish Caves are high profile prefabricated steel reef units manufactured by Hae Joo Artificial Reefs. They are 11x11m and weigh 14.4 tonnes



off Albany. However, pressure from the peak angling body, Recfishwest, has been a factor in the consideration of artificial reef deployment by the WA Department of Fisheries. As a result, the Department sent a delegation to South Korea and China in 2010 to investigate the effectiveness of purpose built artificial reefs for stock enhancement and to disperse fishing effort away from current popular natural reef areas. In particular, the delegation was concerned about whether artificial reefs simply aggregated fish for easier harvest or whether they actually contributed to fisheries production. Buoyed by their findings, the Delegation recommended that the Government proceed with an artificial reef program and sent two subsequent delegations of researchers (to China and to South Korea and Japan) in 2011 to foster collaborative research on artificial reefs.

With regard to when any reef development will likely be deployed, the WA fisheries website [16] states “the deployment of artificial reefs in Western Australia will not proceed until suitable sites are selected and all appropriate regulatory approvals completed. This process is expected to take at least two years, as the approvals process will include environmental baseline surveys and impact assessments, together with analysis of the likely community and economic impacts”.

### **South Australia**

The Department of Primary industries and Resources of South Australia (PIRSA) officially recognised 19 artificial reefs in South Australian waters; however, numerous unofficial reefs also reportedly exist. All reefs have been constructed using ‘materials of opportunity’ and snapper is the key target species.

The creation of additional reefs in the near future appears unlikely according to information posted on the PIRSA website [17], despite receiving considerable interest from the South Australian Recreational Fishing Advisory Council (SARFAC). In particular, doubts exist over the ability of artificial reefs to contribute to fisheries production and not merely aggregate fish for easier extraction. Furthermore, the PIRSA website states that “further research is needed

into the effects of artificial reefs on the availability of fish and the ecology and productivity of the marine ecosystem in South Australian waters before any future reef building projects should be considered”.

### **Tasmania**

The Leven SCUBA Club deployed fifty Reef Balls™ off Moorlands Beach in about 20 metres of water in 2001, primarily for recreational diving. The Reef Balls™, which were purchased with funds supplied from a Natural Heritage Trust grant, were deployed to provide fish habitat in an area far from natural reef substrate. While formal biological monitoring has not been conducted, an online report states that various fish species including long-snouted boarfish, silver trevally, bearded cod and various species of leather-jacket have been observed at the site [18].

Despite having numerous shipwrecks that are popular with recreational fishers, no purpose built reefs for recreational fishing have been deployed in Tasmania. The most recent shipwreck was the *Troy D*, which was scuttled in the Mercury Passage near Maria Island in 2007. A biological monitoring report has identified 36 different fish species observed utilising the wreck [19].

## **REEF DESIGN AND CONSTRUCTION**

Until relatively recently, artificial reef design has typically focussed on structural integrity, with less emphasis placed on the habitat requirements of individual species and life stages [20, 21, 22, 23]. While the ability of structures in the marine environment to attract and support fish communities have been long recognised, the particular structural characteristics favoured by individual species and at different life stages are less clear and need to be closely considered when designing artificial reefs. There is also a growing body of research demonstrating that site characteristics such as exposure to physical processes and proximity to other structures are crucial in meeting pre-deployment objectives. Accordingly, in order to maximise the potential of an artificial reef, “there is need to integrate biological investigations of species requirements with engineering studies of materi-

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als design, placement and performance physically” [25; p 529].

## Size

As for all design elements to be considered when designing an artificial reef for fisheries enhancement, size considerations will depend on deployment objectives and target species. While reef size requirements will differ between species, some generalised relationships between reef size, species richness, fish size and biomass are evident.

Intuitively, larger reefs will generally support greater species richness, a higher number of individuals and a greater overall biomass than smaller reefs. However, in terms of such measures per unit of reef (i.e. volume of reef material or area of reef coverage), the results of related studies underscore the importance of understanding ecological characteristics of individual species in the design process. As a general rule, numerous studies have demonstrated that smaller reefs support greater biodiversity and fish numbers than larger reefs per unit measure [22, 25, 26, 27]. However, larger reefs may support greater biomass per unit measure, which is generally composed of fewer but larger individuals, and is likely to be attributed to the success of larger fish through competition and predation on smaller fish [22].

Furthermore, other studies suggest that larger reefs are more successful in attracting residential, as opposed to transitory species by providing greater habitat heterogeneity [28, 29]. A recent Australian report proposing guidelines for artificial reefs [31] suggests a minimum volume of 500m<sup>3</sup> for low profile reefs and 800m<sup>3</sup> for high profile reefs.

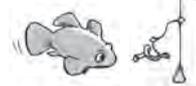
## Configuration

The reef design process will need to consider whether reef units should form a single reef or be dispersed across a wider area. However, the optimal configuration of reef components appears to vary according to deployment objectives, fish species and site characteristics. Nonetheless, a substantial body of research suggests that when reef modules or groups of modules are dispersed to create a ‘patchy’ reef, fish abundance and species richness are greater than if the modules formed a single reef [22, 26, 27, 31, 32]. This phenomenon, sometimes referred to as the ‘edge effect’, is assumed to increase effectiveness by maximising the perimeter to reef area ratio. This increases the likelihood of attracting transient fish and also increasing the foraging zone around the reef area for reef inhabitants. This rationale was adopted by the Victorian Department of Primary Industries when designing their Reef Ball reefs in Port Phillip Bay, principally for snapper [15]. From a practical perspective, dispersing units within reefs deployed for recreational fishing may also alleviate congestion of fishing vessels.

While dispersed reef configurations are assumed to support greater abundance and diversity, a comparable volume of research has not been published on the ‘edge effect’ on fish size and/or total biomass. However, by virtue of reef size, a single larger reef is expected to accommodate larger fish [22].

## Structural Complexity

Numerous studies have demonstrated that the structural complexity of reefs, particularly the presence and variety of void spaces, contributes significantly to species richness and biological productivity of reef systems [20]. The degree of structural complexity of a reef is related to its ability to attract fish and to moderate the predation of prey species, through providing refuges [22, 33]. While understanding the ecology and behaviour of target species is paramount when planning reefs for fisheries enhancement, there are general inferences relating to structural complexity. In particular, high profile reefs are more effective in attracting pelagic fish,



while lower profile reefs with sufficient void spaces are more effective in attracting demersal fish [34]. Research relating to void space and reef height are summarised below.

### **Void Space**

Optimal void space is species and life stage dependent (35, 36). Therefore, to maximise void space for fisheries enhancement purposes, designers and managers will need to carefully consider the optimal void sizes for the species and life history stages being managed. As a general rule, small voids will provide refuge for small fish and large voids will be utilised by large fish [37]. The same study also found that the number of smaller fishes declined when the number of larger voids was increased, even when the number of smaller voids remained constant. This was attributed to predation pressure from larger fish occupying the larger voids. From these results, the authors concluded that artificial reefs designed for fisheries enhancement should include both small voids for small fishes (as predation refuges) in addition to large voids for predatory target species. However, for some reef-dwelling species, the provision of voids for adult fish may be unnecessary [38].

The relationship between void size and number, and measures of reef effectiveness (i.e. species diversity, number and size of individuals, and biomass), is not necessarily straightforward. For example, three studies have demonstrated greater fish abundance (across all fish size classes examined), species diversity and overall fisheries biomass around artificial reefs when the large void spaces of reef modules (including Reef Balls™) were filled with concrete blocks [33, 35, 39]. While the addition of material effectively created a larger number of smaller voids (i.e. the smaller spaces between the blocks), and therefore promoted the abundance of smaller fish, the results for larger fish were less intuitive. It appears that the increased abundance of smaller fish, in turn, provided a plentiful food source for piscivorous fish, despite the lack of larger void spaces for them to utilise. These findings have implications for the deployment of commonly used prefabricated concrete structures,

including many of the recent deployments of Reef Balls™ in eastern Australian states. Future deployments should heed the results of these studies and consider trials comparing the relative effectiveness of 'filled' and 'unfilled' reef modules on local fish species.

### **Reef Height**

Considerations of reef height are important when attracting pelagic species. Elevated structures are thought to act as a spatial reference or as a visual or audio stimulant [40], and the importance of elevation in attracting pelagic fish is thought to increase with water depth [20]. The provision of vertical relief within a reef system has been implicated in enhancing fish abundance and species diversity when compared with reefs offering less elevation [41]. In addition to attracting pelagic fish, vertical relief within a reef structure can provide a diversity of microhabitats for a wide variety of species by altering water flow and turbulence patterns, light levels and temperature [20].

### **Construction Materials**

While many materials have been, and continue to be used for reef construction worldwide, modern prefabricated reef structures are generally constructed from either concrete or steel. For detailed information on a large variety of reef construction materials, see Lukens *et al* (2004) [42].

#### **Concrete**

High strength marine grade concrete has proven to be durable in marine environments, suitable for mass production and is mouldable for required shapes. Commercially available concrete reef units are generally non-toxic and pH balanced for marine environments. Different textured finishes can also be applied based on the habitat requirements of individual species. In a 2001 review of artificial reef design and application, concrete was easily the most prominent material used for reef construction [34].

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## Steel

Low corrosion steel is generally used to construct high profile reef structures used for offshore deployment. For the high profile reefs recently deployed in Queensland, the steel is thought to have a minimum life-span of 30 years when deployed at a depth of 25 metres (R. Paik 2012, pers. comm.).

## ECOLOGICAL AND ENVIRONMENTAL CONSIDERATIONS

For an artificial reef project to generate broad public support (and presumably, to meet its objectives), it is desirable that any deployments will not have detrimental impacts on fish stocks, or other measures of environmental health. Potential negative impacts include chemical leaching from construction materials, the displacement of natural habitat and unfavourable changes to the surrounding ecology. However, in most cases, the issue of greatest contention concerns the manner and degree in which artificial reefs may excessively contribute to the exploitation of fish by aggregating them for easier extraction. While conventional wisdom may suggest that the provision of additional structure will offset this by contributing to fisheries production (i.e. by providing food and refuge for fish and structure for larval settlement), this assumption is often not supported by a considerable body of research into this issue, commonly referred to as the 'aggregation versus production hypothesis'. Due to the preoccupation with this issue in the literature on artificial reefs, and the potential implications regarding ecological sustainability and community acceptance, the aggregation versus production hypothesis will be discussed in detail.

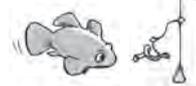
### Aggregation versus Production

In relation to artificial reefs used for fishing enhancement, the aggregation versus production issue centres on whether artificial reefs simply aggregate fish from surrounding areas for easier extraction and/or whether they also contribute to the abundance and biomass of fish by providing additional habitat. While the processes involved in attracting fishes to

artificial reefs are relatively well understood, [43] most of the uncertainty lies in whether artificial reefs contribute to production, and if so, to what extent. According to a literature review on the aggregation-production issue [20], the potential for an artificial reef to enhance production may be realised via four mechanisms: 1) by increased growth of fish by providing habitat for benthic prey organisms; 2) through decreased mortality by providing refuges from predation; 3) by increasing the recruitment success of larval and juvenile fish by providing suitable habitat for their settlement, and; 4) by reducing harvesting pressure on natural reefs.

The attraction/production issue has been the focus of much research and is fundamental in justifying considerable resources used in deploying reefs for both fishing enhancement and fisheries enhancement. Despite this, consensus among researchers has not been reached. While the lack of consensus is partly related to difficulties involved in measuring production [20, 23], it appears that a broad-scale consensus is unlikely to be reached due to the wide variety of reef types, varying rates of exploitation associated with different reefs, differences in species communities, and differences in physical and biological processes particular to different marine systems. However, there does seem to be growing understanding that artificial reefs are likely to contribute to both processes and the attraction/production status of a particular reef will probably lie within a continuum between the two opposing scenarios.

Underpinning the productive potential of an artificial reef is whether or not the availability of reef habitat is a factor limiting overall fisheries production within the area of deployment. In other words, production will largely depend on whether or not an increase in productive capacity (i.e. for increased growth, survival and/or larval settlement) is dependent on the provision of new hard substrate material. Under a completely 'habitat limited' production scenario, production increases would be proportional to any new increases in additional habitat: however, this is usually only relevant for fisheries that experience no exploitation pressure. For most fisheries how-



ever, sufficient reef space has already been vacated through human fishing activity [20, 44, 45]. As such, production for most exploited fisheries is usually not 'habitat-limited' but limited by other processes – usually by the number of larvae that settle (recruitment) or through post-recruitment processes such as food availability for juvenile and adult fishes [20]. Nonetheless, due to many factors including species-specific ecological traits and species-specific exploitation, both habitat-limitation and recruitment limitation may occur with a fish community. In the following section, these factors and others are discussed in light of their potential effects on the attraction/production continuum. Inferences for reef design, planning and site selection will also be made.

### *Fishing Activity*

Potential production gains from artificial reefs may be eroded by intense recreational fishing pressure [46]. Through concentrating residential species from neighbouring natural habitats, and providing temporary structure for transitory species, artificial reefs have the potential to increase local and regional recreational catches beyond that which would have occurred prior to reef deployment. Most of the studies that indicate increases in fisheries production from artificial reefs relate to benthic invertebrates [47, 48], non target fish species [49, 50] or fish in areas protected from fishing [5, 6, 51].

The potential for adverse impacts is reinforced when the densities of targeted species on artificial reefs are greater than on natural reefs, which is often the case [41, 43, 49, 52, 53], therefore increasing the ease of which fish are captured. Compounding this, there is a reasonable likelihood that the presence of an artificial reef may increase overall fishing effort within a region, such as when the location of a reef increases the accessibility of fishing opportunities and/or provides fishing opportunities for fishers who would have not previously fished reef habitats [54].

While it is well understood that artificial reefs redistribute the exploitable fisheries biomass, one study suggests that their greatest potential impact is their

ability to aggregate previously unexploited fish stocks [45]. Under this scenario, some species or populations may not have been previously exploited due to low densities around natural habitat and/or fishery access issues. The greatest species-level impacts due to recreational fishing are for target species, schooling species and for larger and thus more fecund individuals. One study demonstrated that the biomass of grouper declined by 77% over eight months after opening an artificial reef to recreational fishing [56]. However, the same study also found that non-target species biomass increased over the same period, presumably due to greater food availability and decreased predation from the removal of grouper.

This example highlights the disparity of potential impacts between target and non-target species and the difficulties associated with determining whether artificial reefs deployed for fishing result in production benefits. However, the bulk of relevant studies support the assertion that "artificial reefs are unlikely to benefit heavily exploited or overfished populations without other management actions" [43; p631]. As such, planners and managers of artificial reefs must carefully consider the potential effects of artificial reefs on different species and ecosystem function. In doing so, they need to evaluate whether prevailing regulations are adequate in light of the degree of pressure they are likely to sustain.



## *Structural Complexity*

As previously outlined, the degree of structural complexity of reefs, particularly the presence and variety of void spaces, can significantly contribute to biodiversity and biological productivity [20]. The likelihood of a reef contributing to fisheries production will increase if it provides suitable habitat for species with specific habitat requirements: specific habitats are more likely to be limited than more generalised habitats. As a general rule, habitat specificity is likely to be more pronounced for larval and juvenile fish than for adults, reinforcing the general value of the provision of small voids. However, scientific understanding of the early life history of many species is currently insufficient to enable appropriate reef designs for recruitment enhancement [4]. Nonetheless, the same study, which assessed artificial reef implications for Victorian waters, suggests that sufficient information is available to design reefs accommodating the early life history stages of rock lobster and abalone.

The deployment of specially designed structures have also been used successfully as spawning substrate for the spotted handfish in Tasmania's Derwent estuary [57].

## *Reef Size and Configuration*

In habitat limited environments, the potential for fisheries production will be roughly proportional to the volume of new habitat [22, 27]. However, whether or not reef habitat is limited is a more complex issue and is likely to vary considerably between species and location. One study suggests that the provision of artificial habitat is most likely to contribute to production for species with specific early life habitat requirements (i.e. for larval settlement): under this scenario, production will be enhanced when the amount of artificial habitat represents a considerable proportion of the overall available suitable habitat [4]. For other means of enhancing overall production (i.e. through increased growth rates and decreased mortality), there is little evidence that increasing reef size will result in production increases for reefs deployed for fishing purposes, particularly if production is recruitment-limited rather than habitat limited.

The information outlined earlier in this report with regard to the relationship between fish abundance and diversity and the spatial configuration of reefs is also applicable when assessing the potential for fisheries production. In summary, smaller reefs generally support greater fish abundance and diversity per unit area than larger reefs which support greater biomass through the attraction of larger, but fewer fish. Consistent with this, a study comparing larval settlement between reefs of different sizes [22] concluded that although settlement rates were not different between reefs, post-settlement survival was greater on smaller reefs due to lower numbers of larger, predatory fish. As such, the author concluded that "larger reefs may be better for fishing while smaller reefs may be better for overall recruitment" (p.27).

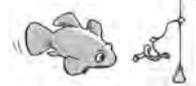
## *Reef Location*

Various studies suggest that the potential for an artificial reef to contribute to overall production within a region will be maximised through deployment in locations isolated from natural reefs [22, 23, 44, 46]. The greater the distance from natural reefs, the less likely that larvae settling on artificial reefs would find natural suitable habitat. By virtue of isolation, juvenile and adult reef species are also less likely to be attracted to artificial reefs from neighbouring natural reef habitat. Also, as many reef dwelling fish feed on surrounding soft bottom habitats (i.e. snapper), deploying a reef far from natural reefs may facilitate feeding opportunities previously unexploited by reef species.

## *Species Ecology*

By considering the biology and behaviour of species likely to utilise artificial reefs, the potential benefits of artificial reefs can be maximised. However, by virtue of the ecological diversity of fishes that frequent reefs, the manner in which fish respond to the addition of new reef material will vary according to life history.

Production enhancement is more likely for demersal reef species with high site fidelity: these species are more likely to be habitat limited [20, 43]. Conversely,



attraction is more likely to be important for transitory, pelagic or facultative reef species with less site fidelity [20, 43].

Artificial reefs are more likely to contribute to production if bottlenecks to population growth (e.g. larval settlement) occur on reef habitat. However, for many species of recreational or commercial importance, larval settlement often occurs on sand, sea-grass or in estuaries [43].

### Loss of pre-existing habitat and species

Artificial reef deployment effectively replaces pre-existing habitat (usually soft-bottom habitat) with artificial habitat. While soft-bottom habitats may appear relatively barren, they may still have high ecological and conservation value [54]. Altering benthic habitats and increasing fish biomass through artificial reef deployment may affect the integrity and functioning of the marine ecosystem [57].

Therefore, the negative impacts on soft-bottomed species need to be evaluated against the potential benefits of providing habitat for reef species.

### Pollution and Contamination

Risks associated with the leaching of toxins and contaminants have been frequently identified from reefs constructed of 'materials of opportunity'- particularly building materials, tyres and decommissioned vessels. While modern purpose built reef modules have alleviated many of these concerns, considerable effort should be made to seek assurances from reef manufacturers that materials will not corrode, leach or degrade over time.

### Physical Processes

Artificial reef deployment may alter tidal flows, current and wave action [4], which in turn may cause accumulation or erosion of sand in the vicinity of the reef. A comprehensive pre-deployment planning process would need to model the likelihood of physical effects including erosion/accumulation, reef structure stability and impacts on adjacent habitats.

## SOCIAL ISSUES

From an ecological/environmental perspective, the ultimate objective of an artificial reef is the "successful maintenance of or increase in abundance of target species by increased production instead of potential reduction via attraction" [23, p.57]. However, the primary goals driving the deployment of reefs to enhance fishing are social/community and/or economic [59].

### Social Benefits

Artificial reefs for fishing enhancement are deployed to improve existing fishing opportunities, or to create fishing opportunities where limited opportunities existed – particularly for species that utilise reef habitat. Sutton and Bushnell [2] describe four ways in which artificial reefs may confer social benefits by creating or enhancing (recreational) fishing opportunities. These are summarised below:

- 1 By introducing different types of structure, artificial reefs can attract different fish species to an area, thereby providing different fishing experiences
- 2 When strategically placed near access points, artificial reefs can provide fishing opportunities for people otherwise limited by boat size/power, time, money or experience.
- 3 By attracting or producing marine life, artificial reefs can increase the likelihood of catching fish.
- 4 By providing additional habitat, artificial reef can alleviate user congestion and crowding on natural habitats.

Clearly, the potential social benefits provided by artificial reefs will only be realised if reefs are used by fishers (and/or divers) who derive positive experiences and attitudes towards them, particularly over long periods of time. In a 2011 survey of recreational fisher use of artificial reefs in Victoria, over 70% of anglers indicated satisfaction with their fishing experience and over 90% expressed intentions to fish the reef again [15]. While these results are encouraging,

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the survey was conducted on relatively new reefs: longer term assessments of reefs in marine environments similar to those in Tasmania would be useful in informing any deployment proposals. Similar surveys of recreational fishers and divers in the United States [59, 60, 61] suggest that reef users prefer natural to artificial habitats, with other variables (e.g. catch rates) being equal.

As social benefits depend on positive fishing experiences, overfishing at reef sites has the potential to erode such benefits if unsustainable exploitation results in lower catch rates around artificial reefs and/or adjacent natural habitats. This underscores the need for informed planning, careful management of fishing activity and regular fishery assessments and monitoring, both ecological and socio-economic.

## Conflict within and between user groups

Conflicts within and between artificial reef stakeholders are well recognised [2, 62, 63]. Common causes of conflict relate to different modes of reef use, crowding and congestion, and issues surrounding resource availability [2]. These causes will be described below, and ways to minimise and manage conflicts are outlined.

Use mode conflict occurs when different user groups (i.e. recreational fishers, commercial fishers, divers) conduct activities around artificial reefs. As the goals, values and activities of different groups are often incompatible, conflict naturally arises. Clearly, management decisions need to be made regarding which user groups can access artificial reefs, or whether spatial or temporal segregation of users is a more appropriate means of avoiding or mitigating conflict. At most recent reef deployments within Australian waters, commercial fishing has either been excluded, or reefs have been deployed in areas previously designated for recreational fishing only. However, excluding groups from previously accessible areas can generate further conflict which will also need to be managed.

Congestion at artificial reef sites may have detrimen-

tal effects on fishers' mobility and enjoyment. Divers are particularly affected by crowding due to their orientation to natural values [63] and potential fishing gear interactions. Problems associated with crowding could be alleviated through selective access controls such as user fees or limited licensing. However, such measures also have the potential to generate conflict among users. For the offshore reef in New South Wales, the Department of Primary Industries has produced a code of conduct which, among other things, prevents SCUBA diving. For the offshore reefs in Moreton Bay, Queensland, the Department of Environment and Resource Management restricts visitations by charter fishing boats to a single one hour visit per day.

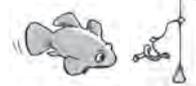
Conflicts due to resource competition may arise when exploitation of fish by a particular user group results in an actual or perceived decline in fish available to competing groups [62]. This may occur between recreational and commercial fishers (if the latter is excluded from accessing reefs) or between different sub-groups within the recreational fishing sector (i.e. between fishers utilising artificial and natural habitats). These effects will likely be exacerbated if artificial reefs attract and deplete fish from neighbouring reefs.

## ECONOMIC ISSUES

The costs associated with deploying and managing artificial reefs are considerable, and vary according to design and construction materials, the scale (i.e. the size and number of units) of development, deployment location, and the extent of monitoring and assessment programs, among other things. However, these may be partially or fully offset by positive economic impacts (and economic value) associated with reef deployment. These issues are outlined below.

### Costs of Reef Deployment and Management

In Australia and North America, where artificial reefs are predominantly used to enhance recreational fishing and diving, a variety of funding sources have been used for reef deployment and management. In



the United States, one of the major sources of funds is through an excise tax on fishing equipment under the Federal Aid in Sport Fish Restoration program [9]. The recent deployments in Victoria and New South Wales have been funded through recreational fishing licence revenue.

For future artificial reef projects in Tasmania, potential funding sources are unclear. Compared to reef deployments in larger States, monies raised through Tasmanian recreational fishing licence revenue are unlikely to be sufficient to support projects of a similar scale. As such, alternative funding sources would need to be considered. Possible sources include grant schemes and through the private sector [8]. Due to the high number of recreational fishers in Tasmania [64], Government funds could be committed through lobbying efforts, particularly prior to elections. Another option could be to offset costs through reef user fees, in a similar way that some dive wreck deployments have been financed [2]. However, this would also introduce a suite of administrative and logistical difficulties, and it is not clear whether Tasmanian recreational fishers would be willing to pay such costs.

### **Economic Impacts**

A common argument in support of artificial reef proposals is that reefs may generate economic activity within local communities through expenditure from increased recreational activity and tourism. Increased expenditure within a region generally results in positive economic impacts measured as income, employment and tax revenue. In determining economic impacts however, expenditure incurred by visitors outside the region in question is most important. Expenditure by 'locals' is assumed to occur on other goods and services within the region regardless of whether money was spent fishing at artificial reefs or used for another purpose. Therefore, if Tasmania is viewed as a region for the intent of assessing the economic impact of an artificial reef, increased visitation and/or increased expenditure by non-Tasmanians would need to be demonstrated. However, for smaller regions within Tasmania, an increase in visitation

(by anglers residing outside the region) resulting from artificial reef deployment is likely to impart positive economic impacts through an increase in expenditure.

In the United States, studies have demonstrated significant regional economic impacts due to artificial reef visitation, from both divers and fishers [60, 65]. The Cochrane artificial reef in Queensland has been estimated to inject around AU\$1 million dollars into the Burnett Coast region annually [66]. While these examples provide good economic arguments for artificial reefs deployment, the potential economic impacts for future deployments in Tasmania are unknown. It should be considered however, that the significant economic impacts observed in US studies are for regions with highly depleted natural fishing habitats/ In contrast, Tasmania's relatively healthy natural ecosystems are, in relative terms, unlikely to result in a comparable level of demand for artificial reef usage.

## **ISSUES SURROUNDING ARTIFICIAL REEF PLANNING AND MANAGEMENT**

### **Legislative and Policy Framework**

The process of gaining the necessary approvals to deploy an artificial reef is complex and will involve addressing numerous requirements under the administration of Commonwealth, State and local authorities. As the exact process will depend on the specific nature of a proposal, it is not possible to provide an accurate overview of the steps involved for future development applications. Further uncertainty is imparted by the absence of any artificial fishing reef proposals to date in Tasmania: as such, a precedent does not exist. However, the approvals process involved in the scuttling of the *Troy D* in 2007 provides an instructive overview of key legislation and agencies implicated (C. Peterson, pers. Comm.).

The construction and placement of artificial reefs in Australian waters is regulated under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* and is administered by the Department of Sustainability, Environment, Water,

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Population and Communities (DSEWPC). Under the Act, permits are required to ensure that appropriate sites are selected, materials are suitable and appropriately prepared, the reef does not pose a danger to users and there are no significant adverse impacts on the marine environment. Key steps in preparing a reef for placement and for preparing a sea dumping application include the evaluation and securing or adequate resources, stakeholder consultations, site selection, determination of deployment methods and preparing a post-deployment management and monitoring plan. For the *Troy D* sea dumping application, the reports required included the following: an ecological assessment, a baseline environmental survey of the proposed site, a deployment plan, a post-deployment management plan, a business plan, and a marketing plan. The DSEWPC currently charges an application fee of \$10,000 and recommends a timetable of between 12 and 18 months from application to deployment.

As part of the stakeholder consultation process, numerous State Government agencies (and State legislation) are likely to be engaged. Relevant laws and policies at the State level relate to development control and planning, fisheries, environmental protection, ports and navigation, resource allocation and management, and the management of public land in the coastal zone. In the case of the *Troy D*, State Government authorities involved included the Department of Primary Industry, Parks, Water and Environment, the Environment Protection Authority, Marine and Safety Tasmania, the Department of Economic Development, and Workplace Standards Tasmania. In securing a seabed lease for an artificial reef, an application would need to be approved under the *Crown Lands Act, 1976*.

Another key piece of Commonwealth legislation is the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The EPBC Act concerns rare, threatened and endangered species. If a proposed development is thought to have detrimental impact, the project will require further assessment by the

DSEWPC.

The DSEWPC is currently working on producing guidelines for artificial reefs in Australia.

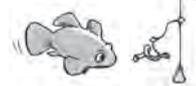
## Operational Management and Administration

Significant resources will be required to manage an artificial reef development. Such resources may be required for policy development, engaging Government authorities and stakeholders, public consultation, public information/outreach efforts, fishery and environmental assessments, compliance activities and conflict resolution. Management arrangements may also need to be implemented to control catch and/or effort (in addition to fishery management tools already in place) to avoid over-fishing, particularly for species deemed to be vulnerable. Other issues that may need addressing relate to reef ownership and liability, shipping and navigation. In the event of storm damage, or if reefs were considered detrimental to their objectives, considerable resources may also be required to remove artificial reefs.

## Monitoring and Assessment

The approvals process is likely to necessitate ongoing monitoring and assessment of reef sites against pre-deployment objectives, environmental performance and principles of ecologically sustainable development. A monitoring program may be required at designated intervals over the life of the structure. Depending on the nature, scale and location of a reef development, pre-deployment surveys may also be necessary to establish baseline information for post-deployment comparisons.

Detailed descriptions of biological monitoring regimes are available for both Victorian [15] and New South Wales [13] artificial reefs. These studies have used a variety of techniques (i.e. diver visual census, still and video photography, baited underwater video, angler surveys) to assess the diversity, abundance and colonisation of fish and epibenthic species. Assessments also extend to neighbouring soft-bottom and natural reef sites, with the latter



being instrumental in addressing the aggregation/production issue. To comprehensively address the issue in future studies, a recent paper [23] suggests how more sophisticated techniques may be useful.

Monitoring of the reef site may also be required to assess the structural integrity of reefs and potential effects on physical processes (i.e. sand accumulation and deposition), particularly after storm events.

In addition to biological/ecological and physical monitoring, socio-economic monitoring is necessary in evaluating progress against socio-economic goals [2]. In particular, surveys should assess use levels, satisfaction with reef activities, perceptions of crowding and congestion, conflict, expenditures, and reef-related attitudes and opinions.

## CONCLUSIONS

Artificial reefs have been used extensively around the world to fulfil a variety of functions including habitat restoration and fisheries enhancement. While a growing body of research indicates ecological benefits attributed to artificial reef deployments, little research has demonstrated such benefits for reefs deployed for fishing enhancement purposes. As such, managers need to exercise caution when considering proposals of this nature, particularly in relation to the potential of reefs to contribute to localised stock depletions through the aggregating effects of artificial reef structures.

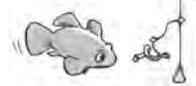
Integral to the success of any reef deployment is a structured and thorough planning process. This includes the development of clear objectives and extensive consultation on the potential ecological, social and economic impacts of artificial reefs. Of particular note is whether or not an artificial reef is the most appropriate, logistically feasible and financially cost-effective means of achieving key objectives. If a reef is deemed to be the most appropriate means of achieving them, a prudent approach considering expert advice and reports from the assessment of reefs deployed in areas with similar species and/or environmental conditions is advisable. Completed and impending monitoring studies con-

ducted for inshore and offshore reefs in Victoria and New South Wales may provide useful information to inform future Tasmanian proposals. Assessing species utilisation of reefs already deployed in Tasmania (i.e. the *Troy D* and the Leven SCUBA club Reef Ball™ site) may also be instructive. Furthermore, and in view of higher than global average water temperature increases observed and predicted for south-eastern Australia [67], artificial reef proposals need to consider changes in the composition of species likely to utilise reef habitats. Of particular importance for recreational fishers are increasing reports of snapper and yellowtail kingfish in Tasmanian waters [68].

Based on a large volume of published material, artificial reef creation for recreational fishing enhancement should not be viewed as a panacea for fisheries enhancement. However, with careful planning and management, artificial reefs may not be inconsistent with the goals of fisheries management, stock conservation and the goals of other agencies. In short, the deployment of artificial reefs is a complex issue that will involve considerable management resources to increase the likelihood of delivering social and economic benefits without diminishing ecological values. While reefs intended for recreational activity enhancement are primarily deployed for social and/or economic outcomes, careful attention to reef design, siting, management and monitoring can reduce negative impacts on species and ecosystems. In doing so, attention should be given to the provision of suitably designed and placed habitat for species with vulnerable life stages. Such investigations could foster important collaborations with research institutions and make significant contributions to the growing body of research on artificial reefs.

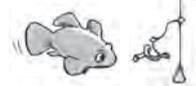
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