Ghoti

Ghoti papers

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Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

Petrarch's Principle: how protected human-made reefs can help the reconstruction of fisheries and marine ecosystems

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Abstract

Petrarch's Principle, named here, is to know things unseen, yet to ignore things seen. We apply the principle to the debate over the appropriate role and utility of human-made reefs (HMRs) in fishery and ecosystem management by reviewing four linked issues that were discussed at the recent 7th International Conference on Artificial Reefs and Related Aquatic Habitats. First, deploying protected HMRs can help to mitigate the depletion of fishery stocks through overharvest and habitat degradation. Secondly, to achieve this objective effectively, it is essential that HMRs are protected as no-take areas, and that, thirdly, HMRs are large, well-planned, evaluated and monitored. Finally, ecosystem modelling and adaptive management responses are necessary to forecast and manage the benefits of HMRs. Moreover, uncertainty about the resolution of the well-rehearsed attraction/production debate may be resolved by ensuring that HMRs are managed as protected no-take areas. And to ensure an unbiased attitude that will aid the clarification of consequences, costs and benefits, we propose a change in terminology, from artificial reefs to human-made reefs.

Keywords artificial reefs, attraction/production debate, CARAH conference, human-made reefs, protected no-take areas

Introduction

Francesco Petrarch (1358) (Fig. 1), the visionary Renaissance poet, ostensibly giving advice to a friend travelling the Ligurian coast west from Genoa, said, ''There are many things we know without having seen them, and many things we ignore despite having seen them''. This paper presents a point of

view reflecting Petrarch's Principle, rather poorly disguised as a selective review of a conference held on the said Ligurian coast, in San Remo, in October 1999 by the 7th International Conference on Artificial Reefs and Related Aquatic Habitats (CARAH). Here, we not only echo a view of the conference that protected human-made reefs (HMRs) can be an important tool in fisheries and ecosystem recovery, but we also deliberately use the term 'human-made reefs' instead of artificial reefs, signalling an attempt to turn a tide.

On the one hand, some elements of the conservation movement have come to regard artificial reefs with alarm, seeing them as merely fish aggregators that speed the depletion of vulnerable large reef fish (e.g. Polovina 1989a, 1989b; Romero 1996). On the other hand, proponents see HMRs as replacing lost habitat by allowing encrusting organisms to grow, providing cover, and hence enhancing the production of large reef fish. This dichotomy has become characterized as the attraction/production debate (Bohnsack *et al.* 1997; Grossman *et al.* 1997; Pickering and Whitmarsh 1997; Bortone 1998). Lindberg (1997) suggests that other questions about HMRs may be important, and to those closely concerned with research on HMRs the debate may seem well-rehearsed. Nevertheless, the attraction/production question is fundamental because it is the first issue that must be resolved before HMRs are widely adopted as mitigation devices. Eklund (1997), in one of the few rigorous experimental approaches, showed that cover provided by HMRs reduced predation and hence increased biomass of benthic fishes in Florida. This result supports earlier findings by Hixon and Beets (1989), Herrnkind *et al.* (1997) and Butler and Herrnkind (1997). In contrast, Waltemath and Schirm (1995), McManus (1995) and Balgos (1995) discuss evidence that HRMs in the Philippines have exacerbated stock depletion by making fish more catchable, with little or no associated benefit to net production. At the CARAH conference, Osenberg *et al.* (1999) presented an experimental design that could efficiently distinguish between the alternatives. In reality, to date, neither side has a lot of field evidence to back up their claims, perhaps hoping – like the courtiers who insisted that the Anglo-Saxon king Knut remain in his chair on the beach – that sitting in position long enough will cause the tide to recede.

Figure 1 Francesco Petrarch really did wear a laurel wreath when crowned as poet in Rome on April 8th 1341. Petrarch survived two episodes of the Black Death, and his poems of chaste love for 'Laura', who herself died of the plague, founded modern lyric poetry and inspired the humanist traditions of the Renaissance. On one level, Petrarch's Principle reflects the trauma of witnessing the pandemic that killed his love, while on another level, it signals a shift to secular logic from medieval casuistry. Today, it is an apposite description of a science at the cusp of a paradigm shift.

We structure our discussion of human-made reefs around four ecosystem and management issues: (i) the response to the present fisheries crisis; (ii) the scale of the response; (iii) the importance of protected no-take areas; and (iv) the need for ecosystem modelling. There are additional applications of HMRs beyond the mitigation of fisheries depletion and the protection and restoration of habitat and biodiversity, as covered in this paper. These additional uses include recreational diving, nature-based ecotourism and aquaculture. The 'Full Monty' of HMR uses was noted at CARAH, and is fully described by Seaman (1995, 2000).

The response to the present crisis

First, and perhaps most important, the disastrous state of fisheries around the world (e.g. Ludwig *et al.* 1993; Sissenwine and Rosenberg 1993; Walters 1995; Parsons 1996; Botsford *et al.* 1997; Garcia and Newton 1997; Mace 1997; Watling and Norse 1998; NRC 1999), accompanied by a very public perception of serious crisis (e.g. Safina 1995; Harris 1998), needs drastic, rapid and visible remedies; another tide to turn (Pitcher and Pauly 1998).

Indeed, aquatic ecosystems are currently experiencing deleterious ecological impacts and a set of local extinction events (Parrish 1995; Pauly *et al.*

1998a; Pitcher 2000), and some incipient global extinctions (Bruton 1995; Casey and Myers 1998), so numerous that natural adaptive responses may take millions of years to remedy (Kirchner and Weil 2000). Until recently, fishery scientists were in a 'seen-but-ignored' denial of the possibility of fish extinctions (see Pitcher *et al.* 1998), but here too the tide is turning (see Musick 1998, 1999). For example, Punt (2000) has shown that a fishing effort that would bring about extinction is only slightly higher than MSY for *K*-selected species, and as a consequence Mace (1999) wishes to treat 'MSY' as an upper-limit reference point that should be avoided if approached. Protected HMRs clearly have a role to play as hedges against extinction. For example, in Hong Kong the giant yellow croaker (*Bahaba flavolabiata*, Sciaenidae) became locally extinct in the 1950s (Pitcher *et al.* 1998). An ambitious HMR programme in Hong Kong (see below) may, if successful, lead to reintroduction of this valuable fish, traditionally used in wedding processions and feasts[1].

What is the role of HMRs in this crisis? According to presentations at CARAH, HMRs already sustain regional commercial and local artisanal fishing. However, rigorous evaluations of long-term HMR effectiveness at achieving applied objectives are few. One of the best databases comes from Italy, the host country to the 7th CARAH, and covers the Ancona area of the Adriatic Sea (Fabi *et al.* 1999). The actual role of HMRs in rebuilding stocks where effort is extreme – and presumably therefore habitat is not limiting – warrants investigation. In an earlier CARAH conference, Polovina (1991) laid out the bases for attraction and production in fishery systems.

Human-made reefs can also restore lost habitat for coral reef fishes, and provide refugia from which recolonization may take place. Long-lived, slow-growing valuable species like groupers (Huntsman *et al.* 1999) and reef-associated sharks are especially vulnerable to fishing, and hence can show significant, if slow, responses to protection (Musick 1999). Where coral reef habitat has been lost, as in Hong Kong (see below), we don't need to see the evidence to know it will work. But if natural reef habitat is plentiful, then there may be no need for human-made reefs. Indeed, the issues become more complex and hold less generality because fish can be attracted from natural to artificial reefs (the basis of Osenberg *et al.*'s 1999 paper).

It is useful to know how quickly any recovery may be taking place, and indeed a whole section of the CARAH conference covered monitoring. It was clear from keynote papers by one of us (Seaman 1999) and by Margaret Miller (Miller 1999) that many HMR systems had been set up without much thought to either the design or financing that would be needed to monitor performance, and few reefs to date had been monitored well (Portier and Seaman 1999). In contrast, Sayer *et al.* (1999) reported the planning stage of a proposed human-made reef system in Scotland which included rigorous monitoring and seemed admirably thorough.

The scale and nature of the response

Secondly, we must be innovative and think big for human-made reefs to work for restoration of fisheries – otherwise it will be 'too little, too late'. In a keynote paper, Antony Jensen (Jensen *et al.* 1999) quoted Japanese work suggesting that reefs of less than 600 000 m^3 will not work as intact functioning ecosystems (this represents a structure of about a 0.25 km^2 by 10 m deep). Most structures deployed in Europe and America are tiny by comparison. However, Relini reported work from a 5-km^2 area of the Ligurian Sea that has been set with human-made reefs designed as anti-trawling devices since 1986 (Relini *et al.* 1999a). In Malaysia (Wong 1991) and Thailand (Sinanuwong 1991) human-made reefs are also used as anti-trawling devices. The CARAH conference thought it appropriate that some of the first evidence of production enhancement from HMRs may come from the home base of the host of the meeting. There is clear evidence of trophic input to fish from organisms living on and around the reefs, and two species of groupers (rare due to relentless fishing pressure in the Mediterranean) have recolonized the area (Relini 2000).

On the other hand, tens of thousands of small refrigerator-sized, human-made reefs in Alabama, USA, waters are probably too small to enhance fish production, although some small organisms may grow on them. CARAH learned that most are actually owned by commissioning sport fishers, and can be moved, using welded hooks, around the sea bed to secret locations. Such devices are clearly designed to enhance local catch through fish attraction to cover and could subvert attempts at fishery and ecosystem restoration.

[1]Wedding fish procession, 1815, oil painting, catalogue no. AH1964.002, artist unknown, Hong Kong Museum of Art.

The 'oil-rigs-to-reefs' programme is certainly innovative and may offer a means of addressing the question of scale for regional fisheries enhancement. In California, complexes of abandoned oil rigs, whether officially ready or not, already serve as fish habitat (Love *et al*., in press), especially for the Pacific rockfish guild (*Sebates* spp., Scorpaenidae). One of us (WS) has personal experience of dramatic and extensive colonisation of an redeployed oil rig in Florida by a coral reef community. At a session of the CARAH meeting devoted to this topic, Caselle *et al*. (1999) showed that discarded oilfield debris can serve a similar function, while Helvey (1999) presented evidence that oil rigs can support important ecological functions for fish. A potential rig-to-reefs programme in Europe seemed less advanced[2] and in both hemispheres, the concept is under fire from the conservation movement. Sceptics question the motives of the oil industry in supporting this, as it could save lots of money in decommissioning costs.

In the past, we all know without needing to cite the evidence, that both the oil and fishing industries have damaged fisheries. The CARAH conference pointed to several ways in which support from both industries could be harnessed to assist the rebuilding of fisheries. A properly controlled and monitored rigs-to-reefs programme, if large enough, might become a part of this reconciliation. As Desmond Tutu, who set up a rather famous reconciliation commission in post-apartheid South Africa, said, ''Love your enemy – it will ruin his reputation!''.

The Importance of protected no-take, human-made reefs

Walters (1998) suggests that for truly sustainable fisheries, the norm should be that most of the ocean should be closed to fishing most of the time. But fishery scientists often display a surprising resistance to supporting the closure of large areas to fishing, the idea being dismissed as 'impractical'. Leaving aside a temptation to deconstruct the basis of this attitude, the question here is what can we expect from protecting or not protecting human-made reefs? Given the present extent of our knowledge about marine ecosystems and fisheries, and even if we are uncertain about the outcome of the attraction/production debate, we can look at the most likely best and worst outcomes of the protect/no-protect policies as though they were the four cells of a game (Table 1). The matrix shows clearly that the best policy in the face of uncertainty is to protect HMRs as no-take areas. At CARAH, in the rigs-to-reefs debate, Frumkes and Frumkes (1999) showed why California rigs used as reefs should be protected from fishing. In a HMR programme in Hong Kong, Clarke *et al*. (1999) described stakeholder consultations that provided unexpected support for no-take reefs. In one interesting plan, a small number of reefs would be opened to licensed fishing so that coastal fishers would learn its effects and help in monitoring.

The Philippines government, evidently influenced by those supporting the 'attraction' side of the debate, is rumoured to have banned artificial reefs (A. Vincent, personal communication). Romero (1996) called for the protection of HMRs in the Philippines to preserve depleted fish stocks. Although protection and enforcement are, at first sight, expensive, local community support may not be so hard to achieve. For example, the Philippine fishing village of Handumon set up a pilot no-take marine reserve. Soon, neighbouring villages asked to join in the scheme after witnessing the success for local small-scale fisheries (A. Vincent, personal communication). We suggest that, far from banning human-made reefs, the value and popularity of such a community-supported, no-take reserve could be enhanced by deploying HMRs where reef habitat is limited or has been damaged.

The need for ecosystem modelling

In 1623, another famous Italian living near the Ligurian coast, Galileo, published *Il Saggiatore* (*The Assayer*), dedicated to Pope Urban, who, unlike Galileo's later books, received this one enthusiastically. Galileo wrote ''The book of Nature . . . is written in the language of mathematics' (Pitcher 1999). At the CARAH meeting, the keynote paper by one of us (Seaman 1999) pointed out that the 'language of mathematics' had been sadly lacking in human-made reef studies, and called for more quantitative modelling studies of HMR systems. In the event, the keynote paper by the other of us (Pitcher *et al*. 1999) presented some spatial ecosystem simulations that attempt to forecast the recovery of fisheries after the planned deployment of HMRs in Hong Kong.

[2]But see the Society for Underwater Technology's conference on 'Man-made (*sic*) Objects on the Sea Floor', London, UK, May 2000 (http://www.sut.org.uk/htmfoldr/sut_events.htm).

Table 1 Probable best- and worst-case scenarios of protected and unprotected HMRs.

	Best outcome – production	Worst outcome – attraction only
Protect	Biomass recovers and provides a major enhancement to fishery catch	Attracted biomass maintained inside protected area
Not protect	Minor advantage to catch as biomass recovers faster than depletion	Attraction to reef causes depletion

The South China Sea and the adjacent East China Sea have been devastated by fishing (Chen *et al.* 1997; Silvestre and Pauly 1997; Pitcher *et al.* 1998). In Hong Kong, where heavy trawling has changed benthic structure and fauna (Gomez *et al.* 1990), there is a brave attempt to turn the tide by deploying protected HMRs (Wilson and Cook 1998). Because single species models do not stand much chance of capturing the quantitative and qualitative shifts in ecosystem processes after the establishment of HMRs, Pitcher *et al.* (1999, 2000) reported to six different sectors of the Hong Kong fishery a new method of ecosystem modelling to forecast the relative costs and benefits of alternative reef sizes and designs. This work used ECOSPACE (Walters *et al.* 1998, 1999) a spatially explicit derivation of the ECOSIM modelling system (Walters *et al.* 1997), and a quasi-spatial modelling tool that can examine the consequences of a range of sizes of closed areas (Watson and Walters 1998; Watson *et al.* 2000).

Ecosystem modelling is a relatively new departure in fisheries research that is part of a major shift in paradigm from an essentially single-species view, associated with a belief that fishing causes only minor and reversible changes to marine ecosystems, to an ecosystem perspective that analyses large, ratchet-like impacts (Pauly *et al.* 1998b; Pitcher 2000).

Conclusion: how Petrarch's Principle can help

Petrarch's 'knowing things without seeing them'[3] means that we should act to use common-sense methods to restore and protect today's depleted ecosystems even when we do not yet have definitive scientific evaluation. *In extremis*, to hesitate is to be lost. We now know enough about the effects of fishing on aquatic ecosystems to adopt policies that minimize the risks of incomplete information, uncertain process and poor compliance, and put the burden of proof of no-harm onto those who benefit from exploitation (Dayton 1998). This aspect of Petrarch's Principle foreshadows the Precautionary Principle (Clark 1996).

But secondly, Petrarch's 'seeing things while ignoring them' means, at best, to fail to recognize evidence, or, at worst, to hide behind false objectivity and to pretend that the obvious is not so. A now-classic example of this second aspect of Petrarch's Principle in fisheries is the failure of Canadian fisheries scientists to 'see' evidence of the collapse of the northern cod in the 1980s (Finlayson 1994). Indeed, many still do not 'see' the evidence of devastation in the oceans caused by fishing. So the second aspect of Petrarch's Principle reflects the paradigm shift described by Kuhn (1996), who showed how scientists on opposite sides of a revolutionary divide ''work in different worlds'', just as those who 'see' or 'do not see' fishing human-made reefs prejudicing the recovery of ecosystems, fish stocks and fishery catches.

Applied to protected HMRs, the concepts derived from both faces of Petrarch's Principle can be used to hedge the risks of wrong models, inaccurate data and ineffective management. It supports the evidence reviewed at the CARAH conference that suggests that HMRs will restore depleted fish production and fishery catches if designed and deployed carefully, and if (and probably only if) they are protected from fishing. Moreover, Allison *et al.* (1998) show that protection from fishing in no-take marine reserves is necessary but not sufficient for rebuilding – here we suggest, following Bortone's (1998) call for the broader application of reefs in fisheries management, that protected HMRs may plug the gap.

Nevertheless, although it is tempting to claim that protection from fishing is sufficient to promote a beneficial outcome from HMRs, and despite the encouraging increase in studies between Seaman and Sprague (1991) and Seaman (2000), there is still a paucity of data such that rigorous examination and experiment will be needed to turn the tide definitively on the production/attraction debate. It is also essential that the objectives of reef building be articulated carefully and that the life-history requirements of species be understood and addressed in reef design. But while it is always true that ''more

[3]Note that this echoes the preamble of the US constitution: ''We hold these truths to be self-evident ...''.

work is needed'', in this case Petrarch's Principle allows us to make some informed sense of the large amount of data we already have.

Finally, we return to our use of the term 'human-made reefs'. The term 'artificial' has negative connotations (in the sense of *ersatz*) that do not help us to see clearly the potential benefits and the dangers of these reef systems. A similar example is the replacement of the term 'artificial lake' vs. 'human-made lake' (Pitcher 1995).

The proceedings of the 7th CARAH conference are available (see Relini *et al*. 1999b), and readers will be interested to learn that about 50 peer reviewed papers will be published in a special issue of the *ICES Journal of Marine Science*, while others will appear in *Biologia Marina Mediterranea*.

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