ARTIFICIAL REEFS: NOTHING MORE THAN BENTHIC FISH AGGREGATORS

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ABSTRACT

The potential for artificial reefs to substantially increase standing stock of marine resources is considered. Three sources—the Japanese artificial reef program; relationships between fishery production and the area of natural habitat for several fisheries; and population dynamics—offer evidence that artificial reefs do not substantially increase the standing stock of marine resources.

RESUMEN

Se considera el potencial de los arrecifes artificiales para aumentar sustancialmente el stock disponible de los recursos marinos. Tres fuentes de evidencia: el programa de arrecifes artificiales japonés, la relación entre producción y área del hábitat natural de varias pesquerías, y la dinámica de poblaciones, indican que los sustratos artificiales no aumentan sustancialmente el stock disponible de los recursos marinos.

DISCUSSION

Artificial reefs can be excellent fish aggregators, but they do not effectively increase standing stock. This position will be supported with three types of evidence: first, with observations from the Japanese artificial reef program; second, from the relationship between habitat and fishery production; and finally from considerations of population dynamics.

Between 1976 and 1987, the Japanese spent U.S. $4.2 billion to construct and deploy 6,443 artificial reefs, covering 9.3% of the ocean bottom from shore to a depth of 200 m (Yamane, in press). But despite this enormous volume of artificial reefs deployed in coastal water, there has not been any measurable increase in coastal fishery landings (Japan: Statistics and Information Department 1984). Studies specifically investigating the impact of the artificial reefs have generally not documented any significant increases in fish production that can be attributed to the reefs (Kawasaki 1984; Kakimoto and Okubo 1985). After three visits to Japan and numerous discussions with people involved in all aspects of the Japanese artificial reef program, I believe the real benefit of the reefs is that they aggregate wide-ranging fishes close to shore so they can be harvested by fishermen with small vessels and thus keep the fleet of small vessels economically viable.

Outside of Japan, artificial reefs have not been deployed on a large enough scale to evaluate their effectiveness in increasing standing stocks. However, examining the relationship between habitat and fishery production can provide estimates of the level of fishery yield per area of habitat that might be expected from appropriately designed and sited artificial reefs. One example is penaeid shrimp: worldwide fishery yields range from 8 to 200 kg/hectare of intertidal nursery habitat (Turner 1977). In the case of artificial reefs, yields are measured in production per unit of reef volume. Thus if a square meter of intertidal habitat is assumed to also contain about a meter of vertical structure, grass, or mangrove, then these yield figures are equivalent to 0–0.02 kg/m^2. Another example is the coral reef systems, from which fishery yields have been reported in the range of 5–20 t/km^2 (Marten and Polovina 1982). If one square meter of coral reef habitat is conservatively assumed to be equal to one cubic meter of reef volume, then production per volume of reef habitat is 0.005–0.02 kg/m^3.

To put this production-per-unit-of-habitat volume in perspective, I will relate it to an example from California, where recent annual commercial landings for rockfishes are about 15,000 metric tons (MT) (California Department of Fish and Game 1987). I will assume that the average figure for fishery production per habitat volume from coral reef fisheries, 0.01 kg/m^3, can be applied to rockfishes. I will further assume that artificial reefs can be ten times more effective than natural habitat that might include barren or unproductive areas. With a level of fishery production of 0.1 kg/m^3 of habitat volume, it would require 15 million m^3 of artificial reefs to increase the annual rockfish catches by 10%. At the extremely low cost of $10/m^3 of reef for construction and deployment, this would cost $150 million. To put 15 million m^3 of artificial reefs into perspective, consider a space 100 × 50 m, about the size of a football field, covered with 1-m cubes. One such field would contain 5,000 m^3; therefore, 3,000 such fields covered with 1-m cubes would equal 15 million m^3. Of course the major flaw in this brute force approach to fishery enhancement is that even if this enormous volume of artificial reefs was built and deployed, any benefits would not be noticeable, because landings annually fluctuate by 10% to 20%. That is exactly one of the lessons the Japanese learned with their $4.2 billion experiment.

There is also the question of which resources lose habitat when low-relief habitat is covered with artificial reefs. There is a perception that low-relief habitat is not used by important commerical species, whereas high-relief habitat is preferred by valuable species. This is often based on the observation that the adults are seen and caught in high-relief habitat. This has been commonly accepted in Hawaii, but recently, when correct sampling gear was used, the juvenile habitat of the very valuable deepwater snappers was found to be the low-relief, flat-bottomed, sandy habitat, which had been considered a biological desert. Large-scale deployment of artificial reefs on this flat, sandy-bottom habitat would have attracted shallow-water reef fishes at the cost of destroying juvenile habitat for the more commercially valuable deepwater snappers. In Japan, a study around an artificial reef site found that the artificial reef attracted some species and repelled others and that the effectiveness of the reef could be negative, depending on which species were attracted or repelled (Kawasaki 1984).

The wide ranges in the levels of fishery production per area of habitat suggest that, although habitat is necessary, it is not limiting to production. Current research suggests that for many species, population size is determined during the larval rather than benthic phase. For example, the adult population of the Caribbean coral reef fish, *Thalassoma bifasciatum*, is determined primarily by recruitment and not by the supply of space on the reef (Victor 1983). In another study, the survival of juvenile reef fishes was estimated for varying levels of recruitment, and survivorship appeared constant—independent of juvenile density on the reef (Sale and Ferrell 1988). These studies indicate that even for coral reef fishes that require reef habitat during juvenile and adult phases, more reef habitat would not increase standing stock.

Insight into whether a resource can be enhanced with artificial reefs can be obtained from the relationship between larval settement density and fishery catches. If the relationship is linear, then the same percentage of the larval settlement is caught by the fishery, independent of density. However, if the fraction of the settled larvae, which ultimately contribute to the fishery, declines as the density of settled larvae increases, then density dependence may be a factor, and artificial reefs, which provide additional habitat and reduce the density at some stage, may increase fishery production. A relationship between larval settlement and fishery catches is available for a spiny lobster (*Panulirus cygnus*) fishery in western Australia (Phillips 1986). This relationship is linear, indicating that the same fraction of the settled larvae are captured as adults by the fishery, independent of the level of larval settlement. Thus, even for a spiny lobster which requires shelter, larval settlement is the limiting factor to production, and even at high postlarval densities, habitat is not limiting to fishery production.

Artificial reefs are often suggested as a solution to overfishing. Yet they do not help if either growth or recruitment overfishing is occurring. In the case of growth overfishing, they may aggregate younger fish, making them more vulnerable to capture and actually increasing overfishing. In the case of recruitment overfishing, standing stock is a fraction of its unexploited level, and habitat is certainly not limiting. Aggregating adults further simply increases catchability, and hence fishing mortality, which further reduces the spawning stock biomass.

Reefs are popular as management options because they do not require reductions in fishing effort and they aggregate fish, resulting in higher catches in the initial stages. Thus artificial reefs may actually be detrimental to the fishery and the stock simply because they allow managers to delay making hard but necessary decisions, such as imposing size limits or reducing effort.

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