

Biological Studies and Materials Comparisons on a Puget Sound Artificial Reef

By Jeffrey C. Laufle

For centuries, fishermen have known the value of artificial reefs. These structures, when placed on otherwise barren lake or ocean bottoms, attract and concentrate fishes. Several scientific studies have been done to determine how fishes use artificial reefs. It has become apparent that both food and shelter benefits are derived by the fishes.

The Washington Department of Fisheries (WDF) began a program of artificial reef installation in Puget Sound in the mid-70s, with the goal of enhancing sport fishing. So far, four reefs have been constructed, and more are planned. Two are associated with public fishing piers, and two are off-islands and aimed at boat anglers.

The reefs were constructed of concrete rubble, bundled automobile tires, or both. The WDF contracted with the Washington Cooperative Fishery Research Unit at the University of Washington to determine which was the more effective material from biological and other standpoints. The study site was Blake Island, near Seattle in Puget Sound, where one of the boat-angling reefs had been built with both tires and rubble. The natural bottom there is a mix of sand, gravel and cobble. The tires were in a configuration called "triads" and about 50 of these units were placed in groups of around five to eight, both on and off a large area of previously placed concrete rubble. These materials were at about 45 to 60 feet depth (mean lower low water), although a smaller pile of concrete rubble lay at a depth of 85 to 95 feet.

We established six experimental survey areas: three on and three off the rubble. The areas (each 36 m²) contained either three triads bundled together, two separated triads, or no triads for a control. In addition, the entire deep rubble reef (about 464 m²) was used as a seventh survey area, and a kelp bed transect inshore was an eighth. These areas were censused for fishes, using SCUBA, once each month

during the day for 15 months, and once a month at night for 12 months, starting in fall 1980.

All fishes that we saw in an area were identified, counted, and their lengths estimated with the aid of ruled edges on plastic recording slates. From the length estimates, we could estimate weights later with length-weight equations already available. Fishes that were inside, under, touching, or otherwise positioned very close to the tires were defined as associated, for this study.

We found 24 species of fishes in all the study areas combined. For the individual habitats the totals ranged from six species (for the bare natural substrate) to 12 to 14 on the artificial habitats. The dominant family was the *Embiotocidae*, or surfperches. The four species representing this family were the only schooling species in the study areas. The striped seaperch (*Embiotoca lateralis*) was often the most important of any species, in terms of numbers and frequency of occurrence, and sometimes biomass. Rockfish (family *Scorpaenidae*, *Sebastes* spp.) were the second most common and abundant group, and were represented by three species. Copper rockfish (*Sebastes caurinus*) were the most important of these.

Although schooling species of rockfish are found in Puget Sound, we saw none. The Hexagrammidae, or greenlings, and the Cottidae, or sculpins, were the two remaining families we saw with any regularity. Very small (2-5 cm.) sculpins were present on all habitats, but they were difficult to detect and were ignored because of the large effort which would have been required to census them. Similar patterns of species groupings occurred on the various artificial habitats. Although no statistical similarity occurred between assemblages on artificial and natural habitats, neither were there any radical differences between these two habitat types.

We found that density and biomass of fishes were



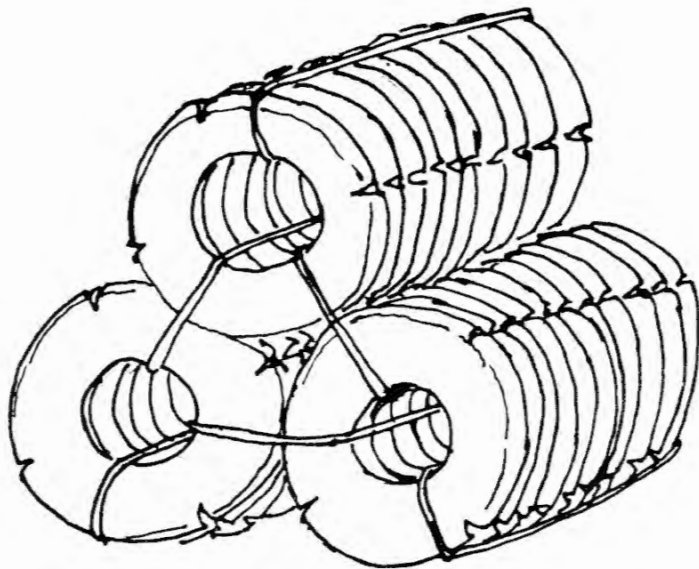
Striped seaperch (*Embiotoca lateralis*) near large scrap manhole box forming part of concrete rubble reef at Blake Island. Encrusting organisms on concrete are primarily barnacles and tubeworms, which build calcareous tubes.

much higher on the artificial habitats than on the natural habitats (including the kelp bed). That the reef should concentrate fishes was not surprising, since this was the premise behind its installation. It seemed puzzling, though, that fishes should have been so sparse in the kelp bed. Kelp provides another form of structure, and such areas are well-known to sport fishermen for their productivity. Part of the explanation is that the kelp forest virtually disappeared in the winter, but even in summer the fishes simply were not found there in any great numbers.

Of the three triad arrangements in the experimental areas, including the control areas with no triads, the three bundled triads were somewhat better at attracting fishes than the others. Two factors qualified this result. First, the separated triads on the natural substrate moved in the tidal current. They remained connected by a length of rope, but when they were relocated, they had accumulated a layer of sand, and appeared to have dug into the surrounding sediment. Very few fishes were associated with them until much later in the study; we think that this sort of disturbance may be detrimental to resident fish communities.

A second qualification on the superior attractiveness of the bundled triads was that they were not as consistent for fishes on the rubble as on the natural substrate. The fish seemed to orient more toward the general vertical relief than they did to one material or the other. The schooling species (the surfperches) moved around the entire reef in small or large aggregations. They foraged for small crustaceans in the algae growing on the different materials, as well as on the sand/cobble substrate. The rockfish could be found near the bottom, either associated with the tires or not. It was difficult to predict where they would occur. Much the same was true of the other species of bottomfish on the reef.

Fishes oriented to triads on natural sand/cobble substrate over a broader area than they did to the triads on the concrete rubble. On the natural substrate, the triads were the only nearby relief, whereas those on the concrete rubble had the rubble itself sur-



Triad unit, made of automobile tires tied together with polypropylene line and slit to allow air to escape. Triads were either further bundled together or kept separated for the Blake Island artificial reef study.

rounding them. Fishes might be associated with either tires or concrete, but the important variable was the vertical relief.

It was apparent, then, that most fish species were not choosing between the two types of material. The exception was the lingcod (*Ophiodon elongatus*), not a cod at all, but a large, economically important demersal predator of the family Hexagrammidae. This species spawns in the wintertime, with the male setting up a territory where the female deposits an approximately basketball-sized egg mass. The best areas for spawning appear to be those with good currents for ventilation and where there are crevices in which to lodge the egg mass. The male then guards the mass over a six to seven week incubation time.

Lingcod spawned on the concrete rubble reef, but never on the tires. There are moderately strong currents at the site, and plenty of crevices among the rubble. We monitored the nests in the winter of 1981 and part of the winter of 1982. In 1982 we found that three nesting sites marked in 1981 were being used again, confirming observations of others in northern Puget Sound on the recurring use by lingcod of natural substrates.

These results are significant for several reasons. First, the lingcod made a choice between materials, spawning on rubble exclusively. Second, outside of current WDF research, we know of no documentation of lingcod spawning on artificial reefs. Spawning has been reported on breakwaters, but the material was natural quarry rock. Third, egg masses observed on the deep rubble, at 89 and 95 feet, represent the deepest documented spawning thus far. Fourth, and perhaps of greatest importance, fishery statistics have indicated a serious decline in lingcod stocks in Puget Sound, prompting a total moratorium by the WDF on sport and commercial lingcod fishing in the south and central Sound, starting in 1978. The WDF has had a multifaceted program of lingcod research and enhancement in operation, and while artificial reefs are a separate program, we see great potential for their use in resorting lingcod populations.

Other factors in the analysis are cost and stability. Based on figures made available by the WDF, who were responsible for installation of the reefs, the concrete was much cheaper than were the tires per unit of bottom area covered. Costs vary depending on the scale of the operation, whether materials are donated or must be paid for, and whether they must be barged any distance. One large reef built of tires by the WDF off a mainland shore in Puget Sound was cheaper per unit area than the tires at the Blake Island site, but still somewhat more expensive than concrete rubble. In addition, the tires were less stable in currents than was the concrete, and required careful anchoring and several man-hours of diving to install. The concrete needed only to be transported to the site and unloaded from a bottom-dumping barge.

So we have the cost and stability aspects, and apparent lack of preference by fishes for either material, with the important exception that lingcod chose the rubble over the tires for spawning. The main result from additional monitoring of invertebrate and algal populations on the reef is that a food web in probably adequately supported on both tires and concrete. Thus, we came to the conclusion that of the two materials tested, concrete is probably better for this environment.

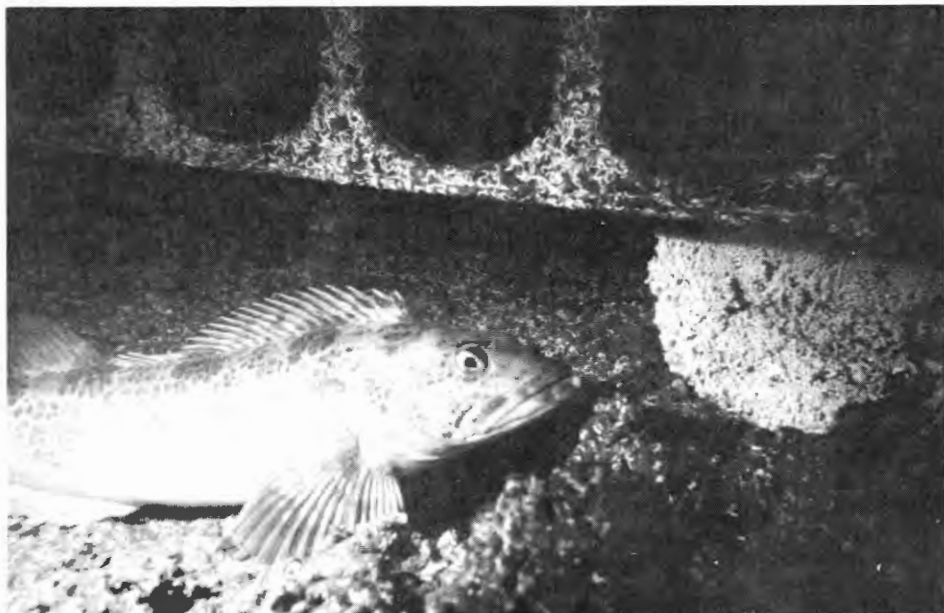
The work reported here is only a beginning, however. The Japanese and Taiwanese have advanced artificial reef technology well beyond work in this

country, with large scale operations, and examination of chemical, geological, and hydraulic factors. Patented designs are being marketed, and we have much to learn from their efforts. A major obstacle is the lack of good translations of reports.

It may be some time before we reach the level of sophistication the Asians have attained in this field. As long as we use scrap materials to build our own reefs, it would be appropriate to caution against planning a reef whenever we need to dispose of nondegradable waste such as tires. Artificial reefs can be good avenues by which to do this, but a careful approach and wise planning cannot be overemphasized.

Park managers who wish to create new recreational areas using this technique obviously need to consider several factors, not all of which have been discussed here. The reef we studied was created for fishing, and not SCUBA diving, although the latter is apparently going on there. However, since spearfishing, for example, is so efficient, it would seem better to design an underwater park for nonconsumptive uses such as photography. To this end a natural area might be better than an artificial reef.

Laufle, a master's research assistant, works out of the University of Washington Fishery Research Unit.



Male lingcod (*Ophiodon elongatus*) guarding egg mass (right), which has been deposited under concrete slab at Blake Island artificial reef. Fish is about 60 cm in length; egg mass is about 25-30 cm in diameter.



Quillback rockfish (*Sebastes maliger*, top center), and **copper rockfish** (*S. caurinus*, center), associated with tire unit at Blake Island artificial reef.