Marine Habitat Enhancement and Urban Recreational Fishing in Washington

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Introduction

In 1974 the Washington Department of Fisheries began a marine fish enhancement program designed to establish marine habitat enhancement (artificial reefs) and public fishing piers as accepted forms of fishery technology for improving urban recreational fishing in the Puget Sound region (Fig. 1). Both artificial reefs and fishing piers have been used extensively for many years in some of the Atlantic and Gulf Coast States and in California to improve recreational fishery catches and access in previously unproductive fishing locations (Steimle and Stone, 1973; Rickards, 1973; Fable and Saloman, 1974). In contrast, Washington's pier fishing facilities were limited to a few access areas on commerce docks, and earlier artificial reef efforts were small-scale projects designed to provide underwater recreation areas for scuba divers. None of these projects were primarily for shore fishing access or urban fishery enhancement.

Recreational fishing in Pacific Northwest marine waters has been synonymous with fishing for Pacific salmon (*Oncorhynchus* sp.) from small boats, and this axiom has pervaded from anglers, through fishery managers, to the funding sources. Consequently, a new program directed at enhancement of other marine fish species—using locally unproven techniques, and partially targeting these fish for an essentially unrecognized clientele—was met initially with feelings ranging from skepticism to enthusiasm. Fortunately, a significant amount of the enthusiasm to try habitat enhancement and public fishing piers was generated with the State government funding sources (i.e., the legislature and the Interagency Committee for Outdoor Recreation), the fishery clientele, and local government agencies and service organizations. This provided the broad base of public awareness and support which resulted in rapid funding of the initial projects.

During the first 7 years, the concepts of the marine fish enhancement program have been well received by the fishery clientele and have proven relevant to fishery management in Washington. Biologically, habitat enhancement structures placed in open, relatively unproductive marine locations successfully increase the areas' density and biomass of biota common to productive natural rocky reefs. Sociologically, public fishing piers have become extremely popular access locations for shore anglers previously denied use of the marine resources, and offshore "fishing reefs" near metropolitan areas have created valuable recreational benefits which are easily accessible to all boat anglers. Economically, habitat enhancement projects and public fishing piers compete very favorably with other forms of outdoor recreation for the public funds dedicated to recreational use.

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ABSTRACT—A marine fish enhancement program started in 1974 has emphasized the use of habitat enhancement structures (artificial reefs), both in conjunction with public fishing piers and to create "fishing reefs" for boat anglers, to improve urban recreational fishing in Puget Sound. The enhanced areas were designed and sited to develop biologically into replicates of natural rocky reef communities in order to promote productive fisheries.

The site selection process was based on indexes of the macrobiota assemblages on rocky reef control areas in the same region and on consideration of potential impacts on fisheries and commerce. Experimental design strategies for both the entire habitat enhancement area and the individual enhancement structures were used to determine the optimum balance between aggregation and production of target species and management for sustained, quality fisheries. Major structural design elements were found to be horizontal and vertical relief and numbers and sizes of interstitial spaces. Abundant and diverse algal growth on the enhancement structures increases habitat complexity and heterogeneity, and may well be the most important element in the transition from introduced materials to replicates of productive natural reefs. Successional development of fish communities appears to proceed from a principally aggregated species base during initial colonization to a "forager-aggregater" community structure as food items develop on the enhancement structures.

This progress justifies application of enhancement technology to "real" fishery management problems, in which solutions maximizing accessibility to all facets of the recreational fishery provided the greatest benefits to the public.

The objective of habitat enhancement, used either in conjunction with fishing piers or to create "fishing reefs" for boat anglers, was to establish enhanced areas that developed biologically into replicates of productive, natural rocky reef communities, with resilient populations of target species of fish which could withstand frequent fishing. The biological investigations related to habitat enhancement have been designed to understand and utilize the artificial reefs from the perspective that the only "artificial factor" in the reef is the original placement of the inert base material around and upon which the living, natural reef community evolves. An understanding of the factors influencing this development enables construction of habitat enhancement complexes compatible with environmental and biological constraints.

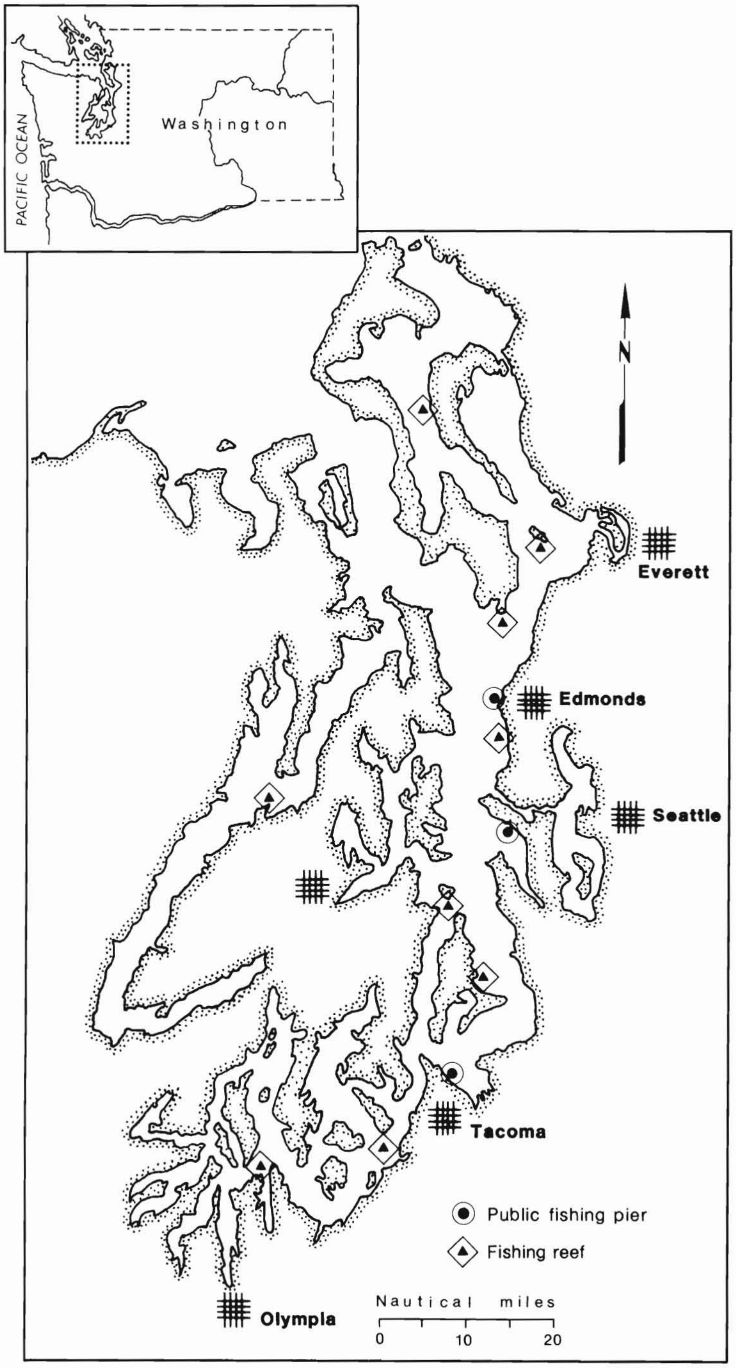

Figure 1.—Locations of habitat enhancement areas in Puget Sound, Wash.

Program Design and Methodology

The increasing demands for improvements in urban recreational fishing opportunities that were being recognized on a national level in the mid-1970's were also developing in the metropolitan areas of Puget Sound (PNRBC, 1970; BOR, 1977; Stroud, 1977). This emphasis on urban recreation offered the most potentially productive situations where applications of marine habitat enhancement would demonstrate the value of this technology in modern fishery management.

Many target fishing locations for rocky reef-oriented fishes adjacent to the metropolitan centers of Puget Sound began receiving more frequent use in the middle to late 1970's. This resulted from increasing interest in these previously less popular fishes, caused, in part, by curtailments in the fisheries for Pacific salmon dictated by the 1974 Boldt Decision (Williams and Neubrech, 1977) on treaty Indian fishing rights and, in part, by dramatic increases in energy (fuel) costs to reach more distant fishing grounds.

Many of these rocky reef sites were limited in area and habitat diversity and, therefore, supported vulnerable populations of the resident demersal fishes needed for a continuous fishery. Catches began decreasing in many of the more popular and accessible locations, and anglers either invested the additional

Figure 2.—The Edmonds Public Fishing Pier.

costs to travel to more productive locations, modified their criteria for productive catches, or withdrew from the fishery. Strong public sentiments developed for more productive urban fishing locations accessible (economically) to a broad spectrum of recreational anglers. The use of marine habitat enhancement to create productive nearshore fishing sites was an obvious and timely solution to this problem.

The introduction in 1975 of large public fishing piers (Fig. 2) to the urban recreational fishery scene in Washington presented an excellent "vehicle to gain visibility" for marine habitat enhancement in an essentially risk-free manner. Metropolitan areas in Puget Sound had the potential for developing a large pier fishing clientele, but there were no available facilities designed and sited specifically for recreational fishing. Most of the metropolitan centers bordered marine waters with good biological production potential and excellent fishing depths (from −27 to −55 m MLLW [mean lower low water]). This new urban fishery was virtually guaranteed to provide popular, accessible, and affordable participation in marine recreational fishing for all anglers, regardless of age or physical ability (Buckley and Walton, 1981).

The public fishing piers in Puget Sound created intense, concentrated fisheries that could not enjoy sustained catches without dramatically increased aggregation and production of important species of fish in the pier areas. The construction of large habitat enhancement complexes around the piers increased the areas' production of resident and semiresident species, and provided feeding and orientation sites for aggregation of transient species—both important in sustaining quality catches in a continuous fishery situation. This combination of fishing piers and habitat enhancement brought the concepts and benefits of habitat enhancement into contact with the maximum number of anglers in a "high profile" fishery at the start of the marine fish enhancement program.

Later use of habitat enhancement to create "fishing reefs" for the boat fishing clientele was the first application of this technology to benefit an established recreational fishery in Washington. These "boat angler reefs" were sited every 18-28 km along the 185 km cruising route from southern Puget Sound north to the San Juan Islands, and were also accessible from major recreational fishing boat launch facilities. This provided the opportunity both to occasional "yachting anglers" and avid small-boat anglers, representing the bulk of the recreational fishing effort on Puget Sound, to utilize habitat-enhanced fishing locations.

The base of interest and support for the marine fish enhancement program that developed in the public sector was complemented by the very important acceptance of the same concepts within the relevant scientific community. This resulted primarily from the promotion and use of marine habitat enhancement as a fishery management tool which secondarily had the capacity to recycle specific types of solid wastes under ecologically acceptable conditions. There is some evidence that earlier local (and national) emphasis on relating artificial reef construction to deposition of a variety of solid waste materials in the marine environment resulted in waste disposal often being perceived and promoted as the primary justification for reef construction. A further consequence of this misconception was the trend that artificial reef projects had to be minimal budget operations supported by donations of materials and volunteer labor, which led to the traditional corollary that artificial reef projects did not require public funds and, therefore, had little intrinsic value. In contrast, the representation of marine habitat enhancement as a valid fishery management technique worthy of investment, the same as freshwater fish-producing facilities (and lacking anything synonymous with the term "artificial"), utilized this traditional view in a positive manner and supported the investment of public funds through the use of donated materials, when appropriate.

The Washington Department of Fisheries receives construction funds for marine fish enhancement projects as part of the State legislative biennial appropriations for the agency's Capital Outdoor Recreation Budget. The source of these appropriations is a 50 percent State Government/50 percent Federal Government matching fund administered through the State's Interagency Committee for Outdoor Recreation. The State's share of the fund is obtained from voter-approved Referendum Bonds for recreation. The Land and Water Conservation Fund, administered by the Heritage, Conservation, and Recreation Service (absorbed by the National Park Service in June 1981) of the Department of Interior, supplies the Federal matching funds. The implementation of these capital appropriations, and the research supporting the marine fish enhancement program, are funded by the biennial Operational Budget of the Marine Fish Program.

Since the inception of the marine fish enhancement program in 1974, $3.2 million in capital funds have been appropriated for marine habitat enhancement and public fishing pier projects. The 1981-83 Capital Budget included $2.5 million for 14 habitat enhancement projects, three associated with public fishing piers. An additional $1.2 million is scheduled for appropriation for another fishing pier project in 1983. This funding base, which has established two public fishing piers and two "boat angler fishing reefs" and has one fishing pier and eight fishing reefs under construction, is only as stable as its two funding sources. Anticipated Federal reductions and delays in the Land and Water Conservation Fund appropriations to the states in 1982 will cause severely curtailed construction schedules, and have created interest in establishing a 50 percent Federal Government/50 percent local government matching fund approach for some projects. This release of State Government funds would enable 100 percent State funding of some projects, if current economic inflation factors do not prohibit continued sale of recreation bonds.

Site Selection, Facility Design, and Fishery Management

Successful biological development of habitat enhancement projects in marine waters is a key prerequisite to productive fisheries on the enhancement structures. To maximize the potential for biological development, a site-selection process was used which relied heavily on a biota indexing comparison system developed for the Puget Sound region (Hueckel and Buckley[1]). This system was based on indexes of the macrobiota assemblages on three natural rocky reef control areas which had stable, diverse communities of algae, invertebrates, and fishes, and were productive recreational fishery sites. Biota common to all three areas were assumed to typify those that would occur on habitat enhancement structures placed in areas with the environmental parameters conducive to productive biological development.

Transects conducted on potential habitat enhancement sites qualitatively assessed the biota in relation to prevailing substrate characteristics. Artifacts and substrate anomalies on the site (such as atypically large rocks, logs, and man-made debris, Fig. 3) were examined carefully. Their attached and related biota were representative of the biota that would develop on the site with the addition of stable material to increase the diversity and relief of the substrate. A high percent overlap between the control site and enhancement site biota was indicative of a good habitat enhancement site, although the opposite relationship was not necessarily true, espe-

[1]Hueckel, G. J., and R. M. Buckley. Site selection procedures for marine habitat enhancement in Puget Sound, Washington. In prep.

Figure 3.—Auto-tire artifact on sand substrate.

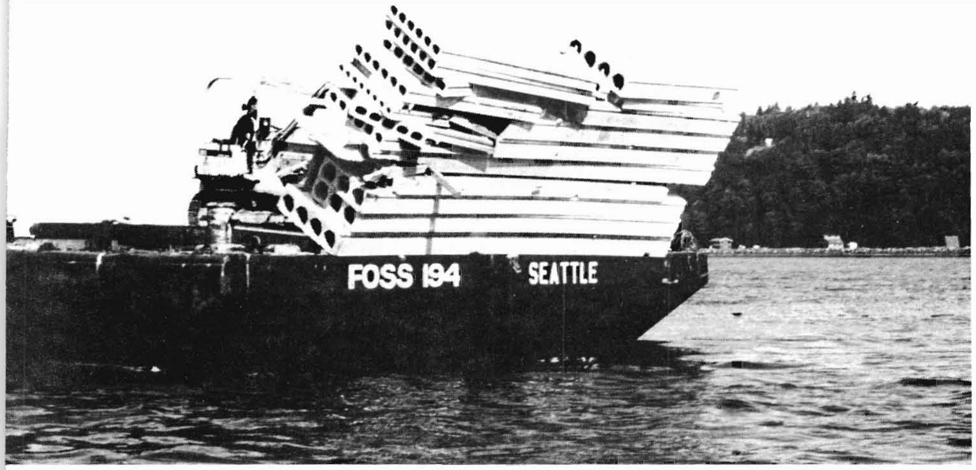

Figure 4.—Scrap concrete used for habitat enhancement construction.

cially if rocky reef simulating substrates were not available.

The site-selection process also considered several other factors relevant to ensuring that the habitat enhancement structures attracted desirable biota and fishery utilization, and not unwanted sediments or commercial fishery nets. Conflicts with existing and future fisheries were analyzed to avoid overlapping utilization of the area, if possible, or to determine the most beneficial use of the site. Conflicts with commercial vessel traffic were avoided, both in relation to vessel draft restrictions caused by the enhancement structures and to surface congestion caused by fishing boats. The proximity of the enhanced site to recreational access locations was also important to facilitate utilization and, therefore, maximum public benefits.

Various design strategies for both the entire habitat enhancement areas and the individual enhancement structures were used to determine the optimum balance between aggregation and production of target species and management for sustained, quality fisheries. These experimental design considerations required habitat enhancement construction techniques that went far beyond the "random dump and hope" methods used in earlier artificial reef projects, occasionally involving underwater construction and placement of enhancement structures by scuba divers.

The habitat enhancement complexes surrounding public fishing piers cover from 1.5 to 2.0 hectares, which are far larger areas than can be fished from the piers. This design strategy makes 20-30 percent of each pier's enhanced area accessible to pier angler's gear, and allows the bulk of the enhancement structures to build reserve populations of resident and semiresident fishes to replenish removals by the pier fishery. A companion management strategy reserves these populations for pier anglers by closing the enhancement areas to all other fisheries. The "extra large" enhanced areas and the associated biota also serve as attractive target feeding locations for transient (often pelagic) species of fish, holding them within reach of the pier fisheries for extended periods.

Individual habitat enhancement structures are located either under the pier or outside of a 23-30 m perimeter surrounding the pier. This creates an "open zone" around the pier to minimize gear fouling on the enhancement structures and makes both open sand-bottom and rocky reef fish species available to the pier fishery harvest. Conservative harvest management regulations are being tested to provide recreational enjoyment at reduced levels of impact on these, usually resident, target species.

The habitat enhancement complexes creating fishing reefs for boat anglers utilize up to 10 hectares of the bottom between the −13 to −27 m MLLW depths. These rather extensive areas allow a design strategy that distributes and spaces both the enhancement material and the ensuing fishing effort. Research has shown that large peripheral open feeding areas are important to some rocky reef fishes during specific life history stages (Hueckel and Stayton, 1982) and that aesthetic enjoyment in a recreational fishery can be increased by reducing crowding in the fishing area. An extensive enhanced area also enables management strategies that disperse or relocate fishing effort to reduce the impacts on fish populations inhabiting specific enhancement structures, such as spawning aggregations, juvenile recruitment areas, or overfished target locations. This can often be accomplished by utilizing the "magnetic buoy factor" which results in recreational anglers fishing only around the buoy that marks the fishing reef. Fishing effort can be evenly distributed by periodically moving the buoy to different locations throughout the enhanced area.

Theoretically, a fishing reef for boat anglers is totally accessible (if totally locatable), and it is not practical to offset fishery removals through building reserve populations of fish by closing a portion of the reef to fishing. The potential for overfishing is, therefore, much greater on a boat angler's fishing reef than in an enhanced area associated with a fishing pier, and this factor must be considered in the fishery management strategy. Conservative harvest management regulations are usually inappropriate in these situations, as they would have to apply to large geographic areas surrounding the fishing reef to be enforceable and would unnecessarily restrict other fisheries.

Experimentation with the design of the individual habitat structures is being examined as a method to control the rate of fishery removals over a long period of time, especially for the resident and semiresident species which utilize the structures for productive habitat. Enhancement structures constructed from large, angular material (such as long, flat concrete planks, Fig. 4) create large cave-like habitats which have a high refuge potential from anglers' gear. This reduces (or controls) the fishability of the enhancement complex through physically preventing frequent contact between fish and fishing gear, but still allows harvest of those fish on the periphery of the structures. This construction technique also appears to minimize gear fouling on the structures.

Habitat Design, Colonization, and Ecosystem Development

The design of the marine habitat enhancement program in Puget Sound is based on directing the biota development on, and in close association with, the habitat structures toward a multispecies and multilife-history stage community. This follows the premise that biota diversity will lead to productive, relatively stable communities of organisms which have the resiliency to respond to fishery removals throughout development. However, it is apparent from other research that this premise may be flawed. In discussing a general hypothesis of species diversity, Huston (1979) pointed out that diversity has been both positively and negatively correlated with productivity by many authors. Sale and Dybdahl (1975) found that communities of coral reef fishes are likely to demonstrate only weak stability and that the equation "diversity = stability" has questionable validity. A saving (or modifying) factor may be that most of this work relates to tropical patch-reef situations and may not be totally applicable to temperate rocky reefs. Sale and Dybdahl (1975) also pointed out that a fuller understanding of community structure (and responses?) will urgently require far greater information on the biology of the species involved.

The work carried out to date in Washington's marine habitat enhancement program has shown that the design and relative spacing of enhancement structures influence ecosystem development in the enhanced area, from initial placement of the structures throughout their long-term development. Major structural design elements are 1) horizontal and vertical relief and 2) numbers and sizes of interstitial spaces. The latter element directly affects the sizes of the more cryptic fishes that colonize the structures and may also influence the species of fish and the sizes of some invertebrates. The spacing and sizes of the habitat structures affect the amount of interface with the surrounding pelagic and benthic environments, which has, as yet, an incompletely understood effect on interstructure relationships. It has been demonstrated that maintaining open

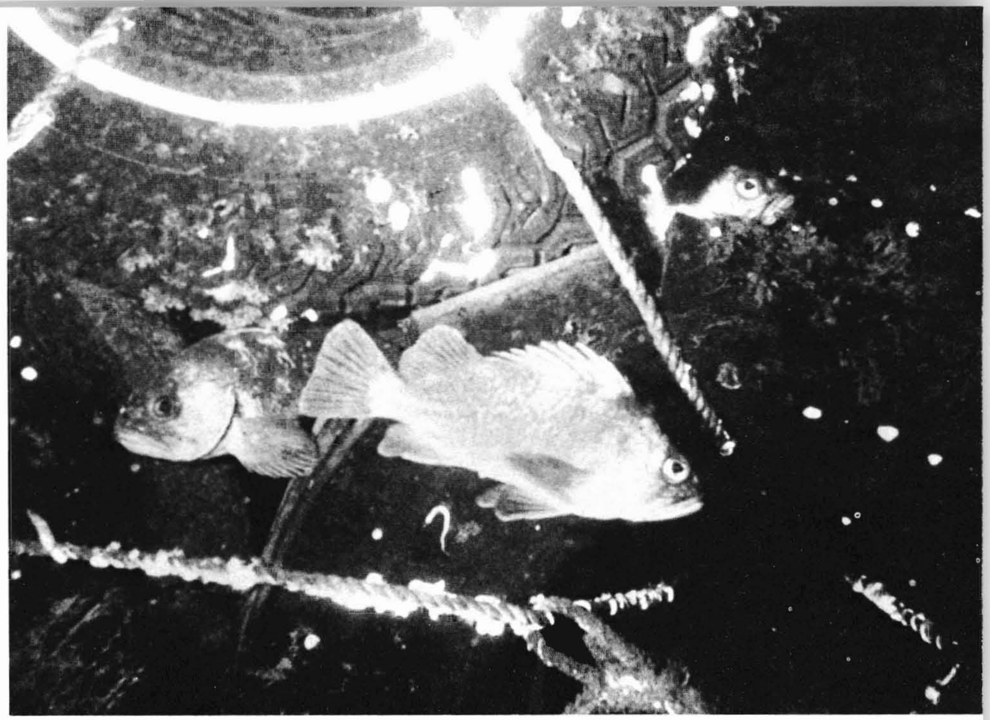

Figure 5.—Rockfish (*Sebastes* sp.) utilizing small habitats on an auto-tire module.

zones within the enhancement areas is beneficial to both reef species (Hueckel and Stayton, 1982) and nonreef species (Walton, 1979).

Current literature on reef colonization supports the view that determination of the actual factors controlling this process is a continuing question, especially in temperate regions (Fager, 1972; Talbot et al., 1979; Stephens and Zerba, 1981; and others). Brock et al. (1979) examined recolonization in coral reef communities and found that "the structure of reef fish communities may be the result of a mosaic of deterministic patterns and stochastic processes that occur during initial colonization and continue through time." This finding supports the general consensus in the literature that the various resource-partitioning, space-limited, predator-limited, lottery-hypothesis, resource-sharing viewpoints all have their own areas of credibility as mechanisms which influence colonization, diversity, and stability in reef fish communities. For example, Russell et al. (1974, in Brock et al., 1979) working on the Great Barrier Reef, noted that the physical structure of artificial reef habitats was relatively unimportant in determining early colonization community structure, and Nolan (1975, in Brock et al., 1979), working in the Marshall Islands, could not find any obvious correlation between artificial reef substrate complexity and fish species diversity. However, Walton (1979), working in the Pacific Northwest, found that the structural design and physical placement of artificial reef modules affected the density and biomass of associated fish populations.

The structure of temperate reef fish communities in Puget Sound may be heavily influenced by chance factors on the species level, as long as suitably sized habitats are available to meet the needs of the life history stages (sizes) of the species recruiting to the reef (somewhat deterministic biological patterns?). Rockfish (*Sebastes* sp.) colonization of the auto-tire module and rubble rock enhancement structures associated with the Edmonds Public Fishing Pier followed a definite pattern of association between fish size and habitat selection. Small interstitial spaces formed by rubble rock were utilized by small rockfish up to 15 cm in length, and tire modules (triads) with large cave-like openings and small crevices showed rockfish distributions based directly on habitat size (Fig. 5, 6). This same pattern was observed in the initial colonization of scrap concrete enhancement structures at Gedney Island by both juvenile and adult rockfish,

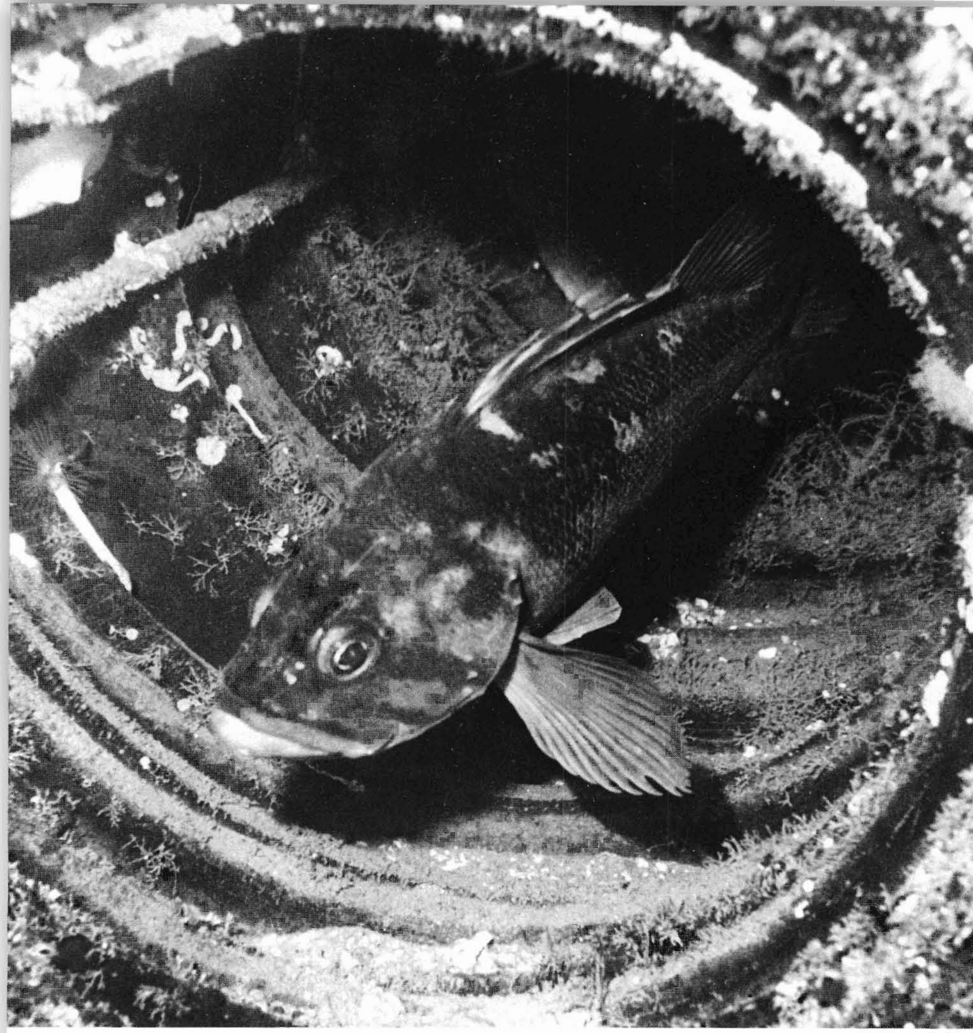

Figure 6.—Rockfish (*Sebastes* sp.) utilizing a large habitat on an auto-tire module.

Figure 7.—Juvenile rockfish (*Sebastes* sp.) utilizing a narrow protective habitat.

where (protective?) habitat selection was strongly size-related and the area appeared to be habitat-limited for juveniles (Fig. 7).

The suitability of the habitats formed by enhancement structures has also been observed to affect initial colonization by such diverse biota as 8 cm shrimp and 100 cm predatory fish. Protective habitat for the coon-striped shrimp, *Pandalus danae*, a major food item for many fishes, consisted of the smaller interstitial spaces and often included the same crevices used by juvenile rockfish which would later become shrimp predators. Spawning territories for lingcod, *Ophiodon elongatus*, were established at sites with the appropriate semiexposed crevice habitats suitable for retaining large egg masses (up to 0.5 m diameter), which solidify to the shape of the crevice to prevent dislodging when washed by tidal currents (Fig. 8).

Selection of construction materials and techniques which allow optimum vertical and horizontal distribution of a variety of interstitial spaces provides the best potential base for successful habitat enhancement in local marine waters. Equally important, however, are the long-term physical and chemical stability of the construction materials and the amount of photic-zone exposure of the enhancement structures, both of which influence algal community development. Scrap concrete, auto tires, and quarry rock are all acceptable substrate materials, offering firm, textured surfaces, although concrete is currently the most cost-effective, durable, and structurally desirable for local marine habitat enhancement.

Abundant and diverse algal growth on the enhancement structures significantly adds to habitat complexity and heterogeneity, allowing more species and more organisms to coexist in the enhanced areas. This may well be the most important element in the transition from introduced materials to productive natural reef replicates with stable communities. Sessile algae are major contributors to the physical structure of communities in the marine environment (Fager, 1972), and the microhabitats created by their holdfasts and upper structures are used extensively by a variety of invertebrates that are potential food organisms (Hueckel, 1980). The increased predator-prey interactions availed by the increased production of food items provide greater choices for energy transfer through the food web in

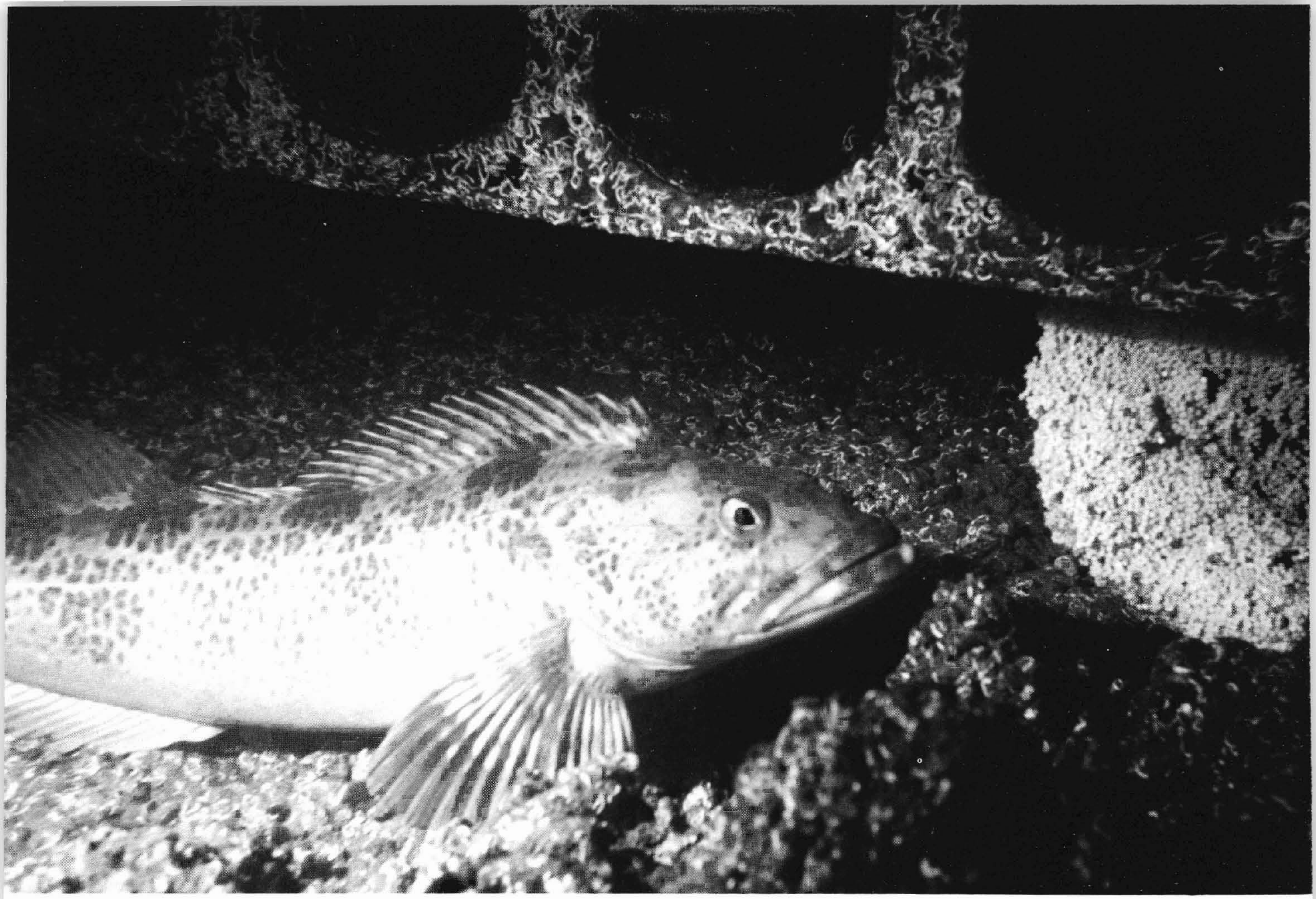

Figure 8.—Male lingcod, *O. elongatus*, guarding an egg mass.

the community, and the number of links in the food web is a measure of the stability of the community (Odum, 1953 in MacArthur, 1955).

The successional development of algae and invertebrates on substrates introduced into the marine environment has been well documented for many regions (Coe and Allen, 1937; Tsuda and Kami, 1973; Saito et al., 1976). Hueckel (1980) studied colonization of auto tire habitat enhancement structures at the Edmonds Public Fishing Pier for 24 months (1977-79) and found that algal development was very important to subsequent invertebrate colonization: "Prior to algal colonization, only [the crevice-related] coon-striped shrimp (*Pandalus danae*), two species of starfish (*Pycnipodia helianthoides* and *Evasterias troscheli*), acorn barnacles (*Balanus glandula*), and a sea anemone (*Metridium senile*) had been observed on the tires. After the development of algae on the tires, large numbers of gammarid amphipods, caprellid amphipods, harpacticoid copepods and hippolytid shrimp were observed associating with the algae .... *Platythamnion pectinatum* was the dominant red algae [Rhodophyceae] species on the artificial reef throughout the study. The filamentous structure and profuse branching of this species provided refuge for most of the microinvertebrates on the artificial reef." Walton (1979), studying the same enhancement structures, found that the species and numbers of fish increased with the age (increased development) of the habitats, the same pattern of development noted on nearshore artificial reefs in California and related to increasingly available food and shelter (Turner et al., 1969).

Acorn barnacles colonized the Edmonds enhancement structures in high numbers during the first spring, followed by rapid mortalities over a 4-month period, and never regained the initial high concentrations (Fig. 9). There is good evidence that this decrease was directly related to grazing by starfish (*P. helianthoides* and *E. troscheli*) and surfperch (*Embiotoca lateralis* and *Rhacochilus vacca*). Subsequent algal colonization occurred on the basal plates left after grazing and may have inhibited barnacle repopulation by preventing the larvae (cypris) from setting on the solid substrate. Red algae dominated the enhancement structures (approximately 95 percent coverage by *P. pectinatum*, and 5 percent by *Callophyllus* spp. and *Poly-*

neura latissima) and commenced to show the expected seasonal abundance cycle (Fig. 10).

This enriched habitat on the enhancement structures supplied microinvertebrate prey organisms (<2.5 cm in length) in concentrations up to 400/m^2, and macroinvertebrate prey organisms (including coon-striped shrimp) in concentrations up to 37/m^2 (Hueckel, 1980). Combined with additonal prey organisms occurring naturally in the surrounding sand substrate (Table 1), the entire enhanced area adjacent to the Edmonds Public Fishing Pier provided a productive feeding location for many species of fish (Hueckel and Stayton, 1982).

It is interesting to speculate (and possibly worth future consideration) whether ecosystem development on habitat enhancement structures could be controlled, or periodically altered, to increase the abundance and types of prey organisms. For example, would the introduction of large numbers of herbivores on some of the enhancement structures at Edmonds graze down the algae and allow recolonization by acorn barnacles? Could this be carried out immediately adjacent to the fishing pier to provide a prime feeding site for surfperch, which would be removed by the pier fishery before they could heavily impact the barnacle population, leaving an abundant food source to attract more surfperch (baited-trap equilibrium?)? Sale (1977) expressed the view that the diversity of coral reef fish communities was directly correlated with the rate of small-scale, unpredictable disturbances to the supply of living space, and that this could be tested experimentally by manipulating the rate of disturbance through increased predation (spear fishing). It seems equally plausible to experimentally control sessile and motile invertebrate populations on island-like enhancement structures.

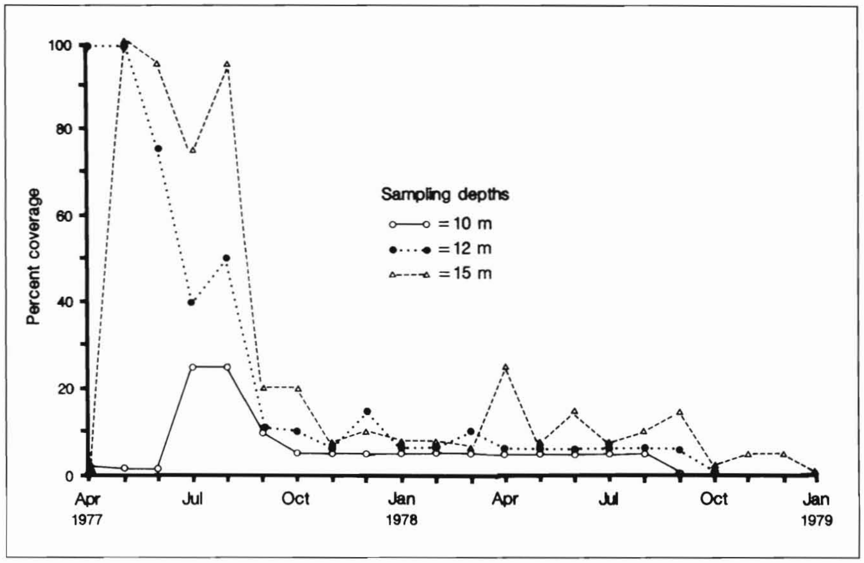

Figure 9.—Percent coverage of the acorn barnacle, *Balanus glandula*, on habitat enhancement structures at the Edmonds Public Fishing Pier (from Hueckel, 1980).

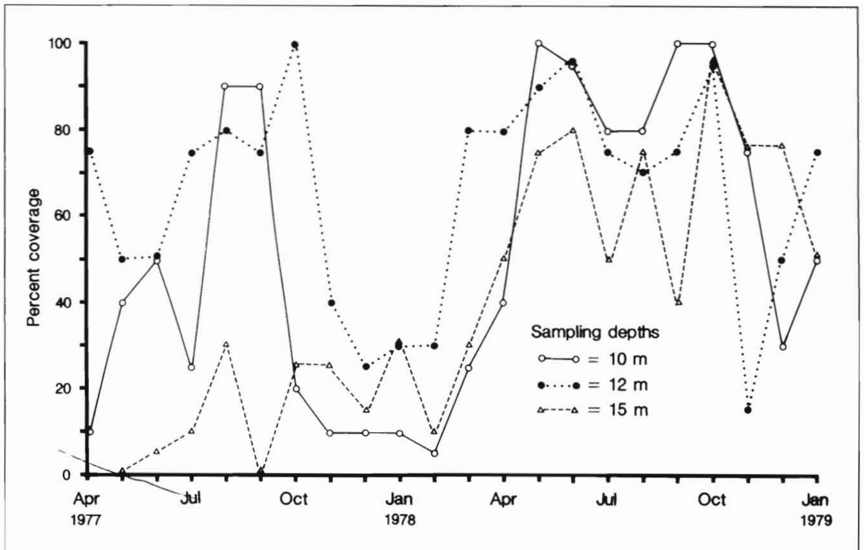

Figure 10.—Percent coverage of algae on habitat enhancement structures at the Edmonds Public Fishing Pier (from Hueckel, 1980).

Table 1.—Prey organisms identified in benthic cores, benthic plankton-net tows, and successional development studies in the habitat enhanced area at the Edmonds Public Fishing Pier, August 1977-December 1978.

Prey organisms	Percent: Habitat enhancement structures	Percent: Sand substrate
Microinvertebrates[1]	80	46
Caridean shrimp	20	
Polychaete annelids		33
Bivalve mollusks		15
Nematodes		6

[1]Less than 2.5 cm in length.

Long-Term Fish Community Structure

The successional development of fish communities on habitat enhancement areas in Puget Sound appears to proceed from a principally aggregated species base during initial colonization to a "forager-aggregater" community structure as food items develop on the enhancement structures. A composite of research information from several enhancement areas shows that the early colonizing fishes represent 1) five species of aggregaters, averaging 43 g each, which utilize the habitat structures for orientation and protection while feeding primarily on organisms from the surrounding benthic and pelagic environ-

Table 2.—Harvests of resident (R), semiresident (S-R), and transient-feeding (T-F) fishes from the Edmonds Public Fishing Pier.

Fishery year		Percent of harvest				
		First qtr[1]	Second qtr.	Third qtr	Fourth qtr	Total
March 1979-	R + S-R	92.2	81.3	6.8	38.4	32.6
March 1980	T-F	7.8	18.7	93.2	61.6	67.4
May 1980-	R + S-R	83.5	22.5	49.6	65.8	40.1
May 1981	T-F	16.5	77.5	50.4	34.2	59.9

[1]Quarters overlap only 1.5 months between fishery years.

ments, and 2) two species of (predatory) foragers, averaging 1,553 g each, which utilize the habitat structures as a place to feed on structure-related organisms (principally aggregated fishes). After several years of biological development, the fish community structures change to represent five species of aggregaters, averaging 545 g each, and eight species of foragers, averaging 364 g each, with at least 60 percent species overlap in each group. These disparities in average sizes of early colonizing fishes demonstrate that the aggregaters were primarily juveniles (seeking unoccupied habitat?) and the foragers were (wandering?) adult predators. In comparison, the average sizes in the developed fish communities demonstrate a more balanced distribution of all aggregater and forager life history stages. This pattern of early colonization of reef structures by mainly juveniles, with some (itinerant) adult fishes, has been reported by many researchers (Talbot et al., 1979; Brock et al., 1979; and Stone et al., 1979).

Persistent aggregation of fishes by habitat enhancement structures is very important to continued fishery utilization of the sites. Foragers represent many of the resident and semiresident species that are limited in abundance by the amount of food and habitat (area) provided by the enhancement structures. The aggregaters include the transient species that utilize the enhanced areas as "patchy" feeding locations in rather broad geographic regions. These large populations occur intermittently in the target fishing locations, providing excellent catches and reducing pressure on resident and semiresident stocks, but are less vulnerable to overharvest. The first two fishery years on the Edmonds Public Fishing Pier produced harvests dominated by the transient-feeding fishes (67.4 and 59.9, respectively), but quarterly catch estimates demonstrated the equally important role of the resident and semiresident fishes in carrying the fishery through less productive periods (Table 2).

Stone et al. (1979) are the most recent researchers to show that marine habitat enhancement (an artificial reef) will increase carrying capacity and reef fish biomass in the immediate vicinity of a natural coral reef, without diminishing the resident population of the natural reef through attraction to the new habitat. Similar results have been found to occur in local temperate waters between new and old habitat enhancement structures which simulate rocky reef-like habitats. A quarry rock breakwater—rubble rock-covered pipeline habitat established in 1968-71, had fish densities averaging 0.27 fish/m^2 (quarterly, July 1975 to June 1976) just prior to construction of an adjacent tire-module artificial reef (Walton, 1979). Five years later, fish densities on this habitat had increased to 0.44 fish/m^2 while the tire modules had developed fish populations of 1.77 fish/m^2 (Washington Department of Fisheries survey data).

These examples of an absence of long-term detrimental effects between the new and old habitats, and the apparent relatively independent development of associated fish populations, support the idea that increasing the amount of reef-simulating habitat in the nearshore marine environment increases fish production. Local marine waters do not (currently) represent a nutrient-limited system that can be adversely affected by an expanding habitat enhancement program; in fact, there is a closer representation of a habitat-limited system that responds to increased habitat diversity with increased production of desirable biota.

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