The Effects of an Artificial Reef on Resident Flatfish Populations

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Introduction

The placement of artificial reefs in areas where historically only flounder populations were prevalent has been a common practice among those determining reef placement sites. This decision, based on the now accepted premise that addition of higher relief substrates increases the diversity, quantity, and biomass of fish species, assumes that these species are more desirable than the resident flatfishes. However, concern has been expressed by researchers and users about the effects these reefs have on the resident population. This question was aptly posed to researchers by Hoese (1978): "While it is clear that surface area is increased, addition of a hard substrate where a soft one prevailed, may discriminate against species preferring the soft bottom. As a flounder fisherman perhaps I do not want stocks of black sea bass, tautog and cunner increased if it interferes with flounder production. Does that happen?"

At the time this question was posed, a study was already being conducted in the Pacific Northwest to determine what effects artificial reefs have on resident species. To do so and ensure proper controls, it was first necessary to determine certain population characteristics (i.e. species, density, biomass, and size of the local flatfishes (Pleuronectidae and Bothidae)), construct an artificial reef, then continue the monitoring program to study the changes that resulted.

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This was accomplished between May of 1975 and March of 1979 as a portion of the Puget Sound Artificial Reef Study (Walton, 1979) and the marine habitat enhancement program of the Washington Department of Fisheries Marine Fish Enhancement Unit.

Materials and Methods

The study site is located at lat. 47°48′N and long. 122°23′W on central Puget Sound approximately 24 km north of Seattle, Wash. (Fig. 1). The flat compacted sand surveyed in the study area from a depth of 6 to 18 m below mean lower low water (MLLW), approximately 200 m from shore, is typical of much of the nearshore area in central Puget Sound. Although tidal fluctuations average 3.4 m daily, the maximum current at the study site rarely exceeds 0.9 km/hour. This minimal current and closeness to shore allows effective scuba sampling at essentially any time.

The flatfish population on the open sand was surveyed monthly beginning in May 1975 and ending in June the following year. Sampling was conducted using a flounder sampler (Fig. 2) (Walton and Bartoo, 1976). During the sampling dives, the diver proceeded to the maximum depth to be sampled and placed the stake at that depth. The flounder sampler was pushed through the sand along the desired depth contour, dislodging flatfish in a 30 × 2 m swath. The diver recorded each species, then estimated its length by comparing the length of the fish with the 10 cm spacing of washers on the head of the sampler. After a transect was completed, the diver rewound the reel to the stake and made

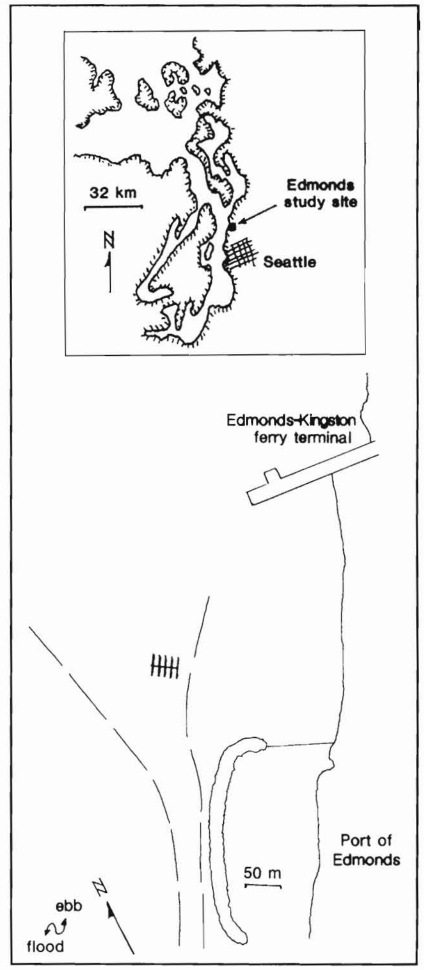

Figure 1.—Study site on central Puget Sound.

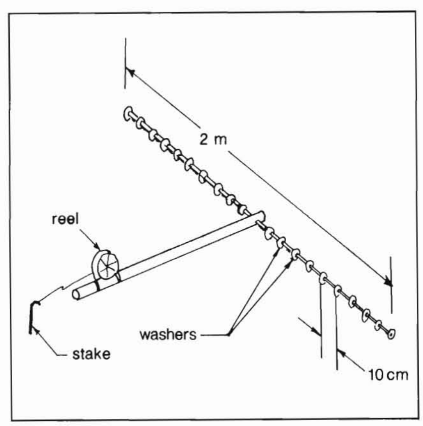

Figure 2.—Flounder sampler used to determine flatfish densities.

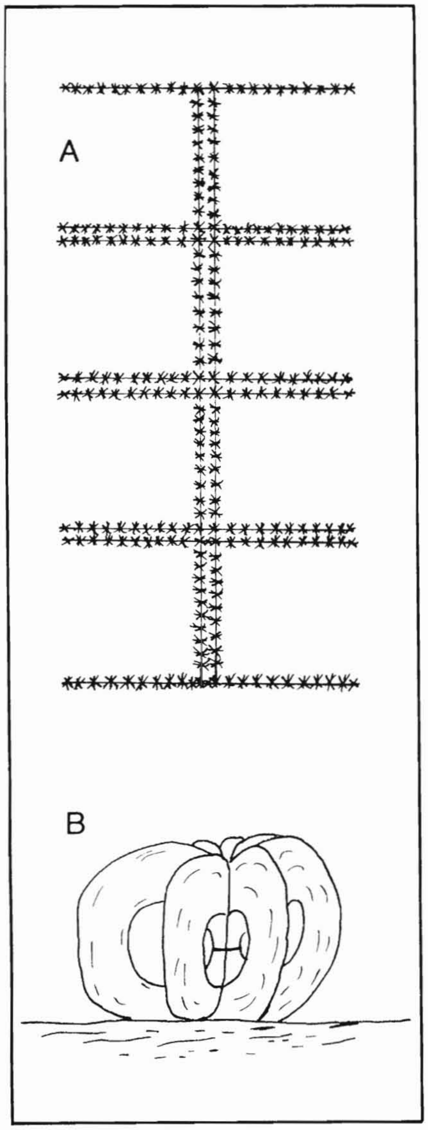

Figure 3.—The horseshoe tire reef configuration (A) is composed of individual bundles of tires (B). The individual bundles and the entire structure are held together with polypropylene line.

another transect run in the opposite direction. The monthly transects were run at 18.2 m, 15.2 m, 12.2 m, 9.1 m, and 6.1 m depths below MLLW. The weight of each individual was calculated from length-weight regressions determined for each species (Walton, 1979).

After completion of this survey an artificial reef was designed and constructed for the flatfish study. This reef design was termed the "horseshoes." The horseshoes (Fig. 3) were composed of rows of daisy patterns (a group of 8-10 tires secured at the tread by a short piece of line). Each of the three sides of a horseshoe was 7.62 m enclosing 58.1 m^2. The entire structure measured 30.5 × 15.2 m and encompassed a bottom area of 465 m^2. The total bottom surface area actually covered by tires was 228 m^2. The horseshoes were placed 12-15 m below MLLW.

The horseshoes were sampled using flounder sampler transects inside the horseshoe openings. An area of 15.2 m^2 was surveyed inside each randomly selected horseshoe by swimming the 2 m wide transect from a line between the ends of the two legs to the back of the structure. Species were recorded as in the original sand bottom survey. Sampling commenced in October 1976, continued on a monthly basis through December of 1977, and then was conducted quarterly through March 1979.

Results

From May 1975 to June 1976, 427 fish were observed (Table 1, 2) of which 36 percent were rock sole, *Lepidopsetta bilineata:* 16 percent English sole, *Parophrys vetulus:* 16 percent C-O sole, *Pleuronichthys coenosus:* 15 percent sanddabs, *Citharichthys sordidus* and *C. stigmaeus;* and 17 percent unidentified flatfish. The two sanddab species in many instances were found to be indistinguishable underwater when less than 15 cm long and therefore were recorded only as *Citharichthys* sp. No significant difference in densities or biomass were detected between the 3 m depth intervals over the period studied (Friedman's 2-way analysis, $P = 0.20$); therefore, the data were pooled for further analyses. The average density for 1 year (January through December) summarized over the survey period was 0.07 flatfish/m^2 and the average biomass was 6.9 g/m^2.

Density and biomass would be expected to vary if the same size distribu-

Table 1.—Density and biomass of flatfish associated with the sand bottom from May 1975 to June 1976.

Month	Area surveyed (m^2)	No. of fish observed	Density (fish/m^2)	Biomass (g/m^2)
May	400	22	0.06	10.7
June	300	21	0.07	4.1
July	300	22	0.07	5.0
Aug.	600	56	0.09	6.2
Sept.	600	62	0.10	8.5
Oct.	600	73	0.12	10.6
Dec	600	29	0.05	2.3
Jan.	600	16	0.03	5.2
Feb.	600	18	0.03	2.9
Mar	600	18	0.03	5.8
Apr	600	29	0.05	10.0
May	600	29	0.05	11.5
June	600	32	0.05	7.3
Average			0.07	6.9

Table 2.—Descriptive statistics of the species of flatfish on the open sand and within the horseshoe tire reefs.

Species	Habitat	Percent occurrence (n 12 open sand) (n 19 horseshoes)	No. of fish observed	Percent of no. observed	Average length (mm)	Average weight (g)
Rock sole	Open sand	100	152	36	209	106
	Horseshoes	100	210	40	198	90
English sole	Open sand	77	69	16	206	77
	Horseshoes	74	116	22	207	78
C-O sole	Open sand	92	68	16	298	356
	Horseshoes	100	39	7	307	389
Sanddabs	Open sand	92	66	15	145	32
	Horseshoes	68	43	8	143	31
Unidentified flatfish	Open sand	77	72	17	99	10
	Horseshoes	79	114	22	76	5
Sand sole	Open sand	0	0	0	0	0
	Horseshoes	5	1	1	300	300
Total	Open sand		427			
	Horseshoes		523			

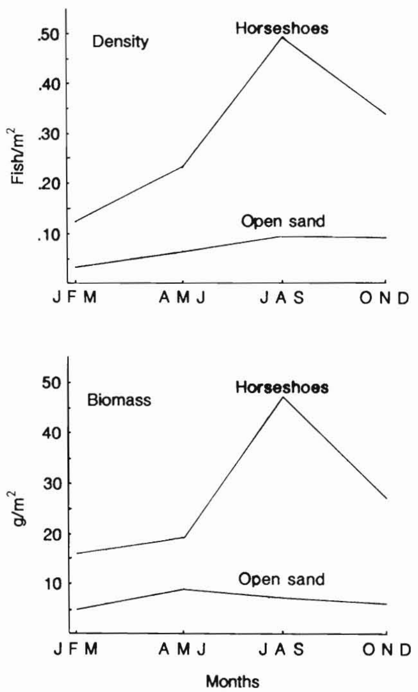

Figure 4.—A comparison of the density and biomass of flatfish observed on the open sand and within the horseshoe tire reef. Data points gathered over the entire study period are averaged by quarter.

Table 3.—The density and biomass of flatfish within the horseshoe structure from October 1976 to March 1979.

Year and month	Area (m^2)	No. of fish observed	Density ($fish/m^2$)	Biomass (g/m^2)
1976				
Oct	84	32	0 38	31 7
Nov	76	25	0 33	23.4
Dec	76	13	0 17	26.9
1977				
Jan	91	11	0 12	4.9
Feb	76	6	0 08	16 0
Mar	61	6	0 10	27 7
Apr	61	7	0 11	11 1
May	76	18	0 24	33 8
July	122	72	0 59	56.2
Aug	122	56	0 46	36 8
Sept	91	38	0 42	54 6
Oct	122	38	0 31	30 3
Nov	122	43	0.35	18 4
Dec	122	8	0 06	4.2
1978				
Feb	122	7	0 07	3 5
May	76	35	0 46	37.9
Aug	76	33	0 43	25 4
Nov	61	61	1.00	58.5
1979				
Mar	61	14	0 23	21 4
Average			0 31	27.5

tion of fish existed throughout the year. However, a few relatively large flatfish were encountered in the first quarter of the year increasing in numbers through the second. These were joined by large numbers of juveniles in the third quarter which remained through the end of the year before moving out of the study area. All of the flatfish species occurred in at least 77 percent of the sample dives. The unidentified flatfish group (UIF) averaged 10 g or about 5-10 cm. These small individuals were assumed to be juveniles of the other species, based on an otter trawl survey through the area.

For the period of October 1976 to March 1979 after the horseshoe shaped artificial reef had been constructed only one additional species, the sand sole, *Psettichthys melanosticus*, was observed. Rock sole composed 40 percent of the 523 fish recorded, English sole 22 percent, C-O sole 7 percent, sanddabs 8 percent, unidentified flatfish 22 percent, and sand sole less than 1 percent. The average density and biomass for the January to December cycle was 0.31 $fish/m^2$ and 27.5 g/m^2 (Table 3). Within the horseshoes, large fish were again encountered at relatively low densities in the first quarter. Juveniles, however, began appearing in the second quarter almost doubling the average density but only slightly increasing the biomass. The juveniles again remained through the third and fourth quarter.

A plot of the two sets of data for density and biomass calculations averaged by quarter appears as Figure 4. For the year and during each quarter the density and biomass of flatfishes are significantly higher within the horseshoes than on the open sand ($P \leq 0.05$) (Wilcoxon, 1945). The density of flatfish within the horseshoes was an average of 5 times that on the open sand while the biomass was 4.1 times greater inside the horseshoes.

Each of the species occurring on the open sand also occurred within the horseshoes. The sand sole was the only fish which did not occur in the initial survey. There was little difference in the percent of the samples in which each species occurred except for the sanddabs which were present in 92 percent of the samples on the open sand but in the horseshoe samples were only 68 percent. The proportions of rock sole, English sole, and unidentified flatfish increased slightly within the horseshoes while C-O sole and sanddabs constituted lesser percentages.

The average sizes of the rock sole, sanddabs, and unidentified flatfish were slightly smaller than those found on the open sand while the English sole and C-O sole were slightly larger. The overall average weight of the flatfish on the open sand was 106 g while that within the horseshoes was 79 g. Over 90 percent of this difference can be accounted for by the reduced numbers of C-O sole within the horseshoes.

Before the artificial reef construction there would be, on the average, 33 fish encountered in the 465 m^2 of the study site at a density of 0.07 $fish/m^2$. Construction of the reef eliminated about half of the area (228 m^2) leaving an exposed bottom area of 237 m^2 with a resultant population of approximately 73 fish at a density of 0.31 $fish/m^2$. The net gain in flatfish as a direct result of the reef was approximately 40 flatfish or a gain of 0.24 $fish/m^2$.

Discussion

Do artificial reefs affect flounder production? The evidence gathered during this study indicates that they do. Even though a certain number of fish are physically displaced by the construction of an artificial reef and the covered habitat is no longer accessible to them, the net result is an increase in flatfish abundance within the confines of the reef area.

In this study the four- to fivefold increase in density and biomass of the five most prevalent species of flatfish was the most significant change encountered. Only minor changes in species composition size and percent occurrence were detected. The fact that these five species were encountered both before and after reef placement is not surprising in that Moulton (1974) also reported that these five species were the only flatfish recorded in otter trawl samples on the sand bottom between a depth of 3 and 18 m at two similar central Puget Sound sites.

However, the placement of a reef on a

previously open sand bottom is a major perturbation at the site, undoubtedly resulting in small-scale current changes and changes in settling out patterns of detritus and debris, and it would seem likely that one or more of the species or a size range of one of the species would be better adapted to take advantage of these changes rather than all increasing about equally. As this was not the case several explanations might be postulated.

With changes in currents perhaps a greater settling out of algae, detritus, and plankton would occur on the bottom, being trapped by the legs of the horseshoes. This algae harbors many crustaceans (Hueckel, 1980) while the detritus and plankton contribute to clam and polychaete worm production. Flatfish commonly feed on small crustaceans, clam necks, and polychaete worms. Although no definitive studies have been completed comparing the food preferences of these flatfish at this site, generalized summaries of their preferences (Hart, 1973) suggest that there is a considerable overlap in their diets. This being the case, then an increase in food alone might account for the majority of the increase in flatfish abundance.

Other possible fish attractants include orientation and shelter (McVey, 1971). In this case the fish might simply be using the structures to hide behind, staying out of the direct line of sight of such roving predators as the lingcod, *Ophiodon elongatus*, then moving out to the nearby open areas to feed. This explanation is further supported by the fact that the changes in density occurred immediately after reef placement. In actuality all three factors are probably working simultaneously.

It should be noted that the artificial reef modules constructed for this study were designed with the idea that a semienclosed structure might increase the densities of flatfish species and that if so, other reefs, even though constructed of other components or materials, might be arranged so as to maximize flatfish species while also attracting other species. In a subsequent limited study the Washington Department of Fisheries could find no increase in flatfish abundance surrounding concrete reefs not placed in a semienclosed pattern[1]. The success of the horseshoe design should warrant attention to this pattern of placement in future reef construction.

Additional research could help determine what the relationship is between the size of the semienclosed space and the density of fish it will harbor. If adequate densities can be maintained within wider semicircles then there is less likelihood of entangling fishing gear.

This study was conducted along with a simultaneous assessment of the species associated with the tire reef structure itself (Walton, 1979). In addition to the six species of flatfish observed within the reef, 16 other species were noted on the reef at an average density of 0.72 fish/m^2 and a biomass of 53 g/m^2 during the day. This additional species assemblage results in an average of 203 fish being within the reef site compared with 28 fish before the reef placement.

The concerns of Hoese (1978) that artificial reefs which change the nature of the substrate and result in increases in reef population which might interfere with flounder production appear to be unfounded in the Puget Sound region and in fact the evidence strongly suggests that increases in fishes available to both flounder fishermen and reef fishermen can occur.

[1]Hueckel, G. J. 1981. Washington Department of Fisheries, Olympia. Pers. commun.

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